



**EFFECT OF TILLAGE AND GREEN MANURING ON SOIL  
PROPERTIES FOR ASSESSING THE PERFORMANCE OF  
MAIZE (*Zea mays* L.)**

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF  
PHILOSOPHY

By

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BY

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Submitted

In partial fulfillment of the requirements for the Degree of Doctor of  
Philosophy in Soil and Water Conservation of Nagaland University

*Affectionately  
Dedicated  
To  
My loving Family*

**Nagaland University**

**September, 2025**

I, Hapemo Ngullie K, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute. This is being submitted to School of Agricultural Sciences, Nagaland University for the degree of Doctor of Philosophy in Soil and Water Conservation.

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The results of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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*Dated :*

*(Hapemo Ngullie K)*

*Place :*



## CONTENT

| CHAPTER | TITLE                                                                         | PAGE NO. |
|---------|-------------------------------------------------------------------------------|----------|
| 1       | INTRODUCTION                                                                  | 1-3      |
| 2       | REVIEW OF LITERATURE                                                          | 4-23     |
|         | 2.1 Effect of tillage on soil properties and soil moisture status             |          |
|         | 2.2 Effect of tillage on nutrient content, uptake and quality of maize        |          |
|         | 2.3 Effect of tillage on growth, yield attributes and yield of maize          |          |
|         | 2.4 Effect of green manuring on soil properties and soil moisture status      |          |
|         | 2.5 Effect of green manuring on nutrient content, uptake and quality of maize |          |
|         | 2.6 Effect of green manuring on growth, yield attributes and yield of maize   |          |
| 3       | MATERIALS AND METHODS                                                         | 24-45    |
|         | 3.1 General information                                                       |          |
|         | 3.1.1 Site of experiment                                                      |          |
|         | 3.1.2 Climatic and weather conditions                                         |          |
|         | 3.1.3 Soil condition                                                          |          |
|         | 3.2 Details of experimental techniques                                        |          |
|         | 3.2.1 Design and experimental layout                                          |          |
|         | 3.2.2 Experimental details                                                    |          |
|         | 3.2.3 Treatment details                                                       |          |
|         | 3.2.3.1 Main plot                                                             |          |
|         | 3.2.3.2 Sub-plot                                                              |          |

3.2.3.3 Treatment combinations

### **3.3 Agronomic practices**

3.3.1 Selection and preparation of field

3.3.2 Design and layout

3.3.3 Fertilizers application

3.3.4 Seed rate and method of sowing

3.3.5 Irrigation

3.3.6 Intercultural operations

3.3.7 Harvesting and threshing

### **3.4 Soil analysis**

3.4.1 Soil sample collection and preparation of analysis

3.4.1.1 Soil pH

3.4.1.2 Total acidity {cmol (p+) kg<sup>-1</sup>}

3.4.1.3 Exchangeable acidity {cmol (p+) kg<sup>-1</sup>}

3.4.1.4 Organic carbon content (%)

3.4.1.5 Cation exchange capacity {cmol (p<sup>+</sup>) kg<sup>-1</sup>}

3.4.1.6 Available nitrogen (kg ha<sup>-1</sup>)

3.4.1.7 Available phosphorus (kg ha<sup>-1</sup>)

3.4.1.8 Available potassium (kg ha<sup>-1</sup>)

3.4.1.9 Bulk density (g cm<sup>-3</sup>)

3.4.1.10 Particle density (g cm<sup>-3</sup>)

3.4.1.11 Hydraulic conductivity (cm hr<sup>-1</sup>)

3.4.1.12 Water holding capacity (%)

3.4.1.13 Percent aggregates >0.25 mm (%) and mean weight diameter (mm)

3.4.1.14 Soil microbial biomass carbon (SMBC) ( $\mu\text{g g}^{-1}$  soil)

3.4.1.15 Soil respiration ( $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ )

### **3.5 Determination of soil moisture content**

### **3.6 Estimation of quality and chemical analysis of plant materials of maize**

3.6.1 Protein content in maize seed (%)

3.6.2 Carbohydrate content in maize seed (%)

3.6.3 Estimation of oil content in maize seed (%)

3.6.4 Determination of ash content in maize seed (%)

3.6.5 Chemical analysis of plant materials

3.6.5.1 N, P and K content in seed and stover (%)

3.6.5.1.1 Nitrogen

3.6.5.1.2 Phosphorous

3.6.5.1.3 Potassium

3.6.5.2 N, P and K uptake in seed and stover ( $\text{kg ha}^{-1}$ )

### **3.7 Recordings of yield and yield attributes of maize**

3.7.1 Growth attributes

3.7.1.1 Plant height (cm)

3.7.2 Yield attributes and yield

3.7.2.1 Number of cobs per plant

3.7.2.2 Length of cob (cm)

3.7.2.3 Number of grains per cob

3.7.2.4 Grain yield ( $\text{kg ha}^{-1}$ )

3.7.2.5 Stover yield ( $\text{kg ha}^{-1}$ )

### **3.8 Statistical analysis**

#### **4.1 Effect of tillage and green manuring on soil properties and soil moisture status**

##### **4.1.1 Soil pH**

###### **4.1.1.1 Effect of tillage on soil pH**

###### **4.1.1.2 Effect of green manuring on soil pH**

###### **4.1.1.3 Interaction effect**

##### **4.1.2 Total acidity**

###### **4.1.2.1 Effect of tillage on total acidity**

###### **4.1.2.2 Effect of green manuring on total acidity**

###### **4.1.2.3 Interaction effect**

##### **4.1.3 Exchangeable acidity**

###### **4.1.3.1 Effect of tillage on exchangeable acidity**

###### **4.1.3.2 Effect of green manuring on total acidity**

###### **4.1.3.3 Interaction effect**

##### **4.1.4 Organic carbon content**

###### **4.1.4.1 Effect of tillage on organic carbon content**

###### **4.1.4.2 Effect of green manuring on organic carbon content**

###### **4.1.4.3 Interaction effect**

##### **4.1.5 Cation exchange capacity**

###### **4.1.5.1 Effect of tillage on cation exchange capacity**

4.1.5.2 Effect of green manuring on cation exchange capacity

4.1.5.3 Interaction effect

4.1.6 Available nitrogen

4.1.6.1 Effect of tillage on available nitrogen

4.1.6.2 Effect of green manuring on available nitrogen

4.1.6.3 Interaction effect

4.1.7 Available phosphorus

4.1.7.1 Effect of tillage on available phosphorus

4.1.7.2 Effect of green manuring on available phosphorus

4.1.7.3 Interaction effect

4.1.8. Available potassium

4.1.8.1 Effect of tillage on available potassium

4.1.8.2 Effect of green manuring on available potassium

4.1.8.3 Interaction effect

4.1.9 Bulk density

4.1.9.1 Effect of tillage on bulk density

4.1.9.2 Effect of green manuring on bulk density

4.1.9.3 Interaction effect

4.1.10 Particle density

4.1.10.1 Effect of tillage on particle density

4.1.10.2 Effect of green manuring on particle density

4.1.10.3. Interaction effect

4.1.11. Water holding capacity

4.1.11.1. Effect of tillage on water holding capacity

4.1.11.2. Effect of green manuring on water holding capacity

4.1.11.3 Interaction effect

4.1.12 Hydraulic conductivity

4.1.12.1 Effect of tillage on hydraulic conductivity

4.1.12.2 Effect of green manuring on hydraulic conductivity

4.1.12.3 Interaction effect

4.1.13 Mean weight diameter

4.1.13.1 Effect of tillage on mean weight diameter

4.1.13.2 Effect of green manuring on mean weight diameter

4.1.13.3 Interaction effect

4.1.14 Percent aggregates > 0.25 mm

4.1.14.1 Effect of tillage on Percent aggregates > 0.25 mm

4.1.14.2 Effect of green manuring on Percent aggregates > 0.25 mm

4.1.14.3 Interaction effect

4.1.15 Soil microbial biomass carbon

4.1.15.1 Effect of tillage on soil microbial biomass carbon

4.1.15.2 Effect of green manuring on soil microbial biomass carbon

4.1.15.3 Interaction effect

4.1.16 Soil respiration

4.1.16.1 Effect of tillage on soil respiration

4.1.16.2 Effect of green manuring on soil respiration

4.1.16.3 Interaction effect

4.1.17 Soil moisture status

4.1.17.1 Soil moisture status at 30 Days After Sowing (DAS)

4.1.17.1.1 Effect of tillage on soil moisture status at 30 (DAS)

4.1.17.1.2 Effect of green manuring on soil moisture status at 30 (DAS)

4.1.17.1.3 Interaction effect

4.1.17.2 Soil moisture status at 60 Days After Sowing (DAS)

4.1.17.2.1 Effect of tillage on soil moisture status at 60 (DAS)

4.1.17.2.2 Effect of green manuring on soil moisture status at 60 (DAS)

4.1.17.2.3 Interaction effect

4.1.17.3 Soil moisture status at 90 Days After Sowing (DAS)

4.1.17.3.1 Effect of tillage on soil moisture status at 90

(DAS)

4.1.17.3.2 Effect of green manuring on soil moisture status at 90 (DAS)

4.1.17.3.3 Interaction effect

4.1.17.4 Soil moisture status at 120 Days After Sowing (DAS)

4.1.17.4.1 Effect of tillage on soil moisture status at 120 (DAS)

4.1.17.4.2 Effect of green manuring on soil moisture status at 120 (DAS)

4.1.17.4.3 Interaction effect

**4.2 Effect of tillage and green manuring on growth, yield attributes and yield of maize**

4.2.1 Plant height

4.2.1.1 Plant height at 30 Days After Sowing (DAS)

4.2.1.1.1 Effect of tillage on plant height at 30 DAS

4.2.1.1.2 Effect of green manuring on plant height at 30 DAS

4.2.1.1.3 Interaction effect

4.2.1.2 Plant height at 60 Days After Sowing (DAS)

4.2.1.2.1 Effect of tillage on plant height at 60 DAS

4.2.1.2.2 Effect of green manuring on plant height at 60 DAS

4.2.1.2.3 Interaction effect

4.2.1.3 Plant height at 90 Days After Sowing (DAS)

4.2.1.3.1 Effect of tillage on plant height at 90 DAS



4.2.1.3.2 Effect of green manuring on plant height at 90 DAS

4.2.1.3.3 Interaction effect

4.2.1.4 Plant height at harvest

4.2.1.4.1 Effect of tillage on plant height at harvest

4.2.1.4.2 Effect of green manuring on plant height at harvest

4.2.1.4.3 Interaction effect

4.2.2 Number of cobs per plant

4.2.2.1 Effect of tillage on number of cobs per plant

4.2.2.2 Effect of green manuring on number of cobs per plant

4.2.2.3 Interaction effect

4.2.3 Length of cob

4.2.3.1 Effect of tillage on length of cob

4.2.3.2 Effect of green manuring on length of cob

4.2.3.3 Interaction effect

4.2.4 Number of grains per cob

4.2.4.1 Effect of tillage on number of grains per cob

4.2.4.2 Effect of green manuring on number of grains per cob

4.2.4.3 Interaction effect

4.2.5 Seed yield

4.2.5.1 Effect of tillage on seed yield

4.2.5.2 Effect of green manuring on seed yield

4.2.5.3 Interaction effect

4.2.6 Stover yield

4.2.6.1 Effect of tillage on stover yield

4.2.6.2 Effect of green manuring on stover yield

4.2.6.3 Interaction effect

### **4.3 Effect of tillage and green manuring on quality attributes of maize**

4.3.1 Protein content

4.3.1.1 Effect of tillage on protein content

4.3.1.2 Effect of green manuring on protein content

4.3.1.3 Interaction effect

4.3.2 Carbohydrate content

4.3.2.1 Effect of tillage on carbohydrate content

4.3.2.2 Effect of green manuring on carbohydrate content

4.3.2.3 Interaction effect

4.3.3 Oil content

4.3.3.1 Effect of tillage on oil content

4.3.3.2 Effect of green manuring on oil content

4.3.3.3 Interaction effect

4.3.4 Ash content

4.3.4.1 Effect of tillage on ash content

4.3.4.2 Effect of green manuring on ash content

4.3.4.3 Interaction effect

#### **4.4 Effect of tillage and green manuring on plant analysis**

##### 4.4.1 Nutrient content of maize seed and stover

##### 4.4.1.1 Nitrogen content of maize seed and stover

###### 4.4.1.1.1 Effect of tillage on nitrogen content of maize seed and stover

###### 4.4.1.1.2 Effect of green manuring on nitrogen content of maize seed and stover

###### 4.4.1.1.3 Interaction effect

##### 4.4.1.2 Phosphorus content of maize seed and stover

###### 4.4.1.2.1 Effect of tillage on phosphorus content of maize seed and stover

###### 4.4.1.2.2 Effect of green manuring on phosphorus content of maize seed and stover

###### 4.4.1.2.3 Interaction effect

##### 4.4.1.3 Potassium content of maize seed and stover

###### 4.4.1.3.1 Effect of tillage on potassium content of maize seed and stover

###### 4.4.1.3.2 Effect of green manuring on potassium content of maize seed and stover

###### 4.4.1.3.3 Interaction effect

##### 4.4.2 Nutrient uptake of maize seed and stover

#### 4.4.2.1 Nitrogen uptake of maize seed and stover

##### 4.4.2.1.1 Effect of tillage on nitrogen uptake of maize seed and stover

##### 4.4.2.1.2 Effect of green manuring on nitrogen uptake of maize seed and stover

##### 4.4.2.1.3 Interaction effect

#### 4.4.2.2 Phosphorus uptake of maize seed and stover

##### 4.4.2.2.1 Effect of tillage on phosphorus uptake of maize seed and stover

##### 4.4.2.2.2 Effect of green manuring on phosphorus uptake of maize seed and stover

##### 4.4.2.2.3 Interaction effect

#### 4.4.2.3 Potassium uptake of maize seed and stover

##### 4.4.2.3.1 Effect of tillage on potassium uptake of maize seed and stover

##### 4.4.2.3.2 Effect of green manuring on potassium uptake of maize seed and stover

##### 4.4.2.3.3 Interaction effect

|   |                                |         |
|---|--------------------------------|---------|
| 5 | <b>SUMMARY AND CONCLUSIONS</b> | 199-206 |
|   | <b>REFERENCES</b>              | i-xxi   |

## LIST OF TABLES

| TABLE NO. | TITLE                                                                                                                           | PAGE NO. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------|----------|
| 3.1       | Mean weekly meteorological data recorded during the cropping season ( <i>kharif</i> 2022)                                       | 25       |
| 3.2       | Mean weekly meteorological data recorded during the cropping season ( <i>kharif</i> 2023)                                       | 26       |
| 3.3       | Initial soil properties of the experimental field                                                                               | 28       |
| 4.1(a)    | Effect of tillage and green manuring on pH, total acidity and exchangeable acidity of the soil after harvest                    | 54       |
| 4.1(b)    | Interaction effect of tillage and green manuring on pH, total acidity and exchangeable acidity of the soil after harvest        | 55       |
| 4.2(a)    | Effect of tillage and green manuring on organic carbon and cation exchange capacity of the soil after harvest                   | 61       |
| 4.2(b)    | Interaction effect of tillage and green manuring on organic carbon and cation exchange capacity of the soil after harvest       | 62       |
| 4.3(a)    | Effect of tillage and green manuring on available N, available P and available K of the soil after harvest                      | 72       |
| 4.3(b)    | Interaction effect of tillage and green manuring on available N, available P and available K of the soil after harvest          | 73       |
| 4.4(a)    | Effect of tillage and green manuring on bulk density and particle density of the soil after harvest                             | 79       |
| 4.4(b)    | Interaction effect of tillage and green manuring on bulk density and particle density of the soil after harvest                 | 80       |
| 4.5(a)    | Effect of tillage and green manuring on water holding capacity and hydraulic conductivity of the soil after harvest             | 86       |
| 4.5(b)    | Interaction effect of tillage and green manuring on water holding capacity and hydraulic conductivity of the soil after harvest | 87       |

|         |                                                                                                                                     |     |
|---------|-------------------------------------------------------------------------------------------------------------------------------------|-----|
| 4.6(a)  | Effect of tillage and green manuring on mean weight diameter and percent aggregates > 0.25 mm of the soil after harvest             | 94  |
| 4.6(b)  | Interaction effect of tillage and green manuring on mean weight diameter and percent aggregates > 0.25 mm of the soil after harvest | 95  |
| 4.7(a)  | Effect of tillage and green manuring on soil microbial biomass carbon and soil respiration of the soil after harvest                | 103 |
| 4.7(b)  | Interaction effect of tillage and green manuring on soil microbial biomass carbon and soil respiration of the soil after harvest    | 104 |
| 4.8(a)  | Effect of tillage and green manuring on soil moisture content at 30, 60, 90 and 120 Days After Sowing                               | 117 |
| 4.8(b)  | Interaction effect of tillage and green manuring on soil moisture content at 30, 60, 90 and 120 Days After Sowing                   | 118 |
| 4.9(a)  | Effect of tillage and green manuring on plant height at 30 DAS, 60 DAS, 90 DAS and at harvest                                       | 131 |
| 4.9(b)  | Interaction effect of tillage and green manuring on plant height at 30 DAS, 60 DAS, 90 DAS and at harvest                           | 132 |
| 4.10(a) | Effect of tillage and green manuring on number of cobs per plant, length of cob and number of grains per cob                        | 141 |
| 4.10(b) | Interaction effect of tillage and green manuring on number of cobs per plant, length of cob and number of grains per cob            | 142 |
| 4.11(a) | Effect of tillage and green manuring on number of seed yield and stover yield of maize                                              | 149 |
| 4.11(b) | Interaction effect of tillage and green manuring on number of seed yield and stover yield of maize                                  | 150 |
| 4.12(a) | Effect of tillage and green manuring on protein content, carbohydrate content, oil content and ash content of maize seed            | 161 |
| 4.12(b) | Interaction effect of tillage and green manuring on protein content, carbohydrate content, oil content and ash                      | 162 |

content of maize seed

|         |                                                                                                                      |     |
|---------|----------------------------------------------------------------------------------------------------------------------|-----|
| 4.13(a) | Effect of tillage and green manuring on nitrogen content and phosphorus content of maize seed and stover             | 176 |
| 4.13(b) | Interaction effect of tillage and green manuring on nitrogen content and phosphorus content of maize seed and stover | 177 |
| 4.14(a) | Effect of tillage and green manuring on potassium content of maize seed and stover                                   | 178 |
| 4.14(b) | Interaction effect of tillage and green manuring on potassium content of maize seed and stover                       | 179 |
| 4.15(a) | Effect of tillage and green manuring on nitrogen uptake and phosphorus uptake of maize seed and stover               | 195 |
| 4.15(b) | Interaction effect of tillage and green manuring on nitrogen uptake and phosphorus uptake of maize seed and stover   | 196 |
| 4.16(a) | Effect of tillage and green manuring on potassium uptake of maize seed and stover                                    | 197 |
| 4.16(b) | Interaction effect of tillage and green manuring on potassium uptake of maize seed and stover                        | 198 |

## LIST OF FIGURES

| FIGURE<br>NO. | CAPTION                                                                                          | IN<br>BETWEEN<br>PAGES |
|---------------|--------------------------------------------------------------------------------------------------|------------------------|
| 3.1           | Graphical representation of meteorological data during crop growing season ( <i>kharif</i> 2022) | 25-26                  |
| 3.2           | Graphical representation of meteorological data during crop growing season ( <i>kharif</i> 2023) | 26-27                  |
| 3.3           | Field layout of the experiment (Split Plot Design)                                               | 32-33                  |
| 4.1(a)        | Effect of tillage and green manuring on soil pH                                                  | 55-56                  |
| 4.1(b)        | Interaction effect of tillage and green manuring on soil pH                                      | 55-56                  |
| 4.2(a)        | Effect of tillage and green manuring on total acidity                                            | 55-56                  |
| 4.2(b)        | Interaction effect of tillage and green manuring on total acidity                                | 55-56                  |
| 4.3(a)        | Effect of tillage and green manuring on exchangeable acidity                                     | 55-56                  |
| 4.3(b)        | Interaction effect of tillage and green manuring on exchangeable acidity                         | 55-56                  |
| 4.4(a)        | Effect of tillage and green manuring on organic carbon content                                   | 62-63                  |
| 4.4(b)        | Interaction effect of tillage and green manuring on organic carbon content                       | 62-63                  |
| 4.5(a)        | Effect of tillage and green manuring on cation exchange capacity                                 | 62-63                  |
| 4.5(b)        | Interaction effect of tillage and green manuring on cation exchange capacity                     | 62-63                  |
| 4.6(a)        | Effect of tillage and green manuring on available N                                              | 73-74                  |
| 4.6(b)        | Interaction effect of tillage and green manuring on available N                                  | 73-74                  |



|         |                                                                                  |         |
|---------|----------------------------------------------------------------------------------|---------|
| 4.7(a)  | Effect of tillage and green manuring on available P                              | 73-74   |
| 4.7(b)  | Interaction effect of tillage and green manuring on available P                  | 73-74   |
| 4.8(a)  | Effect of tillage and green manuring on available K                              | 73-74   |
| 4.8(b)  | Interaction effect of tillage and green manuring on available K                  | 73-74   |
| 4.9(a)  | Effect of tillage and green manuring on bulk density                             | 80-81   |
| 4.9(b)  | Interaction effect of tillage and green manuring on bulk density                 | 80-81   |
| 4.10(a) | Effect of tillage and green manuring on particle density                         | 80-81   |
| 4.10(b) | Interaction effect of tillage and green manuring on particle density             | 80-81   |
| 4.11(a) | Effect of tillage and green manuring on water holding capacity                   | 87-88   |
| 4.11(b) | Interaction effect of tillage and green manuring on water holding capacity       | 87-88   |
| 4.12(a) | Effect of tillage and green manuring on hydraulic conductivity                   | 87-88   |
| 4.12(b) | Interaction effect of tillage and green manuring on hydraulic conductivity       | 87-88   |
| 4.13(a) | Effect of tillage and green manuring on mean weight diameter                     | 95-96   |
| 4.13(b) | Interaction effect of tillage and green manuring on mean weight diameter         | 95-96   |
| 4.14(a) | Effect of tillage and green manuring on percent aggregates > 0.25 mm             | 95-96   |
| 4.14(b) | Interaction effect of tillage and green manuring on percent aggregates > 0.25 mm | 95-96   |
| 4.15(a) | Effect of tillage and green manuring on soil microbial biomass carbon            | 104-105 |

|         |                                                                                      |         |
|---------|--------------------------------------------------------------------------------------|---------|
| 4.15(b) | Interaction effect of tillage and green manuring on soil microbial biomass carbon    | 104-105 |
| 4.16(a) | Effect of tillage and green manuring on soil respiration                             | 104-105 |
| 4.16(b) | Interaction effect of tillage and green manuring on soil respiration                 | 104-105 |
| 4.17(a) | Effect of tillage and green manuring on soil moisture content at 30 DAS              | 118-119 |
| 4.17(b) | Effect of tillage and green manuring on soil moisture content at 60 DAS              | 118-119 |
| 4.17(c) | Effect of tillage and green manuring on soil moisture content at 90 DAS              | 118-119 |
| 4.17(d) | Effect of tillage and green manuring on soil moisture content at 120 DAS             | 118-119 |
| 4.18(a) | Interaction effect of tillage and green manuring on soil moisture content at 30 DAS  | 118-119 |
| 4.18(b) | Interaction effect of tillage and green manuring on soil moisture content at 60 DAS  | 118-119 |
| 4.18(c) | Interaction effect of tillage and green manuring on soil moisture content at 90 DAS  | 118-119 |
| 4.18(d) | Interaction effect of tillage and green manuring on soil moisture content at 120 DAS | 118-119 |
| 4.19(a) | Effect of tillage and green manuring on plant height at 30 DAS                       | 132-133 |
| 4.19(b) | Effect of tillage and green manuring on plant height at 60 DAS                       | 132-133 |
| 4.19(c) | Effect of tillage and green manuring on plant height at 90 DAS                       | 132-133 |
| 4.19(d) | Effect of tillage and green manuring on plant height at harvest                      | 132-133 |
| 4.20(a) | Interaction effect of tillage and green manuring on plant height at 30 DAS           | 132-133 |

|         |                                                                              |         |
|---------|------------------------------------------------------------------------------|---------|
| 4.20(b) | Interaction effect of tillage and green manuring on plant height at 60 DAS   | 132-133 |
| 4.20(c) | Interaction effect of tillage and green manuring on plant height at 90 DAS   | 132-133 |
| 4.20(d) | Interaction effect of tillage and green manuring on plant height at harvest  | 132-133 |
| 4.21(a) | Effect of tillage and green manuring on number of cobs per plant             | 142-143 |
| 4.21(b) | Interaction effect of tillage and green manuring on number of cobs per plant | 142-143 |
| 4.22(a) | Effect of tillage and green manuring on length of cob                        | 142-143 |
| 4.22(b) | Interaction effect of tillage and green manuring on length of cob            | 142-143 |
| 4.23(a) | Effect of tillage and green manuring on number of grains per cob             | 142-143 |
| 4.23(b) | Interaction effect of tillage and green manuring on number of grains per cob | 142-143 |
| 4.24(a) | Effect of tillage and green manuring on seed yield                           | 150-151 |
| 4.24(b) | Interaction effect of tillage and green manuring on seed yield               | 150-151 |
| 4.25(a) | Effect of tillage and green manuring on stover yield                         | 150-151 |
| 4.25(b) | Interaction effect of tillage and green manuring on stover yield             | 150-151 |
| 4.26(a) | Effect of tillage and green manuring on protein content                      | 162-163 |
| 4.26(b) | Interaction effect of tillage and green manuring on protein content          | 162-163 |
| 4.27(a) | Effect of tillage and green manuring on carbohydrate content                 | 162-163 |
| 4.27(b) | Interaction effect of tillage and green manuring on carbohydrate content     | 162-163 |

|         |                                                                 |         |
|---------|-----------------------------------------------------------------|---------|
| 4.28(a) | Effect of tillage and green manuring on oil content             | 162-163 |
| 4.28(b) | Interaction effect of tillage and green manuring on oil content | 162-163 |
| 4.29(a) | Effect of tillage and green manuring on ash content             | 162-163 |
| 4.29(b) | Interaction effect of tillage and green manuring on ash content | 162-163 |

## LIST OF PLATES

| PLATE<br>NO. | CAPTION                                    | IN<br>BETWEEN<br>PAGES |
|--------------|--------------------------------------------|------------------------|
| 1            | General view of the experimental plot      | 45-46                  |
| 2            | Field preparation                          | 45-46                  |
| 3            | Cultivation of dhaincha for green manuring | 45-46                  |
| 4            | Cultivation of cowpea for green manuring   | 45-46                  |
| 5            | Development of maize cob                   | 45-46                  |
| 6            | Harvested maize cobs                       | 45-46                  |

## LIST OF ABBREVIATIONS AND SYMBOLS

|                                         |                                                        |
|-----------------------------------------|--------------------------------------------------------|
| @                                       | At the rate of                                         |
| &                                       | And                                                    |
| A.O.A.C                                 | Association of Official Analytical Chemists            |
| C                                       | Carbon                                                 |
| CO <sub>2</sub>                         | Carbon dioxide                                         |
| CEC                                     | Cation exchange capacity                               |
| cm                                      | Centimetre                                             |
| cm hr <sup>-1</sup>                     | Centimetre per hour                                    |
| cmol                                    | Centimole                                              |
| cmol (p <sup>+</sup> ) kg <sup>-1</sup> | Centimoles of positive charge per kilogram of exchange |
| CD @ 5%                                 | Critical difference at 5 per cent probability          |
| conc.                                   | Concentrated                                           |
| DAS                                     | Day after sowing                                       |
| ° C                                     | Degree Celsius                                         |
| C <sub>T</sub>                          | Conventional tillage                                   |
| <i>et al.</i>                           | <i>et allia</i> (and others/ co-workers)               |
| <i>etc.</i>                             | Etcetera                                               |
| Fig.                                    | Figure                                                 |
| g                                       | Gram                                                   |
| g cm <sup>-3</sup>                      | Gram per cubic centimetre                              |
| HC                                      | Hydraulic Conductivity                                 |
| <i>i.e.</i>                             | Id est (that is)                                       |
| kg                                      | Kilogram                                               |
| kg ha <sup>-1</sup>                     | Kilogram per hectare                                   |
| K                                       | Potassium                                              |
| ha                                      | Hectare                                                |

|                                                    |                                               |
|----------------------------------------------------|-----------------------------------------------|
| hr                                                 | Hour                                          |
| HC                                                 | Hydraulic Conductivity                        |
| L                                                  | Litre                                         |
| Max                                                | Maximum                                       |
| MSL                                                | Mean Sea Level                                |
| MWD                                                | Mean Weight Diameter                          |
| m                                                  | Metre                                         |
| MT                                                 | Metric Tonnes                                 |
| µg                                                 | Microgram                                     |
| µg g <sup>-1</sup> soil                            | Microgram per gram of soil                    |
| µg CO <sub>2</sub> g <sup>-1</sup> h <sup>-1</sup> | Microgram of Carbon dioxide per gram per hour |
| M <sub>T</sub>                                     | Minimum Tillage                               |
| mm                                                 | Millimetre                                    |
| MOP                                                | Muriate of Potash                             |
| NU                                                 | Nagaland University                           |
| N                                                  | Nitrogen                                      |
| NS                                                 | Non-significant                               |
| No.                                                | Number                                        |
| OC                                                 | Organic carbon                                |
| <sup>-1</sup> or /                                 | Per                                           |
| %                                                  | Percentage                                    |
| P                                                  | Phosphorus                                    |
| p <sup>+</sup>                                     | Protons                                       |
| RDF                                                | Recommended Dose of Fertilizers               |
| RCM 76                                             | Research Centre Maize 76                      |
| SAS                                                | School of Agricultural Sciences               |
| Sl. No.                                            | Serial Number                                 |
| SSP                                                | Single superphosphate                         |
| SMBC                                               | Soil microbial biomass carbon                 |
| SMC                                                | Soil Moisture Content                         |

|                    |                        |
|--------------------|------------------------|
| SPD                | Split Plot Design      |
| SEm±               | Standard error of mean |
| t                  | Tonne                  |
| t ha <sup>-1</sup> | Tonne per hectare      |
| <i>viz.</i>        | Videlicet (Namely)     |
| WHC                | Water holding capacity |



## ABSTRACT

A field experiment entitled “**Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)**” was conducted during the *kharif* season of 2022 and 2023 at the experimental farm of Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus. The experiment was laid out in split-plot design with two main plots and seven sub plots with fourteen treatment combination which was replicated thrice. The main plot consisted of Minimum tillage ( $T_M$ ) and Conventional tillage ( $T_C$ ) and the sub plots were Control ( $G_0$ ), Green manuring through dhaincha @ 2 tonnes  $ha^{-1}$  ( $G_1$ ), Green manuring through dhaincha @ 4 tonnes  $ha^{-1}$  ( $G_2$ ), Green manuring through cowpea @ 2 tonnes  $ha^{-1}$  ( $G_3$ ), Green manuring through cowpea @ 4 tonnes  $ha^{-1}$  ( $G_4$ ), Green manuring through dhaincha (1 t  $ha^{-1}$ ) and cowpea (1 t  $ha^{-1}$ ) @ 2 tonnes  $ha^{-1}$  ( $G_5$ ) and Green manuring through dhaincha (2 t  $ha^{-1}$ ) and cowpea (2 t  $ha^{-1}$ ) @ 4 tonnes  $ha^{-1}$  ( $G_6$ ). As per the outcomes obtained from the two-year investigation Minimum tillage ( $T_M$ ) significantly outperformed Conventional tillage ( $T_C$ ) in different aspects of soil properties and performance of crop. With the implementation of minimum tillage operation, superior results were obtained in the pooled average recorded data: pH (5.76), available N, P and K (482.35  $kg\ ha^{-1}$ , 14.05  $kg\ ha^{-1}$  and 164.14  $kg\ ha^{-1}$ ), cation exchange capacity {12.35  $cmol\ (p^+)\ kg^{-1}$ }, hydraulic conductivity (13.24  $cm\ hr^{-1}$ ), bulk density (1.24  $g\ cm^{-3}$ ), water holding capacity (46.29%), mean weight diameter (2.33mm), per cent aggregates (83.09%), soil microbial biomass carbon (219.64  $\mu g\ g^{-1}$ ) and soil respiration (11.61  $\mu g\ CO_2\ g^{-1}\ h^{-1}$ ), respectively. Soil moisture content at 30, 60, 90 and 120 DAS was also significantly improved in minimum tillage. Conventional tillage increased the total acidity {10.81  $cmol\ (p^+)\ kg^{-1}$ }, exchangeable acidity {2.36  $cmol\ (p^+)\ kg^{-1}$ } and particle density (2.48  $g\ cm^{-3}$ ). Plant study and quality analysis showed that  $M_T$  outperformed  $C_T$  in plant height (30, 60, 90 and 120 DAS), number of cobs plant $^{-1}$ , length of cob, number of grains cob $^{-1}$ , grain yield and stover yield. Nutrient content and uptake, protein, carbohydrate, oil and ash content was also observed to be higher with the implementation of minimum tillage. Higher pH (5.84) of the soil was observed in the treatment combination  $T_CG_6$  whereas  $T_CG_2$  significantly lowered the

total and exchangeable acidity of the soil. The organic carbon content (2.27 %) was noticeably enhanced in the treatment combination  $T_CG_2$  and the CEC {14.61 cmol ( $p^+$ )  $kg^{-1}$ } in  $T_MG_2$ . The available N (554.03  $kg\ ha^{-1}$ ) and K (175.95  $kg\ ha^{-1}$ ) were considerably increased in the treatment combination  $T_MG_6$  while the available K (15.95  $kg\ ha^{-1}$ ) increased the most in  $T_MG_2$ . Bulk density, water holding capacity, hydraulic conductivity and percent aggregates > 0.25 mm was enhanced considerably with the implementation of  $T_MG_6$ . The SMBC and soil respiration was found to be significantly influenced in the treatment combination of  $T_MG_2$ . Plant growth, yield attributes and yield of maize was also improved with the adoption of  $T_MG_6$ . The protein and ash content were noticed to be boosted in the treatment combination of  $T_MG_6$  whereas the carbohydrate and oil content was escalated with the implementation of  $T_MG_2$ . Escalated and enhanced outcomes of nutrient content and uptake of maize was also observed in the treatment combination  $T_MG_6$ . Thus from the outcomes of the investigation obtained, considering the improvement in soil properties and crop performance  $T_MG_6$  *i.e.* Minimum tillage + Green manuring through dhaincha (2 t  $ha^{-1}$ ) and cowpea (2 t  $ha^{-1}$ ) @ 4 tonnes  $ha^{-1}$  and  $T_MG_2$  *i.e.* Minimum tillage + Green manuring through dhaincha @ 4 tonnes  $ha^{-1}$  can be recommended for practical application.

**Keywords:** Cowpea, crop performance, dhaincha, manuring, nutrients

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# **CHAPTER I**

## **INTRODUCTION**

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## INTRODUCTION

Due to escalating land degradation, decreasing soil fertility and rising erosion related aspects, the need for soil and water conservation is of the utmost necessity in India, where a large proportion of the population is directly dependent on agriculture for their livelihood (Manivannan *et al.*, 2017). Excessive uses of chemical fertilizers, mono-cropping, excessive extraction of water from aquifers and human related accelerated soil erosion have made the soil barren. To prevail over this trend, the need to follow conservation measures is essential if a sustainable farming is to be achieved so as to meet the global food demand whilst maintaining environmental stability. The adoption of certain conservation measures like appropriate tillage implementation and incorporation of organic sources of nutrient like green manures can provide a concrete solution for natural resource management.

Maize (*Zea mays* L.) belongs to the family poaceae is one of the most important crop in the world. In India, it is produced in all the states in the *kharif* season although *rabi* maize is also popular in the state of Bihar and Southern India. In many region of India, maize is grown both in rainfed and irrigated condition and is also rotated with legumes to maintain soil fertility and eliminate mono cropping. Maize is used for both human consumption and animal feed. Maize seed is rich in carbohydrate about 63.03-69.36%, protein approximately 10.82-13.59% and oil around 4.16-5.76% (Khan *et al.*, 2014). It also contains fibers and vitamins like thiamine and niacin. The production of maize is very important in livestock production as most of the feed in animal's diet is dependent on maize seed and powder especially pig and poultry (Erenstein *et al.*, 2022). Tillage is the physical manipulation of soil, either by the use of machinery or manually, to create a favorable seedbed where the planted seed could germinate without much struggle and effort (Dekemati *et al.*, 2019). It breaks the hard pan and the compactness of the soil, so that the roots of the germinating crop could spread making it to establish well and fast. Tillage also helps to eradicate and control weeds and insects by exposing

the soil in the sun which destroys their habitat and lifecycle (Rowen *et al.*, 2020). Physical and biological characteristics of soil are utterly dependent on tillage practices when in turn influence the crop's yield and its components (Sharma *et al.*, 2018).

Minimum tillage is a system of tillage operation where the seedbed is prepared in such a way that least possible stress is given to the soil's natural condition and maximum benefits can be achieved (Shukla *et al.*, 2023). Minimum tillage involves only primary tillage and excludes the use of secondary tillage operations, keeping the soil to its natural state as much as possible. Results have shown that cropping involving minimum tillage for extended years have resulted in an increase in maize yield by 4.33% and reduction in food insecurity by 42.31% (Adam and Abdulai, 2023). Conventional tillage is a method of tillage operation where both primary and secondary tillage operations are involved. Its main aim is to create a seed bed where the seed could germinate and the crop could maintain its growth and yield. Less consideration is given to the conservation aspect of soil or water. Although, better results may be observed in the initial years of cultivation, sustainability of soil and crop in the long run may be difficult due to increase in varied aspects of problems like erosion, fertility, microbial losses etc.

There is vast number of leguminous crops that can be incorporated into the soil as a green manure. Dhaincha (*Sesbania* spp.) is one of the oldest and most important green manuring crop that have been used for ages to improve soil fertility, nutrient availability and influence the yield of crop (Sarwar *et al.*, 2017). Cowpea (*Vigna unguiculata*) is an annual herbaceous legume, cultivated for its green pods and seeds. It is also used as a green manuring crop due to its fast-growing ability and excellent nutrient providing ability when incorporated into the soil. The use of cowpea as green manures tends to augment in soil properties, soil health and water retention capacity of the soil (Draghici *et al.*, 2024). They provide the soil with macro and micro nutrients which replenish the soil fertility and organic matter which in turn helps the soil to hold moisture that can be judiciously used by the plants (Prajapati *et al.*, 2023). Tillage and green manuring together can sustain soil health, improve water holding capacity, reduce erosion and influence the yield and yield

components of the crop which in the long run would maintain sustainability in the farming ecosystem.

The state of Nagaland is located in the hilly North-Eastern Region of India. With its undulating topography and steep slopes, landslides, soil erosion and degradation pose serious risk. The region still follows the traditional shifting cultivation (jhum) practices which may hamper the soil and environment as vast deforestation of trees and burning of stubbles takes place during the cropping season. The state receives heavy rainfall during the monsoon season which may aid in soil and water erosion washing away the fertile top soil which can ultimately hamper crop production. Adoption of conservation measures like appropriate tillage practices, green manuring, agro forestry, and permanent system of farming such as terracing may help stabilize and sustain future generations of farming. Awareness and transfer of technology to the rural people who depend entirely farming is of the utmost priority for a sustainable farming approach.

In the light of the aforementioned points, the present investigation entitled “Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)” was conducted to evaluate the influence of implementing minimum and conventional tillage practices and how the addition of green manures in different composition can help retain soil moisture and improve soil properties, yield and yield attributes, nutrient composition, uptake and quality of maize seeds with the following objectives.

1. To assess the effect of tillage and green manuring on soil properties and soil moisture status
2. To study the effect of tillage and green manuring on quality of maize
3. To evaluate the effect of tillage and green manuring on yield attributes and yield of maize.

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## **CHAPTER II**

### **REVIEW OF LITERATURE**

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## REVIEW OF LITERATURE

In this chapter, initiatives are undertaken to examine and present the relevant reviews and finding of various researchers and scholars from India and abroad on relevant aspects corresponding to the topic entitled **“Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)”** is presented under the following headings:

1. Effect of tillage on soil properties and soil moisture status.
2. Effect of tillage on nutrient content, uptake and quality of maize.
3. Effect of tillage on growth, yield attributes and yield of maize.
4. Effect of green manuring on soil properties and soil moisture status.
5. Effect of green manuring on nutrient content, uptake and quality of maize.
6. Effect of green manuring on growth, yield attributes and yield of maize.

### 2.1 Effect of tillage on soil properties and soil moisture status

Bhattacharyya *et al.* (2006) in their investigation outlined that hydraulic conductivity of the soil was lower with the implementation of minimum tillage (MT) than in zero tillage (ZT). Conventional tillage showed an increase in hydraulic conductivity at different soil depths. An enhancement in unsaturated hydraulic conductivity was observed with the implementation of minimum tillage as compared to conventional tillage. The study concluded that MT helps maintain soil structure and moisture content more effectively than other tillage practices.

Application of mulching *via* maize straw significantly increased the P content in soil at a depth of 20-40cm, supporting with variations observed in soil organic matter. This outcome may be ascribed because of certain two factors like mulching and no tillage as soil P reserves were enhanced in fruit trees which helped the growth and other aspects. Accumulation of phosphorus was also observed in the rhizospheric zone at greater depths (Fan *et al.*, 2013).



Abdullah (2014) stated in his two years' study on different types of tillage that minimum tillage with residue management as compared to conventional tillage plays an eminent role in conserving soil moisture. 26% increase in soil moisture content was observed with the implementation of minimum tillage as compared to conventional tillage. Minimum tillage which involves less disturbance and the incorporation of residue helps the soil conserve moisture more effectively than conventional tillage.

Liu *et al.* (2013) reported that long term study of 12 years was conducted which compared the different effects of minimum tillage and conventional tillage system in cambisol soils of Slovenia. It was evident in the study that minimum tillage (MT) improved soil physical properties efficiently. Compared to conventional tillage, minimum tillage increased the water stable aggregates by 80.9%, water holding capacity by 24.8% and plant available water by 13.4% as compared to conventional tillage which was at 61.3%, 22.2% and 10.3% respectively, in the upper soil layer of 0-10 cm.

Kaurin *et al.* (2015) concluded that soil microbial biomass carbon using minimum tillage ( $13.19 \mu\text{g g}^{-1}$ ) was significantly greater in the soil depth of 0-10 cm range in comparison to conventional tillage ( $10.02 \mu\text{g g}^{-1}$ ). With the increase in soil depth there was a reversal in trend where soil microbial biomass carbon was found to be lower in minimum tillage ( $7.86 \mu\text{g g}^{-1}$ ) than conventional tillage ( $10.74 \mu\text{g g}^{-1}$ ) in the soil depth of 10-20 cm. These findings suggest that SMBC under MT is concentrated in the surface layer, whereas under CT it is more evenly distributed across soil depths. Soil organic carbon also indicates a positive linear relationship with SMBC.

Minimum tillage demonstrated the increase in particle density of soil which was measured at  $2.64 \text{ g cm}^{-3}$ . The study concludes that implementation of minimum tillage resulted in denser soil structure, limits root penetration and reduced water infiltration, which in turn affected plant growth, yield attributes and overall soil health. (Khan *et al.*, 2017)

Acar *et al.* (2018) concluded that soil aggregates within the size range of 4.0-2.0 mm were the most prevailing and while those in the 1.0-0.5 mm range were the least common across all tillage system studied. No-till and reduced tillage operations increased the mean weight diameter of soil aggregates as compared to conventional tillage practices. MWD increased by 137% as compared to conventional tillage in 0-15 cm soil depth. Soil organic carbon related with aggregates present in the top soil of 15 cm was found to be higher in conservation related tillage practices which also shows improved soil structure and carbon sequestration.

Yeboah *et al.* (2018) reported multiple studies that have indicated the adoption of conservation tillage system like no till or minimum tillage increase soil micro-aggregates (<0.25 mm) and leads to a significant in macro-aggregates (>0.25 mm) as compared to conventional tillage.

Li *et al.* (2019) reported that bulk density of the soil increased with the implementation of tillage practices such as no-till, minimum tillage and no-till with residue management. An increase of 1.4%, 2.1% and 2.6% respectively as compare to conventional tillage practices. Bulk density was also increased with the interaction of minimum tillage with residue retention by 3.9% as compared to lone no till practice. This may be due to the compaction of soil that is attributed by residue retention and less tillage operations.

Zapata *et al.* (2021) in their investigation observed that maximum breakdown of organic matter occurred under conventional tillage. This enhanced soil microbial activity, which in turn elevated soil respiration rates. Emission of CO<sub>2</sub> was also observed to be increasing which may be influenced by certain tillage practices. Carbon plays an important role in soil respiration and soil microbial biomass carbon (SMBC). The amount of carbon content in soil directly indicates the activity of soil respiration and soil microbial biomass carbon.

Zhao *et al.* (2021) stated that acidity factors such as total acidity, soil pH, exchangeable acidity etc., are totally dependent on the type of tillage employed and soil depth. A considerable to significant increase in soil total acidity was observed

under no-tillage and minimum tillage systems compared to conventional tillage. This may be because build-up of hydrogen ions ( $H^+$ ) may be more in reduced tillage system than in extensive tillage operation.

Stankowski *et al.* (2022) in their investigation concluded that Minimum tillage involves fewer disturbances in the soil, this process may increase the total and exchangeable acidity in the soil as it could reduce the integration of soil layers. This augment in soil acidity may involve a decrease in soil pH and increase in exchangeable aluminum and generally exchangeable acidity levels. Limited mixing of different soil layers under minimum tillage contributed largely in the accumulation of elements of acidity and reduces neutralization of acidic compounds.

Khalil and Suliman (2023) observed that reduced tillage practices such as no-till and minimum tillage increased the soil moisture content by 13.3% as compared to tillage operation where cultivator and harrow were used especially in the soil depth of 0-15 cm. The influence of soil cover played a significant part in conservation of moisture in reduced tillage practices, they reduced exposure of soil to direct sunlight which reduced evaporation and decreased surface runoff and helped in storing more moisture in the soil profile.

It was observed that reduction in soil pH was observed with the implementation of no till or minimum tillage. A 1.33% reduction in soil pH was recorded under reduced tillage practices such as no-till or minimum tillage, compared to conventional tillage. This result may be because in reduced tillage practice organic matter decomposition tends to lower pH of the soil (Muindi *et al.*, 2023).

The interaction of minimum tillage with residue mulching enhanced the soil to hold more moisture (24-35%) as compared to extensive tillage operations like conventional tillage. Higher soil moisture content was observed when minimum tillage (MT) was combined with manure + fertilizers at 30 kg ha<sup>-1</sup> in the critical stages of crop growth and development (Nathan *et al.*, 2023).

Ozbolat *et al.* (2023) reported that soil organic carbon content was observed to be increasing with the implementation of conventional tillage and green manuring combined. Addition of green manures typically increases the SOC sequestration by providing organic matter in the soil as different tillage system turns the soil and helps to distribute the nutrients evenly in the soil. Intensity of tillage practices, type of green manures and the condition of the initial soil also play a major role.

Zulu *et al.* (2023) stated that no-tillage resulted in the highest concentrations of  $\text{NO}_3^-$  ( $7.728 \text{ mg kg}^{-1}$ ) and  $\text{NH}_4^+$  ( $0.762 \text{ mg kg}^{-1}$ ) which outclassed all other treatments. The lowest  $\text{NH}_4^+$  concentration ( $0.648 \text{ mg kg}^{-1}$ ) was observed in conventional tillage. In contrast,  $\text{NO}_3^-$  levels under conventional tillage ( $6.755 \text{ mg kg}^{-1}$ ) were higher than that of reduced tillage ( $4.720 \text{ mg kg}^{-1}$ ). It was observed that in 0-10 cm soil depth higher concentrations of both  $\text{NO}_3^-$  ( $6.787 \text{ mg kg}^{-1}$ ) and  $\text{NH}_4^+$  ( $0.851 \text{ mg/kg}$ ) was reported, followed by the 20-30 cm depth, where  $\text{NO}_3^-$  was  $6.229 \text{ mg kg}^{-1}$  and  $\text{NH}_4^+$  was  $0.832 \text{ mg kg}^{-1}$ .

Modiba *et al.* (2024) reported that minimum tillage compared to conventional tillage significantly increased soil moisture content primarily due to the depth of ploughing involved. The study also concludes that appropriate tillage practice can immensely increase the ability of soil to hold more moisture which in turn will help the crop to increase its yield and yield attributes.

Rekwar (2024) observed that permanent bed (PB) and zero tillage (ZT-flat) systems increased the available K in the soil in maize-chickpea-*sesbania* spp. (MCS) and maize-wheat-mung bean (MWMb) cropping system. As compared to the traditional farming system the above system significantly improves the soil health and quality which ultimately boosts the crop productivity while maintaining soil fertility.

Types of tillage system influence the cation exchange capacity of the soil significantly. The implementation of reduced tillage not only increased the cation exchange capacity of the soil but also the holding and exchange of nutrients was extensively enhanced (Carlos *et al.*, 2025)

## **2.2 Effect of tillage on nutrient content, uptake and quality of maize**

Pedo *et al.* (2008) in their findings mentioned that production of maize silage and improvement in carbohydrate content in maize seeds were observed and were significantly dependent on the various tillage methods employed. Appropriate agronomic practice also improved the concentration of vital carbohydrate fractions, starch and other non-fiber carbohydrate. These components are very essential for better digestibility and enhancement of energy content in silage.

Costa *et al.* (2009) observed that reduced tillage like no till and minimum tillage as compared to other extensive tillage could be the solution to increase the soil potassium availability and accessibility. Crops may utilize nutrients more efficiently as they become more readily available.

Tillage practices considerably increase the protein content in maize and soybean seeds. The overall grain yield of both the crop was increased with the implementation of reduced tillage than that of intensive tillage systems (Spoljar *et al.*, 2009).

Kabiri *et al.* (2016) outlined that minimum tillage (MT) combined with residue incorporation resulted in an increase in ash content in canola seeds. The biochemical configuration of canola seed improved with minimum tillage practice as compared to sole cropping. The protein, oil and mineral composition of maize also improved under minimum tillage.

Sime and Aune (2016) suggested in their investigation that increase in nutrient composition of maize seeds were observed with the implementation of minimum tillage. Minimum tillage helps the soil to enhance its moisture and establish a good soil structure which helps the plant to be more productive. Root development and increased nutrient availability were also observed with the implementation of minimum tillage.

Placement of concentrated bands of phosphorus close to the soil surface significantly enhanced the phosphorus uptake by the crop especially in farming

system attributed by no tillage or minimum tillage practices. This type of tillage causes fewer disturbances to the soil and the application of nutrients like phosphorus may improve the availability and its efficiency (Alam *et al.*, 2018).

Duminda *et al.* (2018) commented that the phosphorus availability, crop phosphorus content and its uptake varies across different soil types. The physical condition of the soil is key to availability of phosphorus to the plants, soils where minimal disturbance is present tends to be more phosphorus available to the plants as compared to soil where the physical condition is weakened.

Singh *et al.* (2018) concluded that the phytic acid is present in maize seed which is also considered as the most important phosphorus base. Phytic acid makes up to 80% of maize seed total phosphorus content and about 1.50% of maize dry weight. Forms and type of tillage operations may influence the seed quality and production. As compared to excessive tillage, minimum tillage which contributes less soil disturbance may be more beneficial to improve the quality of seed.

Nitrogen uptake in maize plant notably increased with the induction of reduced tillage practices like chisel and minimum tillage practices as relative to conventional tillage. Minimum tillage employed with split fertilizer application stimulated the crop growth and productivity, increasing the nutrient composition and uptake by the seed and plant (Wasaya *et al.*, 2018).

Gotosa *et al.* (2021) reported that with the implementation of reduced tillage (RT) the nitrogen uptake in seed was twice that of conventional tillage (CT) practices. Increase from 8 to 60 kg ha<sup>-1</sup> was observed with the use of reduced tillage as compared to conventional tillage. The rise in nitrogen recovery efficiency was also observed from 5% to 40% under reduced tillage. Reduced tillage enhanced the recovery of applied N showing the benefits of this tillage practices.

Nyamwange *et al.* (2021) outlined that the implementation of appropriate tillage method which involves less disturbance to the soil like minimum tillage enhances the available nitrogen and soil microbial biomass carbon in comparison to

conventional tillage system. Which in turn help the crops to absorb more nitrogen and overall productivity of the crop.

Jha *et al.* (2023) in their study discovered that reduced tillage method increases the water-soluble potassium, exchangeable and non-exchangeable potassium (K) content and uptake in seed under maize-chickpea cropping system. This result indicates the competence of reduced tillage practice and its role in improving nutrient composition and dissemination to soil and plant.

Availability of potassium in the soil notably increased with the implementation of zero and minimum tillage. The uptake of potassium increased in contrast to conventional tillage system. This result was concluded in maize-chickpea cropping system (Kumar *et al.*, 2022)

Wang *et al.* (2023b) reported that the introductions of reduced tillage like minimum tillage or no-till in concurrence with cover crops led to prominent influence in microbial phosphorus and readily available phosphorus present in the soil. These may potentially support improved P mineralization, phosphorus uptake and crop performance in maize cropping.

Nassir *et al.* (2024) in their findings outlined that reduced tillage as compared to intensive tillage was found to be more suitable for improving the quality of seeds including oil content in maize. Intensive tillage practice hinders the soil by making it more compact which may lead to plants inability to penetrate the soil for root development. Yield components of maize as well as other quality related aspects of maize seeds may be hampered if appropriate tillage methods are not employed.

Deubel *et al.* (2011) expressed that adoption of reduced tillage practice or zero tillage as compared to conventional tillage practices increases the exchangeable, non-exchangeable and water-soluble potassium in the soil which helps the plant to absorb the nutrients efficiently. The disturbance of soil is minimal with the incorporation of reduced tillage operation, which helps the plant to enhance its yield and yield attributes.

### 2.3 Effect of tillage on growth, yield attributes and yield of maize

Boomsma *et al.* (2010) claimed that minimum or no-till practices had a significant impact on crop yield, plant population and plant height at 4 and 8 weeks after sowing. Although overall plant height may not reliably indicate yield in no-till systems, superior variability in plant height at 4 weeks after planting was linked to abridged relative yields in incessant maize under no-till conditions.

Minimum tillage (MT) impacted the height of tobacco plants (*Nicotiana tabacum*), notably extending the duration of the vegetative growth phase. At harvest, MT showed significantly taller stems than conventional tillage (CT) practices (Orlando *et al.*, 2011).

Mtyobile and Mhlontlo (2021) asserted that significant augmentation of maize yield was observed with the implementation of minimum tillage (MT) in research carried out in South Africa. An increase from 2.3 t ha<sup>-1</sup> to 4.78 t ha<sup>-1</sup> was observed under minimum tillage. Conventional tillage averaged relatively lower yield of about 4.16 t ha<sup>-1</sup> as compared to other tillage practices.

Liu *et al.* (2023) reported that about 20.2% increase in plant height of maize was observed with the implementation of minimum tillage as compared to conventional shallow moldboard plowing. Plants under the minimum tillage system exhibited rapid height gains early in the growing season, which later plateau underscoring that this practice notably enhances maize growth and development.

Mustapha *et al.* (2024) outlined that explicit tillage practices develop soil structure and soil moisture retention capacity which plays a crucial role in enhancing better plant development. Root development, nutrient efficiency and moisture uptake by the plant are also improved. Consequently, maize exhibits better growth, improved cob formation and increased seed yield.

Studies involving various tillage practices revealed that incorporation of crop residues into the soil irrespective of treatment involving microbial agent improved the growth and stover yield of maize crop when compared with outcomes under



conventional tillage practices. This concludes that suitable tillage practices and crop residue management are essential for better crop establishment and its yield components in maize (Naveen *et al.*, 2023).

Sun *et al.* (2023) reported that the use of staggered planting system with strip rotary tillage in maize cultivation especially high-density plantation improves the structure of the soil and canopy of the plant. It also reduces the bulk density of the soil and increases root dry weight by 51.26% and grain yield by 25.44%. This advocates that seed filling and cob development of maize is directly related to the physical aspects of the soil.

Appropriate tillage implementation enhances vital soil properties such as soil moisture and bulk density. These soil properties are crucial for development of maize plant and its yield components. For example, Mould board plough increases the soil temperature and helps in germination of seeds and its establishment which supports the plant for better crop stand and ultimately superior cob formation (Shevchenko *et al.*, 2024).

Sonnad *et al.* (2024) stated that the implementation of minimum tillage significantly increases maize plant height, signifying more complimentary growing conditions. Ensuring a suitable blend of tillage practices and nutrient management is crucial for optimizing maize height and achieving peak productivity in yield of the crop.

#### **2.4 Effect of green manuring on soil properties and soil moisture status**

Ray and Gupta (2001) reported that enhancement in saturated hydraulic conductivity of soil was observed with the incorporation of green manures prior to puddling in rice field. Improvements in soil aggregation, reduced bulk density, and increased macropores (<0.03 mm) were observed with green manure application, which may be directly related to the increased hydraulic conductivity, especially in the rice-wheat cropping system.

It was observed that after the conclusion of a four years' study in green manuring implementation in cereal plantation it was found that P content in green manure treated plots increased by 4.24% compared to fallow treated plots. 22.10% increase in available phosphorus in soil was also observed with green manure addition. Application of green manures can also augment the soil bio-available P by 25-30% (Varalakshmi *et al.*, 2005).

The investigation revealed that the incorporation of green manures increased the soil moisture content judiciously especially when it was incorporated without any nitrogen supplements. Soil compaction and bulk density were reduced which resulted in more moisture conservation. C/N ratio of the soil was also marked at 20 which indicated lower bulk density (Mosavi *et al.*, 2010).

Sharma *et al.* (2010) outlined in their research that treatments or mulching with green manuring crops like sunnhemp and leucaena improved soil moisture retention by 1.15-2.29% as compared to bare or fallow treated plots. Harvest as well as overall development of maize crop was significantly improved with the application of green manures. Sunnhemp or leucaena enhanced the yield of maize by about 10.20% individually and by 27.90% when applied together in the soil.

Hasan *et al.* (2014) expressed that cowpea as a green manure supplement acted as a source for more moisture conservation particularly in areas or region where there is scarcity of water. Runoff and percolation of water were reduced with green manure application resulting into greater moisture conservation. Cultivation of wheat was profoundly elevated as the green manure maintained the supply of essential nutrients, preventing runoff, reducing soil compaction and ultimately helping in growth and yield of wheat.

Incorporation of green manures may slightly increase the soil pH by 0.19% but a significant increase in available phosphorus (18.47 kg ha<sup>-1</sup>) and organic carbon (25 mg L<sup>-1</sup>) was observed. The maximum effect was observed in the rhizosphere zone of the plant (Azimzadeh *et al.*, 2015).

The movement of calcium ions from the deep layers of the soil especially subsoil as influenced by green manuring tends to reduce the acidity of the soil to a commendable extent. As compared to fallow land, soils with green manure application exhibit a better acid-base balance particularly in the cultivated layer, which ultimately helps the development of plants (Hospodarenko and Lysianskyi, (2016).

Sujatha *et al.* (2017) remarked that application of potassium fertilizers @ 120 kg K<sub>2</sub>O ha<sup>-1</sup> increased the soluble, exchangeable, fixed and non- exchangeable form of K in soil. The incorporation of green manures with K fertilizer can significantly enhance the exchangeable potassium and yield of a crop. It is recommended that in rice cultivation 40 kg K<sub>2</sub>O ha<sup>-1</sup> with dhaincha as a green manure to optimize potassium availability and increase the yield components of a crop.

Ali *et al.* (2018) stated in their findings that green manures like dhaincha, sunnhemp and pillipesara, decreased the soil bulk density markedly when after harvest soil in maize cropping was tested. Organic carbon of the soil was also increased with the application of green manures like dhaincha (0.73%), sunnhemp (0.71%) and pillipesara (0.64%).

Rafique Sajjad (2018) outlined that in the first year, application of green manures *via* cowpea enhanced the soil moisture level by 12.8% in 0-15 cm depth and 13.7% in 15-30 cm soil depth. In the second year, fields where green manures were not provided the moisture content was recorded at 12.6% and 14.4% at the soil depth of 0-15 cm and 15-30 cm respectively. The plots where green manures were incorporated increased the soil moisture and water holding capacity evidently.

Organic matter content in the soil was significantly increased with the application of organic manures which in turn increased the cation exchange capacity of the soil as well as the total organic carbon in the soil as it may have improved the ability to seize cations (Saria *et al.*, 2018).

Zhang *et al.* (2019) concluded in their research that soil aggregates > 0.25mm and mean weight diameter of the soil were increased with the application of green manures as it increases the organic matter content. Physical quality and stability of the soil were also improved with the addition of green manures as compared to bare soil under dryland conditions. Moisture retention, root penetrating ability of the plant and overall plant establishment was improved with the enhancement of soil aggregates.

Increase in soil moisture content by 34% to 65% was observed with the incorporation of green manures with gypsum. Soil moisture is vital for the overall development of plant as well as its yield components especially in the rainfed region. In this wheat cultivation study, crop yield significantly increased with the augmentation of green manures with gypsum resulting in an increase from 38% to 76%. This finding concludes that the interaction of green manures with gypsum plays a pivotal role in increasing soil moisture as well as yield of wheat (Kausar *et al.*, 2020).

Incorporation of green manures influences the particle density by enhancing the soil structure. Improvement in soil structure results in reducing compaction and increase in soil porosity. This may lead to proper development of roots and movement of moisture in the soil (Joshna *et al.*, 2024).

Li *et al.* (2024) stated that 34.82% increase in soil organic carbon was observed with the application of green manures as compared to control or bare soil. This shows that green manures are vital in enhancing soil microbial activity, nutrient availability, improvement in soil structure and maintaining the health and productivity of soil.

Shang *et al.* (2024) reported that conventional tillage practices combined with green manures tend to influence total soil respiration as well as heterotrophic respiration in the soil due to the elevated activity of microbes and decomposition of organic matter. No-till practices with green manure application tend to reduce the soil respiration by 6.7% to 8.7% and heterotrophic respiration by 8.5% to 9.8%.

Xu *et al.* (2024) in their study asserted that considerably higher levels of  $\text{NO}_3^-$  were observed in the soil with the application of green manures, which resulted in mended availability of nitrogen to the crops. While, discharge of  $\text{N}_2\text{O}$  was recorded, the incorporation of green manures significantly reduced the leaching and volatilization of  $\text{NH}_3$ . This finding suggests that the use of organic amendments via green manures can contribute to nitrogen accumulation as well as promote soil health and productivity.

Zhu *et al.* (2024) mentioned that the use of animal manures and green manuring may reduce the acidity characteristics of the soil by neutralizing acidifying compounds and also mitigating human related acidification of soil. The use of nitrogenous fertilizers may also reduce the soil acidity to some extent. The use of green manures helped immensely to reduce the exchangeable acidity of the soil by lowering the net acid load and maintaining base cation levels. This conclusion was reported from a study in Southern China.

Green manures may produce more  $\text{CO}_2$  and  $\text{CH}_4$  than NPK but significant improvement is also observed with its application. Significant improvement in soil physical properties was indicated by the increase in mean weight diameter by 21.9%. Addition of green manures also enhanced the soil structure and aggregate stability compared to typical NPK fertilization (Park and Lee, (2025).

Zhang *et al.* (2025) asserted in their conclusion that an extensive experiment using eight different organic amendments were carried out which also included green manures cultivating paddy. The results of the study revealed that soil microbial biomass carbon and organic carbon showed the highest results with the application of green manures surpassing all the other treatments. The carbon sequestration and humus content in the soil also showed massive improvement with green manure treatment. It enhanced the fertility of the soil and revitalized the SMBC to a prodigious extent.

## 2.5 Effect of green manuring on nutrient content, uptake and quality of maize

Mweta *et al.* (2007) reported that green manuring via *Gliricidia sepium* may play a pivotal role in enhancing the phosphorus availability. The decrease in soil sorption capacity may limit the P availability to the plants but with the addition of green manures the availability of P may be more accessible to the crops. *Gliricidia sepium* combined with inorganic phosphorus amendment showed a synergetic effect providing more nutrient availability and uptake efficiency in maize cropping.

Platace *et al.* (2015) highlighted that addition of soil amendments and type and application of fertilizers and other agronomic practices enhanced the ash content of different grasses. Organic amendments as compared to inorganic fertilizers performed significantly better in improving the ash content. Better biomass production was observed with the input of organic than inorganic fertilizers.

Organic manures like FYM and green manures significantly boost the potassium content and uptake by the plant. It maintains steady supply of nutrients, in an environment friendly way ensuring that the plants absorb the nutrients. It rejuvenates the plant in its growth, better physiological stand and overall productivity of the maize crop (Chaudhary *et al.*, 2017).

Plantations involving incorporation of leguminous biomass in maize cultivation resulted in an increase in sugar and carbohydrate content in maize seeds, showing a significant influence on the carbohydrate composition of maize seeds. The quality of maize seed was substantial with the involvement of biomass incorporation as compared to sole cropping (Marques *et al.*, 2018).

Yang *et al.* (2018) outlined in their research that the amount of mineral nitrogen and dissolved organic nitrogen saw an increase with the application of green manures. Green manure application also enhanced N content and uptake in maize stover by increasing the availability of different nitrogen forms. The overall productivity and dry matter accumulation is boosted with the incorporation of green manures.

An increase of 300% in phosphorus content and uptake in maize seed was observed with the incorporation of green manure *via Arachis pinto*i mixed with natural phosphate. Phosphorus availability was significantly influenced with the synergy of both the applied components improving the growth and yield components of maize (Medeiros *et al.*, 2019).

Research indicates that potassium is one of the key macronutrients for crops. It helps to better crop growth, yield components and nutrient composition and uptake. Green manuring either sole or combined with inorganic fertilizer boosted the maize performance by increasing the ability to absorb nutrients (Asante-Badu *et al.*, 2020).

Wanniang and Singh (2020) in their study found out that multiple studies have supported the use of green manures under maize cultivation which increased the yield by 22% and quality of maize as compared to sole maize. Enhancement in nutrient composition and uptake was also observed along with increases in yield in yield and protein content in maize kernels. The application of green manures not only improved the maize seeds in various factors but also rejuvenated the soil which in turn enhances the crop performance.

Akbarian *et al.* (2021) revealed in their findings that the nitrogen absorption capacity of planted maize crop remarkably improved with the incorporation of green manures. N uptake in maize plant and seed was significantly enhanced with the application of green manures.

Rani *et al.* (2021) stated that dhaincha as a green manure resulted in the highest nitrogen uptake by the cultivated maize plant in contrast to other treatments. Green manuring through dhaincha applied with 100% RDF proved to be the most beneficial combination amongst all treatment combination. The nutrient absorption capacity and efficiency of the crop was enhanced with the addition of green manures, improving overall development of the crop.

Wen *et al.* (2021) declared that the long-term use of milk vetch and ryegrass as a green manure amendment increased the potassium uptake in red paddy cultivation. It enhanced the potassium absorption by the rice crop and grains and also helped the soil to retain the potassium. This finding concludes that green manures not only improve the soil fertility but also helps in nutrient composition and uptake especially in cereals like rice.

Absorption of potassium from the soil by the plant may be more accessible with the incorporation of various green manures like common vetch and hairy vetch. Vetch efficiently accumulates and mobilizes nutrients like potassium through its deep root systems, enhancing nutrient cycling. Subsequent crop rotation is also more beneficial with the plantation and application of common and hairy vetch as it not only provides nutrients but also maintains the soil health and environment (Gabhane *et al.*, 2023).

Gu *et al.* (2023) reported that improvement in soil microbial biomass carbon and nutrient cycling was observed with the addition of green manures which enhanced the soil's ability to accumulate and disseminate available phosphorus to the plants. Green manure addition not only enriches the soil quality and fertility but also to better nutrient content and uptake in the plant biomass.

Hu *et al.* (2023) in their findings stated that the nitrogen content in seed and N uptake was significantly improved with the incorporation of green manures. The N uptake in seed varied from 93.10 to 129.3 kg ha<sup>-1</sup> with the incorporation of green manures. This suggest that the incorporation of green manures enriches the soil with organic carbon, improves soil structure and maintains the microbial activity enriching the soil nitrogen mineralization making it efficiently available to the plants, which tends to increase its accumulation in the seed.

Leguminous plants such as sunnhemp and dhaincha improve the nutrient composition and uptake by crops. Research indicated that sunnhemp performed notably better than dhaincha in phosphorus uptake by the maize plant (Gutema *et al.*, 2024).



Katral *et al.* (2024) declared that oil composition of maize with specific genotypes demonstrates elevated concentration of oil 3.4% to 6.8% which may be optimized further by involving certain agronomic practices like green manure incorporation in the soil as it may provide the essential nutrients and make the soil sustainable in the long run.

## **2.6 Effect of green manuring on growth, yield attributes and yield of maize**

*Crotalaria juncea* application as a green manure, enhanced shoots development and plant height in maize. The study indicated that the high nitrogen content in *Crotalaria* was crucial in promoting shoot growth. Furthermore, *Tithonia diversifolia* contributed to improved root development, supported plant height by increasing nutrient and water uptake. The collective use of inorganic fertilizers further augmented the positive effect of green manures on shoot growth, facilitating enhanced overall plant establishment (Sangakkara *et al.*, 2004).

Arantes *et al.* (2016) in their study revealed that sole maize planting as compared to intercropping maize with perennial green manures did not show a significant change in plant height. Plant height, stem diameter, and related traits, remained unaltered by the addition of green manures. However, the highest plant population was recorded when green manures were introduced at the V4 growth stage of maize, possibly due to improved soil moisture conservation.

Pattanaik *et al.* (2020) in their study found that maize grown with in-situ green manuring, particularly with a nitrogen application of 150 kg ha<sup>-1</sup>, exhibited a significant enhance in plant height, reaching 289.30 cm. This treatment outperformed all other methods, indicating the positive effect of green manures on maize growth. These findings suggest that combining green manures with optimal nitrogen levels can greatly enhance maize yield and yield attributes.

Plants that acquired 5 t ha<sup>-1</sup> of green manure showed the tallest height, measuring 60.7 cm. This is significantly superior to the control plots height of 52.76 cm. This demonstrates that green manure has a positive effect on the growth of

soybean plants. The results suggest that application of green manure can improve growth attributes, which may lead to elevated soybean yields in the Mount Cameroon Region (Egbe *et al.*, 2022).

Research conducted in the Northern China Plains revealed that the yield of spring maize boosted by 5.38% to 11.68% with the incorporation of green manures as compared to common traditional winter fallow practices. Maize yield was at its peak with the augment of optimized nitrogen application with 14,312.2 kg ha<sup>-1</sup>. This shows the capacity of green manuring to enhance maize growth and productivity and limit the use of synthetic fertilizers (Su *et al.*, 2022).

Acs *et al.* (2024) reported in their findings that enrichment of soil properties, improved crop growth and enhanced yield and yield attributes were observed with the use of green manures. The improvement in soil subsequently led to an increase in crop performance resulting in higher yield and better stover production in maize plantation.

Increase in maize yield up to 3000 kg ha<sup>-1</sup> was observed with the incorporation of green manures like pea and dhaincha. Green manure helps in increasing the cob count and seed production which ultimately increases the yield of the crop (Balazs *et al.*, 2024).

Kucerik *et al.* (2024) stated that the use of green manures in a diverse range of cover crops can increase the biomass production of maize. It was reported that incorporation of mustard as a green manure improved the plant growth attributes. Biomass yield was also improved by 18.4 g plant<sup>-1</sup> as compared to control which was at 8.6 g plant<sup>-1</sup>. This shows that the use of green manures particularly mustard not only improves soil properties but also enhances the overall productivity of maize.

Opier *et al.* (2024) outlined in their study that green manuring @ 20 t ha<sup>-1</sup> increases the cob length of sweet corn (*Zea mays saccharata* L.) significantly. Green manuring + NPK compound fertilizer also known as phonska was instrumental in enhancing yield and yield attributes of maize like plant height, cob development.

This study concludes that the combination of balanced fertilization is essential for the overall development of maize crop.

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## **CHAPTER III**

### **MATERIALS AND METHODS**

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## **MATERIALS AND METHODS**

This chapter outlines the experimental details, methods employed and materials utilized throughout the period of investigation to study the “**Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)**”.

### **3.1 General information**

#### **3.1.1 Site of the experiment**

The experiment was conducted in the experimental farm of the Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus during the *kharif* seasons of 2022 and 2023. The site of the experiment was located at 310 meters above mean sea level (MSL) with a geographical location of 25°45’01” North latitude and 93°51’20” East longitude.

#### **3.1.2 Climatic and weather conditions**

The experimental site is located in the humid sub-tropical zone of Medziphema, Nagaland which experiences high humidity in the summer and low to moderate wind speed. The monsoon starts from the early June and ends by late October receiving an annual rainfall of 2000 to 2500 mm. The mean temperature ranges from 21 °C to 32 °C during summer and rarely goes below 8 °C in winter. The detailed information concerning the meteorological data is presented in Table 3.1 and Table 3.2 and illustrated in Fig 3.1 and Fig 3.2, respectively.

**Table 3.1: Mean weekly meteorological data recorded during the cropping season (*kharif* 2022)**

| Week No. | Temperature |          | Relative humidity |         | Rainfall (mm) | Rainy days | Sunshine hours |
|----------|-------------|----------|-------------------|---------|---------------|------------|----------------|
|          | Max (°C)    | Min (°C) | Max (%)           | Min (%) |               |            |                |
| 22       | 33.31       | 23.30    | 93.01             | 65.12   | 22.51         | 2          | 4.80           |
| 23       | 33.02       | 24.00    | 94.13             | 74.16   | 51.12         | 4          | 2.90           |
| 24       | 30.31       | 23.33    | 95.02             | 74.15   | 46.71         | 4          | 1.30           |
| 25       | 31.25       | 23.42    | 95.12             | 75.23   | 34.83         | 3          | 1.80           |
| 26       | 33.34       | 24.91    | 93.05             | 68.14   | 9.92          | 2          | 4.50           |
| 27       | 34.21       | 24.75    | 91.11             | 66.12   | 77.11         | 3          | 7.20           |
| 28       | 34.13       | 24.54    | 90.04             | 69.23   | 22.92         | 3          | 6.90           |
| 29       | 33.90       | 24.56    | 92.02             | 75.14   | 135.35        | 4          | 3.40           |
| 30       | 31.82       | 23.22    | 96.01             | 70.30   | 135.34        | 5          | 3.60           |
| 31       | 33.61       | 23.91    | 93.05             | 68.14   | 48.81         | 2          | 3.10           |
| 32       | 33.35       | 23.95    | 96.02             | 71.23   | 114.79        | 5          | 5.10           |
| 33       | 33.64       | 24.20    | 91.02             | 72.14   | 27.52         | 2          | 6.10           |
| 34       | 34.10       | 24.50    | 94.01             | 68.21   | 64.21         | 1          | 4.10           |
| 35       | 32.73       | 24.33    | 93.62             | 68.11   | 9.01          | 1          | 4.60           |
| 36       | 33.42       | 24.41    | 89.32             | 67.23   | 21.76         | 2          | 4.90           |
| 37       | 31.91       | 23.51    | 91.11             | 72.14   | 42.83         | 3          | 4.10           |
| 38       | 33.50       | 24.02    | 91.21             | 65.00   | 15.31         | 2          | 5.60           |
| 39       | 32.80       | 23.22    | 91.11             | 70.02   | 81.25         | 2          | 6.30           |
| 40       | 31.92       | 23.53    | 95.12             | 74.05   | 31.01         | 3          | 4.40           |
| 41       | 31.81       | 22.72    | 91.12             | 71.10   | 2.96          | 1          | 5.00           |
| 42       | 30.96       | 20.61    | 94.20             | 65.11   | 19.74         | 3          | 5.90           |
| 43       | 28.13       | 19.90    | 95.21             | 71.11   | 41.05         | 2          | 4.70           |
| 44       | 29.82       | 17.14    | 96.11             | 60.01   | 0.0           | 0          | 8.00           |
| 45       | 29.31       | 16.71    | 96.21             | 57.15   | 0.0           | 0          | 8.20           |
| 46       | 27.93       | 14.60    | 98.10             | 56.12   | 0.0           | 0          | 8.20           |
| 47       | 27.72       | 12.83    | 96.00             | 52.10   | 0.0           | 0          | 8.00           |
| 48       | 27.81       | 14.30    | 96.12             | 67.21   | 0.0           | 0          | 7.40           |
| 49       | 27.62       | 12.00    | 95.15             | 49.13   | 0.0           | 0          | 8.00           |
| 50       | 26.43       | 11.32    | 96.10             | 50.18   | 0.0           | 0          | 7.00           |
| 51       | 25.70       | 11.01    | 96.12             | 51.12   | 0.22          | 0          | 6.40           |
| 52       | 33.30       | 23.31    | 93.10             | 65.10   | 22.54         | 1          | 3.90           |

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema

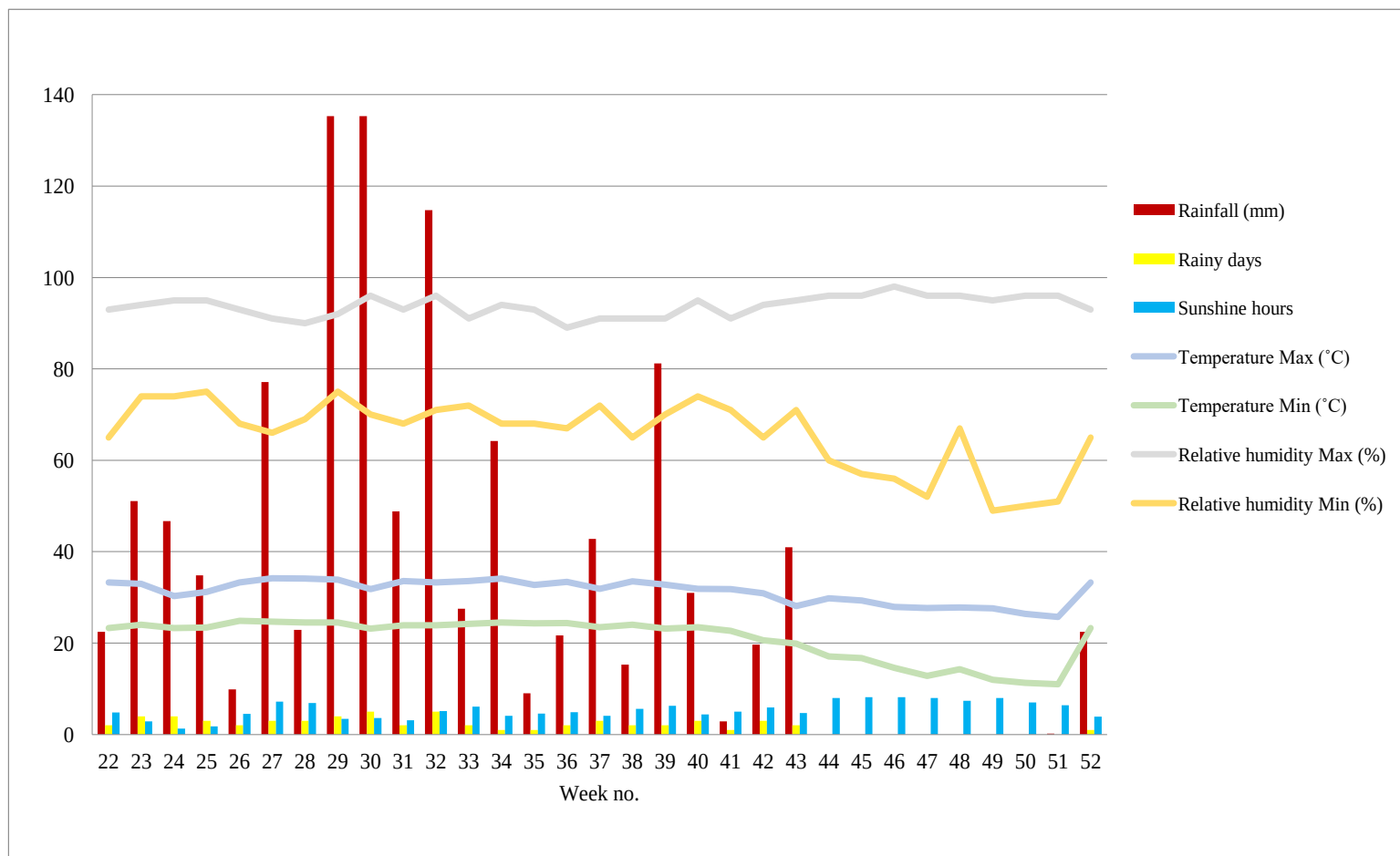


**Fig. 3.1: Graphical representation of meteorological data during crop growing season (*kharif* 2022)**

**Table 3.2: Mean weekly meteorological data recorded during the cropping season (*kharif* 2023)**

| Week No. | Temperature |          | Relative humidity |         | Rainfall (mm) | Rainy days | Sunshine hours |
|----------|-------------|----------|-------------------|---------|---------------|------------|----------------|
|          | Max (°C)    | Min (°C) | Max (%)           | Min (%) |               |            |                |
| 22       | 33.18       | 22.90    | 91.20             | 60.20   | 15.21         | 1          | 4.30           |
| 23       | 33.16       | 23.60    | 91.14             | 62.25   | 30.21         | 2          | 2.70           |
| 24       | 33.05       | 24.71    | 93.23             | 76.58   | 15.62         | 2          | 3.80           |
| 25       | 33.09       | 24.14    | 93.45             | 60.29   | 30.45         | 5          | 4.20           |
| 26       | 34.18       | 25.14    | 91.02             | 75.25   | 25.02         | 2          | 1.80           |
| 27       | 34.01       | 24.95    | 90.09             | 65.48   | 59.63         | 3          | 2.40           |
| 28       | 33.07       | 25.12    | 92.23             | 73.26   | 4.40          | 3          | 3.50           |
| 29       | 33.48       | 25.19    | 94.54             | 72.85   | 41.50         | 2          | 3.60           |
| 30       | 34.04       | 25.02    | 93.63             | 70.35   | 123.60        | 4          | 6.50           |
| 31       | 34.24       | 25.10    | 92.25             | 74.31   | 112.30        | 4          | 3.40           |
| 32       | 32.31       | 25.11    | 91.45             | 76.26   | 73.21         | 2          | 3.40           |
| 33       | 33.05       | 25.32    | 92.28             | 74.28   | 41.93         | 2          | 1.20           |
| 34       | 31.52       | 24.63    | 93.36             | 81.61   | 70.62         | 5          | 3.10           |
| 35       | 32.67       | 24.55    | 93.54             | 67.45   | 16.22         | 4          | 3.00           |
| 36       | 35.38       | 25.14    | 92.02             | 68.53   | 21.37         | 3          | 6.50           |
| 37       | 33.46       | 24.95    | 93.03             | 70.51   | 18.20         | 1          | 5.90           |
| 38       | 32.33       | 24.36    | 94.11             | 75.27   | 48.41         | 2          | 5.20           |
| 39       | 33.54       | 24.18    | 92.21             | 70.49   | 70.95         | 2          | 7.10           |
| 40       | 31.57       | 24.14    | 93.28             | 76.51   | 23.80         | 2          | 5.00           |
| 41       | 31.01       | 22.72    | 92.75             | 67.46   | 1.20          | 2          | 7.80           |
| 42       | 30.80       | 20.33    | 94.41             | 62.58   | 0             | 0          | 5.40           |
| 43       | 29.22       | 21.04    | 94.84             | 70.16   | 1.40          | 1          | 7.20           |
| 44       | 30.09       | 18.52    | 95.10             | 55.26   | 0.00          | 0          | 7.40           |
| 45       | 29.25       | 15.10    | 96.08             | 48.65   | 4.02          | 1          | 8.40           |
| 46       | 28.12       | 16.25    | 94.70             | 55.58   | 2.20          | 1          | 7.50           |
| 47       | 27.42       | 13.12    | 96.42             | 49.89   | 0.00          | 0          | 8.00           |
| 48       | 25.23       | 11.21    | 95.26             | 46.45   | 0.00          | 0          | 7.90           |
| 49       | 25.67       | 15.28    | 95.10             | 57.25   | 7.23          | 1          | 5.00           |
| 50       | 25.39       | 11.75    | 94.78             | 51.11   | 0.00          | 0          | 6.70           |
| 51       | 24.92       | 8.99     | 95.20             | 46.20   | 0.00          | 0          | 6.70           |
| 52       | 25.20       | 9.12     | 94.58             | 45.61   | 0.00          | 0          | 5.00           |

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema



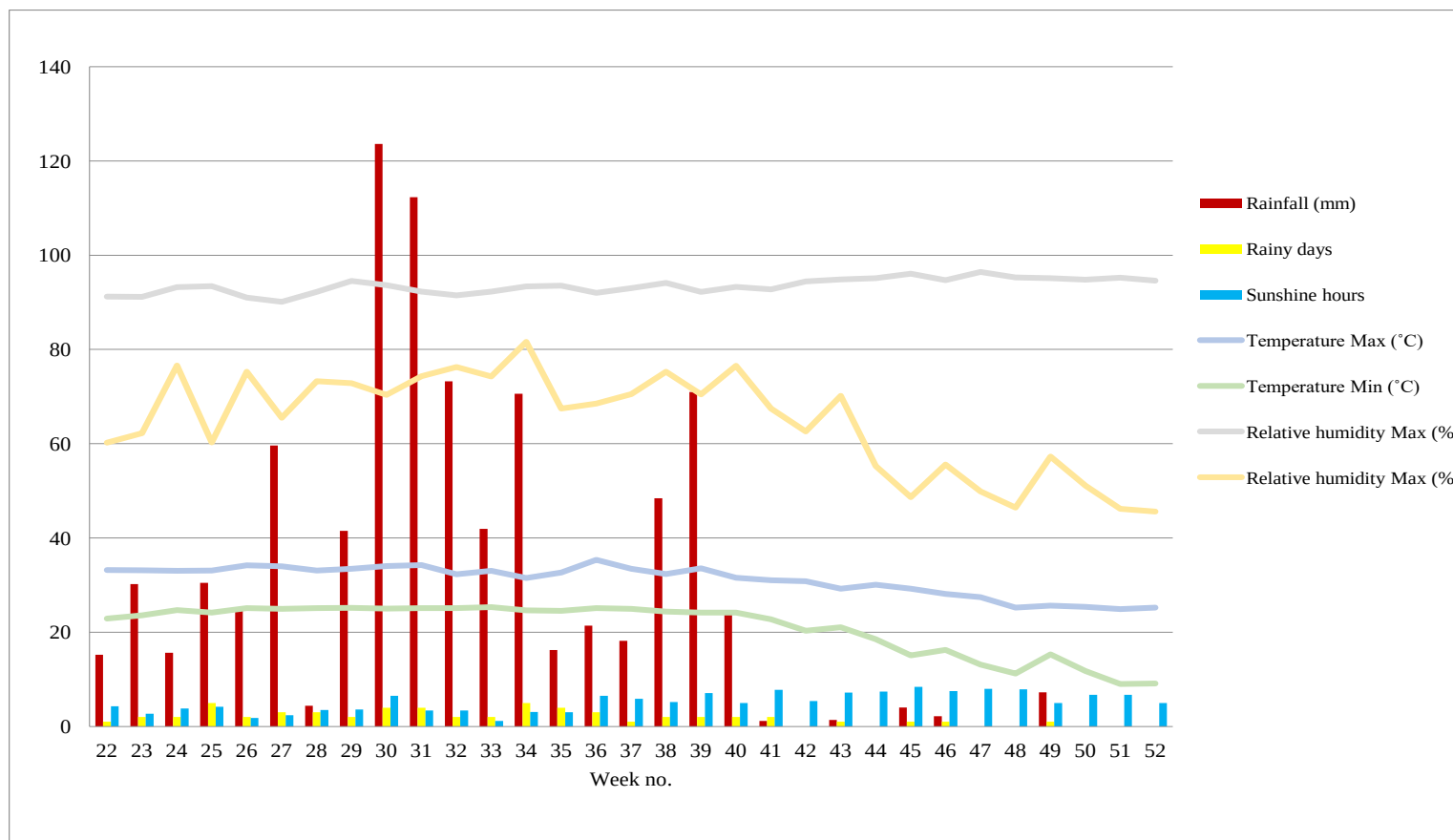


**Fig. 3.2: Graphical representation of meteorological data during crop growing season (*kharif* 2023)**

### **3.1.3 Soil condition**

The soil condition of the experimental plot was well drained, low in pH and high in organic carbon. To determine the fertility status of the soil, soil samples were collected from a depth of 0-15 cm from different locations using soil auger, mixed, air dried, grinded and sieved for analysis of different parameters following standard procedures as mentioned in Table 3.3.

## **3.2 Details of experimental techniques**

### **3.2.1 Design and experimental layout**

The field experiment was laid out in split plot design (SPD) with fourteen treatment combinations consisting of two tillage practices as the main plot and seven green manuring treatments as sub-plots including control, which were replicated thrice. The whole experimental field was divided into four equal blocks (main plot) and each block was again divided into twenty-one equal-sized subplots measuring 3m x 2m to accommodate the green manuring treatments. The details of the plan and layout of the experimental field have been presented in Figure 3.3.

**Table 3.3: Initial soil properties of the experimental field**

| Characteristics                                                               | Methods employed                                                             | Initial       |                 |
|-------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------|-----------------|
|                                                                               |                                                                              | Content       | Inference       |
| <b>Soil pH</b>                                                                | Glass electrode pH meter<br>(1: 2.5 soil and water ratio)<br>(Jackson, 1973) | <b>5.50</b>   | <b>Acidic</b>   |
| <b>Total acidity</b><br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> }            | Kappen method<br>(Baruah and Barthakur, 1997)                                | <b>11.18</b>  | -               |
| <b>Exchangeable acidity</b><br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> }     | Sokolov method<br>(Baruah and Barthakur, 1997)                               | <b>2.53</b>   | -               |
| <b>Organic carbon content (%)</b>                                             | Walkley and Black method<br>(Walkley and Black, 1934)                        | <b>2.05</b>   | <b>High</b>     |
| <b>Cation exchange capacity</b><br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> } | Centrifuge method<br>(Baruah and Barthakur, 1997)                            | <b>10.30</b>  | <b>Moderate</b> |
| <b>Available N (kg ha<sup>-1</sup>)</b>                                       | Alkaline Potassium Permanganate<br>method<br>(Subbiah and Asijia, 1956)      | <b>376.32</b> | <b>Medium</b>   |
| <b>Available P (kg ha<sup>-1</sup>)</b>                                       | Bray's No. 1 method<br>(Bray and Krutz, 1945)                                | <b>11.81</b>  | <b>Low</b>      |
| <b>Available K (kg ha<sup>-1</sup>)</b>                                       | Neutral Normal Ammonium Acetate<br>Method<br>(Hanway and Heidal, 1952)       | <b>152.14</b> | <b>Medium</b>   |
| <b>Bulk density (g cm<sup>-3</sup>)</b>                                       | Pycnometer method<br>(Majumdar and Singh, 2000)                              | <b>1.31</b>   | <b>Ideal</b>    |
| <b>Particle density (g cm<sup>-3</sup>)</b>                                   | Pycnometer method<br>(Baruah and Barthakur, 1997)                            | <b>2.57</b>   | -               |
| <b>Hydraulic conductivity</b><br>(cm hr <sup>-1</sup> )                       | Constant head method<br>(Klute, 1965)                                        | <b>11.65</b>  | <b>Moderate</b> |
| <b>Water holding capacity (%)</b>                                             | Keen Rackzowski boxes<br>(Piper, 1966)                                       | <b>42.50</b>  | -               |

|                                                                                       |                                                              |               |   |
|---------------------------------------------------------------------------------------|--------------------------------------------------------------|---------------|---|
| <b>Mean weight diameter (mm)</b>                                                      | Yoder's apparatus<br>(Van Bavel, 1950)                       | <b>2.01</b>   | - |
| <b>Percent aggregates &gt;0.25 mm (%)</b>                                             | Yoder's apparatus<br>(Van Bavel, 1950)                       | <b>80.16</b>  | - |
| <b>Soil microbial biomass carbon (<math>\mu\text{g g}^{-1}</math> soil)</b>           | Fumigation extraction method<br>(Vance <i>et al.</i> , 1987) | <b>200.32</b> | - |
| <b>Soil respiration (<math>\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}</math>)</b> | Alkali entrapment method<br>Anderson, 1982                   | <b>10.08</b>  | - |

### 3.2.2 Experimental details

The experiment which was conducted consisted of the following components:

- a. Crop : Maize (*Zea mays* L.)
- b. Variety : RCM-76
- c. Duration : 120 days
- d. Experimental Design : Split Plot Design (SPD)
- e. Number of factors : 2
- f. Number of treatment combination : 14
- g. Number of replication : 3
- h. Total no. of plots : 42
- i. Plot size : 3m x 2m
- j. Spacing : 60cm x 25cm
- k. Fertilizer doses : 120:60:40 (N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O)

### 3.2.3 Treatment details

#### 3.2.3.1 Main plot

The two forms of tillage practices implemented in the main plots are described below-

- |                         |                   |
|-------------------------|-------------------|
| 1. Minimum tillage      | (T <sub>M</sub> ) |
| 2. Conventional tillage | (T <sub>C</sub> ) |

### 3.2.3.2 Sub-plot

Seven green manuring composition allotted in the sub-plots are described below-

- |                                                                                                                              |                   |
|------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1. Control                                                                                                                   | (G <sub>0</sub> ) |
| 2. Green manuring through Dhaincha @ 2 tonnes ha <sup>-1</sup>                                                               | (G <sub>1</sub> ) |
| 3. Green manuring through Dhaincha @ 4 tonnes ha <sup>-1</sup>                                                               | (G <sub>2</sub> ) |
| 4. Green manuring through Cowpea @ 2 tonnes ha <sup>-1</sup>                                                                 | (G <sub>3</sub> ) |
| 5. Green manuring through Cowpea @ 4 tonnes ha <sup>-1</sup>                                                                 | (G <sub>4</sub> ) |
| 6. Green manuring through Dhaincha (1 t ha <sup>-1</sup> ) and Cowpea (1 t ha <sup>-1</sup> )<br>@ 2tonnes ha <sup>-1</sup>  | (G <sub>5</sub> ) |
| 7. Green manuring through Dhaincha (2 t ha <sup>-1</sup> ) and Cowpea (2 t ha <sup>-1</sup> )<br>@ 4 tonnes ha <sup>-1</sup> | (G <sub>6</sub> ) |

### 3.2.3.3 Treatment combinations

A total of 14 treatment combinations were acquired from the multiplication of two main factors and seven sub-factors.

| Treatment combination                                                         | Symbols                       |
|-------------------------------------------------------------------------------|-------------------------------|
| Minimum tillage + Control                                                     | T <sub>M</sub> G <sub>0</sub> |
| Minimum tillage + Green manuring through Dhaincha @ 2 tonnes ha <sup>-1</sup> | T <sub>M</sub> G <sub>1</sub> |
| Minimum tillage + Green manuring through Dhaincha @ 4 tonnes ha <sup>-1</sup> | T <sub>M</sub> G <sub>2</sub> |
| Minimum tillage + Green manuring through Cowpea @ 2 tonnes ha <sup>-1</sup>   | T <sub>M</sub> G <sub>3</sub> |

|                                                                                                                                               |                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Minimum tillage + Green manuring through Cowpea @ 4 tonnes ha <sup>-1</sup>                                                                   | T <sub>M</sub> G <sub>4</sub> |
| Minimum tillage + Green manuring through Dhaincha (1 t ha <sup>-1</sup> ) and Cowpea (1 t ha <sup>-1</sup> ) @ 2 tonnes ha <sup>-1</sup>      | T <sub>M</sub> G <sub>5</sub> |
| Minimum tillage + Green manuring through Dhaincha (2 t ha <sup>-1</sup> ) and Cowpea (2 t ha <sup>-1</sup> ) @ 4 tonnes ha <sup>-1</sup>      | T <sub>M</sub> G <sub>6</sub> |
| Conventional tillage + Control                                                                                                                | T <sub>C</sub> G <sub>0</sub> |
| Conventional tillage + Green manuring through Dhaincha @ 2 tonnes ha <sup>-1</sup>                                                            | T <sub>C</sub> G <sub>1</sub> |
| Conventional tillage + Green manuring through Dhaincha @ 4 tonnes ha <sup>-1</sup>                                                            | T <sub>C</sub> G <sub>2</sub> |
| Conventional tillage + Green manuring through Cowpea @ 2 tonnes ha <sup>-1</sup>                                                              | T <sub>C</sub> G <sub>3</sub> |
| Conventional tillage + Green manuring through Cowpea @ 4 tonnes ha <sup>-1</sup>                                                              | T <sub>C</sub> G <sub>4</sub> |
| Conventional tillage + Green manuring through Dhaincha (1 t ha <sup>-1</sup> ) and Cowpea (1 t ha <sup>-1</sup> ) @ 2 tonnes ha <sup>-1</sup> | T <sub>C</sub> G <sub>5</sub> |
| Conventional tillage + Green manuring through Dhaincha (2 t ha <sup>-1</sup> ) and Cowpea (2 t ha <sup>-1</sup> ) @ 4 tonnes ha <sup>-1</sup> | T <sub>C</sub> G <sub>6</sub> |

### 3.3 Agronomic practices

The details regarding the various agronomical practices conducted during the research period is presented below.

#### 3.3.1 Selection and preparation of field

A newly cleared forest area with no slope was selected for the investigation in the experimental farm of the Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus. Two levels of tillage practices *i.e.* minimum and conventional tillage were implemented as main plot. For minimum tillage only primary tillage was implemented with tractor drawn cultivator and for conventional tillage, cultivator was used for primary tillage and rotavator for secondary tillage followed by harrowing and planking. For sub plots, the green manuring crop which is to be incorporated into the soil was grown *ex-situ* for this experiment. Before flowering *i.e.* 30 DAS the green manures were slashed and chopped, and prepared for incorporation. The green manures were incorporated 45 days before sowing of crop for proper decomposition.

### **3.3.2 Design and layout**

After the tillage operations were completed, as per procedure and statistical design (Split plot design) of the field plots were laid out there was two main plots and seven subplots. The first main plot was transformed to minimum tillage (only primary tillage using tractor drawn cultivator was initiated) and conventional tillage (primary as well as secondary tillage operations were performed using tractor drawn cultivator and rotavator). A total of 42 plots were obtained with 21 subplots in each main plot having a gross plot size of 17 m × 10 m, and the subplot was 3 m × 2 m each. Appropriate care was taken for drainage in the field and other soil loss measures. Bunds were constructed subsequently for good drainage. The layout of the experiment has been presented in Fig 3.3.

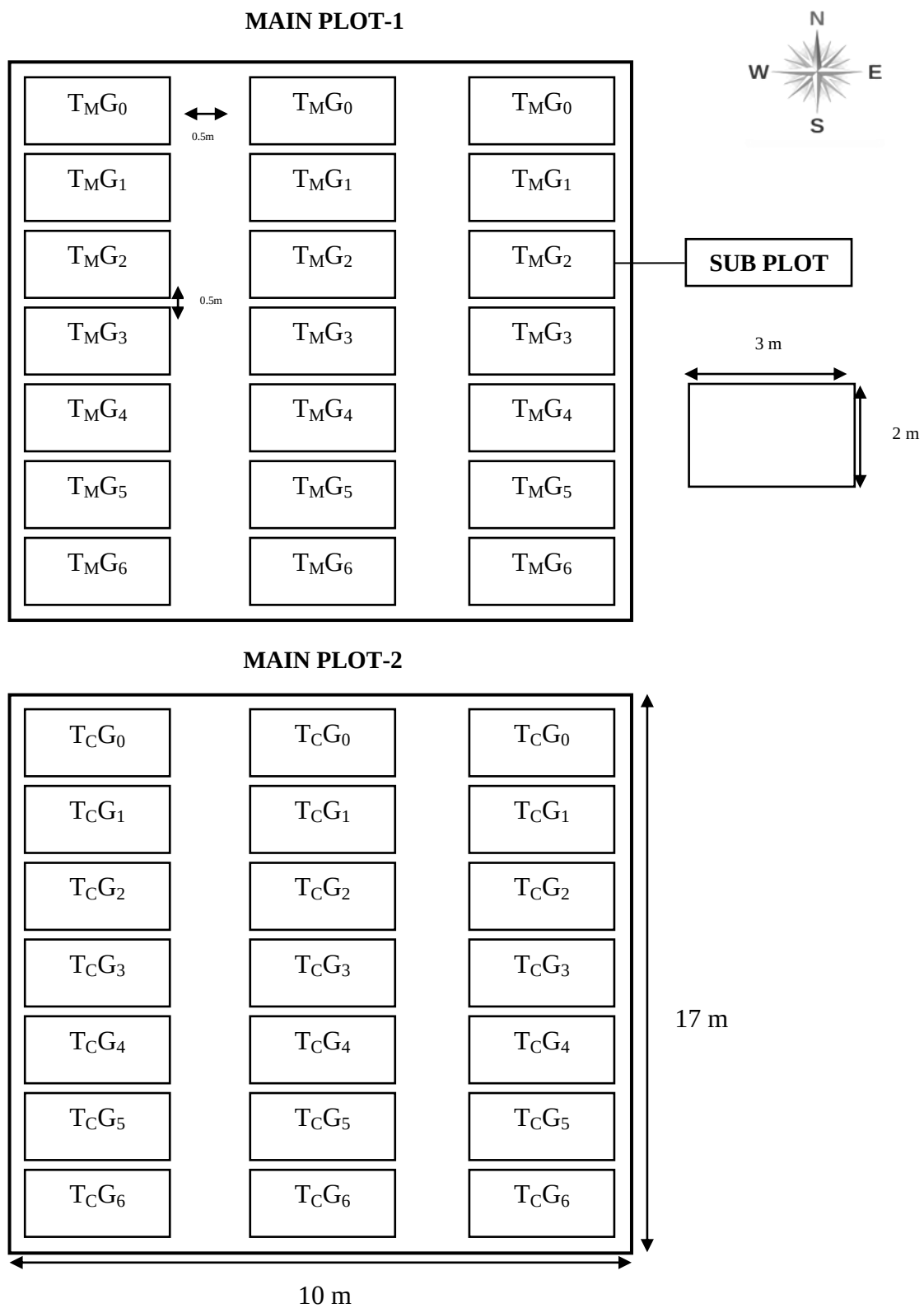


**Fig 3.3: Field layout of the experiment (Split Plot Design)**



### **3.3.3 Fertilizers application**

The recommended dose fertilizer nitrogen, phosphorus and potassium @ 120:60:40 kg ha<sup>-1</sup> through Urea (46.6% N), SSP (16% P<sub>2</sub>O<sub>5</sub>) and MOP (60% K<sub>2</sub>O), respectively were applied in each plot as basal dose mixed with the soil. The green manures were chopped using manual chaff cutter and machete on the field and incorporated 45 days before sowing of crop for proper decomposition.

### **3.3.4 Seed rate and method of sowing**

Maize seeds @ 20 kg ha<sup>-1</sup> were sown on May 15, 2022, and May 16, 2023, respectively. The seeds were sown with a dibbler at a depth of 2 cm - 5 cm maintaining a 60 cm × 25 cm plant to plant spacing.

### **3.3.5 Irrigation**

For proper germination and crop establishment, irrigation was provided as and when required especially in the critical stage of water requirement by the maize crop and depending on the rainfall received.

### **3.3.6 Intercultural operations**

After the germination of seeds, thinning of maize seedlings was initiated to maintain optimum plant population. Manual hand weeding was done at every 15 days' interval to control weeds. Inspection and monitoring of insects, pest and hand picking of insect larvae were conducted from time to time and proper care was provided as and when required at all stages of plant growth.

### **3.3.7 Harvesting and threshing**

The crop was harvested plot-wise when physiological maturity of the plant was attained and drying of leaves and cobs were observed. Hand picking of cobs were conducted and the stover was slashed and left on the field to sundry to take stover weight. After the harvest, cobs were left to dry in the sun and shelling of cob was done and the obtained seeds were sun dried. The seeds were weighed with the

help of a weighing balance and recorded for each plot after cleaning by winnowing. The plant stover was weighed after sun drying for individual plot. Stover was also collected to conduct analysis for plant parameters.

### **3.4 Soil analysis**

For determination of initial soil and after the harvest of crop, soil samples were collected from various locations of the experimental field at 0-15cm depth to evaluate various soil properties.

- pH
- Total acidity
- Exchangeable acidity
- Soil organic carbon
- Cation exchange capacity
- Available N, P and K
- Bulk density
- Particle density
- Hydraulic conductivity
- Water holding capacity
- Mean weight diameter
- Percent aggregates > 0.25 mm (%)
- Soil microbial biomass carbon
- Soil respiration

The soil samples were collected with the help of soil auger from different spots on the field up to a depth of 0-15cm. The soil samples were collected for evaluation of various soil properties. From each sub plots three kg of soil were collected from three different spots, mixed thoroughly and discarded to retain about 1kg as representative soil sample. The samples were dried under the shade at room temperature and grinded with rollers to pass through 2mm sieve. The remaining portion of soil samples was preserved for analysis of mean weight diameter (Van

Bavel, 1950). The final soil samples collected from individual plots after harvest of crops were analysed for various soil properties.

#### **3.4.1 Soil sample collection and preparation for analysis**

The soil samples were collected in a zig-zag manner from the surface from up to 0-15 cm depth after harvest to assess the variation in the soil properties. From each sub plots three kg of soil were collected from three different spots, mixed thoroughly and discarded to retain about 1kg as representative soil sample. The samples were dried under the shade at room temperature and grinded with rollers to pass through 2mm sieve. The remaining portion of soil samples was preserved for analysis of mean weight diameter (Van Bavel, 1950).

##### **3.4.1.1 pH**

The pH of the soil was determined in soil: water (1:2.5) ratio of water suspension using glass electrode as described by Jackson (1973).

##### **3.4.1.2 Total acidity {cmol (p<sup>+</sup>) kg<sup>-1</sup>}**

The total acidity of the soil was determined using the procedure given by Kappen and was expressed in {cmol (p<sup>+</sup>) kg<sup>-1</sup>} as outlined by Baruah and Barthakur (1997).

##### **3.4.1.3 Exchangeable acidity {cmol (p<sup>+</sup>) kg<sup>-1</sup>}**

The exchangeable acidity of the soil was determined using the procedure given by Sokolov and was expressed in {cmol (p<sup>+</sup>) kg<sup>-1</sup>} as outlined by Baruah and Barthakur (1997).

##### **3.4.1.4 Organic carbon content (%)**

The rapid titration method was used to determine the organic carbon content of the soil as outlined by Walkley and Black (1934). It was expressed in percentage as described by Jackson (1973).

#### **3.4.1.5 Cation exchange capacity {cmol (p<sup>+</sup>) kg<sup>-1</sup>}**

The cation exchange capacity of the soil was determined by centrifuge method as outlined by Baruah and Barthakur (1997). It was expressed in {cmol (p<sup>+</sup>) kg<sup>-1</sup>}.

#### **3.4.1.6 Available nitrogen (kg ha<sup>-1</sup>)**

Available Nitrogen was estimated by alkaline potassium permanganate method given by Subbiah and Asija (1956). It was expressed in terms of kg ha<sup>-1</sup>.

#### **3.4.1.7 Available phosphorus (kg ha<sup>-1</sup>)**

The available soil phosphorus was determined by Bray's No. 1 method as illustrated by Bray and Kurtz (1945) using 0.03 N NH<sub>4</sub>F + 0.025 N HCL (pH 3.5) as the extracting solution. In the filtered extract, phosphorus was estimated calorimetrically by adding ammonium molybdate and stannous chloride. The intensity (% transmittance) of characteristics blue color in the solution gives the measure for the concentration of P in the test solution, which was read in the spectrometer at 660 nm wavelength. After getting the % transmittance of the P in the test solution, the concentration of P was read from the standard curve. This method is primarily meant for soils that have moderate to strong acids with a pH of around 5.5 or less. The results were then expressed in kg ha<sup>-1</sup>.

#### **3.4.1.8 Available potassium (kg ha<sup>-1</sup>)**

Available potassium content in soil was determined by the neutral normal ammonium acetate method (Jackson, 1973). In the filtered extract, K was determined using a flame photometer (Hanway and Heidal, 1952). Neutral normal NH<sub>4</sub>OAc (pH= 7.0) was used as an equilibrium solution to exchange the exchangeable K ions of the soil. Available potassium content in the soil solution was converted to available K<sub>2</sub>O and expressed in terms of kg ha<sup>-1</sup>.

#### 3.4.1.9 Bulk density (g cm<sup>-3</sup>)

The bulk density of the soil was determined by pycnometer method as described by Majumdar and Singh (2000) and expressed in g cm<sup>-3</sup>.

$$\text{Bulk density (g cm}^{-3}\text{)} = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of soil (cm}^3\text{)}}$$

#### 3.4.1.10 Particle density (g cm<sup>-3</sup>)

The particle density of the soil was determined by pycnometer method as described by (Baruah & Barthakur, 1997). It was expressed in g cm<sup>-3</sup>.

$$\text{Particle density (g cm}^{-3}\text{)} = \frac{\text{weight of soil solids (g)}}{\text{volume of soil solids (cm}^3\text{)}}$$

#### 3.4.1.11 Hydraulic conductivity (cm hr<sup>-1</sup>)

To determine hydraulic conductivity, soil samples were collected in brass cylindrical rings with the help of a core sampler (0.08 m diameter ring). It was determined as per the constant head method (Klute, 1965) by using the following equation:

$$K_s = \frac{Vx}{At (\Delta H + x)}$$

Where,

K<sub>s</sub> = saturated hydraulic conductivity (cm sec<sup>-1</sup>)

V = Volume of water collected (cm<sup>3</sup>)

A = Cross-sectional area (cm<sup>2</sup>)

(ΔH + x) = Difference in head at inlet and outlet (cm)

t = time (hr)

#### 3.4.1.12 Water holding capacity (%)

The water holding capacity was determined using Keen Raczkowski boxes as described by Piper (1966). The soil samples were kept in Keen Raczkowski boxes

with uniform tapping and saturated overnight. After saturation, the samples are weighed and kept in the oven for 48 hours at an equilibrium temperature of 105°C. The samples were then cooled and weighed. The water holding capacity was calculated by the weight difference and expressed in percentage (%).

#### **3.4.1.13 Percent aggregates >0.25 mm and mean weight diameter (mm)**

For the determination of percent aggregates, air-dried natural clod samples (200 g) were broken by gentle pressure manually and passed through 2 mm mesh sieves. The sieves of all the required sizes were arranged in the order of 2 mm, 1 mm, 0.5 mm, 0.075 mm. The clod samples were kept on top and the nest of the sieves was immersed in water for 30 minutes in Yoder's apparatus. The fractions obtained in each sieve were collected and oven dried at an equilibrium temperature of 105°C for 24 hours. The dried samples were weighed and expressed as per cent of the original sample. These are the percent aggregation of different sizes. The per cent aggregation of different individual sizes gave the percentage of total aggregates.

The mean weight diameter (MWD) was calculated from the equation given by Van Bavel (1950): -

$$\text{MWD} = \sum_{i=1}^N x_i d_i$$

Where,

$x_i$  = Mean diameter of each size fraction, and

$d_i$  = Proportion by weight of each size fraction

Summation of all the fractions > 0.25 mm in wet sieving gave per cent macro-aggregates.

#### **3.4.1.14 Soil microbial biomass carbon ( $\mu\text{g g}^{-1}$ soil)**

Soil microbial biomass carbon (SMBC) was determined by using the fumigation extraction method as described by Vance *et al.* (1987). Ethanol-free chloroform was used to fumigate the fresh soil samples in a vacuum desiccator. After

24 hrs, the vacuum was released and fumigated soil samples along with their non-fumigated counterparts were extracted with 0.5 M K<sub>2</sub>SO<sub>4</sub>. The filtered extract was titrated against 0.005 N ferrous ammonium sulphate after adding K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>, conc. H<sub>2</sub>SO<sub>4</sub> and conc. H<sub>3</sub>PO<sub>4</sub> in the presence of diphenylamine indicator. Thereafter, the total weight of extractable carbon in fumigated and non-fumigated soil samples was calculated. SMBC was calculated by using the following formula:

$$\text{SMBC } (\mu\text{g g}^{-1} \text{ soil}) = E_{\text{CF}} - E_{\text{CNF}} / K_{\text{EC}}$$

Where,

$E_{\text{CF}}$  = Total weight of extractable C in fumigated soil sample

$E_{\text{CNF}}$  = Total weight of extractable C in non-fumigated soil sample

$K_{\text{EC}}$  = Calibration factor  $\sim 0.38$

#### **3.4.1.15 Soil respiration ( $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ )**

Soil respiration is determined by taking 50 g of soil in a desiccator beaker where 20 ml of 1 N NaOH taken in a test tube to be kept in the desiccators for a period of 7 days. The beakers are tightly sealed with the help of paraffin wax. After the required period the NaOH solution is titrated against 1 N HCl with a pinch of barium chloride until the milky pink coloration disappears. It is expressed in  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ . Alkali entrapment method as described by Anderson (1982) was employed for determining the soil respiration.

### **3.5 Determination of soil moisture status**

To determine the status of soil moisture, soil samples were collected from individual plot at every 30 days' interval and were determined gravimetrically using Keen Rackzowaski boxes (Piper, 1996). Soil moisture was determined using the formula:

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where,

$W_1$  = Weight of empty can

$W_2$  = Weight of moist soil + can

$W_3$  = Weight of oven dried soil + can

### **3.6 Estimation of quality and chemical analysis of plant materials of maize**

#### **3.6.1 Protein content in maize seed (%)**

To determine the protein content in maize seed firstly the nitrogen content value of the seed was worked out and the value was multiplied by 6.25 to get the protein content maize seed. The protein content (%) of maize seed was estimated by using the formula as described by (Anonymous, 1965):

$$\text{Crude protein (\%)} = \text{Nitrogen content in seed (\%)} \times 6.25$$

#### **3.6.2 Carbohydrate content in maize seed (%)**

Total carbohydrates content in maize seed were calculated by subtracting from 100 the sum of the crude protein, fat, ash, and crude fibre values (per 100g). The carbohydrate content (%) of maize seed was estimated by using the formula as described by (Anonymous, 1984):

$$\text{Carbohydrate (g/100g)} = 100 - (\text{moisture} + \text{crude fiber} + \text{ash} + \text{crude protein} + \text{fat})$$

#### **3.6.3 Estimation of oil content in maize seed (%)**

The oil content (%) in the seed was determined by referring the Soxhlet ether extraction method (Anonymous, 1960). Seed samples of 5g each were taken and crushed to powder for extraction of oil. The samples were transferred in a thimble



pre-weighed oil flask which was attached to the Soxhlet assembly and extracted with light petroleum ether (A.R. Grade 60 °C - 80 °C) for 6 hours in a Soxhlet extraction unit as per the method described by the Association of Official Analytical Chemists (1960). After extraction, the extract was transferred to a weight flask kept in a hot air oven at 80°C for half an hour or till the last traces of solvent and moisture were removed. The flask was then cooled in desiccators and the weight of the oil was recorded after a constant weight was obtained. From the weight of the oil, the oil content percentage in the seed was calculated using the following formula:

**Per cent oil =**

Where,

$W_2$  = weight of the empty flask (g)

$W_1$  = weight of the empty flask + weight of oil (g)

$W$  = weight of sample taken for extraction (g)

#### **3.6.4 Determination of ash content in maize seed (%)**

For estimation of ash content in maize seed, 5 g of the dried seed samples was weighed in to a dry crucible and then heated in a muffle furnace at 600 °C for 2 hours. It was cooled in desiccator and weighed as described in (Anonymous, 1940): The percentage ash content was calculated using the formula:

$$\% \text{ ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

#### **3.6.5 Chemical analysis of plant materials**

After threshing the plant materials i.e. seed and stover were separated, air dried and finally oven dried at a temperature of 60°C to 70°C to attain a constant

weight. The seed and stover were then grinded in a willy mill, kept in polythene bags and labelled accordingly for chemical analysis.

### **3.6.5.1 N, P and K content in seed and stover (%)**

#### **3.6.5.1.1 Nitrogen**

Half a gram powdered sample was digested with concentrated  $\text{H}_2\text{SO}_4$  in presence of digestion mixture ( $\text{CuSO}_4 + \text{K}_2\text{SO}_4$ ) till the digest gave clear bluish green colour. The digested sample or aliquot was further diluted carefully with distilled water to a known volume. Then a known volume of aliquot was transferred to distillation unit (Micro Kjeldhal apparatus) and liberated ammonia was titrated in boric acid containing mixture indicator. Later it was titrated against standard  $\text{H}_2\text{SO}_4$  and the amount of ammonia liberated was estimated in the form of nitrogen as per the procedure given by Black (1965). It was expressed in  $\text{g kg}^{-1}$ .

#### **Digestion of plant samples for other nutrients**

Half a gram grinded sample was pre-digested with concentrated nitric acid for overnight. Further, pre-digested sample was treated with di-acid (nitric acid perchloric acid in the ratio of 10:4) mixture and kept on hot plate for digestion till the colorless thread like structure was obtained. After complete digestion precipitate was dissolved in 6 N HCl and transferred to 100ml volumetric flask through Whatman No. 42 filter paper and finally the volume of extract was made to 100ml with double distilled water and preserved for further analysis.

#### **3.6.5.1.2 Phosphorous**

Phosphorous in plant was determined by vanadomolybdo-phosphorous yellow color method as outlined by Jackson 1973 by using spectrophotometer at 470 nm.

### **3.6.5.1.3 Potassium**

Potassium in plant samples was determined by flame photometer as described by Chapman and Pratt, 1961.

### **3.6.5.2 N, P and K uptake in seed and stover (kg ha<sup>-1</sup>)**

Nutrient uptake is obtained by multiplying the nutrient content of seed or stover with seed or stover yield and is expressed in kg ha<sup>-1</sup>. The uptake of nutrients was computed by using the formula as follows:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\% in seed or stover)} \times \text{seed or stover yield (kg ha}^{-1}\text{)}}{100}$$

## **3.7 Recordings of yield and yield attributes of maize**

### **3.7.1 Growth attributes**

Five randomly selected, healthy plants were tagged. Observation was carried out on the selected plants and all the findings were recorded. Plant sampling periodically was conducted in both years to observe plant growth attributes.

#### **3.7.1.1 Plant height (cm)**

The plant height of maize was recorded from five tagged plants. The height was recorded from the base of the plant till the flag leaf for 30, 60, 90 and at harvest and was expressed in cm. The average plant height was calculated for each treatment/plot and the mean was computed.

### **3.7.2 Yield attributes and yield**

#### **3.7.2.1 Number of cobs per plant**

At harvest, the cobs of maize were collected from the five tagged plants separately for each plot, counted and the average was figured and recorded.

### 3.7.2.2 Length of cob (cm)

The length of cob was measured in cm. After the harvest of maize cobs, length of cob was measured individually from the five tagged plants and the result was recorded and the average was work out.

### 3.7.2.3 Number of grains per cob

The number of grains per cob was calculated after harvesting and shelling the cob individually from the five tagged plant and the grains were counted and its average was computed and recorded.

### 3.7.2.4 Grain yield (kg ha<sup>-1</sup>)

The harvested cobs were initially sun dried; after the appropriated moisture was attained the cobs were shelled and winnowed. The grain weight of each plot was taken on an individual plot basis and then expressed in terms of kg ha<sup>-1</sup> using the formula:

$$\text{Seed yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the seed per plot (kg)}}{\text{Size of the plot (m}^2\text{)}} \times 10000$$

### 3.7.2.5 Stover yield (kg ha<sup>-1</sup>)

After harvesting of cobs, the maize plants were allowed to be sundried for some days in their respective plots. Subsequently after drying, the stovers were tied in bundles separately for each treatment. The stover yield of each plot was obtained using weighing balance. The recorded weight was expressed in kg ha<sup>-1</sup>. The formula used to compute the stover yield is as follows:

$$\text{Stover yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the stover per plot (kg)}}{\text{Size of the plot (m}^2\text{)}} \times 10000$$

### **3.8 Statistical analysis**

The data recorded during the study were statistically analysed and computed in a split plot design (SPD) using the technique of Analysis of Variance as described by Gomez and Gomez (1984). The significance differences were tested by the 'F' test. Critical difference (CD) of different groups of treatments and their interactions at a 5% probability level were calculated whenever the 'F' test was significant.



Plate No. 1: General view of the experimental plot



Plate No. 2: Field preparation





Plate No. 3: Cultivation of dhaincha for green manuring



Plate No. 4: Cultivation of cowpea for green manuring





Plate No. 5: Development of maize cob



Plate No. 6: Harvested maize cobs



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## **CHAPTER IV**

### **RESULTS AND DISCUSSION**

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## **RESULTS AND DISCUSSION**

In this chapter, a brief and concise discussing relating to the findings from the two years' investigation is documented and tabulated. Data's related to the investigation are included and reflected through appropriate tables and graphs and provided as evidence of the research. Results are meticulously supported by studies conducted by various researchers and scholars. Detailed discussion on the findings is outlined in this chapter.

### **4.1 Effect of tillage and green manuring on soil properties and soil moisture status**

The observations of diverse aspects of soil properties like Soil pH, total acidity, exchangeable acidity, organic carbon content, cation exchange capacity (CEC), bulk density, particle density, hydraulic conductivity, water holding capacity, mean weight diameter, percent aggregates, available N, P and K, soil microbial biomass carbon (SMBC) and soil respiration including soil moisture status @ 30, 60, 90 and at harvest as influenced by tillage and green manuring are tabulated and summarized under the following headings.

#### **4.1.1 Soil pH**

The data and findings recorded from the two-year investigation and their pooled average on soil pH involving minimum and conventional tillage and incorporation of green manuring assorted proportion cultivating maize (*Zea mays* L.) with their interaction effect is concisely summarized in Table 4.1(a) and 4.1(b) and visually illustrated in Fig 4.1(a) and 4.1(b).

#### 4.1.1.1 Effect of tillage on soil pH

The soil pH was apparent to be elevated in both the years of field study with the implementation of conventional tillage ( $T_C$ ). In the first year of investigation *i.e.* 2022 elevated pH was obtained with the employment of  $T_C$  (5.74) while pH in minimum tillage ( $T_M$ ) was measured at 5.72. Similar trend was observed in the second year (2023) where the acquired soil pH was higher in  $T_C$  (5.77) and while  $T_M$  was at (5.75) presenting an increase of 0.34% in soil pH. The pooled average of 2022 and 2023 presented similar result to that of first and second year where  $T_C$  (5.76) was prominent than  $T_M$  (5.74) in managing the soil pH. Due to the innate ability of minimum tillage to enhance organic matter accumulation in the top soil, the pH of the soil typically lowers unlike conventional tillage practice, where the soil is mixed vigorously within all the layers making the acidifying elements more broaden. Crop residues also concentrate in the upper soil profile which promotes acidification process. It was observed that reduction in soil pH was observed with the implementation of no till or minimum tillage. About 1.33% reduction in soil pH was observed with the use of reduced tillage like no till or minimum tillage as compared to conventional tillage practice. This result may be because in reduced tillage practice organic matter decomposition tends to lower pH of the soil (Muindi *et al.*, 2023).

#### 4.1.1.2 Effect of green manuring on soil pH

Table 4.1(a) and Fig 4.1(a) outline and illustrate the diverse findings of data associated to soil pH as influenced by the incorporating green manures. In the initial year (2022) the most notable recorded pH was achieved in the plot  $G_6$  *i.e.* green manuring through dhaincha (2 t ha<sup>-1</sup>) and cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup> with pH noted at 5.81 followed by  $G_2$  *i.e.* green manuring through dhaincha 4 t ha<sup>-1</sup> pH (5.78) while the least effective treatment was tabulated in plots where no green manures were added *i.e.*  $G_0$  containing pH of 5.53, this manifested a rise of soil pH by 5.06% and 4.52% respectively analyzing  $G_6$  and  $G_2$  against  $G_0$ . Matching outcome was also observed in the second year (2023) where 5.97% escalation in soil pH was perceived computing  $G_6$  (5.85) with  $G_0$  (5.52). The pooled average signified a proliferation in

soil pH by 5.61% and 4.89% when elevated values of  $G_6$  *i.e.* green manuring through dhaincha ( $2 \text{ t ha}^{-1}$ ) and cowpea ( $2 \text{ t ha}^{-1}$ ) @ 4 tonnes  $\text{ha}^{-1}$  with (5.83) soil pH and  $G_2$  *i.e.* green manuring through dhaincha  $4 \text{ t ha}^{-1}$  (5.79) soil pH correspondingly equated with the least efficient treatment *i.e.* ( $G_0$ ) control with soil pH (5.52). The release of basic cations and organic acids which neutralizes the soil pH and the contribution of alkaline minerals produced during the decomposition of green manures, the soil which are integrated with green manures may increase the soil pH. Incorporation of green manures may slightly increase the soil pH by 0.19% but a significant increase in available phosphorus ( $18.47 \text{ kg ha}^{-1}$ ) and organic carbon by ( $25 \text{ mg L}^{-1}$ ) was observed. The maximum effect was observed in the rhizospheric zone of the plant. This observation was at par with the findings of Azimzadeh *et al.*, (2015).

#### 4.1.1.3 Interaction effect

The details associated to interaction effect of tillage and green manuring received from the two-year rigorous study conducted in the *kharif* seasons of 2022 and 2023 in soil under maize crop cultivation and its consequence on soil pH is determined in Table 4.1(b) and visually illustrated in Fig 4.1(b). The highest soil pH in 2022 *i.e.* the initial year of study was distinguished in the treatment combination  $T_C G_6$  *i.e.* conventional tillage + dhaincha ( $2 \text{ t ha}^{-1}$ ) and cowpea ( $2 \text{ t ha}^{-1}$ ) @ 4 tonnes  $\text{ha}^{-1}$  which recorded soil pH of 5.82 and subsequently by  $T_M G_6$  *i.e.* minimum tillage + green manures through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  (5.80) followed by  $T_C G_2$  *i.e.* conventional tillage + green manuring through dhaincha @  $4 \text{ t ha}^{-1}$  (5.79) and the least efficient treatment combination was attained in  $T_M G_0$  *i.e.* minimum tillage + control with pH of 5.52, this indicated a growth of pH by 5.43%, 5.07% and 4.89% respectively. Parallel trend to that of initial year was also identified in the second year (2023) where the interaction between  $T_C G_6$  (5.85),  $T_M G_6$  (5.84) and  $T_C G_2$  (5.82) was manifested as the most efficient treatment combinations concerning soil pH, likewise the least efficient combination was noted in  $T_M G_0$  (5.51). These findings demonstrated a growth in pH by 6.17%, 5.98% and 5.62% respectively. The pooled data revealed that soil pH resulting in the interaction of  $T_C G_6$  (5.84) was perceived to be the highest among all the treatment combination, subsequently by

$T_M G_6$  (5.82) and  $T_C G_2$  (5.81). A measurable per cent gain of soil pH by 5.79%, 5.43% and 5.25% was observed assessing  $T_C G_6$ ,  $T_M G_6$  and  $T_C G_2$  contrary to  $T_M G_0$ .

#### 4.1.2 Total acidity

Table 4.1(a) and 4.1(b) and Fig 4.2(a) and Fig 4.2(b) present the facts and figures associated with total acidity of soil as persuaded by the merger of tillage and green manuring and its interaction of the two-year analysis are outlined and described below.

##### 4.1.2.1 Effect of tillage on total acidity

In the initial year (2022) of investigation, elevated observation was recorded in the data analysis of total acidity of soil. Initial year saw the use of ( $T_M$ ) minimum tillage noted the total acidity of soil at  $\{10.83 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and ( $T_C$ ) conventional tillage at  $\{10.79 \text{ cmol (p}^+) \text{ kg}^{-1}\}$ , presenting 0.37% increase of total acidity in soil. The second year (2023) minimum tillage ( $T_M$ ) accumulated total acidity at  $\{10.79 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and  $\{10.77 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  with conventional tillage ( $T_C$ ) practice. Parallel outcome was observed in the pooled average data with minimum tillage  $\{10.81 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  presented elevated total acidity as compared to conventional tillage  $\{10.78 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  where 0.27% increase in total acidity of soil adopting minimum tillage was acknowledged. As minimum tillage induces less soil disturbance it may retain more organic acid especially in the soil surface. The microbial population may thrive in this environment making organic matter decomposition more inevitable which in turn produces more hydrogen ion and may reduce the pH of the soil to a greater extent which ultimately increases the total acidity. The acidity factors like total acidity, soil pH, exchangeable acidity etc. are totally dependent types of tillage employed and depth of soil. Considerable to significant increase in total acidity of the soil was found in the soil where no tillage and minimum tillage system were employed as compared to conventional tillage system. This may be because build-up of hydrogen ions ( $H^+$ ) may be more in reduced tillage system than in extensive tillage operation (Zhao *et al.*, 2021). Parallel findings were also reported by Ebelhar *et al.* (2011).

#### 4.1.2.2 Effect of green manuring on total acidity

The recorded data affiliated with total acidity of soil via the incorporation of green manures is documented in Table 4.1(a) and exemplified in Fig 4.2(a). In 2022, elevated values of total acidity of soil were validated in ( $G_0$ ) control plot with  $\{11.15 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  total acidity. Incorporation of green manures seemed to reduce the total acidity as the lowest total acidity *i.e.*  $\{9.84 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  which was attained with the application of green manuring through dhaincha @  $4 \text{ t ha}^{-1}$  *i.e.* ( $G_2$ ) and subsequently by ( $G_6$ ) green manuring through dhaincha ( $2 \text{ t ha}^{-1}$ ) and cowpea ( $2 \text{ t ha}^{-1}$ ) @  $4 \text{ tonnes ha}^{-1}$   $\{10.90 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and ( $G_4$ ) green manuring through cowpea @  $4 \text{ t ha}^{-1}$   $\{10.92 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  presenting a decrease of 11.74%, 2.24% and 2.06% decrease in total acidity incorporating green manures indicating a significant finding. In the following year of cultivation (2023) total acidity of  $\{11.16 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  was observed in  $G_0$  which was the highest while ( $G_2$ ) recorded  $\{9.82 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  reducing the total acidity to the lowest among all green manure treated plot indicating 12% decrease adopting  $G_2$ . Pooled data revealed parallel outcome analyzing the total acidity it was exposed that  $G_0$   $\{11.15 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  was the most efficient and effective in maintaining total acidity and  $G_2$   $\{9.83 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  which was the least efficient followed by  $G_6$  where the total acidity was  $\{10.87 \text{ cmol (p}^+) \text{ kg}^{-1}\}$ . The role of alkaline organic matter and microbes which neutralizes hydrogen ions comes into play when green manures are added into the soil making the soil to increase the pH of the soil which eventually reduces the total acidity.

#### 4.1.2.3 Interaction effect

Outcomes of the analyzed data concerning the interaction effect of tillage and green manuring implementation is presented in Table 4.1(b) and depicted in Fig 4.2(b).  $T_M G_0$  *i.e.* minimum tillage with control proved to be superior over all the other treatment combinations with the total acidity computing to  $11.16 \text{ cmol (p}^+) \text{ kg}^{-1}$  and  $T_C G_2$  *i.e.* conventional tillage + green manuring through dhaincha @  $4 \text{ t ha}^{-1}$  was verified to have the lowest total acidity  $\{9.76 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  in the initial year (2022) followed by  $T_M G_2$  *i.e.* minimum tillage + green manuring through dhaincha @  $4 \text{ t ha}^{-1}$   $\{9.91 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  presenting upsurge of 14.34% and 12.61% in total

acidity adopting  $T_M G_0$  against  $T_M G_2$  and  $T_M G_2$ . Comparable inclination in the findings was observed in the following year (2023) which showed an escalation of total acidity by 14.28% calculating  $T_M G_0$  {11.20 cmol ( $p^+$ )  $kg^{-1}$ } against  $T_C G_2$  {9.80 cmol ( $p^+$ )  $kg^{-1}$ }. The pooled average inclined in similar development where the peak finding was verified in  $T_M G_0$  {11.18 cmol ( $p^+$ )  $kg^{-1}$ } and  $T_C G_2$  {9.78 cmol ( $p^+$ )  $kg^{-1}$ } attained the lowest performing combination subsequently by  $T_M G_2$  {9.87 cmol ( $p^+$ )  $kg^{-1}$ }, establishing an increase by 14.31% and 13.27% as and when  $T_M G_0$  was contrasted with  $T_C G_2$  and  $T_M G_2$  respectively. The drive of calcium ions from the deep layers of the soil especially subsoil as influenced by green manuring tends to reduce the acidity of the soil to a commendable extent. As compared to a fallow land, soil where green manures are employed the balance of acid-base is much more especially in the cultivated layer, which ultimately helps the plant development (Hospodarenko and Lysianskyi, 2016 and Qaswar *et al.*, 2019).

#### 4.1.3 Exchangeable acidity

Data and findings associated to the effect of tillage and green manuring on exchangeable acidity of soil cultivating maize (*Zea mays* L.) and their interaction is presented in Table 4.1 (a) and 4.1 (b) and represented in Fig 4.3 (a) and Fig 4.3 (b).

##### 4.1.3.1 Effect of tillage on exchangeable acidity

The exchangeable acidity of soil in the initial year (2022) unveiled that implementation of minimum tillage ( $T_M$ ) increased the exchangeable acidity of soil {2.37 cmol ( $p^+$ )  $kg^{-1}$ } relative to conventional tillage ( $T_C$ ) with an exchangeable acidity of {2.34 cmol ( $p^+$ )  $kg^{-1}$ } by 1.28%. A surge in 1.73% elevated exchangeable acidity was observed in the second year (2023) with the implementation of ( $T_M$ ) minimum tillage {2.35 cmol ( $p^+$ )  $kg^{-1}$ } to that of ( $T_C$ ) conventional tillage {2.31 cmol ( $p^+$ )  $kg^{-1}$ }. The elevated trend in exchangeable acidity with the use of minimum tillage was also followed in the pooled average where  $T_M$  attained {2.36 cmol ( $p^+$ )  $kg^{-1}$ } and  $T_C$  {2.33 cmol ( $p^+$ )  $kg^{-1}$ } exchangeable acidity in soil presenting an uplift of exchangeable acidity by 1.28%. It is observed that pH of the soil usually reduces in minimum tillage system as less disturbance is made in the upper layer of the soil,

this reduction in pH usually make the soil to increase the total and exchangeable acidity of the soil as organic acids and hydrogen ions are produced by the decomposition of residues. Stankowski *et al.* (2022) in their investigation concluded that Minimum tillage involves fewer disturbances in the soil, this process may increase the total and exchangeable acidity in the soil as it could reduce the integration of soil layers. This augment in soil acidity may involve a decrease in soil pH and increase in exchangeable aluminum and generally exchangeable acidity levels. Limited mixing of different soil layers under minimum tillage contributed largely in the accumulation of elements of acidity and reduces neutralization of acidic compounds. These outcomes were parallel with the findings of Reeves and Liebig, (2016).

#### **4.1.3.2 Effect of green manuring on exchangeable acidity**

Incorporation of green manures tends to reduce the exchangeable acidity of soil as evident by the finding of the initial year (2022). The highest exchangeable acidity in the first year of cultivation of maize was observed in plots where no green manures were applied ( $G_0$ ) *i.e.* control  $\{2.46 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  in contrast to ( $G_2$ ) *i.e.* green manuring through dhaincha @  $4 \text{ t ha}^{-1}$   $\{2.31 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and ( $G_6$ ) green manuring through dhaincha ( $2 \text{ t ha}^{-1}$ ) and cowpea ( $2 \text{ t ha}^{-1}$ ) @  $4 \text{ tonnes ha}^{-1}$   $\{2.32 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  this presented 6.09% and 5.69% reduction in total acidity of soil adopting  $G_2$  and  $G_6$  respectively in contrary to control ( $G_0$ ). The subsequent year (2023) also maintained similar consequence concerning total acidity of soil, where higher exchangeable acidity was reported in  $G_0$   $\{2.51 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  among all the sub plot treatment, while lower exchangeable acidity was noted in  $G_2$   $\{2.25 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and  $G_6$   $\{2.26 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  correspondingly which presented reduced exchangeable acidity of the soil *via* the use of green manures noted at 10.35% involving  $G_2$  and 11.06 and 9.96% utilizing  $G_6$  computed against  $G_0$ . Pooled average of the two-year investigation revealed similar outcome where 8.06% and 7.66% decrease in exchangeable acidity of soil was distinguished involving  $G_2$   $\{2.28 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  and  $G_6$   $\{2.29 \text{ cmol (p}^+) \text{ kg}^{-1}\}$  respectively contrary to  $G_0$   $\{2.48 \text{ cmol (p}^+) \text{ kg}^{-1}\}$ . Green manure incorporation in the soil leads to lower exchangeable acidity as



the compound released by microbial population binds acidic compounds like hydrogen and aluminum ions which ultimately increase the soil pH and the exchangeable acidity of the soil.

#### 4.1.3.3 Interaction effect

The details of facts and findings as obtained from the two-year rigorous investigation conducted during the *kharif* seasons of 2022 and 2023 and its pooled average is displayed and visually depicted in Table 4.1(b) and Fig 4.3(b). In the first year (2022) the combination of  $T_M G_0$  *i.e.* minimum tillage + control {2.51 cmol ( $p^+$ )  $kg^{-1}$ } demonstrated to increase the exchangeable acidity of soil to the highest extent in contrast to all the treatment combination, while the least efficient treatment combination was attained in the interaction of  $T_C G_2$  *i.e.* conventional tillage with green manuring through dhaincha @ 4 t  $ha^{-1}$  {2.30 cmol ( $p^+$ )  $kg^{-1}$ }. An increase of 9.13% in exchangeable acidity was observed in  $T_M G_0$  in contrast to  $T_C G_2$ . The second year followed comparable trend to that of first year where the recorded exchangeable acidity of  $T_M G_0$  was at {2.51 cmol ( $p^+$ )  $kg^{-1}$ } which was the peak among the combinations while the least efficient or the lowest exchangeable acidity was in  $T_C G_6$  was computed to {2.21 cmol ( $p^+$ )  $kg^{-1}$ } followed by  $T_C G_2$  *i.e.* Conventional tillage + dhaincha (2 t  $ha^{-1}$ ) and cowpea (2 t  $ha^{-1}$ ) @ 4 tonnes  $ha^{-1}$  {2.22 cmol ( $p^+$ )  $kg^{-1}$ }. Increase of 11.06% and 10.57% of exchangeable acidity was also observed comparing  $T_M G_0$  {2.51 cmol ( $p^+$ )  $kg^{-1}$ } with  $T_C G_2$  {2.26 cmol ( $p^+$ )  $kg^{-1}$ } and {2.27 cmol ( $p^+$ )  $kg^{-1}$ } from the pooled average records.

Zhu *et al.* (2024) quoted that the use of animal manures and green manuring may reduce the acidity characteristics of the soil by neutralizing acidifying compounds and also mitigating human related acidification of soil. The use of nitrogenous fertilizers may also reduce the soil acidity to some extent. Comparable outcomes were also revealed by Goda *et al.* (2025) and Aragon *et al.* (2019) where they found out that the use of green manures helped immensely to reduce the exchangeable acidity of the soil by lowering the net acid load and maintaining base cation levels. This conclusion was reported from a study in Southern China.

**Table 4.1 (a): Effect of tillage and green manuring on pH, total acidity and exchangeable acidity of the soil after harvest**

| Treatment             | pH    |       |        | Total acidity<br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        | Exchangeable acidity<br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        |
|-----------------------|-------|-------|--------|-------------------------------------------------------------|-------|--------|--------------------------------------------------------------------|-------|--------|
|                       | 2022  | 2023  | Pooled | 2022                                                        | 2023  | Pooled | 2022                                                               | 2023  | Pooled |
| <b>Tillage</b>        |       |       |        |                                                             |       |        |                                                                    |       |        |
| <b>T<sub>M</sub></b>  | 5.72  | 5.75  | 5.74   | 10.83                                                       | 10.79 | 10.81  | 2.37                                                               | 2.35  | 2.36   |
| <b>T<sub>C</sub></b>  | 5.74  | 5.77  | 5.76   | 10.79                                                       | 10.77 | 10.78  | 2.34                                                               | 2.31  | 2.33   |
| <b>SEm ±</b>          | 0.002 | 0.001 | 0.001  | 0.004                                                       | 0.002 | 0.002  | 0.003                                                              | 0.005 | 0.003  |
| <b>CD at 5%</b>       | 0.013 | 0.004 | 0.004  | 0.022                                                       | 0.011 | 0.008  | 0.020                                                              | 0.032 | 0.012  |
| <b>CV</b>             | 0.168 | 0.054 | 0.125  | 0.150                                                       | 0.074 | 0.119  | 0.655                                                              | 1.021 | 0.855  |
| <b>Green manuring</b> |       |       |        |                                                             |       |        |                                                                    |       |        |
| <b>G<sub>0</sub></b>  | 5.53  | 5.52  | 5.52   | 11.15                                                       | 11.16 | 11.15  | 2.46                                                               | 2.51  | 2.48   |
| <b>G<sub>1</sub></b>  | 5.76  | 5.80  | 5.78   | 10.98                                                       | 10.94 | 10.96  | 2.35                                                               | 2.32  | 2.33   |
| <b>G<sub>2</sub></b>  | 5.78  | 5.81  | 5.79   | 9.84                                                        | 9.82  | 9.83   | 2.31                                                               | 2.25  | 2.28   |
| <b>G<sub>3</sub></b>  | 5.73  | 5.77  | 5.75   | 10.95                                                       | 10.85 | 10.90  | 2.38                                                               | 2.35  | 2.36   |
| <b>G<sub>4</sub></b>  | 5.76  | 5.81  | 5.78   | 10.92                                                       | 10.88 | 10.90  | 2.36                                                               | 2.32  | 2.34   |
| <b>G<sub>5</sub></b>  | 5.75  | 5.79  | 5.77   | 10.96                                                       | 10.94 | 10.95  | 2.33                                                               | 2.30  | 2.31   |
| <b>G<sub>6</sub></b>  | 5.81  | 5.85  | 5.83   | 10.90                                                       | 10.85 | 10.87  | 2.32                                                               | 2.26  | 2.29   |
| <b>SEm ±</b>          | 0.008 | 0.003 | 0.004  | 0.007                                                       | 0.005 | 0.004  | 0.007                                                              | 0.005 | 0.004  |
| <b>CD @ 5%</b>        | 0.023 | 0.010 | 0.012  | 0.021                                                       | 0.016 | 0.013  | 0.021                                                              | 0.015 | 0.013  |
| <b>CV</b>             | 0.333 | 0.145 | 0.256  | 0.162                                                       | 0.121 | 0.143  | 0.748                                                              | 0.543 | 0.655  |

**T<sub>M</sub>**- Minimum tillage; **T<sub>C</sub>**- Conventional tillage; **G<sub>0</sub>**- Control; **G<sub>1</sub>**- Green manuring through Dhaincha @ 2 tonnes ha<sup>-1</sup>; **G<sub>2</sub>**- Green manuring through Dhaincha @ 4 tonnes ha<sup>-1</sup>; **G<sub>3</sub>**- Green manuring through Cowpea @ 2 tonnes ha<sup>-1</sup>; **G<sub>4</sub>**- Green manuring through Cowpea @ 4 tonnes ha<sup>-1</sup>; **G<sub>5</sub>**- Green manuring through Dhaincha (1 t ha<sup>-1</sup>) and Cowpea (1 t ha<sup>-1</sup>) @ 2 tonnes ha<sup>-1</sup>; **G<sub>6</sub>**- Green manuring through Dhaincha (2 t ha<sup>-1</sup>) and Cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup>; **SEm ±** - Standard Error of the mean; **CV**- Coefficient of variation; **CD**- Critical Difference

**Table 4.1 (b): Interaction effect of tillage and green manuring on pH, total acidity and exchangeable acidity of the soil after harvest**

| Treatments                        | pH    |       |        | Total acidity<br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        | Exchangeable acidity<br>{cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        |
|-----------------------------------|-------|-------|--------|-------------------------------------------------------------|-------|--------|--------------------------------------------------------------------|-------|--------|
|                                   | 2022  | 2023  | Pooled | 2022                                                        | 2023  | Pooled | 2022                                                               | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 5.52  | 5.51  | 5.52   | 11.16                                                       | 11.20 | 11.18  | 2.51                                                               | 2.51  | 2.51   |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 5.74  | 5.79  | 5.77   | 10.97                                                       | 10.95 | 10.96  | 2.34                                                               | 2.32  | 2.33   |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 5.76  | 5.80  | 5.78   | 9.91                                                        | 9.84  | 9.87   | 2.32                                                               | 2.28  | 2.30   |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 5.72  | 5.76  | 5.74   | 10.96                                                       | 10.83 | 10.90  | 2.40                                                               | 2.37  | 2.38   |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 5.75  | 5.80  | 5.78   | 10.94                                                       | 10.89 | 10.92  | 2.36                                                               | 2.35  | 2.35   |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 5.74  | 5.77  | 5.76   | 10.96                                                       | 10.94 | 10.95  | 2.33                                                               | 2.31  | 2.32   |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 5.80  | 5.84  | 5.82   | 10.90                                                       | 10.85 | 10.87  | 2.32                                                               | 2.30  | 2.31   |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 5.53  | 5.53  | 5.53   | 11.13                                                       | 11.11 | 11.12  | 2.42                                                               | 2.50  | 2.46   |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 5.77  | 5.81  | 5.79   | 10.98                                                       | 10.93 | 10.96  | 2.35                                                               | 2.31  | 2.33   |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 5.79  | 5.82  | 5.81   | 9.76                                                        | 9.80  | 9.78   | 2.30                                                               | 2.22  | 2.26   |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 5.74  | 5.77  | 5.76   | 10.93                                                       | 10.86 | 10.90  | 2.35                                                               | 2.32  | 2.34   |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 5.78  | 5.81  | 5.79   | 10.90                                                       | 10.87 | 10.89  | 2.35                                                               | 2.30  | 2.33   |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 5.77  | 5.80  | 5.78   | 10.96                                                       | 10.93 | 10.95  | 2.32                                                               | 2.29  | 2.31   |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 5.82  | 5.85  | 5.84   | 10.89                                                       | 10.85 | 10.87  | 2.32                                                               | 2.21  | 2.27   |
| <b>SEm ±</b>                      | 0.011 | 0.005 | 0.006  | 0.010                                                       | 0.008 | 0.006  | 0.010                                                              | 0.007 | 0.006  |
| <b>CD at 5%</b>                   | NS    | NS    | NS     | 0.030                                                       | 0.022 | 0.018  | 0.030                                                              | 0.021 | 0.018  |

**T<sub>M</sub>G<sub>0</sub>**- Minimum tillage + Control; **T<sub>M</sub>G<sub>1</sub>**- Minimum tillage + Green manuring through Dhaincha @ 2 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>2</sub>**- Minimum tillage + Green manuring through Dhaincha @ 4 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>3</sub>**- Minimum tillage + Green manuring through Cowpea @ 2 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>4</sub>**- Minimum tillage + Green manuring through Cowpea @ 4 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>5</sub>**- Minimum tillage + Green manuring through Dhaincha (1 t ha<sup>-1</sup>) and Cowpea (1 t ha<sup>-1</sup>) @ 2 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>6</sub>**- Minimum tillage + Green manuring through Dhaincha (2 t ha<sup>-1</sup>) and Cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup>, **T<sub>C</sub>G<sub>0</sub>**- Conventional tillage tillage + Control; **T<sub>C</sub>G<sub>1</sub>**- Conventional tillage tillage + Green manuring through Dhaincha @ 2 tonnes ha<sup>-1</sup>; **T<sub>C</sub>G<sub>2</sub>**- Conventional tillage tillage + Green manuring through Dhaincha @ 4 tonnes ha<sup>-1</sup>; **T<sub>C</sub>G<sub>3</sub>**- Conventional tillage tillage + Green manuring through Cowpea @ 2 tonnes ha<sup>-1</sup>; **T<sub>C</sub>G<sub>4</sub>**- Conventional tillage tillage + Green manuring through Cowpea @ 4 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>5</sub>**- Conventional tillage + Green manuring through Dhaincha (1 t ha<sup>-1</sup>) and Cowpea (1 t ha<sup>-1</sup>) @ 2 tonnes ha<sup>-1</sup>; **T<sub>M</sub>G<sub>6</sub>**- Conventional tillage + Green manuring through Dhaincha (2 t ha<sup>-1</sup>) and Cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup>; **SEm ±**- Standard Error of the mean; **CD**- Critical Difference

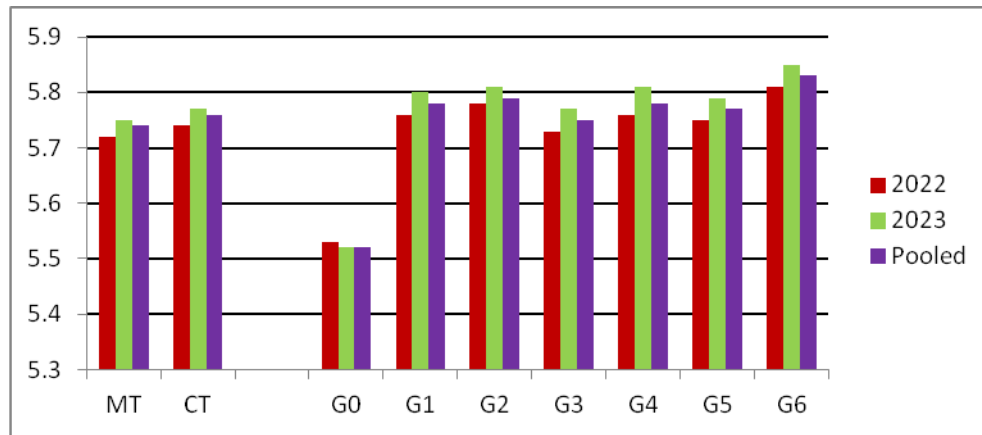


Fig. 4.1(a): Effect of tillage and green manuring on soil pH

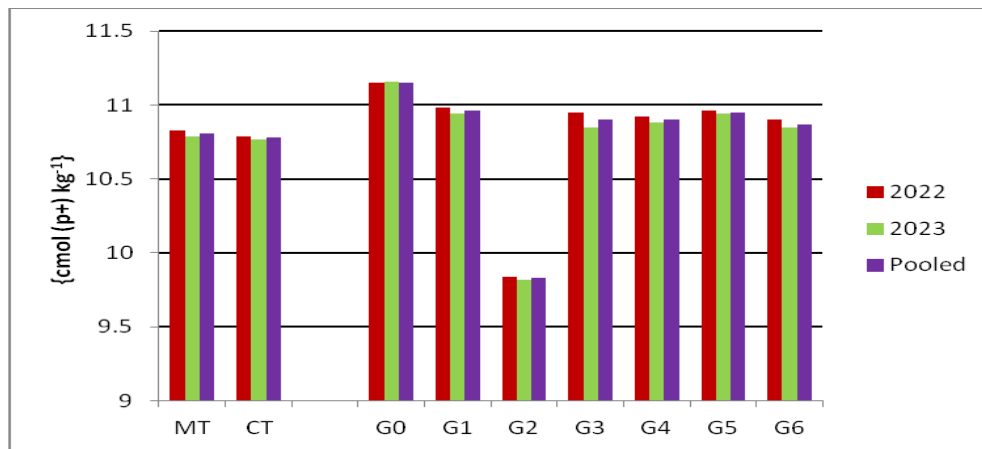


Fig. 4.2(a): Effect of tillage and green manuring on total acidity

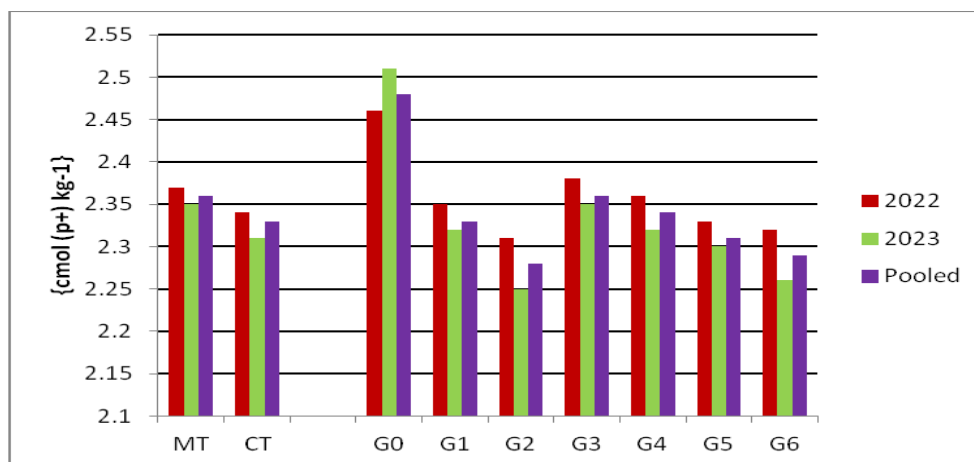


Fig. 4.3(a): Effect of tillage and green manuring on exchangeable acidity

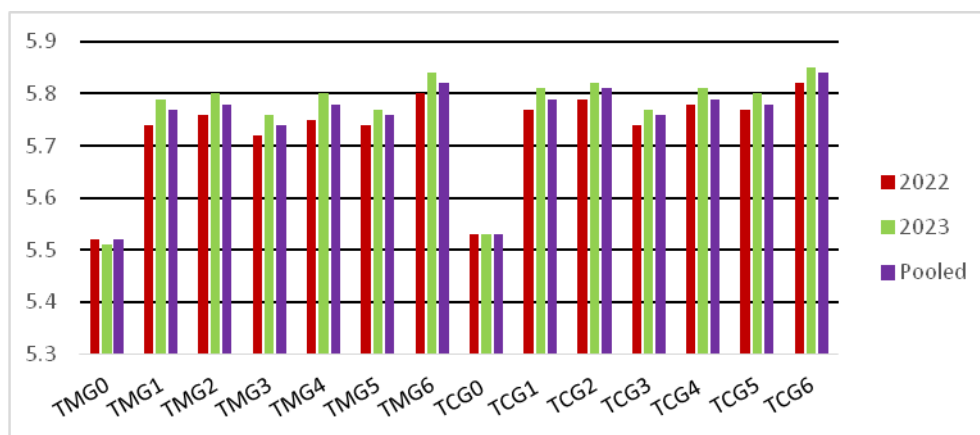


Fig. 4.1(b): Interaction effect of tillage and green manuring on soil pH

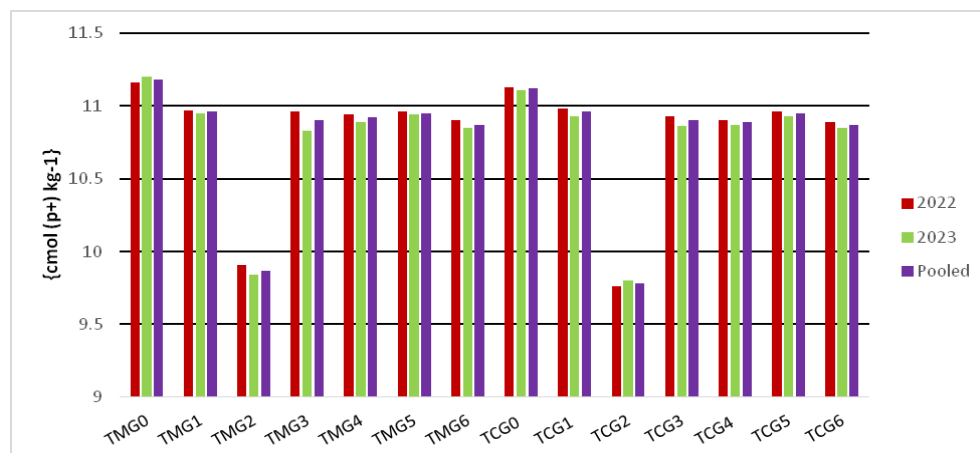


Fig. 4.2(b): Interaction effect of tillage and green manuring on total acidity

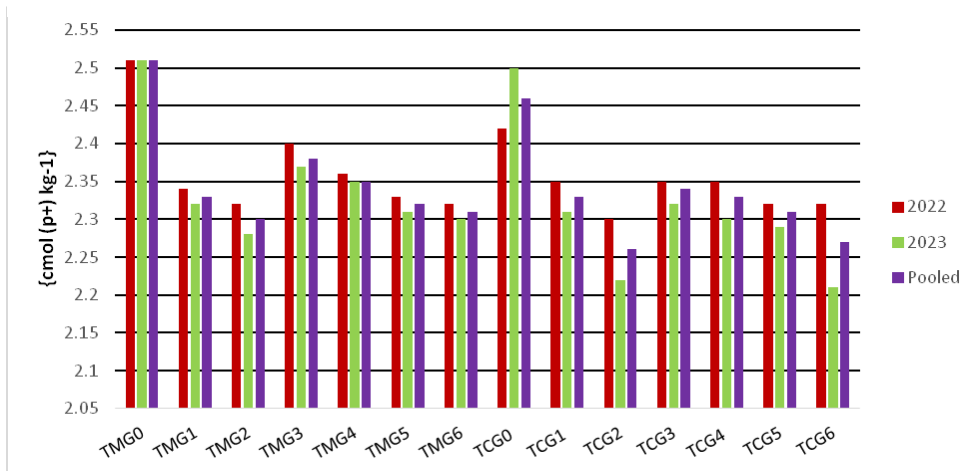


Fig. 4.3(b): Interaction effect of tillage and green manuring on exchangeable acidity

#### **4.1.4 Organic carbon content**

The associated findings concerning the organic carbon content of the soil as a consequence of adopting various tillage practices and integrating varied composition of green manuring and their interaction effect is presented in Table 4.2(a) and 4.2(b) and represented in Fig 4.4(a) and Fig 4.4(b).

##### **4.1.4.1 Effect of tillage on organic carbon content**

The details allied to organic carbon of the soil as influenced by minimum tillage and conventional tillage is provided in Table 4.2(a) and portrayed in Fig 4.4(a). The organic carbon content of the soil was observed to be increasing *via* the enforcement of conventional tillage ( $T_C$ ) rather than minimum tillage ( $T_M$ ). Implementation of  $T_C$  (2.17%) escalated the organic carbon content of the soil by 0.93% as compared to  $T_M$  (2.15%) in the initial year (2022). The second year (2023) resulted in the rise of organic carbon content in the soil by 1.38% contrasting the two tillage practices  $T_C$  (2.20%) and  $T_M$  (2.17%) organic carbon content respectively. In the pooled table similar outcome was observed where  $T_C$  with 2.18% organic carbon influence an increase in organic carbon content by 0.92% as compared to  $T_M$  (2.16%). The mixing of the soil in conventional tillage practice can overturn the crop residue into the soil which may lead to more organic carbon composition. As compared to no-till or minimum tillage practices, conventional tillage practice can break the soil aggregates and speed up the carbon decomposition process. Ozbolat *et al.* (2023) and De Mastro *et al.* (2020) reported that soil organic carbon content was observed to be increasing with the implementation of conventional tillage and green manuring combined. Addition of green manures typically increases the SOC sequestration by providing organic matter in the soil as different tillage system turns the soil and helps to distribute the nutrients evenly in the soil. Intensity of tillage practices, type of green manures and the condition of the initial soil also plays a major part.

##### **4.1.4.2 Effect of green manuring on organic carbon content**

Table 4.2(a) and Fig 4.4(a) precisely describes and represents the results obtained after analyzing the organic carbon content of the soil acquired from the two-year maize cultivated investigation field. The incorporation of green manures amended to the soil amplified the organic carbon content in the soil as backed by the details received from the first year in which addition of ( $G_2$ ) green manures via dhaincha @ 4 t ha<sup>-1</sup> (2.23%) which performed the best amongst all green manure treatment in the sub plot, this augmented the organic carbon of the soil by 7.21% in  $G_2$  in relation to  $G_0$  i.e. control (2.08%) which was the least competent treatment in the sub plot. Increase in organic carbon content in soil by 9.70% was observed with the introduction of green manure as  $G_2$  (2.26%) compared to control plot (2.06%) in the subsequent year (2023).  $G_2$  (2.25%) elevated the organic carbon content by 8.69% as compared to  $G_0$  which was at (2.07%) as reflected in the pooled average. With the addition of fresh green manures into the soil the microbial activity of the soil rejuvenates making the decomposition process faster and promotion of better nutrient cycling which improves the long-term carbon sequestration. Li *et al.* (2024) stated that 34.82% increase in soil organic carbon was observed with the application of green manures as compared to control or bare soil. This shows that green manures are vital in enhancing soil microbial activity, nutrient availability, improvement in soil structure and maintaining the health and productivity of soil. These outcomes were supported by Hu *et al.* (2022).

#### 4.1.4.3 Interaction effect

Table 4.2(b) and Fig 4.4(b) reflects the findings of the interaction effect which is associated with the two-year investigation as influenced by tillage and green manuring. The data for the initial experimental year (2022) reveals that treatment combination of  $T_C G_2$  i.e. conventional tillage with green manuring through dhaincha @ 4 t ha<sup>-1</sup> with (2.25%) organic carbon content and  $T_M G_2$  i.e. minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> (2.21%) which were superior in increasing the organic carbon content of the soil surpassing all the treatment combinations while  $T_M G_0$  i.e. minimum tillage + control with organic carbon content of (2.06%) was the least effective combination. The computation between the highest

and the lowest disclosed that an escalation of 9.22% and 7.28% respectively in organic carbon content was noted. Similar trend was followed in the second year of experimentation (2023) where augment of organic carbon by 12.25% and 9.31% was perceived in organic carbon content computing  $T_C G_2$  (2.29%) and  $T_M G_2$  (2.23%) contrary to  $T_M G_0$  (2.04%). The pooled table regarding the interaction between tillage and green manuring in relation to organic carbon content of the soil disclosed that  $T_C G_2$  (2.27%) and  $T_M G_2$  (2.22%) elevated the organic carbon content by 10.73 and 8.29% in relation to  $T_M G_0$  (2.05%).

#### **4.1.5 Cation exchange capacity**

Data pertaining to the findings of the two-year experimentation associated to cation exchange capacity of the soil as persuaded *via* the assimilation of tillage and incorporation of green manures in varied proportion is acknowledged in Table 4.2 (a) and 4.2 (b) and shown in Fig 4.5 (a) and Fig 4.5 (b).

##### **4.1.5.1 Effect of tillage on cation exchange capacity**

The specific details concerning the cation exchange capacity of the soil as impacted by tillage practices is given in Table 4.2 (a) and visually illustrated in Fig 4.5 (a). The cation exchange capacity of the soil as influenced by tillage practices in the initial year of experimentation reveals that significant increase in CEC was observed with the implementation of minimum tillage ( $T_M$ ) as compared to conventional tillage ( $T_C$ ) in both the experimental years, including the pooled average recordings. In the experimental year of 2022, the highest CEC was observed in the plots involving  $T_M$  {12.29 cmol ( $p^+$ )  $kg^{-1}$ } than  $T_C$  {12.14 cmol ( $p^+$ )  $kg^{-1}$ } presenting 1.23% elevated CEC of soil adopting  $T_M$ . Increase in cation exchange capacity was also observed in the subsequent year of the field experiment (2023) where 1.80% rise in CEC was observed involving  $T_M$  {12.40 cmol ( $p^+$ )  $kg^{-1}$ } and  $T_C$  {12.18 cmol ( $p^+$ )  $kg^{-1}$ }. Parallel outcome to that of first and second year of experimentation was also discovered in the pooled average data where augmentation of CEC of soil was observed involving  $T_M$  {12.35 cmol ( $p^+$ )  $kg^{-1}$ } where 1.56% increase in CEC of soil involving  $T_M$  was attained in contrary to  $T_C$  {12.16 cmol ( $p^+$ )



kg<sup>-1</sup>}. With the integration of minimum tillage preservation of organic matter in the soil and better maintenance of soil structure is induced, these helps the negatively charged ions to hold on to the cations helping the soil to maintain better CEC. Types of tillage system influence the cation exchange capacity of the soil significantly. The implementation of reduced tillage not only increased the cation exchange capacity of the soil but also the holding and exchange of nutrients was extensively enhanced (Carlos *et al.*, 2025 and Loke *et al.*, 2014).

#### 4.1.5.2 Effect of green manuring on cation exchange capacity

Addition of green manures as supplement to the soil significantly revitalized the cation exchange capacity of the soil as evident in Table 4.2(a) and Fig 4.5(a). The CEC of the soil was observed to be significant with the addition of green manures in both the years of experiment including the pooled average data. In the initial year higher values of CEC was obtained where G<sub>2</sub> *i.e.* green manuring through dhaincha @ 4 t ha<sup>-1</sup> was indulged {14.08 cmol (p<sup>+</sup>) kg<sup>-1</sup>} subsequently followed by G<sub>6</sub> *i.e.* dhaincha (2 t ha<sup>-1</sup>) and cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup> {13.51 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and G<sub>4</sub> *i.e.* green manures + cowpea @ 4 t ha<sup>-1</sup> {12.54 cmol (p<sup>+</sup>) kg<sup>-1</sup>} as opposed to G<sub>0</sub> *i.e.* control, where the CEC was {10.33 cmol (p<sup>+</sup>) kg<sup>-1</sup>} which was the lowest, specified 36.30%, 30.78% and 21.39% in G<sub>2</sub>, G<sub>6</sub> and G<sub>4</sub> relative to G<sub>0</sub>, respectively. The second year saw a rise of 37.99%, 32.84% and 22.35% contrasting G<sub>2</sub> {14.20 cmol (p<sup>+</sup>) kg<sup>-1</sup>}, G<sub>6</sub> {13.67 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and G<sub>4</sub> {12.59 cmol (p<sup>+</sup>) kg<sup>-1</sup>} with G<sub>0</sub> {10.29 cmol (p<sup>+</sup>) kg<sup>-1</sup>}. Increase of cation exchange capacity was also determined in the pooled average of 2022 and 2023 where G<sub>2</sub> {14.14 cmol (p<sup>+</sup>) kg<sup>-1</sup>}, G<sub>6</sub> {13.59 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and G<sub>4</sub> {12.57 cmol (p<sup>+</sup>) kg<sup>-1</sup>} elevated the CEC of the soil by 37.14%, 31.81% and 21.92% respectively in G<sub>2</sub>, G<sub>6</sub> and G<sub>4</sub> comparative to G<sub>0</sub> *i.e.* control {10.31 cmol (p<sup>+</sup>) kg<sup>-1</sup>}. Addition of green manures may provide organic matter into the soil especially the negatively charged ions like organic colloids and humus which in the long run may help the soil to hold positively charged ions like Ca, Mg and K. Organic matter content in the soil was significantly increased with the application of organic manures which in turn increased the cation exchange capacity of the soil as well as the total organic carbon in the soil as it may have improved the

ability to seize cations (Saria *et al.*, 2018). Comparable results were also highlighted by (Kumar *et al.*, 2024 and Pimentel *et al.*, 2023).

#### 4.1.5.3 Interaction effect

Documentation of fact and figures concerning the interaction effect as inclined by tillage and green manuring is presented in Table 4.2(b) and Fig 4.5(b). It is evident by the fact that  $T_MG_2$  *i.e.* minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> achieved higher CEC over all the treatment combination over two year of investigation. In the initial first year improvement in CEC of the soil was witnessed with the findings of  $T_MG_2$  *i.e.* minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> with CEC of {14.50 cmol (p<sup>+</sup>) kg<sup>-1</sup>} followed by  $T_CG_2$  *i.e.* conventional tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> {13.65 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and  $T_CG_6$  *i.e.* conventional tillage + dhaincha (2 t ha<sup>-1</sup>) and cowpea (2 t ha<sup>-1</sup>) @ 4 tonnes ha<sup>-1</sup> {13.52 cmol (p<sup>+</sup>) kg<sup>-1</sup>} these treatment combination providing elevated increase of CEC by 40.77%, 32.52% and 31.26% rise in CEC contrary to  $T_CG_0$  *i.e.* conventional tillage + control containing CEC of {10.30 cmol (p<sup>+</sup>) kg<sup>-1</sup>}. A rise of 43.65%, 33.98% and 33.69% was distinguished analyzing  $T_MG_2$  {14.71 cmol (p<sup>+</sup>) kg<sup>-1</sup>},  $T_CG_6$  {13.72 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and  $T_CG_2$  {13.69 cmol (p<sup>+</sup>) kg<sup>-1</sup>} with that of  $T_CG_0$  containing CEC of {10.24 cmol (p<sup>+</sup>) kg<sup>-1</sup>}, this was evident from the facts and findings involving the field study in the subsequent year (2023). Pooled data provided similar result to that of 2022 and 2023 where  $T_MG_2$  {14.61 cmol (p<sup>+</sup>) kg<sup>-1</sup>},  $T_CG_2$  {13.67 cmol (p<sup>+</sup>) kg<sup>-1</sup>} and  $T_CG_6$  {13.61 cmol (p<sup>+</sup>) kg<sup>-1</sup>} increase the CEC by 42.25%, 33.10% and 32.52% CEC of the soil respectively in comparison to  $T_CG_0$  comprising CEC of {10.27 cmol (p<sup>+</sup>) kg<sup>-1</sup>}.

**Table 4.2 (a): Effect of tillage and green manuring on organic carbon and cation exchange capacity of the soil after harvest**

| Treatment             | Organic carbon content (%) |       |        | Cation exchange capacity {cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        |
|-----------------------|----------------------------|-------|--------|---------------------------------------------------------------------|-------|--------|
|                       | 2022                       | 2023  | Pooled | 2022                                                                | 2023  | Pooled |
| <b>Tillage</b>        |                            |       |        |                                                                     |       |        |
| <b>T<sub>M</sub></b>  | 2.15                       | 2.17  | 2.16   | 12.29                                                               | 12.40 | 12.35  |
| <b>T<sub>C</sub></b>  | 2.17                       | 2.20  | 2.18   | 12.14                                                               | 12.18 | 12.16  |
| <b>SEm ±</b>          | 0.001                      | 0.002 | 0.001  | 0.004                                                               | 0.009 | 0.005  |
| <b>CD at 5%</b>       | 0.008                      | 0.013 | 0.005  | 0.025                                                               | 0.053 | 0.019  |
| <b>CV</b>             | 0.285                      | 0.441 | 0.372  | 0.152                                                               | 0.322 | 0.252  |
| <b>Green manuring</b> |                            |       |        |                                                                     |       |        |
| <b>G<sub>0</sub></b>  | 2.08                       | 2.06  | 2.07   | 10.33                                                               | 10.29 | 10.31  |
| <b>G<sub>1</sub></b>  | 2.14                       | 2.16  | 2.15   | 11.63                                                               | 11.76 | 11.70  |
| <b>G<sub>2</sub></b>  | 2.23                       | 2.26  | 2.25   | 14.08                                                               | 14.20 | 14.14  |
| <b>G<sub>3</sub></b>  | 2.15                       | 2.19  | 2.17   | 11.54                                                               | 11.60 | 11.57  |
| <b>G<sub>4</sub></b>  | 2.18                       | 2.21  | 2.20   | 12.54                                                               | 12.59 | 12.57  |
| <b>G<sub>5</sub></b>  | 2.18                       | 2.20  | 2.19   | 11.88                                                               | 11.93 | 11.91  |
| <b>G<sub>6</sub></b>  | 2.18                       | 2.21  | 2.20   | 13.51                                                               | 13.67 | 13.59  |
| <b>SEm ±</b>          | 0.003                      | 0.004 | 0.003  | 0.007                                                               | 0.010 | 0.006  |
| <b>CD @ 5%</b>        | 0.010                      | 0.013 | 0.008  | 0.020                                                               | 0.028 | 0.017  |
| <b>CV</b>             | 0.386                      | 0.501 | 0.448  | 0.139                                                               | 0.192 | 0.168  |

**Table 4.2 (b): Interaction effect of tillage and green manuring on organic carbon and cation exchange capacity of the soil after harvest**

| Treatments                        | Organic carbon content (%) |       |        | Cation exchange capacity {cmol (p <sup>+</sup> ) kg <sup>-1</sup> } |       |        |
|-----------------------------------|----------------------------|-------|--------|---------------------------------------------------------------------|-------|--------|
|                                   | 2022                       | 2023  | Pooled | 2022                                                                | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 2.06                       | 2.04  | 2.05   | 10.35                                                               | 10.33 | 10.34  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 2.12                       | 2.14  | 2.13   | 11.66                                                               | 11.81 | 11.74  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 2.21                       | 2.23  | 2.22   | 14.50                                                               | 14.71 | 14.61  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 2.15                       | 2.18  | 2.17   | 11.57                                                               | 11.65 | 11.61  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 2.17                       | 2.20  | 2.19   | 12.56                                                               | 12.63 | 12.60  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 2.17                       | 2.20  | 2.19   | 11.89                                                               | 11.97 | 11.93  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 2.17                       | 2.20  | 2.19   | 13.50                                                               | 13.72 | 13.61  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 2.09                       | 2.08  | 2.09   | 10.30                                                               | 10.24 | 10.27  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 2.15                       | 2.17  | 2.16   | 11.60                                                               | 11.71 | 11.66  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 2.25                       | 2.29  | 2.27   | 13.65                                                               | 13.69 | 13.67  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 2.15                       | 2.19  | 2.17   | 11.50                                                               | 11.55 | 11.53  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 2.19                       | 2.21  | 2.20   | 12.52                                                               | 12.56 | 12.54  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 2.18                       | 2.20  | 2.19   | 11.88                                                               | 11.90 | 11.89  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 2.19                       | 2.22  | 2.21   | 13.52                                                               | 13.61 | 13.57  |
| <b>SEm ±</b>                      | 0.005                      | 0.006 | 0.004  | 0.010                                                               | 0.014 | 0.008  |
| <b>CD at 5%</b>                   | 0.014                      | 0.018 | 0.011  | 0.029                                                               | 0.040 | 0.024  |

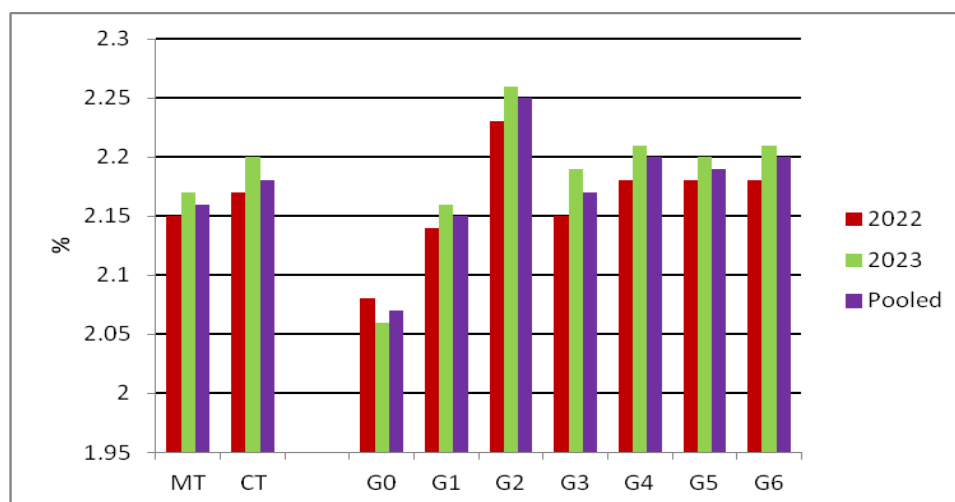


Fig. 4.4(a): Effect of tillage and green manuring on organic carbon content

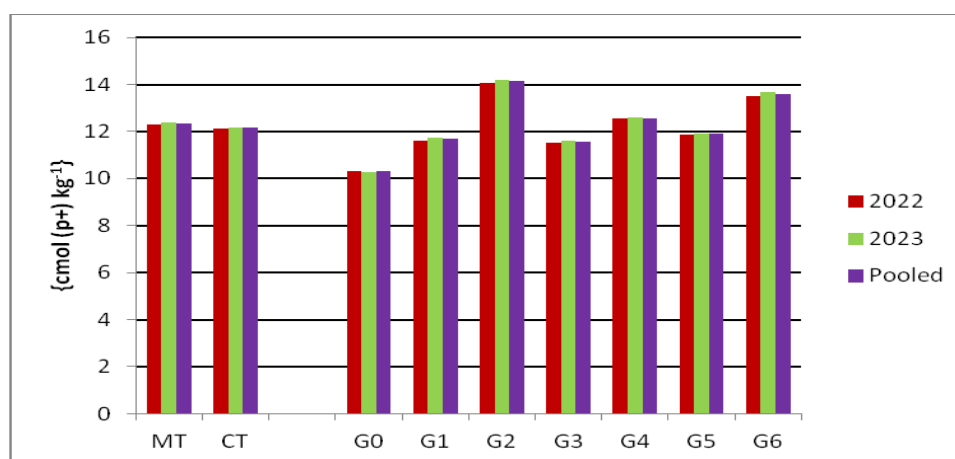


Fig. 4.5(a): Effect of tillage and green manuring on cation exchange capacity

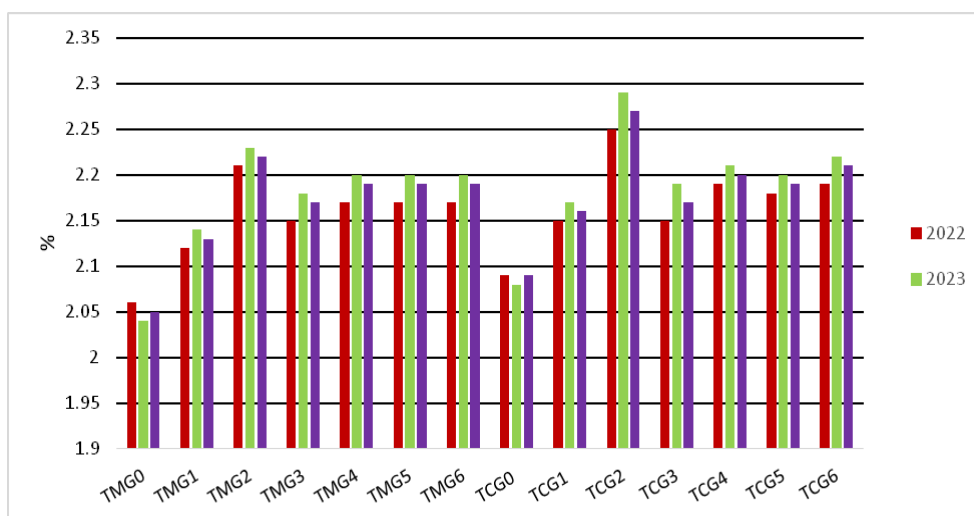


Fig. 4.4(b): Interaction effect of tillage and green manuring on organic carbon content

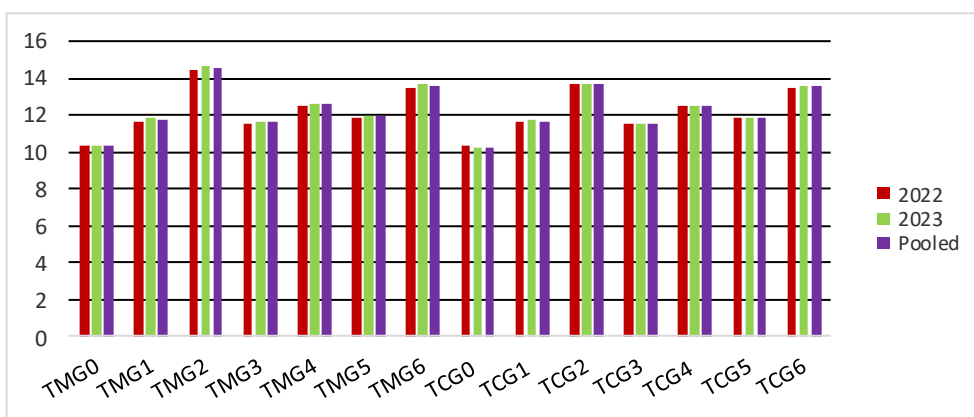


Fig. 4.5(b): Interaction effect of tillage and green manuring on cation exchange capacity

#### 4.1.6 Available nitrogen

Available nitrogen of soil as influenced by implementing and incorporating tillage and green manuring respectively is discussed in this segment. Facts and figures are provided in Table 4.3(a) and 4.3(b) and Fig 4.6(a) and Fig 4.6(b). This section thoroughly converses the achievements of the two-year research that was carried out on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.).

##### 4.1.6.1 Effect of tillage on available nitrogen

In this part of discussion, the results of the investigation focus on the main plot- tillage where available nitrogen was observed to manifest superior performance under ( $T_M$ ) minimum tillage ( $462.93 \text{ kg ha}^{-1}$ ) as distinguished from ( $T_C$ ) conventional tillage ( $436.05 \text{ kg ha}^{-1}$ ) showcasing 6.16% increase in available N in the initial year (2022). The second year (2023) of the experimental study revealed a progression of available N by 8.38% as  $T_M$  ( $501.76 \text{ kg ha}^{-1}$ ) was measured against  $T_C$  ( $462.93 \text{ kg ha}^{-1}$ ). With the support of the findings of the two-year research, the pooled data also leaned towards similar inclination to that of first and second year of study. The superiority of  $T_M$  as compared to  $T_C$  is validated in the provided pooled average table where elevation of 7.31% in available N was distinguished comparing  $T_M$  ( $482.35 \text{ kg ha}^{-1}$ ) with  $T_C$  ( $449.49 \text{ kg ha}^{-1}$ ). The ability of the minimum tillage to preserve and retain the organic matter obtained from the crop residues whilst maintaining the soil structure creates a favorable environment to promote mineralization of nitrogen and boost the nutrient cycling. Zulu *et al.* (2023) stated that no-tillage resulted in the highest concentrations of  $\text{NO}_3^-$  ( $7.728 \text{ mg kg}^{-1}$ ) and  $\text{NH}_4^+$  ( $0.762 \text{ mg kg}^{-1}$ ) which outclassed all other treatments. The lowest  $\text{NH}_4^+$  concentration ( $0.648 \text{ mg kg}^{-1}$ ) was observed in conventional tillage. In contrast,  $\text{NO}_3^-$  levels under conventional tillage ( $6.755 \text{ mg kg}^{-1}$ ) was higher than that of reduced tillage ( $4.720 \text{ mg kg}^{-1}$ ). It was observed that in 0-10 cm soil depth higher concentrations of both  $\text{NO}_3^-$  ( $6.787 \text{ mg kg}^{-1}$ ) and  $\text{NH}_4^+$  ( $0.851 \text{ mg/kg}$ ) was reported followed by the 20–30 cm depth ( $6.229 \text{ mg kg}^{-1}$ ) of  $\text{NO}_3^-$  and  $0.832 \text{ mg kg}^{-1}$   $\text{NH}_4^+$ . Karadihalli *et al.* (2024) and Xiao *et al.*,

2019) also reported similar outcomes where tillage operations especially reduced tillage practices enhanced the available N content in soil.

#### **4.1.6.2 Effect of green manuring on available nitrogen**

A significant increase in the accumulation of available N was observed via the merging of green manures in the soil as apparent from the two-year investigation and the pooled average data. In the first year of experimentation (2022), application of green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> *i.e.* G<sub>6</sub> (522.67 kg ha<sup>-1</sup>), G<sub>2</sub> *i.e.* green manuring through dhaincha @ 4 t ha<sup>-1</sup> (491.31 kg ha<sup>-1</sup>) and G<sub>4</sub> *i.e.* green manuring through cowpea @ 4 t ha<sup>-1</sup> (470.40 kg ha<sup>-1</sup>) significantly boosted the available N in the green manure treated plots by 51.51%, 42.42% and 36.36% respectively in sequence contrary to G<sub>0</sub> *i.e.* control with available N of (344.96 kg ha<sup>-1</sup>). Increase of available N was also observed in the succeeding year (2023) where the measured highest value of available N was witnessed in the plots where green manures through dhaincha (2 t ha<sup>-1</sup>) and cowpea (2 t ha<sup>-1</sup>) @ 4 t ha<sup>-1</sup> (554.03 kg ha<sup>-1</sup>) subsequently followed by (G<sub>2</sub>) green manuring through dhaincha @ 4 t ha<sup>-1</sup> (543.57 kg ha<sup>-1</sup>) and (G<sub>1</sub>) green manuring through dhaincha @ 2 t ha<sup>-1</sup> (512.21 kg ha<sup>-1</sup>) while the least efficient sub plot was noted in plot where no green manures were applied G<sub>0</sub> *i.e.* control (334.51 kg ha<sup>-1</sup>). Significant progression in available N was apparent in the provided pooled average table where the peak N availability was observed in the sub-plot of G<sub>6</sub> with available N (538.35 kg ha<sup>-1</sup>), G<sub>2</sub> (517.44 kg ha<sup>-1</sup>) and G<sub>1</sub> (475.63 kg ha<sup>-1</sup>) while the sub plot with the minimal impact on available N concentration was G<sub>0</sub> with 339.73 kg ha<sup>-1</sup> available N. An escalation in available N of the soil by 58.46%, 52.30% and 40% was manifested analyzing G<sub>6</sub>, G<sub>2</sub> and G<sub>1</sub> opposed to G<sub>0</sub> respectively. Green manures have a symbiotic relationship with nitrogen fixing bacteria. As the green manures are incorporated in the soil it decomposes and releases nutrients which are mineralized by soil microbes into ammonium and nitrate forms available to crops.



#### 4.1.6.3 Interaction effect

The diverse arrangement of tillage and green manuring and its influence on available N is provided in this sub-section, proof of the finding are presented in Table 4.3(b) and concisely illustrated in Fig 4.5(b). The information from the interaction effect table clearly indicates the positive impact of tillage and green manuring on available N of the soil. The most prominent available N in the first year (2022) was observed in the treatment combination of  $T_M G_6$  i.e. minimum tillage + green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> with available N of (543.57 kg ha<sup>-1</sup>) while  $T_C G_0$  i.e. conventional tillage + control accumulated available N of (313.60 kg ha<sup>-1</sup>) which proved to be least significant in improving available N showcasing 73.33% increase in  $T_M G_6$  over  $T_C G_0$ . Observations in the subsequent year (2023) substantiated that  $T_M G_6$  i.e. minimum tillage + green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (564.48 kg ha<sup>-1</sup>) expressed a signified increase in available N by 80% as compared to  $T_C G_0$  i.e. conventional tillage with control (313.60 kg ha<sup>-1</sup>). The trend relating to available N in soil with the introduction of minimum tillage and added green manures follows in the pooled average of 2022 and 2023 where 76.66% elevated available N was recorded with the implementation of  $T_M G_6$  (554.03 kg ha<sup>-1</sup>) contrary to  $T_C G_0$  (313.60 kg ha<sup>-1</sup>).

Xu *et al.* (2024) in their study asserted that considerably higher levels of NO<sub>3</sub><sup>-</sup> was observed in the soil with the application of green manures, which resulted in mended availability of nitrogen to the crops. While, discharge of N<sub>2</sub>O was recorded, the incorporation of green manures significantly reduced the leaching and volatilization of NH<sub>3</sub>. This finding suggests that the use of organic amendments via green manures can contribute to nitrogen accumulation as well as promote soil health and productivity. This finding was at par with the outcomes of Gu *et al.* (2021).

#### 4.1.7 Available phosphorus

Table 4.3(a) and 4.3(b) and Fig 4.7(a) and Fig 4.7(b), portrays the data and provide a graphical representation of the findings of the two-year analysis of the experimentation carried out in the *kharif* seasons of 2022 and 2023 cultivating maize

(*Zea mays* L.) as influenced by tillage practices adopted and different types and composition of green manure incorporated.

#### **4.1.7.1 Effect of tillage on available phosphorus**

The concentration of available phosphorus as influenced by the implementation of minimum tillage ( $T_M$ ) and conventional tillage ( $T_C$ ) is conferred in this segment of discussion. It is apparent from the acquired readings of the analysis belonging to available P that the plots under ( $T_M$ ) minimum tillage ( $14.04 \text{ kg ha}^{-1}$ ) caused a significant surge in available P by 0.42% in relation to ( $T_C$ ) conventional tillage ( $13.98 \text{ kg ha}^{-1}$ ) in the preliminary year (2022) of investigation. In the subsequent year (2023) corresponding outcome to that of 2022 was observed concerning minimum tillage ( $T_M$ ) and conventional tillage ( $T_C$ ).  $T_M$  ( $14.05 \text{ kg ha}^{-1}$ ) and  $T_C$  ( $13.96 \text{ kg ha}^{-1}$ ) depicted 0.64% increase in available P in the second year of field study. Comparable results adopting varied tillage operations in relation to 2022 and 2023 were also observed in pooled average data where 0.57% rise in available P was attained computing and contrasting  $T_M$  ( $14.05 \text{ kg ha}^{-1}$ ) and  $T_C$  ( $13.97 \text{ kg ha}^{-1}$ ). As minimum tillage requires less soil disturbance it retains the surface residues which in turn makes organic acids which helps to mobilize phosphorus. Mineralization of phosphorus also improves with the integration of minimum tillage, as it helps to retain more phosphorus than conventional tillage system. Fan *et al.* (2013) and Xomphoutheb *et al.* (2020) revealed in their studies that the application of mulching via maize straw significantly increased the P content in soil at a depth of 20-40cm, supporting with variations observed in soil organic matter. This outcome may be ascribed because of certain two factors like mulching and no tillage as soil P reserves were enhanced in fruit trees which helped the growth and other aspects. Accumulation of phosphorus was also observed in the rhizospheric zone at greater depths.

#### **4.1.7.2 Effect of green manuring on available phosphorus**

Impact of addition of green manures is noticeable in both the years of cultivation as provided in Table 4.3(a) and Fig 4.3(b) where amplification of

available P by 31.26%, 24.97% and 20.59% respectively was attained comparing G<sub>2</sub> *i.e.* green manuring through dhaincha @ 4 t ha<sup>-1</sup> (15.87 kg ha<sup>-1</sup>), G<sub>6</sub> *i.e.* green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (15.11 kg ha<sup>-1</sup>) and G<sub>4</sub> *i.e.* green manuring through cowpea @ 4 t ha<sup>-1</sup> (14.58 kg ha<sup>-1</sup>) matched with plots where no green manures were added G<sub>0</sub> *i.e.* control treatment (12.09 kg ha<sup>-1</sup>) this aforementioned data has been confirmed for the facts and findings of the initial year research (2022). In 2023, the value of available P was increased by 33.75%, 27.69% and 22.72% respectively was acquired contrasting G<sub>2</sub> (15.89 kg ha<sup>-1</sup>), G<sub>6</sub> (15.17 kg ha<sup>-1</sup>) followed by G<sub>4</sub> (14.58 kg ha<sup>-1</sup>) with that of G<sub>0</sub> (11.88 kg ha<sup>-1</sup>). The received calculated and acquired results in particular green manure treated plots were corresponding and matching in pooled average. After the analysis it was disclosed and noted that G<sub>2</sub> (15.88 kg ha<sup>-1</sup>), G<sub>6</sub> (15.14 kg ha<sup>-1</sup>) followed by G<sub>4</sub> (14.58 kg ha<sup>-1</sup>) with that of G<sub>0</sub> (11.98 kg ha<sup>-1</sup>) this finding provided the following per cent increase received from treating the plots with green manures against untreated plot, the results were 32.55% in G<sub>2</sub>, 26.37% in G<sub>6</sub> followed by 21.70% in G<sub>4</sub> respectively. Green manures provide phosphorus rich organic matter and their decomposition in the soil may produce phosphatase enzymes which mineralizes organic compound and releases phosphorus into the soil. It was observed that after the conclusion of a four years' study in green manuring implementation in cereal plantation it was found that P content in green manure treated plots increased by 4.24% compared to fallow treated plots. 22.10% increase in available phosphorus in soil was also observed with green manure addition. Application of green manures can also augment the soil bio-available P by 25-30% (Varalakshmi *et al.*, 2005) and these conclusions were in line with the findings of Dey *et al.* (2015).

#### 4.1.7.3 Interaction effect

Table 4.3(b) highlights the statistical findings and Fig 4.6(b) provides the illustrative depiction of the diverse interaction effect as persuaded by the adoption of tillage practices and *via* green manuring on cultivated maize crop in the *kharif* seasons of 2022 and 2022. The interaction between tillage and green manuring provided significant results on available phosphorus accumulation in the soil. The

highest available P was observed in the treatment combination of  $T_MG_2$  i.e. minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> (15.91 kg ha<sup>-1</sup>),  $T_CG_2$  i.e. minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup> (15.83 kg ha<sup>-1</sup>) and followed by  $T_MG_6$  i.e. minimum tillage + green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> which was at (15.12 kg ha<sup>-1</sup>) while the least efficient interaction was in  $T_CG_0$  i.e. conventional tillage with control treatment (12.07 kg ha<sup>-1</sup>) calculated increase per cent of 31.81% adopting  $T_MG_2$ , 31.15% upsurge in  $T_CG_2$  and 25.26% in  $T_MG_6$  this findings is based on contrary to  $T_CG_0$ , in the first year of exploration (2022). Growth of available P was also observed in the second year of study (2023) where the top performing combinations were that of  $T_MG_2$  (15.94 kg ha<sup>-1</sup>) followed by  $T_CG_2$  (15.85 kg ha<sup>-1</sup>) and subsequently by  $T_MG_6$  (15.19 kg ha<sup>-1</sup>) while the least performing treatment combination was measured in  $T_CG_0$  (11.81 kg ha<sup>-1</sup>). This highlighted the available P upsurge by 34.97%, 34.20% and 28.61% adopting  $T_MG_2$ ,  $T_CG_2$  and  $T_MG_6$  against  $T_CG_0$ . The pooled average table of 2022 and 2023 revealed surge of 33.33%, 32.66% and 26.96% in available P computing  $T_MG_2$  (15.92 kg ha<sup>-1</sup>),  $T_CG_2$  (15.84 kg ha<sup>-1</sup>) and  $T_MG_6$  (15.16 kg ha<sup>-1</sup>), to that measured in the interaction of  $T_CG_0$  (11.94 kg ha<sup>-1</sup>).

#### **4.1.8 Available potassium**

Results and discussion regarding the two-year field experimentation conducted in the Department of Soil and Water Conservation, Nagaland University, Medziphema Campus, Nagaland, India during the *kharif* seasons of 2022 and 2023 on the subject which outlines the benefits of appropriate tillage practices and incorporation of organic amendments like green manuring, and its impact on overall soil fertility and crop productivity. Table 4.3(a) and 4.3(b) and Fig 4.8(a) and Fig 4.8(b) portrays the findings of available K as influenced by the aforementioned points.

##### **4.1.8.1 Effect of tillage on available potassium**

The available K of the soil in 2022 was pronounced to be in higher proportion as evident in Table 4.3(a) and Fig 4.3(b) with the inclusion of minimum tillage ( $T_M$ )

than conventional tillage ( $T_C$ ). With the introduction of  $T_M$  available K accumulation in the soil was at  $164.02 \text{ kg ha}^{-1}$  while  $T_C$  stands at  $163.03 \text{ kg ha}^{-1}$  upon which increase of 0.60% was examined inducting  $T_M$ . The second year (2023) and the pooled average also tends to support the outcome of the first year (2022) where in 2023 the available K in  $T_M$  was at  $164.27 \text{ kg ha}^{-1}$  and  $164.14 \text{ kg ha}^{-1}$  in the pooled average which was more than available K accumulated in  $T_C$   $163.23 \text{ kg ha}^{-1}$  in 2023 and  $163.13 \text{ kg ha}^{-1}$  in pooled average showing an increase of 0.63% and 0.61% respectively. Minimum tillage only employs primary tillage which means reduced disturbance to the soil. These help the soil to create a more favorable environment for soil microbes to thrive ultimately helping to preserve and maintain judicious potassium availability. Rekwar (2024) observed that methods involving permanent bed (PB) and zero tillage flat (ZT-flat) tillage systems increased the available K in the soil in maize-chickpea-*sesbania* spp. (MCS) and maize-wheat-mung bean (MWMb) cropping system. As compared to the traditional farming system the above system significantly improves the soil health and quality which ultimately boosts the crop productivity while maintaining soil fertility, these results were supported by Calistru *et al.* (2024).

#### **4.1.8.2 Effect of green manuring on available potassium**

Addition of green manures provided a perceptible impact in both the years of crop production as well as in the pooled table as manifested in Table 4.3(a) and Fig 4.3(b). The treatment where no green manures were incorporated ( $G_0$ ) were appalling in the recorded available K data ( $153.87 \text{ kg ha}^{-1}$ ) while the green manure treated plot which expressed most effective managing available K was of  $G_6$  *i.e.* green manures through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  where the available K was ( $174.79 \text{ kg ha}^{-1}$ ),  $G_2$  *i.e.* green manures through dhaincha  $4 \text{ t ha}^{-1}$  ( $166.81 \text{ kg ha}^{-1}$ ) followed by  $G_5$  *i.e.* green manures through dhaincha  $1 \text{ t ha}^{-1}$  and cowpea  $1 \text{ t ha}^{-1}$  @  $2 \text{ t ha}^{-1}$  ( $165.86 \text{ kg ha}^{-1}$ ). This outcome of available K presented 12.86% rise of available K implementing  $G_6$ , 8.40% with  $G_2$  and 7.79% with  $G_5$  as compared to  $G_0$  analyzing the recorded data received from the first year of study (2022). The tabulated observation from 2023 presents a peak rise in available K of the soil in the

treated plots of  $G_6$  (175.01 kg ha<sup>-1</sup>),  $G_2$  (166.98 kg ha<sup>-1</sup>) and  $G_5$  (166.28 kg ha<sup>-1</sup>) which was similar to that of the findings from 2022. The pooled average data relating to available K as received from the findings in 2022 and 2023 exposed that  $G_6$  (174.90 kg ha<sup>-1</sup>),  $G_2$  (166.90 kg ha<sup>-1</sup>) and  $G_5$  (166.07 kg ha<sup>-1</sup>) were the most effective sub plots where available K was measured to be most accumulated as opposed to  $G_0$  which was the least effective treatment where the noted available K was (153.81 kg ha<sup>-1</sup>). A proliferation of available K by 13.71%, 8.15% and 7.97% was denoted utilizing  $G_6$ ,  $G_2$  and  $G_5$  in relation to  $G_0$ . Green manures not only provide potassium but also help the soil to maintain the biochemical process to create and helps absorb the plants. As more stable environment is created for the soil microbes through the residues of the green manures K availability in the soil thrives.

#### 4.1.8.3 Interaction effect

The records pertaining to the interaction effect of tillage and green manuring cultivating maize (*Zea mays* L.) in the year 2022 and 2023 along with its pooled average is provided in Table 4.3(b) and illustrated in Fig 4.8(b). In the initial year of investigation (2022) the recorded highest accumulation of available K was observed in the combination of  $T_M G_6$  i.e. minimum tillage + green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> which was at (175.84 kg ha<sup>-1</sup>) followed by  $T_C G_6$  i.e. conventional tillage + green manures through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> which was noted at (173.74 kg ha<sup>-1</sup>) and subsequently by  $T_M G_2$  i.e. minimum tillage + green manures through dhaincha @ 4 t ha<sup>-1</sup> (167.46 kg ha<sup>-1</sup>). This above aforementioned interactions were the peak performing combinations sustaining available K in the soil amongst all treatment combinations, whereas the least effectual treatment combination was in  $T_C G_0$  i.e. conventional tillage + control with accumulated available K of (153.14 kg ha<sup>-1</sup>). Comparing and contrasting the treatment combinations  $T_M G_6$ ,  $T_C G_6$  and  $T_M G_2$  with that of  $T_C G_0$  rise in available K was noted at 14.82%, 13.45% and 9.35% respectively. The subsequent year (2023) delivered matching findings where  $T_M G_6$  (176.05 kg ha<sup>-1</sup>),  $T_C G_6$  (173.97 kg ha<sup>-1</sup>) and  $T_M G_2$  (167.70 kg ha<sup>-1</sup>) were the best treatment combination involving available K accumulation, pertaining to the least favorable treatment combination preserving the

available K was noted in the interaction of  $T_CG_0$  comprising available K of (152.99 kg ha<sup>-1</sup>). Matching trend involving tillage and green manuring interaction in the year 2022 and 2023 were also acquired and documented in the pooled average table where  $T_MG_6$  (175.95 kg ha<sup>-1</sup>),  $T_CG_6$  (173.86 kg ha<sup>-1</sup>) and  $T_MG_2$  (167.58 kg ha<sup>-1</sup>) were tabulated as the vital treatment combination in concentrating available K. As compared to the treatment with the lowest efficiency  $T_CG_0$  (153.06 kg ha<sup>-1</sup>) it was ascertained that escalation of available K by 20.20%, 23.23% and 35.65% was derived in  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$  in contrary to  $T_CG_0$ . Sujatha *et al.* (2017) remarked that application of potassium fertilizers @ 120 kg K<sub>2</sub>O ha<sup>-1</sup> increased the soluble, exchangeable, fixed and non- exchangeable form of K in soil. The incorporation of green manures with K fertilizer can significantly enhance the exchangeable potassium and yield of a crop. It is recommended that in rice cultivation 40 kg K<sub>2</sub>O ha<sup>-1</sup> with dhaincha as a green manure to optimize potassium availability and increase the yield components of a crop. The findings were parallel with the outcomes of Zhao *et al.* (2024).

**Table 4.3 (a): Effect of tillage and green manuring on available N, available P and available K of the soil after harvest**

| Treatment             | Available N<br>(kg ha <sup>-1</sup> ) |        |        | Available P<br>(kg ha <sup>-1</sup> ) |       |        | Available K<br>(kg ha <sup>-1</sup> ) |        |        |
|-----------------------|---------------------------------------|--------|--------|---------------------------------------|-------|--------|---------------------------------------|--------|--------|
|                       | 2022                                  | 2023   | Pooled | 2022                                  | 2023  | Pooled | 2022                                  | 2023   | Pooled |
| <b>Tillage</b>        |                                       |        |        |                                       |       |        |                                       |        |        |
| <b>T<sub>M</sub></b>  | 462.93                                | 501.76 | 482.35 | 14.04                                 | 14.05 | 14.05  | 164.02                                | 164.27 | 164.14 |
| <b>T<sub>C</sub></b>  | 436.05                                | 462.93 | 449.49 | 13.98                                 | 13.96 | 13.97  | 163.03                                | 163.23 | 163.13 |
| <b>SEm ±</b>          | 3.658                                 | 4.224  | 2.794  | 0.001                                 | 0.006 | 0.003  | 0.038                                 | 0.008  | 0.019  |
| <b>CD at 5%</b>       | 22.258                                | 25.701 | 10.970 | 0.007                                 | 0.037 | 0.012  | 0.232                                 | 0.048  | 0.076  |
| <b>CV</b>             | 3.729                                 | 4.013  | 3.886  | 0.040                                 | 0.199 | 0.143  | 0.107                                 | 0.022  | 0.077  |
| <b>Green manuring</b> |                                       |        |        |                                       |       |        |                                       |        |        |
| <b>G<sub>0</sub></b>  | 344.96                                | 334.51 | 339.73 | 12.09                                 | 11.88 | 11.98  | 153.87                                | 153.75 | 153.81 |
| <b>G<sub>1</sub></b>  | 439.04                                | 512.21 | 475.63 | 12.96                                 | 12.99 | 12.98  | 156.34                                | 156.76 | 156.55 |
| <b>G<sub>2</sub></b>  | 491.31                                | 543.57 | 517.44 | 15.87                                 | 15.89 | 15.88  | 166.81                                | 166.98 | 166.90 |
| <b>G<sub>3</sub></b>  | 439.04                                | 480.85 | 459.95 | 13.80                                 | 13.82 | 13.81  | 161.72                                | 161.92 | 161.82 |
| <b>G<sub>4</sub></b>  | 470.40                                | 459.95 | 465.17 | 14.58                                 | 14.58 | 14.58  | 165.30                                | 165.56 | 165.43 |
| <b>G<sub>5</sub></b>  | 439.04                                | 491.31 | 465.17 | 13.67                                 | 13.69 | 13.68  | 165.86                                | 166.28 | 166.07 |
| <b>G<sub>6</sub></b>  | 522.67                                | 554.03 | 538.35 | 15.11                                 | 15.17 | 15.14  | 174.79                                | 175.01 | 174.90 |
| <b>SEm ±</b>          | 5.588                                 | 17.297 | 9.089  | 0.003                                 | 0.007 | 0.004  | 0.063                                 | 0.015  | 0.032  |
| <b>CD @ 5%</b>        | 16.309                                | 50.487 | 25.843 | 0.009                                 | 0.021 | 0.011  | 0.184                                 | 0.043  | 0.092  |
| <b>CV</b>             | 3.045                                 | 8.784  | 6.757  | 0.057                                 | 0.129 | 0.099  | 0.094                                 | 0.022  | 0.068  |



**Table 4.3 (b): Interaction effect of tillage and green manuring on available N, available P and available K of the soil after harvest**

| Treatments                        | Available N<br>(kg ha <sup>-1</sup> ) |        |        | Available P<br>(kg ha <sup>-1</sup> ) |       |        | Available K<br>(kg ha <sup>-1</sup> ) |        |        |
|-----------------------------------|---------------------------------------|--------|--------|---------------------------------------|-------|--------|---------------------------------------|--------|--------|
|                                   | 2022                                  | 2023   | Pooled | 2022                                  | 2023  | Pooled | 2022                                  | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 376.32                                | 355.41 | 365.87 | 12.11                                 | 11.95 | 12.03  | 154.59                                | 154.50 | 154.55 |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 439.04                                | 501.76 | 470.40 | 13.00                                 | 13.05 | 13.03  | 156.86                                | 157.43 | 157.15 |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 501.76                                | 543.57 | 522.67 | 15.91                                 | 15.94 | 15.92  | 167.46                                | 167.70 | 167.58 |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 439.04                                | 501.76 | 470.40 | 13.86                                 | 13.88 | 13.87  | 161.84                                | 162.06 | 161.95 |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 501.76                                | 543.57 | 522.67 | 14.61                                 | 14.62 | 14.62  | 165.50                                | 165.81 | 165.66 |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 439.04                                | 501.76 | 470.40 | 13.69                                 | 13.71 | 13.70  | 166.03                                | 166.33 | 166.18 |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 543.57                                | 564.48 | 554.03 | 15.12                                 | 15.19 | 15.16  | 175.84                                | 176.05 | 175.95 |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 313.60                                | 313.60 | 313.60 | 12.07                                 | 11.81 | 11.94  | 153.14                                | 152.99 | 153.06 |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 439.04                                | 522.67 | 480.85 | 12.92                                 | 12.94 | 12.93  | 155.81                                | 156.08 | 155.95 |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 480.85                                | 543.57 | 512.21 | 15.83                                 | 15.85 | 15.84  | 166.16                                | 166.26 | 166.21 |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 439.04                                | 459.95 | 449.49 | 13.73                                 | 13.76 | 13.75  | 161.60                                | 161.78 | 161.69 |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 439.04                                | 376.32 | 407.68 | 14.54                                 | 14.54 | 14.54  | 165.10                                | 165.31 | 165.21 |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 439.04                                | 480.85 | 459.95 | 13.64                                 | 13.67 | 13.66  | 165.69                                | 166.23 | 165.96 |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 501.76                                | 543.57 | 522.67 | 15.10                                 | 15.15 | 15.13  | 173.74                                | 173.97 | 173.86 |
| <b>SEm ±</b>                      | 7.902                                 | 24.462 | 12.853 | 0.005                                 | 0.010 | 0.006  | 0.089                                 | 0.021  | 0.046  |
| <b>CD at 5%</b>                   | 23.064                                | 71.400 | 36.548 | 0.013                                 | 0.030 | 0.016  | 0.260                                 | 0.061  | 0.130  |

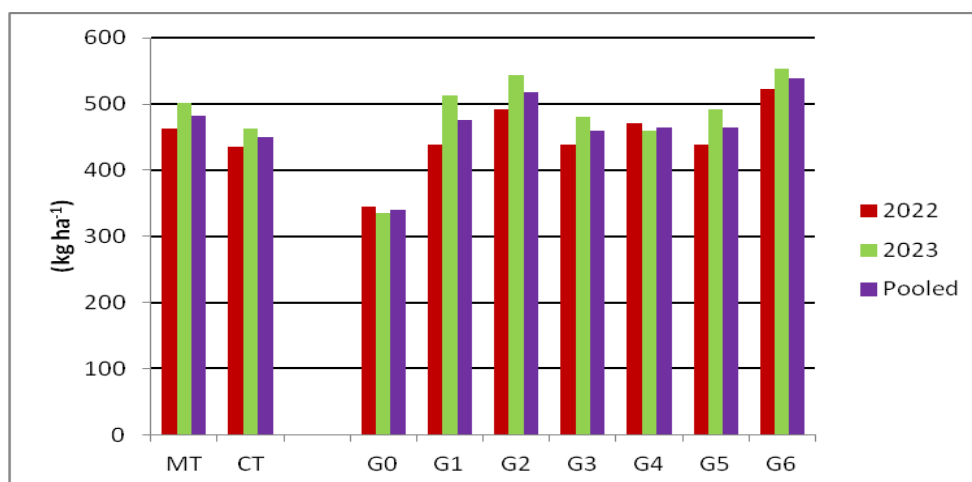


Fig. 4.6(a): Effect of tillage and green manuring on available N

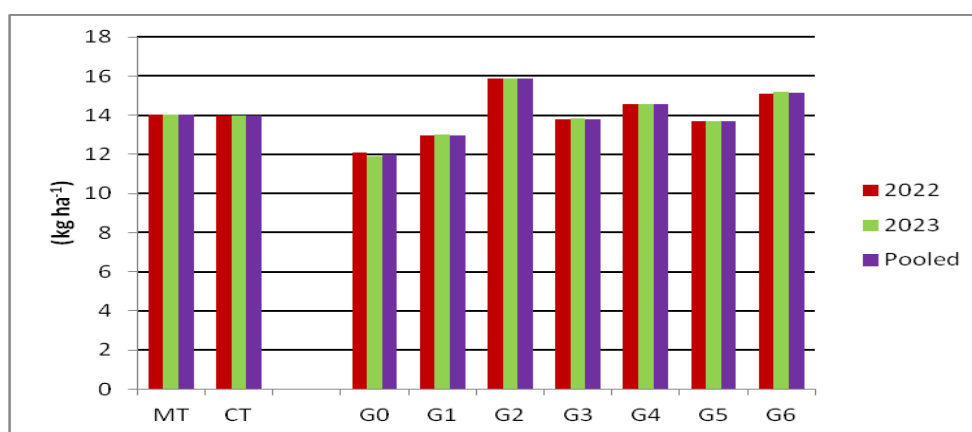


Fig. 4.7(a): Effect of tillage and green manuring on available P

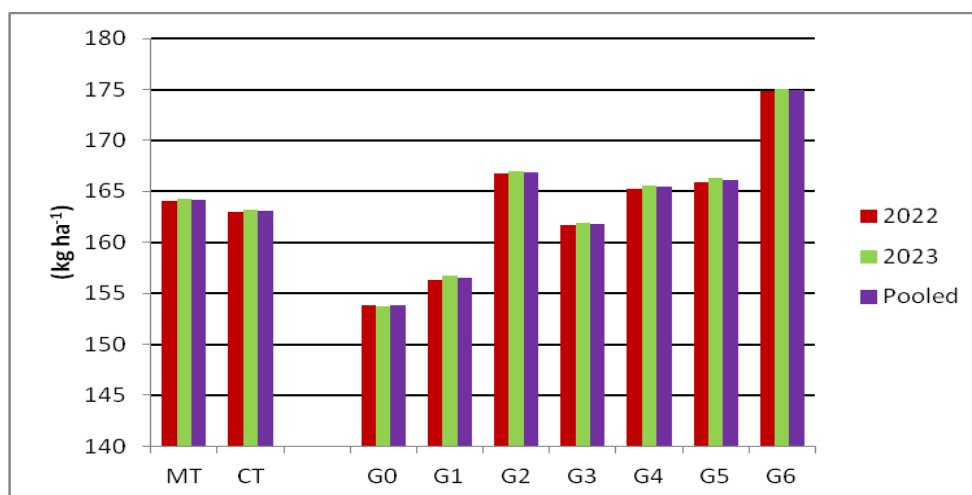


Fig. 4.8(a): Effect of tillage and green manuring on available K

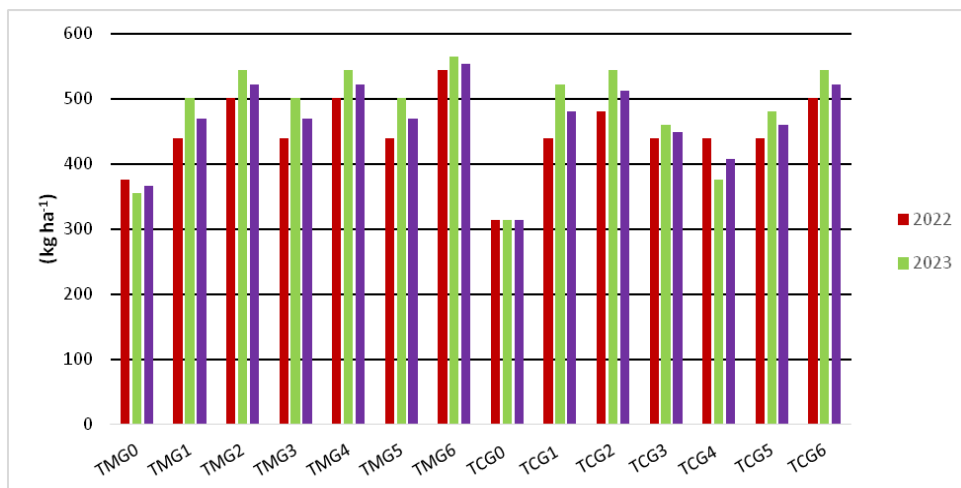


Fig. 4.6(b): Interaction effect of tillage and green manuring on available N

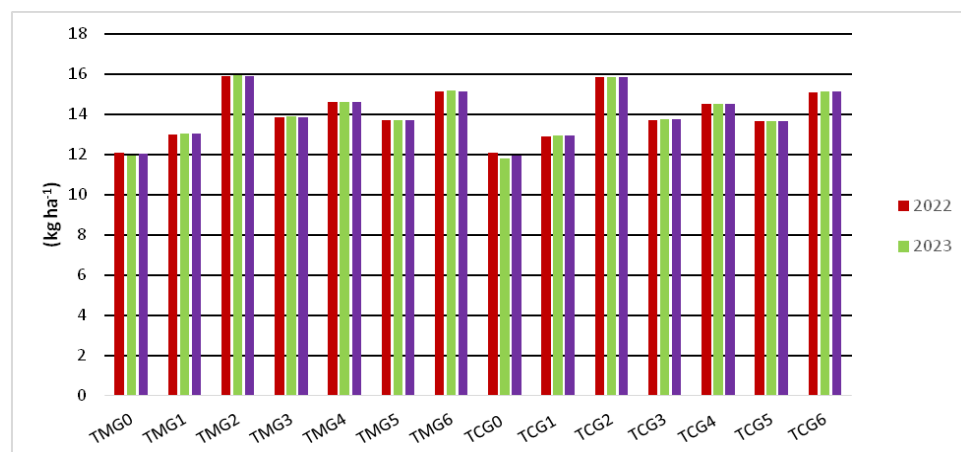


Fig. 4.7(b): Interaction effect of tillage and green manuring on available P

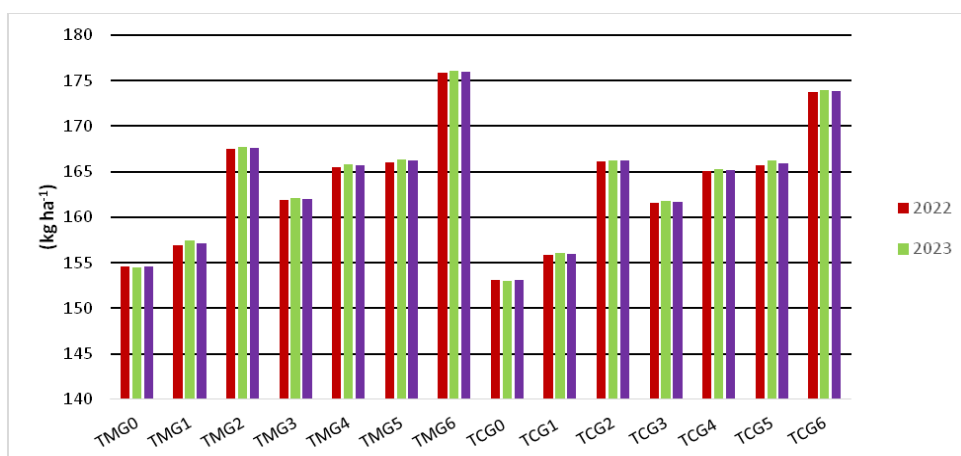


Fig. 4.8(b): Interaction effect of tillage and green manuring on available K

#### 4.1.9 Bulk density

The results associated to bulk density of the soil as an outcome by adopting various tillage practices like minimum and conventional tillage coupled with integration of green manuring and their interaction effect of treatment combination is presented in Table 4.4(a) and 4.4(b) and represented in Fig 4.9(a) and Fig 4.9(b).

##### 4.1.9.1 Effect of tillage on bulk density

The effect of tillage on soil bulk density cultivating maize (*Zea mays* L.) is noted in Table 4.4(a) and exemplified in Fig 4.9(a). Bulk density of the soil was at  $1.21 \text{ g cm}^{-3}$  adopting minimum tillage ( $T_M$ ) which was lower than that of conventional tillage ( $T_C$ )  $1.25 \text{ g cm}^{-3}$  in the first year of cultivation (2022). In the following year (2023) the acknowledged bulk density for  $T_M$  was logged at  $1.19 \text{ g cm}^{-3}$  denoting a decrease of 3.25% comparing  $T_C$  which was at  $1.23 \text{ g cm}^{-3}$ . Comparable outcome was also observed computing pooled table where  $T_M$  performed better than  $T_C$  in decreasing the bulk density of the soil by about 3.22% computing  $1.20 \text{ g cm}^{-3}$  in  $T_M$  i.e. minimum tillage and  $1.24 \text{ g cm}^{-3}$  in  $T_C$  i.e. conventional tillage. Adoption of minimum tillage operation leads to less compaction of soil as minimal disturbance to the soil is carried out leading to natural settling of soil which compact the top soil profile and leads to more bulk density. Li *et al.* (2019) reported that bulk density of the soil was increased with the implementation of tillage practices like no till, minimum tillage and no till with residue management. An increase of 1.4%, 2.1% and 2.6% respectively as compare to conventional tillage practices. Bulk density was also increased with the interaction of minimum tillage with residue retention by 3.9% as compared to lone no till practice. This may be due to the compaction of soil that is attributed by residue retention and less tillage operations. These consequences are supported by the findings of (Amami *et al.*, 2019 and Yankov and Drumeva, 2020).

#### 4.1.9.2 Effect of green manuring on bulk density

The effect of green manuring on soil bulk density is concisely discussed and rightly illustrated in Table 4.4(a) and Fig 4.9(a) correspondingly. The effect of green manuring was fairly significant as evident by the data provided. In the initial year (2022) green manure application through  $G_6$  *i.e.* green manures through dhaincha 2 t  $ha^{-1}$  and cowpea 2 t  $ha^{-1}$  @ 4 t  $ha^{-1}$  (1.07 g  $cm^{-3}$ ) which noted the lowest bulk density among all the green manuring treatment, followed by  $G_2$  *i.e.* green manuring through dhaincha @ 4 t  $ha^{-1}$  (1.16 g  $cm^{-3}$ ) and  $G_4$  *i.e.* cowpea @ 4 t  $ha^{-1}$  (1.19 g  $cm^{-3}$ ). The highest bulk density value was recorded in treatment where no green manures were added ( $G_0$ ) with bulk density of 1.37 g  $cm^{-3}$ , this resulted an decrease of bulk density by 21.89% in  $G_6$ , 15.32% in  $G_2$  and 13.13% in  $G_4$  as compared to  $G_0$ . In the second year of cultivation, the best green manuring composition elevating the bulk density was in  $G_6$  (1.07 g  $cm^{-3}$ ) followed by  $G_2$  (1.14 g  $cm^{-3}$ ) and  $G_4$  (1.17 g  $cm^{-3}$ ) and the worst soil bulk density was observed and recorded in  $G_0$  (1.34 g  $cm^{-3}$ ) in which no green manures were added. This provided the facts where decrease in bulk density of soil by 20.14%, 14.92% and 12.68% analyzing  $G_6$ ,  $G_1$  and  $G_3$  against  $G_0$  respectively. Pooled average data disclosed similar results to that of 2022 and 2023 where  $G_6$  noted bulk density of (1.07 g  $cm^{-3}$ ),  $G_2$  (1.15 g  $cm^{-3}$ ) followed by  $G_4$  at (1.18 g  $cm^{-3}$ ) showcasing 20.74%, 14.81% and 12.59% declination in bulk density in contrast to  $G_0$  (1.35 g  $cm^{-1}$ ). These may be because the addition of green manures leads to more organic matter accumulation the soil moisture retention increases and may lead to lower bulk density.

#### 4.1.9.3 Interaction effect

Table 4.4(b) and Fig 4.9(b) reflects and depict the data graphically the interaction effect of tillage and green manuring and how the combination influences the bulk density of soil in the period of cultivation. Bulk density of soil tends to incline positively towards the treatment combination of  $T_M G_6$  *i.e.* minimum tillage with green manuring through dhaincha 2 t  $ha^{-1}$  and cowpea 2 t  $ha^{-1}$  @ 4 t  $ha^{-1}$  in both the years of cultivation as well as the pooled average table. Analysis of findings from the first year revealed that  $T_M G_6$  *i.e.* minimum tillage with green manuring through

dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (1.05 g cm<sup>-3</sup>) decreased the bulk density of soil by 25% as compared to T<sub>C</sub>G<sub>0</sub> i.e. conventional tillage + control with bulk density of 1.40 g cm<sup>-3</sup> which was compounded to have the highest value. As compared to T<sub>C</sub>G<sub>0</sub>, T<sub>C</sub>G<sub>6</sub> (1.09 g cm<sup>-3</sup>) decreased the bulk density by 22.14% and T<sub>M</sub>G<sub>2</sub> by 17.85%. The analysis in the subsequent year (2023) highlighted that bulk density in T<sub>M</sub>G<sub>6</sub> (1.02 g cm<sup>-3</sup>) was the peak among all the treatment combination followed by T<sub>C</sub>G<sub>6</sub> (1.11 g cm<sup>-3</sup>) and T<sub>M</sub>G<sub>2</sub> (1.12 g cm<sup>-3</sup>) whereas the highest bulk density was observed in the treatment combination of T<sub>C</sub>G<sub>0</sub> (1.37 g cm<sup>-3</sup>) producing an elevation in bulk density by 35.54%, 18.97% and 18.24%, respectively. The pooled table also had a parallel trend where T<sub>M</sub>G<sub>6</sub> (1.04 g cm<sup>-3</sup>), T<sub>C</sub>G<sub>0</sub> (1.10 g cm<sup>-3</sup>) and T<sub>M</sub>G<sub>2</sub> (1.14 g cm<sup>-3</sup>) as compared to T<sub>C</sub>G<sub>0</sub> (1.39 g cm<sup>-3</sup>) elevated the bulk density by 25.17%, 20.86% and 17.98%, respectively.

Ali *et al.* (2018) and Stephens *et al.* (2023) in their findings affirmed that green manures like dhaincha, sunnhemp and pillipesara, decreased the soil bulk density markedly when after harvest soil in maize cropping was tested. Organic carbon of the soil was also increased with the application of green manures like dhaincha (0.73%), sunnhemp (0.71%) and pillipesara (0.64%).

#### **4.1.10 Particle density**

Particle density of soil as prompted by the implementation of tillage and via the exploitation of green manuring is exhibited in the Table 4.4(a) and 4.4(b) and summarized visually in Fig 4.10(a) and Fig 4.10(b).

##### **4.1.10.1 Effect of tillage on particle density**

The effect on soil particle density as stimulated by the action of various tillage operations is presented in Table 4.4(a) and displayed in Fig 4.10(a). It is obvious by the result presented in the table that T<sub>C</sub> (conventional tillage) lifted the values of particle density of soil to that of T<sub>M</sub> (minimum tillage) over both the year of cultivation including the pooled average. The year 2022 which was the first year of cultivation reflected a growth of 0.81% particle density of soil involving T<sub>C</sub> (2.48 g

cm<sup>-3</sup>) and T<sub>M</sub> (2.46 g cm<sup>-3</sup>). In the successive year (2023) conventional tillage (2.47 g cm<sup>-3</sup>) presented a growth over minimum tillage (2.45 g cm<sup>-3</sup>) achieving 0.81% increase in particle density. Comparable outcome was observed in pooled average part where T<sub>C</sub> (2.48 g cm<sup>-3</sup>) was found to be higher in particle density of soil than T<sub>M</sub> (2.46 g cm<sup>-3</sup>). Minimum tillage demonstrated the increase in particle density of soil which was measured at 2.64 g cm<sup>-3</sup>. The study concludes that implementation of minimum tillage resulted in denser soil structure, limits root penetration and reduction in infiltration of water which influences plant growth and its attributes and soil health in particular (Khan *et al.*, 2017 and Agostini *et al.*, 2012).

#### 4.1.10.2 Effect of green manuring on particle density

Findings and data's related to particle density of soil as persuaded *via* the incorporation of green manures is presented in this part of discussion. The information from the first year suggested that the highest particle density of soil was observed in the section of plots where no green manures were supplemented (G<sub>0</sub>) 2.54 g cm<sup>-3</sup> while the plots where green manures were provided reduced the particle density of soil. The least particle density was observed in G<sub>6</sub> *i.e.* green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (2.42 g cm<sup>-3</sup>) followed by followed by G<sub>4</sub> *i.e.* green manuring through cowpea 4 t ha<sup>-1</sup> (2.44 g cm<sup>-3</sup>) and G<sub>5</sub> *i.e.* green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup> (2.46 g cm<sup>-3</sup>), these shows decrease in particle density by 4.72%, 3.93% and 3.25% respectively computing G<sub>6</sub>, G<sub>4</sub> and G<sub>5</sub> against G<sub>0</sub>. The results from the second year findings replicated to those of first year where G<sub>0</sub> (2.58 g cm<sup>-3</sup>) provided the highest particle density amongst all the green manure plots and the reduced particle density plots were observed in G<sub>6</sub> (2.40 g cm<sup>-3</sup>), G<sub>4</sub> (2.42 g cm<sup>-3</sup>) and G<sub>5</sub> (2.45 g cm<sup>-3</sup>). The data from pooled findings showed similar results where the highest particle density was in G<sub>0</sub> (2.56 g cm<sup>-3</sup>) among the green manured plots and the particle density plots were reduction was observed was in G<sub>6</sub> (2.41 g cm<sup>-3</sup>), G<sub>4</sub> (2.43 g cm<sup>-3</sup>) and G<sub>5</sub> (2.45 g cm<sup>-3</sup>) exhibiting decrease of 5.82%, 5.07% and 4.29% respectively analyzing G<sub>6</sub>, G<sub>4</sub> and G<sub>5</sub> in conjunction with G<sub>0</sub>. Incorporation of green manures influences the particle density by enhancing the soil structure. Improvement in soil structure results in

reducing compaction and increase in soil porosity. This may lead to proper development of roots and movement of moisture in the soil (Joshna *et al.*, 2024). This result was at par with the inferences of the works of Wilczewski *et al.* (2024).

#### 4.1.10.3 Interaction effect

The collected data concerning the collaboration of tillage practices and various green manuring treatments on the particle density of soil is conversed in detail in Table 4.4(b) and mapped out in Fig 10(b). Interaction between tillage and green manuring as given in the treatment combination of T<sub>C</sub>G<sub>0</sub> (conventional tillage + control) with particle density of 2.55 g cm<sup>-3</sup> was analysed to be the highest particle density amongst all the treatment combination, in the initial year (2022) whereas the least was observed in T<sub>M</sub>G<sub>6</sub> (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) (2.40 g cm<sup>-3</sup>) followed by T<sub>M</sub>G<sub>4</sub> (minimum tillage + green manuring through cowpea 4 t ha<sup>-1</sup>) (2.43 g cm<sup>-3</sup>). T<sub>M</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>4</sub> reduced the particle density of soil by 5.88% and 4.7% as compared to T<sub>C</sub>G<sub>0</sub>. The second year (2023) recordings are as follows. Highest particle density was observed in T<sub>C</sub>G<sub>0</sub> (2.59 g cm<sup>-3</sup>) while the most reduced particle density among all the treatment combination was in T<sub>M</sub>G<sub>6</sub> (2.38 g cm<sup>-3</sup>) subsequently by T<sub>M</sub>G<sub>4</sub> (2.41 g cm<sup>-3</sup>). The pooled data revealed that T<sub>M</sub>G<sub>6</sub> (2.39 g cm<sup>-3</sup>) and T<sub>M</sub>G<sub>4</sub> (2.42 g cm<sup>-3</sup>) in contrast to T<sub>C</sub>G<sub>0</sub> (2.57 g cm<sup>-3</sup>) reduced the particle density of soil by 7% and 6.19% respectively.



**Table 4.4 (a): Effect of tillage and green manuring on bulk density and particle density of the soil after harvest**

| Treatment             | Bulk density<br>(g cm <sup>-3</sup> ) |       |        | Particle density<br>(g cm <sup>-3</sup> ) |       |        |
|-----------------------|---------------------------------------|-------|--------|-------------------------------------------|-------|--------|
|                       | 2022                                  | 2023  | Pooled | 2022                                      | 2023  | Pooled |
| <b>Tillage</b>        |                                       |       |        |                                           |       |        |
| <b>T<sub>M</sub></b>  | 1.21                                  | 1.19  | 1.20   | 2.46                                      | 2.45  | 2.46   |
| <b>T<sub>C</sub></b>  | 1.25                                  | 1.23  | 1.24   | 2.48                                      | 2.47  | 2.48   |
| <b>SEm ±</b>          | 0.002                                 | 0.001 | 0.001  | 0.001                                     | 0.001 | 0.001  |
| <b>CD at 5%</b>       | 0.011                                 | 0.007 | 0.004  | 0.008                                     | 0.007 | 0.004  |
| <b>CV</b>             | 0.701                                 | 0.443 | 0.588  | 0.250                                     | 0.226 | 0.238  |
| <b>Green manuring</b> |                                       |       |        |                                           |       |        |
| <b>G<sub>0</sub></b>  | 1.37                                  | 1.34  | 1.35   | 2.54                                      | 2.58  | 2.56   |
| <b>G<sub>1</sub></b>  | 1.28                                  | 1.26  | 1.27   | 2.50                                      | 2.48  | 2.49   |
| <b>G<sub>2</sub></b>  | 1.16                                  | 1.14  | 1.15   | 2.47                                      | 2.45  | 2.46   |
| <b>G<sub>3</sub></b>  | 1.27                                  | 1.25  | 1.26   | 2.49                                      | 2.46  | 2.48   |
| <b>G<sub>4</sub></b>  | 1.19                                  | 1.17  | 1.18   | 2.44                                      | 2.42  | 2.43   |
| <b>G<sub>5</sub></b>  | 1.24                                  | 1.22  | 1.23   | 2.46                                      | 2.45  | 2.45   |
| <b>G<sub>6</sub></b>  | 1.07                                  | 1.07  | 1.07   | 2.42                                      | 2.40  | 2.41   |
| <b>SEm ±</b>          | 0.005                                 | 0.004 | 0.003  | 0.002                                     | 0.002 | 0.001  |
| <b>CD @ 5%</b>        | 0.016                                 | 0.013 | 0.010  | 0.005                                     | 0.005 | 0.004  |
| <b>CV</b>             | 1.079                                 | 0.820 | 0.961  | 0.173                                     | 0.186 | 0.180  |

**Table 4.4 (b): Interaction effect of tillage and green manuring on bulk density and particle density of the soil after harvest**

| Treatments                        | Bulk density<br>(g cm <sup>-3</sup> ) |       |        | Particle density<br>(g cm <sup>-3</sup> ) |       |        |
|-----------------------------------|---------------------------------------|-------|--------|-------------------------------------------|-------|--------|
|                                   | 2022                                  | 2023  | Pooled | 2022                                      | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 1.33                                  | 1.31  | 1.32   | 2.53                                      | 2.57  | 2.55   |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 1.26                                  | 1.25  | 1.25   | 2.49                                      | 2.47  | 2.48   |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 1.15                                  | 1.12  | 1.14   | 2.45                                      | 2.43  | 2.44   |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 1.25                                  | 1.24  | 1.24   | 2.48                                      | 2.46  | 2.47   |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 1.17                                  | 1.15  | 1.16   | 2.43                                      | 2.41  | 2.42   |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 1.23                                  | 1.21  | 1.22   | 2.45                                      | 2.44  | 2.45   |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 1.05                                  | 1.02  | 1.04   | 2.40                                      | 2.38  | 2.39   |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 1.40                                  | 1.37  | 1.39   | 2.55                                      | 2.59  | 2.57   |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 1.31                                  | 1.28  | 1.30   | 2.51                                      | 2.48  | 2.50   |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 1.17                                  | 1.15  | 1.16   | 2.48                                      | 2.47  | 2.48   |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 1.29                                  | 1.25  | 1.28   | 2.50                                      | 2.47  | 2.48   |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 1.21                                  | 1.18  | 1.20   | 2.44                                      | 2.43  | 2.44   |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 1.24                                  | 1.23  | 1.24   | 2.47                                      | 2.46  | 2.46   |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 1.09                                  | 1.11  | 1.10   | 2.43                                      | 2.42  | 2.43   |
| <b>SEm ±</b>                      | 0.008                                 | 0.006 | 0.005  | 0.002                                     | 0.003 | 0.002  |
| <b>CD at 5%</b>                   | 0.022                                 | 0.017 | 0.014  | 0.007                                     | 0.008 | 0.005  |

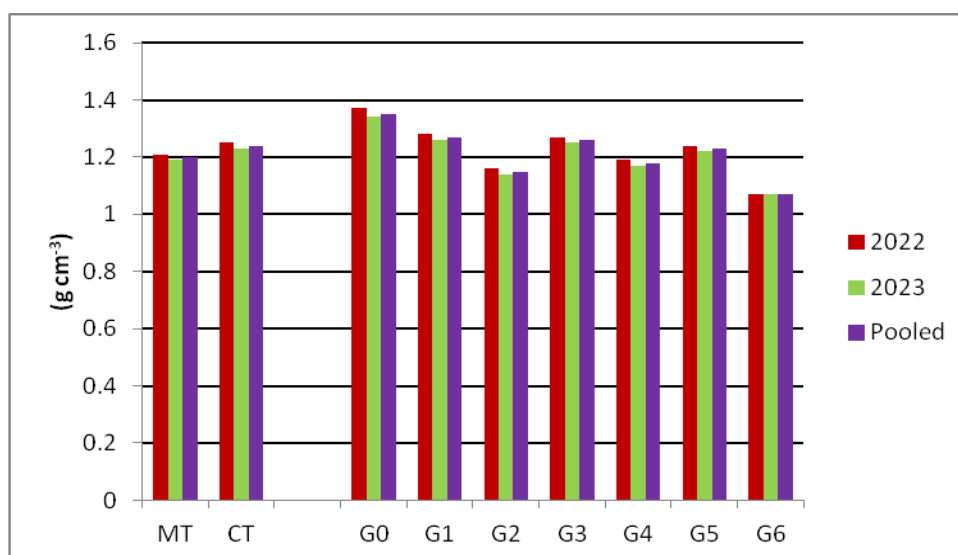


Fig. 4.9(a): Effect of tillage and green manuring on bulk density

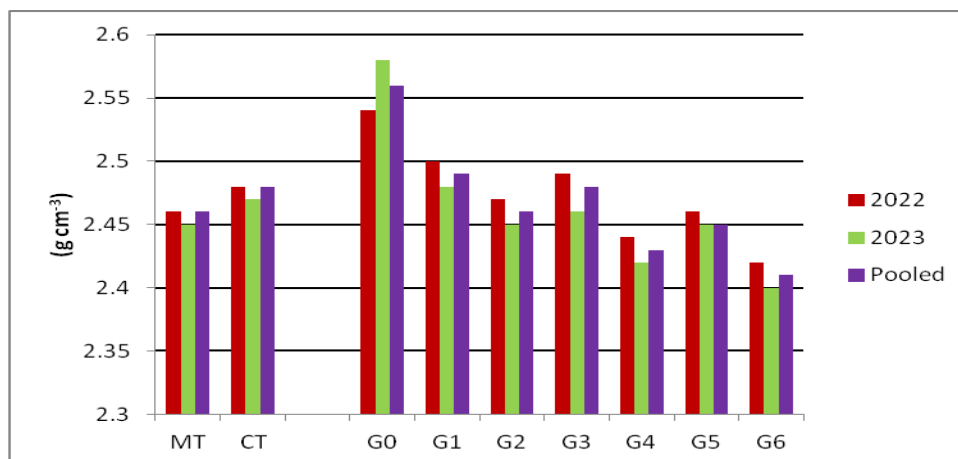


Fig. 4.10(a): Effect of tillage and green manuring on particle density

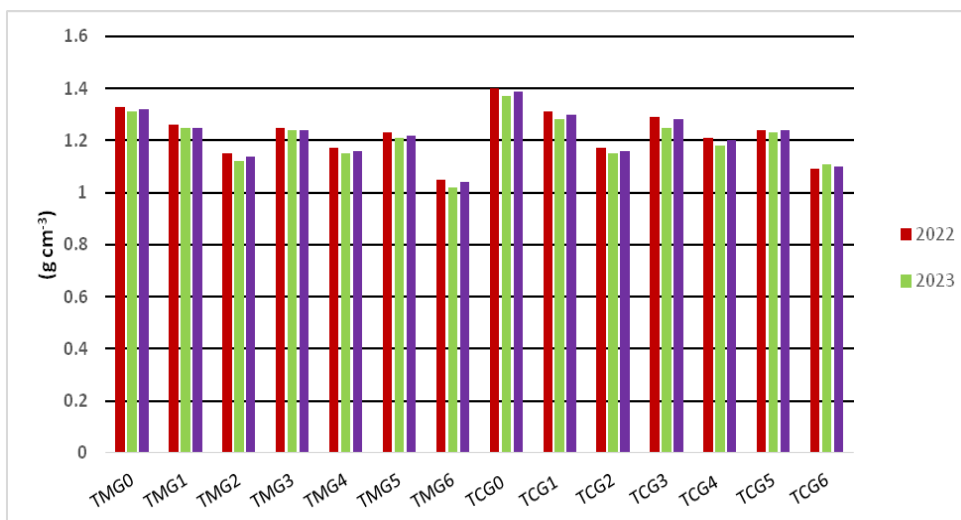


Fig. 4.9(b): Interaction effect of tillage and green manuring on bulk density

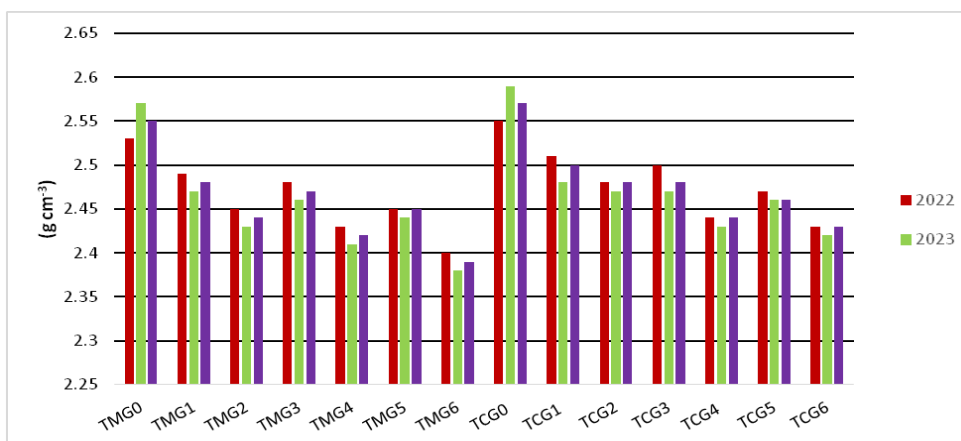


Fig. 4.10(b): Interaction effect of tillage and green manuring on particle density

#### **4.1.11 Water holding capacity**

The water holding capacity of the soil as directed by the combination between tillage and green manuring cultivating maize (*Zea mays* L.) is accessible in Table 4.5(a) and 4.5(b) and visually plotted in Fig 4.11(a) and Fig 4.11(b). Details regarding the two-year investigation and pooled analysis are presented below.

##### **4.1.11.1 Effect of tillage on water holding capacity**

Aspects of particulars regarding water holding capacity of the soil by adoption of minimum and conventional tillage practices are displayed in Table 4.5(a) and Fig 4.11(a). The water holding capacity of the soil was found to be evidently rising in minimum tillage (44.99%) as compared to conventional tillage (44.87%) giving a 0.26% increase adopting  $M_T$  over  $C_T$ . Increase by 1.36% was also observed figuring  $T_M$  (47.58%) and  $T_C$  (46.94%) in the second year of study period (2023). Pooled average data uncovered that ( $T_M$ ) minimum tillage with water holding capacity of 46.29% computed against ( $T_C$ ) conventional tillage 45.90% gave an increase in water holding capacity by 0.84%. Minimum tillage system adopts only primary tillage, which minimizes the soil disturbance leading to better soil structure, porosity and residue retention which helps the soil water holding capacity. Liu *et al.* (2013) and Orlando *et al.* (2011) reported that long term study of 12 years was conducted which compared the different effects of minimum tillage and conventional tillage system in cambisol soils of Slovenia. It was evident in the study that minimum tillage (MT) improved soil physical properties efficiently. Minimum tillage as compared to conventional tillage increased the water stable aggregates by 80.9%, water holding capacity by 24.8% and plant available water by 13.4% as compared to conventional tillage which was at 61.3%, 22.2% and 10.3% respectively, in the upper soil layer of 0-10 cm.

##### **4.1.11.2 Effect of green manuring on water holding capacity**

Improvement of water holding capacity of the soil is clearly observed with the use of green manures in the soil. Table 4.5(a) and Fig 4.11(a) clearly indicates the

impact of green manures over control, lifting the WHC count percentage. In the year 2022, water holding capacity in plots where  $G_6$  (green manuring through dhaincha 2 t  $ha^{-1}$  and cowpea 2 t  $ha^{-1}$  @ 4 t  $ha^{-1}$ ) were applied exhibited maximum WHC (46.43%) amidst all the sub plots of green manuring, followed by  $G_2$  (green manuring through dhaincha @ 4 t  $ha^{-1}$ ) with WHC of 46.31% and  $G_4$  (green manuring through cowpea 4 t  $ha^{-1}$ ) with 46.27% WHC, while the lowest water holding capacity was observed in  $G_0$  (no green manures) *i.e.* control plot (42.66%) WHC. This indicates increase in WHC of soil by 8.83%, 8.55% and 8.46% respectively in  $G_6$ ,  $G_2$  and  $G_4$  against  $G_0$  *i.e.* control. These consequences may be because green manures add organic matter, improve soil structure, help the microbial activity and reduce erosion of soil which in the long run may help the soil to improve its water holding capacity of the soil.

#### 4.1.11.3 Interaction effect

The interaction effect of water holding capacity of the soil as influenced by implementation of tillage in association with green manuring in maize (*Zea mays* L.) field in a two-year research executed in the experimental plot of Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University is discussed in Table 4.5(b) and portrayed in Fig 11(b). The data pertaining to the initial year (2022) indicates that the maximum water holding capacity was observed in the treatment combination of  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t  $ha^{-1}$  and cowpea 2 t  $ha^{-1}$  @ 4 t  $ha^{-1}$ ) which was at 46.49% followed by  $T_MG_2$  (minimum tillage + green manuring through dhaincha 4 t  $ha^{-1}$ ) with 46.38% WHC and  $T_CG_6$  (conventional tillage + green manuring through dhaincha 2 t  $ha^{-1}$  and cowpea 2 t  $ha^{-1}$  @ 4 t  $ha^{-1}$ ) 46.38% WHC. Comparing to  $T_CG_0$  (conventional tillage + control) 42.51% WHC it was revealed that escalation of WHC of 9.36% in  $T_MG_2$  and 9.10% in  $T_MG_6$  and  $T_CG_6$ . Similar results of increase in WHC was also seen in the second year of study period where  $T_MG_6$  (49.53%) and  $T_MG_2$  (49.41%) increased the WHC of soil by 16.76% and 16.47% correspondingly as compared to  $T_CG_0$  (42.42%). Pooled average displayed similar trend where  $T_MG_6$  (48.01%) and  $T_MG_2$  (47.89%) increased the WHC of soil by 13.04% and 12.76% as equated alongside

T<sub>C</sub>G<sub>0</sub> (42.47%). Rafique Sajjad (2018) outlined that in the first year, application of green manures via cowpea enhanced the soil moisture level by 12.8% in 0-15 cm depth and 13.7% in 15-30 cm soil depth. In the second year, fields were green manures were not provided the moisture content was recorded at 12.6% and 14.4% at the soil depth of 0-15 cm and 15-30 cm respectively. The plots where green manures were incorporated increased the soil moisture and water holding capacity evidently. This statement was also highlighted in the study conducted by Mosavi *et al.* (2012).

#### **4.1.12 Hydraulic conductivity**

Table 4.5(a) and 4.5(b) and Fig 4.12(a) and Fig 4.12(b) concisely determine the findings of the two-year exploration on hydraulic conductivity of the soil by the utilization of minimum and conventional tillage systems and various composition of green manures (dhaincha and cowpea). The findings after the analysis of the two-year investigation are specified below.

##### **4.1.12.1 Effect of tillage on hydraulic conductivity**

Hydraulic conductivity of the soil as determined by the exploitation of tillage operations is represented in Table 4.5(a) and depicted in Fig 4.12(a). The first year (2022) indicates the growth of hydraulic conductivity of soil involving plots where (T<sub>M</sub>) minimum tillage (13.19 cm hr<sup>-1</sup>) operations were conducted subsequently by (T<sub>C</sub>) conventional tillage (13.15 cm hr<sup>-1</sup>) showing higher hydraulic conductivity in M<sub>T</sub> over C<sub>T</sub> by 0.30%. Outcomes in the second year (2023) showed 0.52% elevation in hydraulic conductivity involving T<sub>M</sub> (13.28 cm hr<sup>-1</sup>) and T<sub>C</sub> (13.21 cm hr<sup>-1</sup>). The data pertaining to pooled data in the plots involving tillage operations disclosed that higher hydraulic conductivity was observed in T<sub>M</sub> (13.24 cm hr<sup>-1</sup>) than T<sub>M</sub> (13.18 cm hr<sup>-1</sup>) resulting 0.45% increase in hydraulic conductivity of soil. Minimum tillage may lead to improved soil structure, enhancement of pore connectivity, increased organic matter content, and preservation of macro pores and reduce soil surface sealing altogether maintaining and enhancing the soil hydraulic conductivity. Bhattacharyya *et al.* (2006) in their investigation outlined that that hydraulic conductivity of the soil was lower with the implementation of minimum tillage (MT) than in zero tillage

(ZT). Conventional tillage showed an increase in hydraulic conductivity at different soil depths. An enhancement in unsaturated hydraulic conductivity was observed with the implementation of minimum tillage as compared to conventional tillage. The study concluded that MT helps maintain soil structure and moisture content more effectively than other tillage practices. The outcomes of this report coincide with the works conducted by Jabro *et al.* (2023).

#### 4.1.12.2 Effect of green manuring on hydraulic conductivity

Data concerning to hydraulic conductivity of soil as impacted by the addition of different configuration of green manures for two years and pooled average is provided in Table 4.5(a) and represented in Fig 4.12(a). In 2022, incorporation of green manures tended to increase the hydraulic conductivity of soil significantly as evidences from the table. The highest hydraulic conductivity of soil was perceived in the green manures plot  $G_6$  *i.e.* green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (14.34 cm hr<sup>-1</sup>) where peak hydraulic conductivity was recorded followed by  $G_2$  *i.e.* green manuring through dhaincha 4 t ha<sup>-1</sup> (14.10 cm hr<sup>-1</sup>) and  $G_4$  *i.e.* green manuring through cowpea 4 t ha<sup>-1</sup> (13.83 cm hr<sup>-1</sup>). The control plot ( $G_0$ ) exhibited lowest hydraulic conductivity accumulation (11.69 cm hr<sup>-1</sup>). Plots  $G_6$ ,  $G_2$  and  $G_4$  computed hydraulic conductivity growth of 22.66%, 20.61% and 18.30% relative to  $G_0$ . In the second year (2023) hydraulic conductivity was at its highest in plots where green manures were added. Similar to the initial year (2022)  $G_6$  (14.55 cm hr<sup>-1</sup>) exhibited the highest hydraulic conductivity, subsequently followed by  $G_2$  (14.22 cm hr<sup>-1</sup>) and  $G_4$  (13.90 cm hr<sup>-1</sup>). Similarly pooled average totaled  $G_6$  (14.45 cm hr<sup>-1</sup>) as the highest hydraulic conductivity contributor among all the green manuring plots then by  $G_2$  (14.16 cm hr<sup>-1</sup>) and  $G_4$  (13.87 cm hr<sup>-1</sup>) indicating a rise of 23.92% in  $G_6$ , 21.44% in  $G_2$  and 18.95% in  $G_4$  respectively in contrary to  $G_0$  (11.66 cm hr<sup>-1</sup>). Addition of green manures may upsurge the soil hydraulic conductivity by improving the aggregate stability which reduces the bulk density of the soil and enhances the porosity. Surface cover reduces soil crusting, improving infiltration of water and continuous pore networks, allowing faster water movement through the soil and boosting overall permeability of the soil. Ray and Gupta, (2001) and Owusu-



Prempeh *et al.* (2015) in their studies stated that enhancement in saturated hydraulic conductivity of soil was observed with the incorporation of green manures prior to puddling in rice field. Improvement in soil aggregation, reduced bulk density, increased macro pores <0.03 mm was observed with the application of green manures, which may directly have related to increased hydraulic conductivity, especially in rice-wheat cropping system.

#### 4.1.12.3 Interaction effect

Assorted data of hydraulic conductivity of soil received in the interaction amid tillage and green manuring combinations cultivating maize for two years and its pooled average is provided in Table 4.5(b) and explicitly depicted Fig 12(b). Tillage operation involving minimum tillage and incorporation of green manures seemed to increase the hydraulic conductivity of soil as proved in the tables and figures in the first year (2022). T<sub>M</sub>G<sub>6</sub> *i.e.* minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> with hydraulic conductivity of 14.37 cm hr<sup>-1</sup> was the highest amongst all treatment combination followed by T<sub>C</sub>G<sub>6</sub> *i.e.* conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (14.32 cm hr<sup>-1</sup>). Elevated hydraulic conductivity by 23.34% and 22.91% was attained contrasting T<sub>M</sub>G<sub>6</sub> and T<sub>C</sub>G<sub>6</sub> with T<sub>C</sub>G<sub>0</sub> with hydraulic conductivity of (11.65 cm hr<sup>-1</sup>). Second year (2023) recorded similar results to that of the first year involving green manure treatments, elevating hydraulic conductivity count. It was found that T<sub>M</sub>G<sub>6</sub> (14.60 cm hr<sup>-1</sup>) accumulated the peak hydraulic conductivity followed by T<sub>C</sub>G<sub>6</sub> (14.49 cm hr<sup>-1</sup>) and T<sub>M</sub>G<sub>6</sub> (14.25 cm hr<sup>-1</sup>). The pooled average table depicted preminent hydraulic conductivity of soil involving T<sub>M</sub>G<sub>6</sub> (14.49 cm hr<sup>-1</sup>) and T<sub>C</sub>G<sub>6</sub> (14.41 cm hr<sup>-1</sup>) where peak increase of 24.59% and 23.90% increase in hydraulic conductivity was calculated against the treatment combination where the lowest hydraulic conductivity was accumulated T<sub>C</sub>G<sub>6</sub> (11.63 cm hr<sup>-1</sup>).

**Table 4.5 (a): Effect of tillage and green manuring on water holding capacity and hydraulic conductivity of the soil after harvest**

| Treatment             | Water holding capacity (%) |       |        | Hydraulic conductivity (cm hr <sup>-1</sup> ) |       |        |
|-----------------------|----------------------------|-------|--------|-----------------------------------------------|-------|--------|
|                       | 2022                       | 2023  | Pooled | 2022                                          | 2023  | Pooled |
| <b>Tillage</b>        |                            |       |        |                                               |       |        |
| <b>T<sub>M</sub></b>  | 44.99                      | 47.58 | 46.29  | 13.19                                         | 13.28 | 13.24  |
| <b>T<sub>C</sub></b>  | 44.87                      | 46.94 | 45.90  | 13.15                                         | 13.21 | 13.18  |
| <b>SEm ±</b>          | 0.005                      | 0.005 | 0.004  | 0.004                                         | 0.003 | 0.002  |
| <b>CD at 5%</b>       | 0.032                      | 0.032 | 0.015  | 0.022                                         | 0.017 | 0.009  |
| <b>CV</b>             | 0.054                      | 0.051 | 0.053  | 0.124                                         | 0.095 | 0.110  |
| <b>Green manuring</b> |                            |       |        |                                               |       |        |
| <b>G<sub>0</sub></b>  | 42.66                      | 42.57 | 42.62  | 11.69                                         | 11.62 | 11.66  |
| <b>G<sub>1</sub></b>  | 44.15                      | 47.04 | 45.60  | 12.14                                         | 12.20 | 12.17  |
| <b>G<sub>2</sub></b>  | 46.31                      | 49.13 | 47.72  | 14.10                                         | 14.22 | 14.16  |
| <b>G<sub>3</sub></b>  | 44.19                      | 47.18 | 45.69  | 12.79                                         | 12.85 | 12.82  |
| <b>G<sub>4</sub></b>  | 46.27                      | 48.25 | 47.26  | 13.83                                         | 13.90 | 13.87  |
| <b>G<sub>5</sub></b>  | 44.48                      | 47.43 | 45.95  | 13.34                                         | 13.40 | 13.37  |
| <b>G<sub>6</sub></b>  | 46.43                      | 49.23 | 47.83  | 14.34                                         | 14.55 | 14.45  |
| <b>SEm ±</b>          | 0.007                      | 0.010 | 0.006  | 0.006                                         | 0.007 | 0.005  |
| <b>CD @ 5%</b>        | 0.020                      | 0.029 | 0.017  | 0.017                                         | 0.021 | 0.013  |
| <b>CV</b>             | 0.038                      | 0.051 | 0.045  | 0.111                                         | 0.136 | 0.124  |

**Table 4.5 (b): Interaction effect of tillage and green manuring on water holding capacity and hydraulic conductivity of the soil after harvest**

| Treatments                        | Water holding capacity (%) |       |        | Hydraulic conductivity (cm hr <sup>-1</sup> ) |       |        |
|-----------------------------------|----------------------------|-------|--------|-----------------------------------------------|-------|--------|
|                                   | 2022                       | 2023  | Pooled | 2022                                          | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 42.81                      | 42.72 | 42.77  | 11.73                                         | 11.64 | 11.69  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 44.21                      | 47.26 | 45.73  | 12.15                                         | 12.22 | 12.18  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 46.38                      | 49.41 | 47.89  | 14.10                                         | 14.25 | 14.18  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 44.23                      | 47.27 | 45.75  | 12.81                                         | 12.90 | 12.86  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 46.30                      | 49.32 | 47.81  | 13.85                                         | 13.95 | 13.90  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 44.53                      | 47.57 | 46.05  | 13.36                                         | 13.43 | 13.39  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 46.49                      | 49.53 | 48.01  | 14.37                                         | 14.60 | 14.49  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 42.51                      | 42.42 | 42.47  | 11.65                                         | 11.60 | 11.63  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 44.10                      | 46.82 | 45.46  | 12.12                                         | 12.17 | 12.15  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 46.24                      | 48.86 | 47.55  | 14.09                                         | 14.19 | 14.14  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 44.16                      | 47.09 | 45.62  | 12.76                                         | 12.81 | 12.78  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 46.24                      | 47.19 | 46.71  | 13.80                                         | 13.86 | 13.83  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 44.43                      | 47.29 | 45.86  | 13.32                                         | 13.38 | 13.35  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 46.38                      | 48.94 | 47.66  | 14.32                                         | 14.49 | 14.41  |
| <b>SEm ±</b>                      | 0.010                      | 0.014 | 0.009  | 0.008                                         | 0.010 | 0.007  |
| <b>CD at 5%</b>                   | 0.028                      | 0.041 | 0.024  | 0.025                                         | 0.030 | 0.019  |

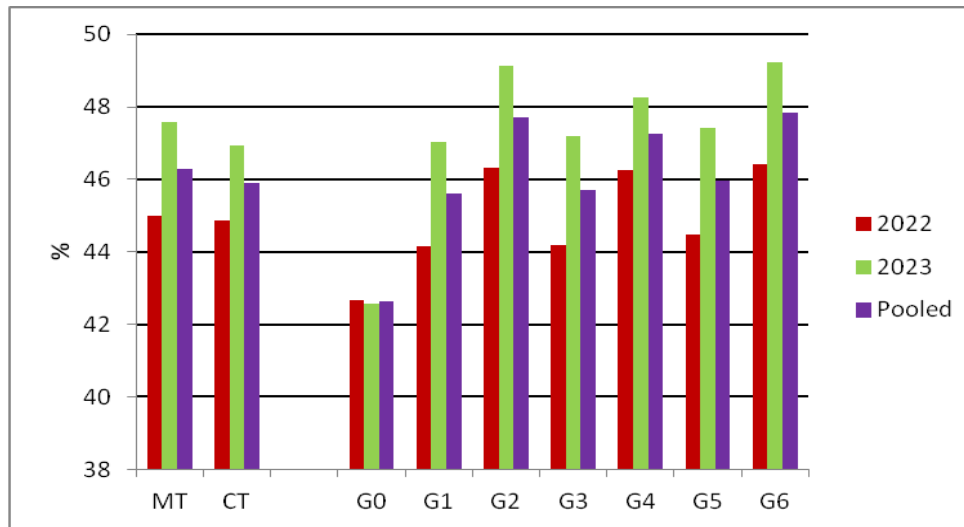


Fig. 4.11(a): Effect of tillage and green manuring on water holding capacity

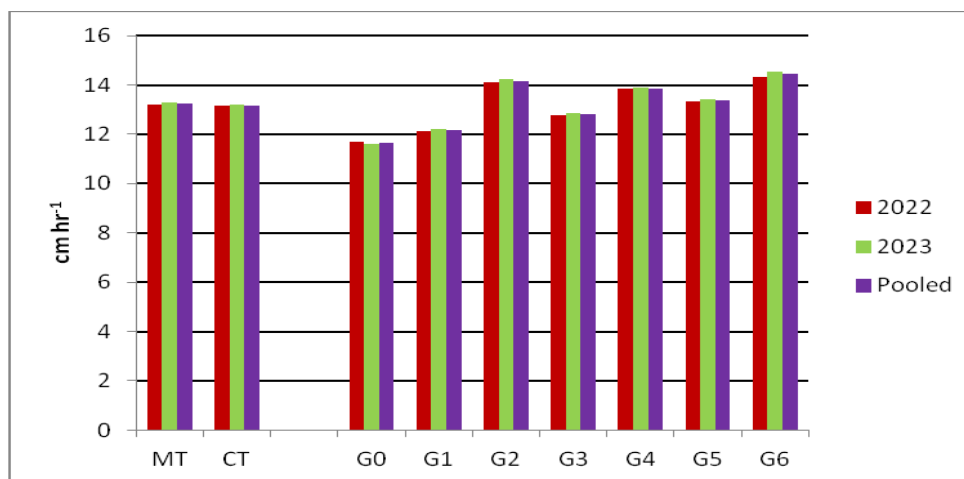


Fig. 4.12(a): Effect of tillage and green manuring on hydraulic conductivity

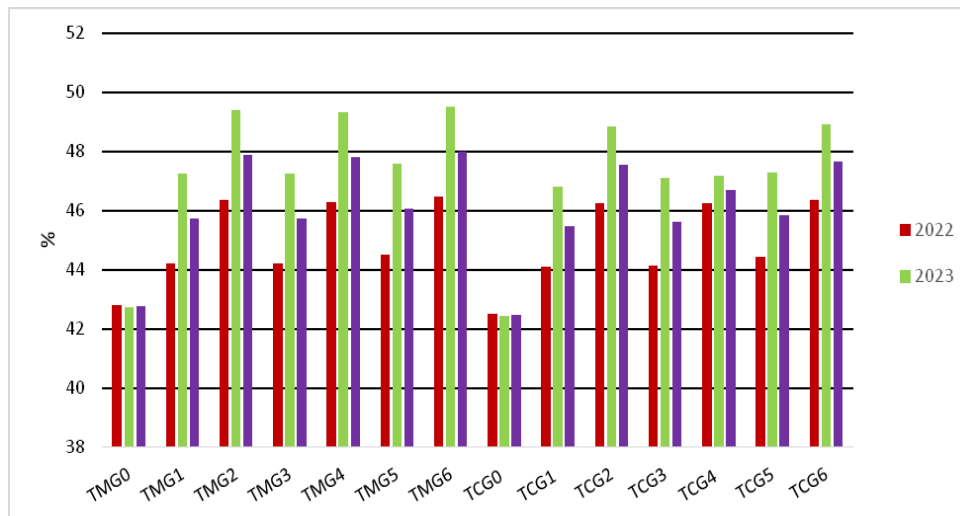


Fig. 4.11(b): Interaction effect of tillage and green manuring on water holding capacity

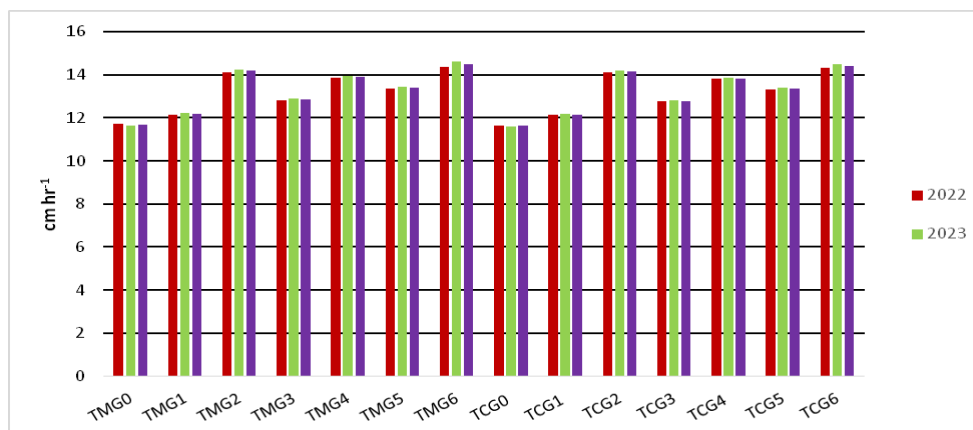


Fig. 4.12(b): Interaction effect of tillage and green manuring on hydraulic conductivity

#### **4.1.13 Mean weight diameter**

The observations concerning mean weight diameter of the soil as mediated by the adoption and incorporation minimum and conventional tillage and green manures like dhaincha and cowpea in the ascertained in the two-year investigation and its pooled average is summarized in detail in Table 4.6(a) and 4.6(b) and Fig 4.13(a) and Fig 4.13(b).

##### **4.1.13.1 Effect of tillage on mean weight diameter**

Discussion on findings and results received by involving different tillage practices with respect to mean weight diameter (MWD) of the soil is conveyed in Table 4.6(a) and depicted diagrammatically in Fig 4.13(a). Mean weight diameter of soil in the initial year witnessed higher values with the implementation of minimum tillage ( $T_M$ ) than conventional tillage ( $T_C$ ). The MWD of the soil with the integration of  $T_M$  (2.31 mm) was higher than that documented using  $T_M$  (2.26 mm). An assessment of increase by 2.21% while amplification of MWD by 2.17% was observed between  $T_M$  (2.35 mm) and  $T_M$  (2.30 mm) in the second year (2023). As minimal disturbances occur to the soil implementing only primary tillage operations organic matter is preserved to a larger extent which helps the soil biodiversity. This practice leads to stable and enhanced soil aggregates, improved infiltration capabilities and overall soil health. Pooled average of the two-year field study revealed that 2.19% elevation of MWD of the soil was obtained analyzing  $T_M$  (2.33 mm) and  $T_C$  (2.28 mm). Acar *et al.* (2018) and Franzluebbers (2022) concluded that soil aggregates within the range of 4.0-2.0 mm size were most prevalent and the least was in 1.0-0.5 mm range within all tillage systems in the study. No till and reduced tillage operations increased the mean weight diameter of the soil as compared to conventional tillage practices. MWD increased by 137% as compared to conventional tillage in 0-15 cm soil depth. Soil organic carbon related with aggregates present in the top soil of 15 cm was found to be higher in conservation related tillage practices which also shows improved soil structure and carbon sequestration.

#### 4.1.13.2 Effect of green manuring on mean weight diameter

Table 4.6(a) and Fig 4.13(a) displays the findings of the effect of green manuring on mean weight diameter (MWD) of the soil assessing the performance of maize (*Zea mays* L.). It is clearly apparent from the empirical evidences received after the analysis that green manures play a vital role managing and improving the mean weight diameter of the soil. The initial year (2022) outcomes revealed that with the introduction of G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with MWD of 2.57 mm trailing by G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) with MWD of 2.45 mm and G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) having MWD of 2.44 mm whereas the least MWD was obtained in plot where no green manures were applied (G<sub>0</sub>) with MWD of 2.02. Evaluating the received data, it was noticed that an elevation of 27.22%, 21.28% and 20.79% respectively analyzing G<sub>6</sub>, G<sub>2</sub> and G<sub>4</sub> contrary to G<sub>0</sub> was observed. The succeeding year (2023) also provided similar measurements where MWD was at its peak with the embedment of green manure. The maximum MWD of the soil was recorded in the plot involving G<sub>6</sub> (2.64 mm) followed by G<sub>2</sub> (2.50 mm) and G<sub>4</sub> (2.49 mm) respectively. Plots where no green manures were provided triggered least mean weight diameter (G<sub>0</sub>) 2.00 mm. This led to increased MWD by 32%, 25% and 24.50% in G<sub>6</sub>, G<sub>2</sub> and G<sub>4</sub> correspondingly in contrary to G<sub>0</sub>. Analogous outcome was also observed in pooled table where escalated MWD of soil involving G<sub>6</sub> (2.61 mm) followed by G<sub>2</sub> (2.47 mm) and G<sub>4</sub> (2.46 mm) which produced increase of 29.85%, 22.88% and 22.38% as compared to G<sub>0</sub> (2.01 mm). The added organic matter obtained by the integration of green manures of the soil in conjunction with root development and soil microbes may help the soil to produce natural soil binding agent which enhances the soil to larger aggregates and better stability.

#### 4.1.13.3 Interaction effect

The interaction involving minimum and conventional tillage adoption and altered configuration of green manures and its effects on mean weight diameter of the soil are reported in Table 4.6(b) and illustrated in Fig 13(b). Positive correlation between tillage and green manuring was obtained concerning mean weight diameter

(MWD) of the soil. In the initial year (2022) the highest MWD was in the treatment combination of  $T_M G_6$  i.e. minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  with MWD of 2.60 mm and  $T_C G_6$  i.e. conventional tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  (2.55 mm) MWD, while the least effective treatment combination regarding MWD was observed in  $T_C G_0$  i.e. conventional tillage + control (1.98 mm). Increase in MWD by 31.31% and 28.78% in  $T_M G_6$  and  $T_C G_6$  respectively in contrary to  $T_C G_0$ . In 2023, treatment combination  $T_M G_6$  (2.70 mm) and  $T_C G_6$  (2.59 mm) executed the best amongst all the combination in elevating MWD of the soil whereas the least effectual combination was of  $T_C G_0$  (1.96 mm). Similar consequence and trend was also highlighted in pooled data to that of 2022 and 2023 where  $T_M G_6$  (2.65 mm) and  $T_C G_6$  (2.57 mm) performed the best amongst all the combination increasing the MWD whereas the least efficient treatment combination was in  $T_C G_0$  (1.97 mm) which gave 34.51% and 30.45% in  $T_M G_6$  and  $T_C G_6$  respectively compared to  $T_C G_0$ . Green manures may produce more  $\text{CO}_2$  and  $\text{CH}_4$  than NPK but significant improvement is also observed with its application. Significant improvement in soil physical properties was indicated by the increase in mean weight diameter by 21.9%. Addition of green manures also enhanced the soil structure and aggregate stability compared to typical NPK fertilization (Park and Lee, 2025 and Mandal *et al.*, 2003).

#### **4.1.14 Percent aggregates > 0.25 mm**

Data concerning varied percent aggregates > 0.25 mm as persuaded by implementation different tillage methods and green manures is concisely discussed and represented in Table 4.6(a) and 4.6(b) and Fig 14(a) and 14(b).

##### **4.1.14.1 Effect of tillage on percent aggregates > 0.25 mm**

Various aspects of results obtained by following appropriate material and methods relating to percent aggregates > 0.25 mm as swayed by adoption of tillage practices is provided in Table 4.6(a) and Fig 14(a). Percent aggregates > 0.25 mm in soil offered superior results implementing minimum tillage ( $T_M$ ) in contrast to conventional tillage ( $T_C$ ) in the initial year (2022).  $T_M$  (83.07%) as compared to  $T_C$



(82.74%) presented 0.39% increase in percent aggregate > 0.25 mm. A comparable trend in the second year was also observed where 0.43% increase in percent aggregate > 0.25 mm was observed computing T<sub>M</sub> (83.12%) and T<sub>M</sub> (82.77%). Pooled average revealed T<sub>M</sub> (83.09%) elevated the percent aggregate > 0.25 mm in the soil by 0.39% in comparison to T<sub>C</sub> (82.76%). Fewer disturbances in the top soil and residues may compel the soil to higher aggregate stability and formation of better aggregate count in minimum tillage than conventional tillage. Yeboah *et al.* (2018) reported multiple studies that have indicated the adoption of conservation tillage system like no till or minimum tillage increase micro aggregates of soil (>0.25 mm) and significant increase in macro aggregates as compared to extensive tillage system like conventional tillage. This statement was supported by the studies conducted by He *et al.* (2021).

#### **4.1.14.2 Effect of green manuring on percent aggregates > 0.25 mm**

Surge of aggregates percentage > 0.25 mm as justified by the inferences provided in Table 4.6(a) and Fig 14(a). With the incorporation of green manures was noticed. Initial year (2022) ascertained the fact that addition of green manures in certain characteristic like G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with 84.77% percent aggregates which was perceived to be the highest among the green manuring treatment subsequently by G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) (84.25%) and G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) (83.24%) respectively and the least efficient sub plot treatment was seen in G<sub>0</sub> *i.e.* control with percent aggregate of 80.14%. It was observed that increase in percent aggregates by 5.77%, 5.12 and 3.86% analyzing G<sub>6</sub>, G<sub>2</sub> and G<sub>4</sub> against G<sub>0</sub> were received upon deriving the percent escalation. The study year (2023) gave analogous readings to that of the first year where percent aggregates > 0.25 mm in G<sub>6</sub> (84.82%), G<sub>2</sub> (84.28%) and G<sub>4</sub> (83.49%) tends to augment as compared to G<sub>0</sub> (80.11%) by 5.87%, 5.20% and 4.21% respectively. Corresponding outcomes relative to that of 2022 and 2023 were obtained in the pooled average where in G<sub>6</sub> (84.80%), G<sub>2</sub> (84.27%) and G<sub>4</sub> (83.47%) compared to G<sub>0</sub> (80.12%) inclined to increase the percent aggregates > 0.25 mm by 5.84%, 5.17% and 4.18%. The green manures incorporated

into the soil helps to produce more soil organic matter and helps enlarge soil microbe's population. These microbes enhance the soil structure by maintaining better soil aggregates and stable aggregates count.

#### 4.1.14.3 Interaction effect

Interaction effect of varied treatment combination as stimulated by the implementing of two types of tillage practices (minimum and conventional tillage) and integration of green manures on percent aggregates  $> 0.25$  mm is provided in Table 4.6(b) and portrayed visually in Fig 14(b). The first year of experimentation (2022) disclosed that the treatment combination comprising  $T_MG_6$  *i.e.* minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  attained percent aggregates  $> 0.25$  mm of (84.89%) which recorded the highest among all the 14 treatment combination followed by  $T_CG_6$  *i.e.* conventional tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  with (84.65%) percent aggregates and subsequently by  $T_MG_2$  *i.e.* minimum tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$  at percent aggregates of (84.32%). The least influential treatment combination was observed in  $T_CG_0$  *i.e.* conventional tillage + control (80.04%), analysing the most effective treatment and the least effective it was observed that a boost in percent aggregates  $> 0.25$  mm by 6.05%, 5.75% and 5.34% respectively. In the following year (2023), the most impactful treatment combination involving percent aggregates  $> 0.25$  mm was acquired in  $T_MG_6$  (84.95%) thereafter by  $T_CG_6$  (84.69%) followed by  $T_MG_2$  (84.38%) whereas treatment combination  $T_CG_0$  (80.00%) was marked as the least efficient. Upsurge of percent aggregates by 6.18%, 5.86% and 5.47% was acquired estimating the percent increase in  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$  respectively contrary to  $T_CG_0$ . In the segment of pooled average data involving two-year investigation (2022 and 2023) it was revealed that the highest percent aggregate was received in the treatment combination of  $T_MG_6$  (84.92%) consequently by  $T_CG_6$  (84.67%) and  $T_MG_2$  (84.35%) whereas  $T_CG_0$  (80.02%) was the least effective treatment combination concerning the percent aggregate  $> 0.25$  mm of the cultivated soil. An increase of 6.12%, 5.81% and 5.41% was obtained assessing the percent improvement computing  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$  respectively against  $T_CG_0$ .

Zhang *et al.* (2019) concluded in their research that soil aggregates  $> 0.25\text{mm}$  and mean weight diameter of the soil was increased with the application of green manures as it increases the organic matter content. Physical quality and stability of the soil was also improved with the addition of green manures as compared to bare soil under dryland conditions. Moisture retention, root penetrating ability of the plant and overall plant establishment was improved with the enhancement of soil aggregates. Similar inferences were also observed in the studies conducted by (Ansari *et al.*, 2022 and Singh *et al.*, 2023a).

**Table 4.6 (a): Effect of tillage and green manuring on mean weight diameter and percent aggregates > 0.25 mm of the soil after harvest**

| Treatment             | Mean weight diameter (mm) |       |        | Percent aggregates >0.25 mm (%) |       |        |
|-----------------------|---------------------------|-------|--------|---------------------------------|-------|--------|
|                       | 2022                      | 2023  | Pooled | 2022                            | 2023  | Pooled |
| <b>Tillage</b>        |                           |       |        |                                 |       |        |
| <b>T<sub>M</sub></b>  | 2.31                      | 2.35  | 2.33   | 83.07                           | 83.12 | 83.09  |
| <b>T<sub>C</sub></b>  | 2.26                      | 2.30  | 2.28   | 82.74                           | 82.77 | 82.76  |
| <b>SEm ±</b>          | 0.001                     | 0.002 | 0.002  | 0.002                           | 0.002 | 0.001  |
| <b>CD at 5%</b>       | 0.006                     | 0.013 | 0.013  | 0.014                           | 0.011 | 0.006  |
| <b>CV</b>             | 0.203                     | 0.414 | 0.328  | 0.013                           | 0.010 | 0.011  |
| <b>Green manuring</b> |                           |       |        |                                 |       |        |
| <b>G<sub>0</sub></b>  | 2.02                      | 2.00  | 2.01   | 80.14                           | 80.11 | 80.12  |
| <b>G<sub>1</sub></b>  | 2.19                      | 2.23  | 2.21   | 82.54                           | 82.59 | 82.56  |
| <b>G<sub>2</sub></b>  | 2.45                      | 2.50  | 2.47   | 84.25                           | 84.28 | 84.27  |
| <b>G<sub>3</sub></b>  | 2.12                      | 2.17  | 2.15   | 82.13                           | 82.18 | 82.15  |
| <b>G<sub>4</sub></b>  | 2.44                      | 2.49  | 2.46   | 83.44                           | 83.49 | 83.47  |
| <b>G<sub>5</sub></b>  | 2.21                      | 2.26  | 2.24   | 83.09                           | 83.13 | 83.11  |
| <b>G<sub>6</sub></b>  | 2.57                      | 2.64  | 2.61   | 84.77                           | 84.82 | 84.80  |
| <b>SEm ±</b>          | 0.006                     | 0.007 | 0.005  | 0.011                           | 0.011 | 0.008  |
| <b>CD @ 5%</b>        | 0.019                     | 0.020 | 0.013  | 0.033                           | 0.031 | 0.022  |
| <b>CV</b>             | 0.693                     | 0.709 | 0.701  | 0.033                           | 0.031 | 0.032  |

**Table 4.6 (b): Interaction effect of tillage and green manuring on mean weight diameter and percent aggregates > 0.25 mm of the soil after harvest**

| Treatments                        | Mean weight diameter (mm) |       |        | Percent aggregates >0.25 mm (%) |       |        |
|-----------------------------------|---------------------------|-------|--------|---------------------------------|-------|--------|
|                                   | 2022                      | 2023  | Pooled | 2022                            | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 2.06                      | 2.03  | 2.05   | 80.24                           | 80.22 | 80.23  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 2.21                      | 2.25  | 2.23   | 82.82                           | 82.89 | 82.86  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 2.47                      | 2.52  | 2.50   | 84.32                           | 84.38 | 84.35  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 2.15                      | 2.20  | 2.18   | 82.39                           | 82.46 | 82.43  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 2.45                      | 2.49  | 2.47   | 83.67                           | 83.72 | 83.70  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 2.22                      | 2.26  | 2.24   | 83.15                           | 83.20 | 83.18  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 2.60                      | 2.70  | 2.65   | 84.89                           | 84.95 | 84.92  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 1.98                      | 1.96  | 1.97   | 80.04                           | 80.00 | 80.02  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 2.16                      | 2.21  | 2.18   | 82.25                           | 82.29 | 82.27  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 2.42                      | 2.47  | 2.45   | 84.18                           | 84.19 | 84.18  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 2.10                      | 2.14  | 2.12   | 81.86                           | 81.90 | 81.88  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 2.43                      | 2.48  | 2.46   | 83.22                           | 83.26 | 83.24  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 2.20                      | 2.26  | 2.23   | 83.02                           | 83.06 | 83.04  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 2.55                      | 2.59  | 2.57   | 84.65                           | 84.69 | 84.67  |
| <b>SEm ±</b>                      | 0.009                     | 0.010 | 0.007  | 0.016                           | 0.015 | 0.011  |
| <b>CD at 5%</b>                   | 0.027                     | 0.028 | 0.019  | 0.047                           | 0.044 | 0.031  |

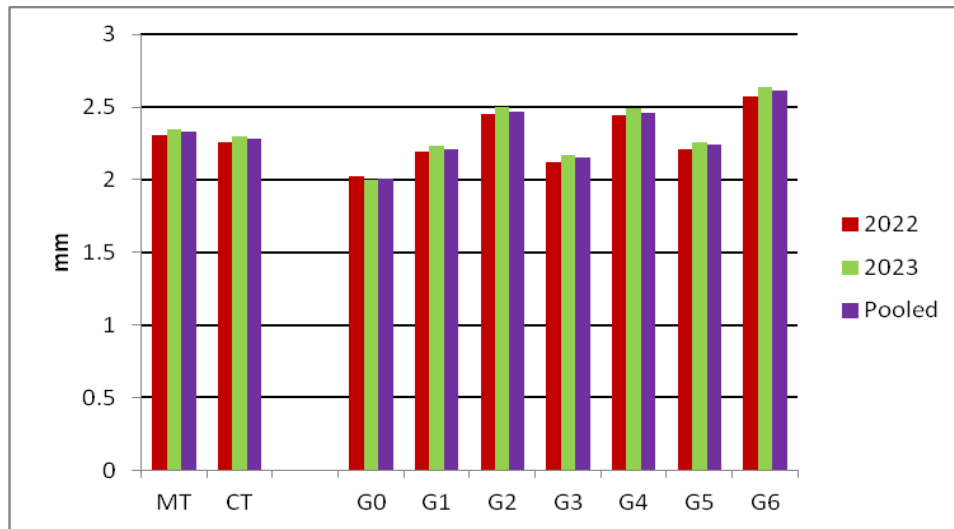


Fig. 4.13(a): Effect of tillage and green manuring on mean weight diameter

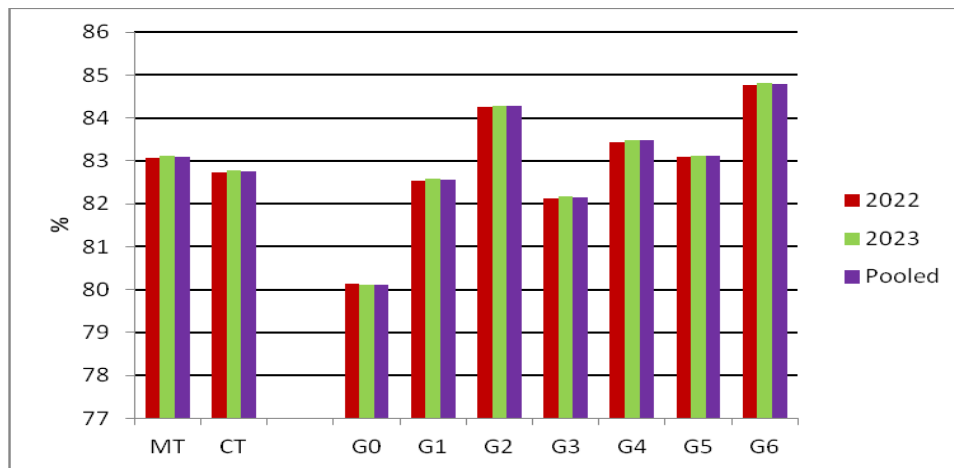


Fig. 4.14(a): Effect of tillage and green manuring on percent aggregates > 0.25 mm

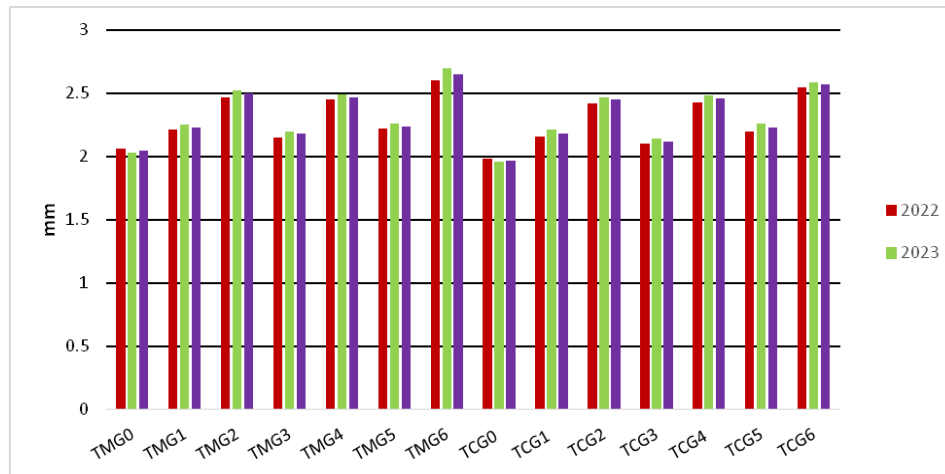


Fig. 4.13(b): Interaction effect of tillage and green manuring on mean weight diameter

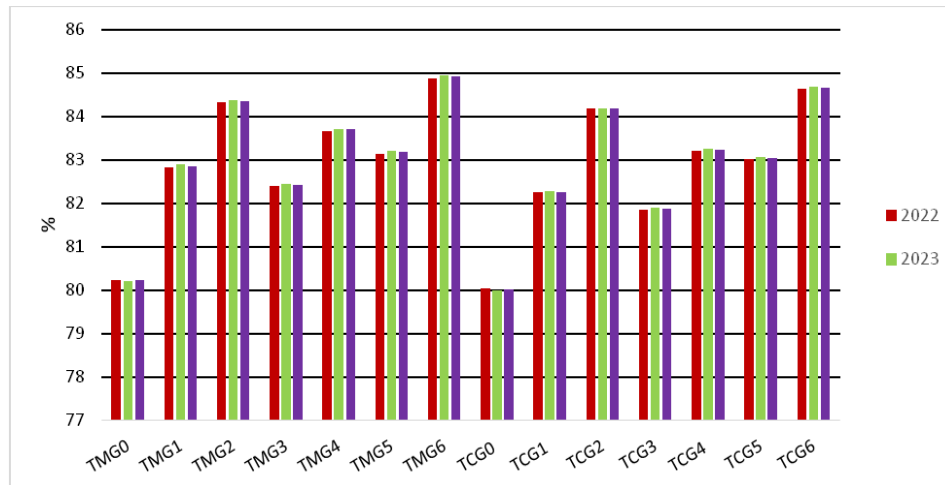


Fig. 4.14(b): Interaction effect of tillage and green manuring on percent aggregates > 0.25 mm

#### 4.1.15 Soil microbial biomass carbon

The findings concurrent to soil microbial biomass carbon of the soil as a result of adopting assorted tillage practices and assimilation of green manures and their interaction effect is provided in Table 4.7(a) and 4.7(b) and graphically represented in Fig 4.15(a) and Fig 4.15(b).

##### 4.1.15.1 Effect of tillage on soil microbial biomass carbon

The details pertaining to soil microbial biomass carbon (SMBC) associated with the first year of field study (2022) revealed that minimum tillage ( $T_M$ ) appeared to execute elevation of soil microbial biomass carbon in contrary to conventional tillage ( $T_C$ ). Implementation of  $T_M$  ( $218.92 \mu\text{g g}^{-1}$ ) seemed to increase the SMBC of soil by 0.66% in relation to  $T_C$  ( $217.48 \mu\text{g g}^{-1}$ ) whereas in the following year (2023) enhancement of SMBC of 0.43% was observed computing  $T_M$  ( $220.35 \mu\text{g g}^{-1}$ ) with that of  $T_C$  ( $219.09 \mu\text{g g}^{-1}$ ). The pooled average of 2022 and 2023 offered enhancement in SMBC of soil by 0.62% contrasting  $T_M$  ( $219.64 \mu\text{g g}^{-1}$ ) against  $T_M$  ( $218.28 \mu\text{g g}^{-1}$ ). Minimal disturbance to the soil often leads to better soil organic matter accumulation and enhanced soil structure. This leads to better soil microbe population and reduction of  $\text{CO}_2$  which occurs mostly in conventional tillage practices. These factors may help the soil to produce more SMBC proportion. Kaurin *et al.* (2015) and Schmidt *et al.* (2018) resolved in their studies that soil microbial biomass carbon using minimum tillage ( $13.19 \mu\text{g g}^{-1}$ ) was significantly greater in the soil depth of 0-10 cm range in comparison to conventional tillage ( $10.02 \mu\text{g g}^{-1}$ ). With the increase in soil depth there was a reversal in trend where soil microbial biomass carbon was found to be lower in minimum tillage ( $7.86 \mu\text{g g}^{-1}$ ) than conventional tillage ( $10.74 \mu\text{g g}^{-1}$ ) in the soil depth of 10-20 cm. With this finding it can be concluded that SMBC increases with the increase in soil depth. Soil organic carbon also indicates a positive linear relationship with SMBC.



#### 4.1.15.2 Effect of green manuring on soil microbial biomass carbon

Findings as per the incorporation of green manuring on soil microbial biomass carbon (SMBC) and its varied proportion of data are furnished in Table 4.7(a) and Fig 4.15(a). Outcome of results as influenced by green manures in 2022 suggested that  $G_2$  *i.e.* green manuring through dhaincha 4 t ha<sup>-1</sup> (224.60  $\mu\text{g g}^{-1}$ ) delivered the most significant effectiveness among all the green manuring treatment, followed by  $G_6$  *i.e.* green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> with SMBC (222.83  $\mu\text{g g}^{-1}$ ) and  $G_4$  *i.e.* green manuring through cowpea 4 t ha<sup>-1</sup> (222.39  $\mu\text{g g}^{-1}$ ) while the minimal influential green manuring treatment was in  $G_0$  *i.e.* control (200.43  $\mu\text{g g}^{-1}$ ). An improvement of 12.05%, 11.17% and 10.95% was documented analyzing  $G_2$ ,  $G_6$  and  $G_4$  was recorded in relation to  $G_0$ . Subsequent year of field study *i.e.* 2023 signified that SMBC was reported maximum in  $G_2$  treated plots (226.66  $\mu\text{g g}^{-1}$ ) succeeded by  $G_6$  (225.01  $\mu\text{g g}^{-1}$ ) and  $G_4$  (224.38  $\mu\text{g g}^{-1}$ ) while the least SMBC was in  $G_0$  (200.22  $\mu\text{g g}^{-1}$ ). Attainment of 13.20%, 12.38% and 12.06% increase in  $G_2$ ,  $G_6$  and  $G_4$  was recorded respectively measured against  $G_0$ . Resembling outcomes were attained tabulating the pooled average data of the field study conducted in 2022 and 2023 where boosted SMBC was obtained in  $G_2$  (225.63  $\mu\text{g g}^{-1}$ ) succeeded by  $G_6$  (223.92  $\mu\text{g g}^{-1}$ ) and  $G_4$  (223.39  $\mu\text{g g}^{-1}$ ) amended plots in contrast to  $G_0$  (200.32  $\mu\text{g g}^{-1}$ ) which was the least efficient treatment, contributed increase of 12.63%, 11.78% and 11.51% respectively on SMBC of soil. The increase organic carbon of the soil enhanced microbial growth and activity in the soil, boosted enzyme activities with the application of green manures may lead to better soil microbial biomass carbon with the integration of green manures into the soil.

#### 4.1.15.3 Interaction effect

The interaction effect adopting different tillage practices and assorted configuration of green manures for the two-year field investigation and pooled average is disclosed and depicted in Table 4.7(b) and Fig 4.15(b). Beneficial effect of as

impacted by merging of tillage and green manuring have induces a positive relation rejuvenating the soil microbial biomass carbon (SMBC) in the cultivated soil of the initial year (2022). The maximum increase in SMBC was observed in the interaction between  $T_MG_2$  (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) contributing SMBC of (225.48  $\mu\text{g g}^{-1}$ ) followed by  $T_CG_2$  (conventional tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) with SMBC of (223.71  $\mu\text{g g}^{-1}$ ) and  $T_MG_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> containing SMBC (223.54  $\mu\text{g g}^{-1}$ ) while the weakest interaction amongst the 14 treatment combination was noted in  $T_CG_0$  i.e. conventional tillage + control comprising SMBC of (198.87  $\mu\text{g g}^{-1}$ ). This presents upsurge of SMBC by 13.38%, 12.49% and 12.40% respectively in  $T_MG_2$ ,  $T_CG_2$  and  $T_MG_6$  relative to  $T_CG_0$ . Escalation in SMBC was also seen in the second year (2023) where  $T_MG_2$  (227.83  $\mu\text{g g}^{-1}$ ),  $T_MG_6$  (225.79  $\mu\text{g g}^{-1}$ ) and  $T_CG_2$  (225.49  $\mu\text{g g}^{-1}$ ) raised the SMBC of soil by 14.75%, 13.73% and 13.57% respectively as compared to  $T_CG_0$  (198.53  $\mu\text{g g}^{-1}$ ). Matching pattern was also observed in the pooled average table of 2022 and 2023 where  $T_MG_2$  (226.66  $\mu\text{g g}^{-1}$ ),  $T_MG_6$  (224.66  $\mu\text{g g}^{-1}$ ) and  $T_CG_2$  (224.60  $\mu\text{g g}^{-1}$ ) elevated the SMBC by 14.07%, 13.06% and 13.03% respectively measured against  $T_CG_0$  (198.70  $\mu\text{g g}^{-1}$ ).

Zhang *et al.* (2025a) asserted in their conclusion that an extensive experiment using eight different organic amendments were carried out which also included green manures cultivating paddy. The results of the study revealed that soil microbial biomass carbon and organic carbon showed the highest results with the application of green manures surpassing all the other treatments. The carbon sequestration and humus content in the soil also showed massive improvement with green manure treatment. It enhanced the fertility of the soil and revitalized the SMBC to a prodigious extent. Comparable results were also summarized from the investigation steered by (Tang *et al.*, 2021 and Ling *et al.*, 2016).

#### 4.1.16 Soil respiration

Soil respiration as directed by the integration of tillage and *via* the use of green manuring respectively in 2022, 2023 and pooled data is deliberated in this part of discussion. Facts and findings are provided in Table 4.7(a) and 4.7(b) and represented in Fig 4.16(a) and Fig 4.16(b). All the findings provided are from the two-year investigation carried out on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.).

##### 4.1.16.1 Effect of tillage on soil respiration

The employment of two tillage method (minimum and conventional tillage) as represented in Table 4.7(a) and Fig 4.16(a) deliberate the diverse relation and consequence adopting the two mentioned tillage operations on soil respiration parameter. In the first year of study (2022), soil respiration was observed to be higher in the section of plots where minimum tillage *i.e.*  $T_M$  ( $11.59 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) was employed as opposed to  $T_C$  ( $11.50 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) while in second year of study (2023) the soil respiration of minimum tillage ( $T_M$ ) was recorded at ( $11.63 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) and conventional tillage ( $T_C$ ) was at ( $11.52 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ). An elevated increase of 0.78% and 0.95% in soil respiration was registered in the first year and second year of study respectively on analyzing  $T_M$  in conjunction with  $T_C$ . Reduced soil disturbance, higher soil moisture, improved organic carbon sequestration and the maintenance of soil temperature with the implementation of minimum tillage may aid the soil for better respiration in comparison to conventional tillage system. Pooled table data were consistent to that of initial year (2022) and the following year (2023). Pooled values of implemented tillage practice of minimum tillage  $T_M$  ( $11.61 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) surpassed the values obtained in conventional tillage  $T_C$  ( $11.51 \mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) causing 0.86% increase in soil respiration. Zapata *et al.* (2021) in their investigation observed that maximum breakdown of organic matter was observed in the treatment of conventional tillage. It enhances the soil microbial activity which tends to elevate the soil respiration rates in

the soil. Emission of CO<sub>2</sub> was also observed to be increasing which may be influenced by certain tillage practices. The carbon plays an important role in soil respiration and soil microbial biomass carbon (SMBC). The amount of carbon content in soil directly indicates the activity of soil respiration and soil microbial biomass carbon. This study was at par with the research conducted by (Lampthey *et al.*, 2017 and Sun *et al.*, 2009).

#### 4.1.16.2 Effect of green manuring on soil respiration

Impact of enriching the soil with added green manures concerning the soil respiration is furnished in Table 4.7(a) and displayed in Fig 4.16(a). With the assessment of data received analyzing the table from the initial year (2022), conclusion regarding the improvement of soil respiration can be drawn with the inclusion of green manures in the soil as green manure treated plot G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) containing soil respiration of (12.77 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) was perceived to be the highest contributor of soil respiration values than all the other green manure treated plots, followed by G<sub>1</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup>) with (12.23 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and G<sub>1</sub> *i.e.* green manuring through cowpea 2 t ha<sup>-1</sup> (11.64 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). The weakest contribution in soil respiration was acknowledged in the plots where no green manures were added *i.e.* G<sub>0</sub> (10.12 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). The assorted data received from the second year of cultivation (2023) indicated the maximum rise of soil respiration in G<sub>2</sub> (12.80 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>), subsequently by G<sub>1</sub> (12.25 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and G<sub>3</sub> (11.67 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and the least in G<sub>0</sub> (10.10 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). Parallel outcome to that of 2022 and 2023 repeated in the pooled average where peak increase of soil respiration was observed in G<sub>2</sub> (12.78 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>), followed by G<sub>1</sub> (12.24 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and G<sub>3</sub> (11.66 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and the least was in G<sub>0</sub> (10.11 µg CO<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). Increase of soil respiration by 11.0%, 11.00% and 11.000% was noted contrasting values of G<sub>2</sub>, G<sub>1</sub> and G<sub>3</sub> against G<sub>0</sub>. The added green manures into the soil may help resource fresh organic substrates, better microbial biomass and enzyme activity, maintaining the soil pH, higher CO<sub>2</sub> flux and better breakdown of organic matter can aid the soil respiration to higher extent.

#### 4.1.16.3 Interaction effect

Table 4.7(b) and Fig 4.16(b) provides a brief overview of the soil respiration data impacted by tillage and green manuring operations during the two-year field investigation conducted on maize crop during the *kharif* seasons of 2022 and 2023. Initial data reveals the impact of minimum tillage and dhaincha as a green manuring deemed excellent in improving the soil respiration of the cultivated soil. Treatment combination  $T_MG_2$  i.e. minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup> (12.87  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) was detected to be the most predominant amidst the rest of combinations, trailed by  $T_{CG_2}$  i.e. conventional tillage + green manuring through dhaincha 4 t ha<sup>-1</sup> (12.67  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) followed by  $T_{MG_1}$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> (12.28  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) while the least effectual combination was observed in  $T_{CG_0}$  i.e. conventional tillage + control (10.11  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ). A remarkable increase in soil respiration was attained where increase of 27.29%, 25.32% and 21.46% was obtained involving  $T_MG_2$ ,  $T_{CG_2}$  and  $T_{MG_1}$  with that of  $T_{CG_0}$  respectively in the base year (2022). The treatment combination  $T_MG_2$  (12.91  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) following the data obtained from the second year (2023) analysis exhibited the best combination in increasing the soil respiration, succeeded by  $T_{CG_2}$  (12.69  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) and  $T_{MG_1}$  (12.30  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) while the minimal effect of tillage and green manuring was observed in  $T_{CG_0}$  (10.09  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ). The data affiliated with pooled average of 2022 and 2023 furnishes the finding where it was observed that  $T_MG_2$  (12.89  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) was the most prominent followed by  $T_{CG_2}$  (12.68  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) and  $T_{MG_1}$  (12.29  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) whilst the lowest efficiency was documented in the combination of  $T_{CG_0}$  (10.10  $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ). Elevation in soil respiration by 27.62%, 25.54% and 21.68% was noted computing  $T_MG_2$ ,  $T_{CG_2}$  and  $T_{MG_1}$  with that of  $T_{CG_0}$ , respectively.

Shang *et al.* (2024) reported that conventional tillage practices combined with green manures tend to influence total soil respiration as well as heterotrophic respiration in the soil due to the elevated activity of microbes and decomposition of organic matter. No till practices with green manure application inclines to reduce the soil respiration by

6.7% to 8.7% and heterotrophic respiration by 8.5% to 9.8%. Xu *et al.* (2023) and Asghar and Kataoka, (2021) also summarized comparable finding from their investigation where conventional tillage practices and green manures rejuvenated the SMBC and soil respiration as soil microbe's population increased with this treatment interaction.

**Table 4.7 (a): Effect of tillage and green manuring on soil microbial biomass carbon and soil respiration of the soil after harvest**

| Treatment                   | Soil microbial biomass carbon<br>( $\mu\text{g g}^{-1}$ ) |        |        | Soil respiration<br>( $\mu\text{g CO}_2 \text{g}^{-1} \text{h}^{-1}$ ) |       |        |
|-----------------------------|-----------------------------------------------------------|--------|--------|------------------------------------------------------------------------|-------|--------|
|                             | 2022                                                      | 2023   | Pooled | 2022                                                                   | 2023  | Pooled |
| <b>Tillage</b>              |                                                           |        |        |                                                                        |       |        |
| <b>T<sub>M</sub></b>        | 218.92                                                    | 220.35 | 219.64 | 11.59                                                                  | 11.63 | 11.61  |
| <b>T<sub>C</sub></b>        | 217.48                                                    | 219.09 | 218.28 | 11.50                                                                  | 11.52 | 11.51  |
| <b>SEm <math>\pm</math></b> | 0.041                                                     | 0.109  | 0.058  | 0.006                                                                  | 0.005 | 0.004  |
| <b>CD at 5%</b>             | 0.250                                                     | 0.662  | 0.228  | 0.035                                                                  | 0.032 | 0.015  |
| <b>CV</b>                   | 0.086                                                     | 0.227  | 0.172  | 0.228                                                                  | 0.205 | 0.217  |
| <b>Green manuring</b>       |                                                           |        |        |                                                                        |       |        |
| <b>G<sub>0</sub></b>        | 200.43                                                    | 200.22 | 200.32 | 10.12                                                                  | 10.10 | 10.11  |
| <b>G<sub>1</sub></b>        | 218.33                                                    | 219.46 | 218.89 | 12.23                                                                  | 12.25 | 12.24  |
| <b>G<sub>2</sub></b>        | 224.60                                                    | 226.66 | 225.63 | 12.77                                                                  | 12.80 | 12.78  |
| <b>G<sub>3</sub></b>        | 219.43                                                    | 221.42 | 220.42 | 11.64                                                                  | 11.67 | 11.66  |
| <b>G<sub>4</sub></b>        | 222.39                                                    | 224.38 | 223.39 | 11.25                                                                  | 11.28 | 11.26  |
| <b>G<sub>5</sub></b>        | 219.41                                                    | 220.89 | 220.15 | 11.59                                                                  | 11.63 | 11.61  |
| <b>G<sub>6</sub></b>        | 222.83                                                    | 225.01 | 223.92 | 11.24                                                                  | 11.29 | 11.26  |
| <b>SEm <math>\pm</math></b> | 0.135                                                     | 0.124  | 0.092  | 0.014                                                                  | 0.013 | 0.009  |
| <b>CD @ 5%</b>              | 0.395                                                     | 0.361  | 0.261  | 0.039                                                                  | 0.037 | 0.026  |
| <b>CV</b>                   | 0.152                                                     | 0.138  | 0.145  | 0.287                                                                  | 0.265 | 0.276  |

**Table 4.7 (b): Interaction effect of tillage and green manuring on soil microbial biomass carbon and soil respiration of the soil after harvest**

| Treatments                        | Soil microbial biomass carbon<br>( $\mu\text{g g}^{-1}$ ) |        |        | Soil respiration<br>( $\mu\text{g CO}_2 \text{ g}^{-1} \text{ h}^{-1}$ ) |       |        |
|-----------------------------------|-----------------------------------------------------------|--------|--------|--------------------------------------------------------------------------|-------|--------|
|                                   | 2022                                                      | 2023   | Pooled | 2022                                                                     | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 201.99                                                    | 201.90 | 201.94 | 10.12                                                                    | 10.11 | 10.12  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 219.33                                                    | 219.51 | 219.42 | 12.28                                                                    | 12.30 | 12.29  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 225.48                                                    | 227.83 | 226.66 | 12.87                                                                    | 12.91 | 12.89  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 219.59                                                    | 221.47 | 220.53 | 12.04                                                                    | 12.09 | 12.07  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 222.70                                                    | 224.57 | 223.64 | 11.34                                                                    | 11.38 | 11.36  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 219.83                                                    | 221.37 | 220.60 | 11.24                                                                    | 11.29 | 11.27  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 223.54                                                    | 225.79 | 224.66 | 11.25                                                                    | 11.31 | 11.28  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 198.87                                                    | 198.53 | 198.70 | 10.11                                                                    | 10.09 | 10.10  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 217.32                                                    | 219.41 | 218.36 | 12.18                                                                    | 12.20 | 12.19  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 223.71                                                    | 225.49 | 224.60 | 12.67                                                                    | 12.69 | 12.68  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 219.27                                                    | 221.36 | 220.32 | 11.24                                                                    | 11.26 | 11.25  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 222.08                                                    | 224.20 | 223.14 | 11.15                                                                    | 11.18 | 11.17  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 218.98                                                    | 220.40 | 219.69 | 11.93                                                                    | 11.96 | 11.94  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 222.13                                                    | 224.23 | 223.18 | 11.22                                                                    | 11.26 | 11.24  |
| <b>SEm <math>\pm</math></b>       | 0.191                                                     | 0.175  | 0.130  | 0.019                                                                    | 0.018 | 0.013  |
| <b>CD at 5%</b>                   | 0.558                                                     | 0.511  | 0.369  | 0.056                                                                    | 0.052 | 0.037  |



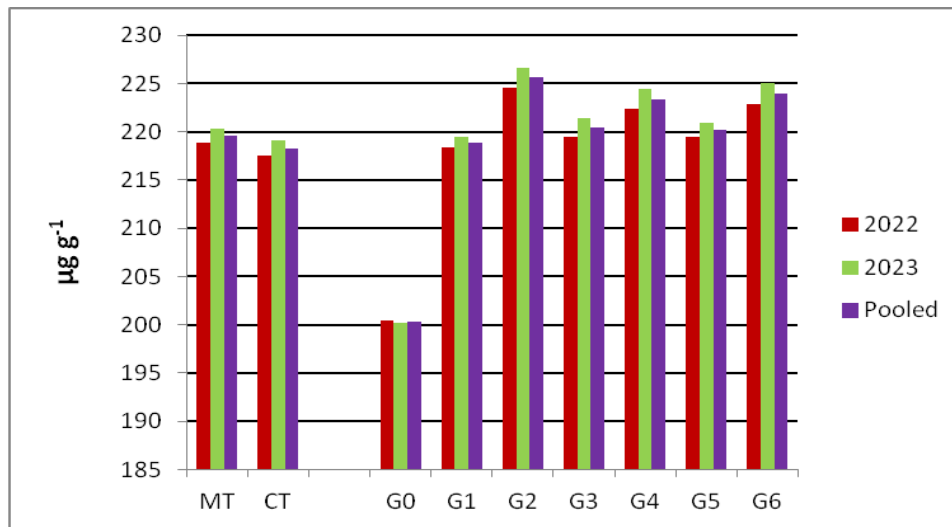


Fig. 4.15(a): Effect of tillage and green manuring on soil microbial biomass carbon

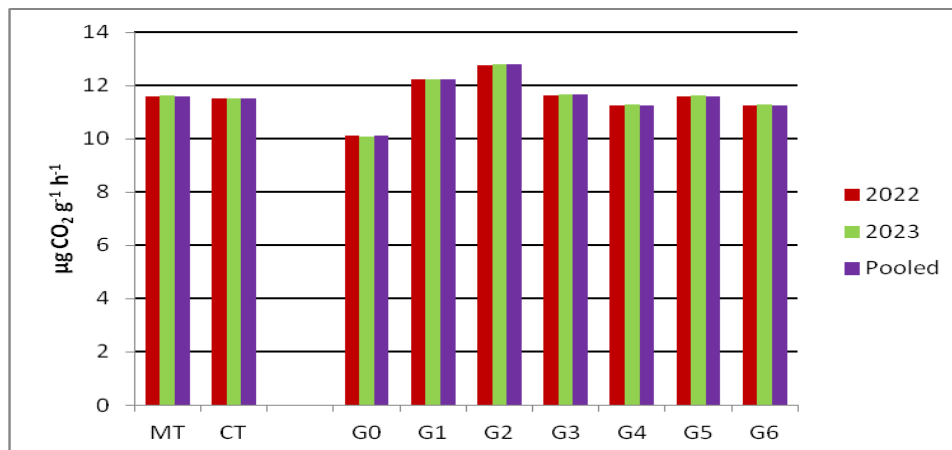


Fig. 4.16(a): Effect of tillage and green manuring on soil respiration

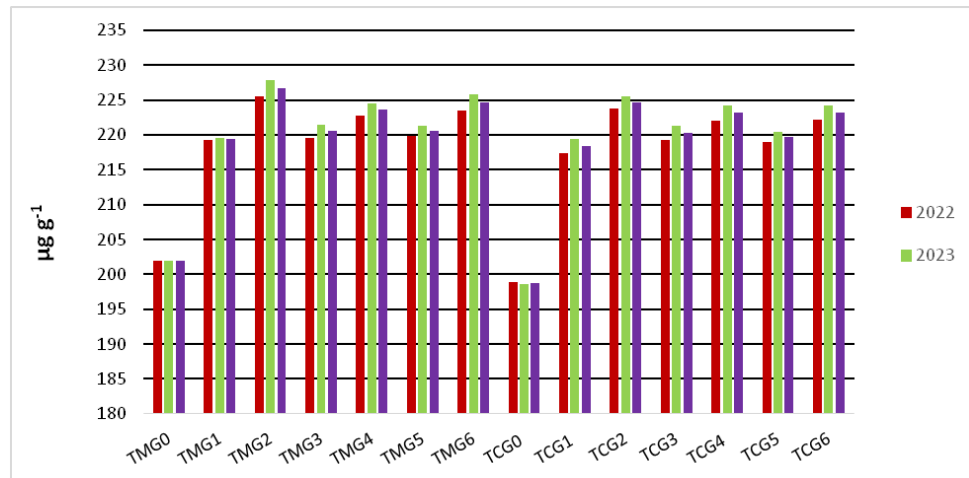


Fig. 4.15(b): Interaction effect of tillage and green manuring on soil microbial biomass carbon

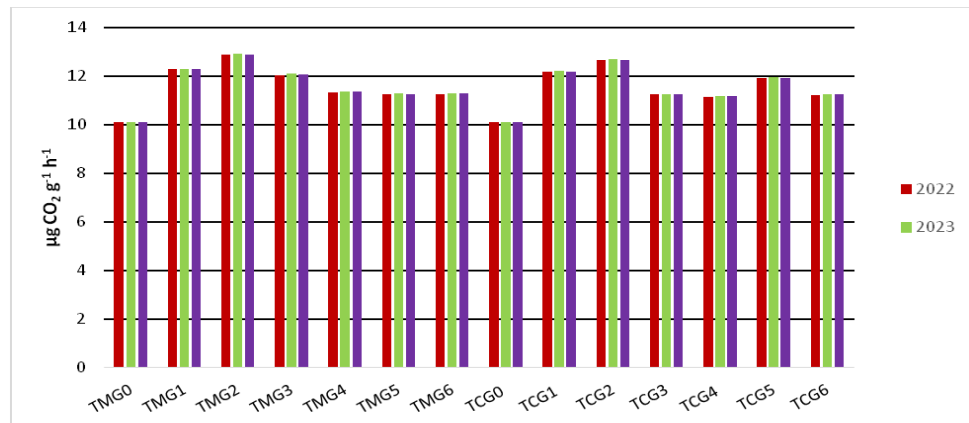


Fig. 4.16(b): Interaction effect of tillage and green manuring on soil respiration

#### **4.1.17 Soil moisture status**

The soil moisture status of the cultivated soil at 30 DAS, 60 DAS, 90 DAS and 120 DAS as influenced by the integration of minimum and conventional tillage practices and the incorporation of green manures like dhaincha and cowpea in different configuration and concentration is detailed in Table 4.8(a) and 4.8(b) and visualized in Fig 17(a), 17(b), 17(c), 17(d) and Fig 18(a), 18(b), 18(c) and 18(d). The soil moisture content of the cultivated soil was analyzed gravimetrically for both the year of investigation. This segment of discussion provides the findings obtained from the two-year analysis and the pooled average as outlined in the aforementioned tables and figures.

##### **4.1.17.1 Soil moisture status at 30 Days After Sowing (DAS)**

The findings from the implementation of varied tillage operations on the cultivated soil and the green manures added in different composition at 30 DAS of maize crop for the two-year analysis and its interaction of treatment combinations is summarized for discussion in Table 4.8(a) and 4.8(b) and visually depicted for validation in Fig 4.17(a) and 4.18(a).

##### **4.1.17.1.1 Effect of tillage on soil moisture status at 30 (DAS)**

The consequences of employing appropriate tillage operations like minimum and conventional tillage in maintaining and sustaining the soil moisture content at 30 DAS is provided for analysis in Table 4.8(a) and depicted in Fig 4.17(a) for consideration. Minimum tillage ( $T_M$ ) with the calculated soil moisture content (SMC) of 35.59% as opposed to soil moisture accumulated with the integration of conventional tillage ( $T_C$ ) with 35.36% soil moisture content revealed an increase of about 0.65% SMC adopting ( $T_M$ ). These aforesaid results were calculated using the data received from the first year of cultivation (2022). In the subsequent year of field study (2023), a rise in soil moisture content of 0.81% was noted involving minimum tillage ( $T_M$ ) with assimilated SMC of 35.72% with that of conventional tillage ( $T_C$ ) which was at 35.43% in recorded SMC. The pooled average of the combined year of

experimentation (2022 and 2023) disclosed that implementing minimum tillage ( $T_M$ ) was beneficial in sustaining the SMC as evident from the pooled average data as ( $T_M$ ) recorded higher SMC (35.66%) in contrary to ( $T_C$ ) which attained only (35.40%) in SMC, presenting 0.73% in SMC integrating minimum tillage. The natural soil structure and pore space of the soil is maintained with the integration of minimum tillage practices. The residues may provide an extra cover to the soil reducing the evaporation of soil moisture and regulating the soil temperature whilst the reduced compaction further enhances the water holding capacity of the soil. Khalil and Suliman, (2023) observed that reduced tillage operations like no till and minimum tillage operations increased the soil moisture content by 13.3% as compared to tillage operation where cultivator and harrow were used especially in the soil depth of 0-15 cm. The influence of soil cover played a significant part in conservation of moisture in reduced tillage practices, they reduced exposure of soil to direct sunlight which reduced evaporation and decreased surface runoff and helped in storing more moisture in the soil profile. The outcomes of this investigation were supported by the investigation conducted by (McVay *et al.*, 2006 and Ugalde *et al.*, 2009).

#### **4.1.17.1.2 Effect of green manuring on soil moisture status at 30 (DAS)**

The influence of integration of green manuring with dhaincha and cowpea using varied configuration and amount concerning soil moisture status at 30 days after sowing (DAS) is specified in Table 4.8(a) and portrayed in Fig 4.17(a). Application of green manures at varied proportion tend to increase the soil moisture content @ 30 DAS as evident by the results obtained from the initial year (2022) analysis. The highest SMC was noted in the sub plot of ( $G_4$ ) where green manures through cowpea @ 4 t ha<sup>-1</sup> was applied, accumulating 37.01% SMC, followed by the treatment ( $G_6$ ) green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, maintaining SMC of 36.87% and subsequently by  $G_2$  *i.e.* green manures through dhaincha @ 4 t ha<sup>-1</sup> was incorporated, concentrating 36.68% SMC. The lowest SMC was obtained in the sub plot treatment of ( $G_0$ ) control possessing SMC of 31.32%. Proliferation of soil moisture content (SMC) by 18.16%, 17.72% and 17.11% was

registered via  $G_4$ ,  $G_6$  and  $G_2$  as computed in relation to the values obtained in  $G_0$ , which logged the treatment with the least soil moisture content (SMC). The succeeding year (2023), disclosed that the maximum soil moisture content (SMC) was detected under the treatment of  $G_4$  with SMC of 37.12%, followed by  $G_6$  (37.02%) and  $G_2$  (36.78%) while the least SMC was uncovered in the treatment  $G_0$  (31.33%). This disclosed the increased SMC adopting green manures by 18.48% in  $G_4$ , 18.16% in  $G_6$  and 17.39% in  $G_2$ , in relation to  $G_0$ . Parallel records as to 2022 and 2023 were also discovered in the pooled analysis where highest soil moisture content (SMC) was perceived in the sub plot treatment  $G_4$  containing soil moisture content (SMC) of 37.06%, subsequently by  $G_6$  (36.95%) and  $G_2$  (36.73%) and the least SMC was disclosed in treatment where no green manures were integrated  $G_0$  (31.32%). This unveiled the elevated SMC in treatment incorporating green manures by 18.32%, 17.97% and 17.27% adopting  $G_4$ ,  $G_6$  and  $G_2$  respectively in relation to  $G_0$ . The enhancement of soil structure, increased water holding capacity, reduction in soil runoff, improved tilth and aeration of the soil, residue mulch effect and improved microbial activity with the employment of green manures into the soil may help the soil to retain more soil moisture and readily available to the plants.

#### **4.1.17.1.3 Interaction effect**

The calculated and statistically analyzed data of the interaction effect on soil moisture status at 30 DAS following the merging of the two tillage aspects (minimum and conventional tillage) with incorporation of dhaincha and cowpea in diverse configuration as green manures is highlighted in Table 4.8(b) and exhibited accordingly in Fig 4.18(a). The initial year (2022) demonstrated increased soil moisture content (SMC) in the treatment combination  $T_M G_4$  (minimum tillage + green manuring through cowpea 4 t ha<sup>-1</sup>) with SMC of 37.32% thereafter by  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with SMC (36.93%) and  $T_C G_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) containing SMC (36.81%) whereas the least competent treatment combination was noted in  $T_C G_0$  (conventional tillage + control) having SMC of (31.20%). This finding presented elevated increase

in SMC by 19.61%, 18.36% and 17.98% respectively in tillage and green manuring interaction of  $T_MG_4$ ,  $T_MG_6$  and  $T_CG_6$  in contrary to that of  $T_CG_0$ . The second year (2023) of cultivation delivered resembling conclusions to that of the first year where higher soil moisture content (SMC) was specified in treatment combination of  $T_MG_4$  containing SMC of 37.49% followed by  $T_MG_6$  (37.12%) and  $T_CG_6$  (36.92%) with the least incidence of SMC occurred in the treatment combination of  $T_CG_0$  (31.15%). Upon comparing the values obtained from  $T_MG_4$ ,  $T_MG_6$  and  $T_CG_6$  in contrary to that of  $T_CG_0$  it was pronounced that an augmentation of SMC by 20.35%, 19.16% and 18.52 was marked respectively. Analysis of the recorded data concerning the pooled average of the two year examination of the soil cultivating maize, it was apparent that interaction of tillage and green manuring in the treatment combination of  $T_MG_4$  (37.40%) was the best combination as the peak SMC was obtained in the mentioned treatment, followed by  $T_MG_6$  (37.03%) and  $T_CG_6$  (36.87%) while the least influential combination was perceived in  $T_CG_0$  (31.18%) which gave a rise in SMC by 19.94%, 18.76% and 18.24% adopting  $T_MG_4$ ,  $T_MG_6$  and  $T_CG_6$  in comparison to that of  $T_CG_0$ .

Increase in soil moisture content by 34% to 65% was observed with the incorporation of green manures with gypsum. Soil moisture is vital for the overall development of plant as well as its yield components especially in the rainfed region. In this investigation cultivating wheat, the yield of the crop significantly increased with the augmentation of green manures with gypsum resulting in an increase from 38% to 76%. This finding concludes that the interaction of green manures with gypsum plays a pivotal role in increasing soil moisture as well as yield of wheat (Kausar *et al.*, 2020 and Rafique Sajjad, 2018).

#### **4.1.17.2 Soil moisture status at 60 Days After Sowing (DAS)**

The documented details obtained from the two-year analysis of adopting tillage operations like minimum tillage and conventional tillage blending with different configurations of green manures, its impact on soil moisture content status and their interaction is briefly furnished in Table 4.8(a) and 4.8(b) and schematically portrayed in Fig 4.17(b) and 4.18(b).

#### **4.1.17.2.1 Effect of tillage on soil moisture status at 60 (DAS)**

The use of minimum and conventional tillage in maize (*Zea mays* L.) cultivation and its impact on soil moisture content at 60 days after sowing (DAS) during the two years of field study including its pooled average is concisely outlined in Table 4.8(a) and visually laid out in Fig 4.17(b). Minimum tillage ( $T_M$ ) containing soil moisture content (SMC) of (36.31%) validates its superiority over ( $T_C$ ) conventional tillage with SMC of (36.21) in the first year of experimentation (2022). The second year of field analysis (2023) unveiled clear increase in SMC integrating ( $T_M$ ) minimum tillage having 36.43% over ( $T_C$ ) conventional tillage accumulating 36.29% SMC. Contrasting the results of both the year of cultivation it was declared that soil moisture content (SMC) in the first year was increased by 0.27% and in the following year by 0.38%, implementing Minimum tillage ( $T_M$ ) over ( $T_C$ ) conventional tillage. Comparable outcome to that of first and second year of study was also portrayed in the pooled data analysis where 0.35% increase in soil moisture content (SMC) was observed integrating ( $T_M$ ) minimum tillage (36.38%) in relation to ( $T_C$ ) conventional tillage (36.25%). Minimum tillage helps preserve the natural structure and porosity. The stratum of crop residues left acts as a protective cover, reducing moisture loss through evaporation and stabilizing soil temperature, while lesser compaction promote augments the soil's water holding capacity. The interaction of minimum tillage with residue mulching enhanced the soil to hold more moisture (24-35%) as compared to extensive tillage operations like conventional tillage. Higher soil moisture content was observed when minimum tillage (MT) was combined with manure + fertilizers at 30 kg ha<sup>-1</sup> in the critical stages of crop growth and development (Nathan *et al.*, 2023 and Handiso *et al.*, 2023).

#### **4.1.17.2.2 Effect of green manuring on soil moisture status at 60 (DAS)**

The incorporation of varied amount of green manures in the experimental soil of the investigative year 2022 and 2023 and its pooled average on soil moisture content at 60 days after sowing is detailed in Table 4.8(a) and displayed in Fig 4.17(b). A clear disclosure of dominance of green manuring addition on soil moisture status on the cultivated soil of initial year at 60 DAS was confirmed as  $G_4$  which is

incorporation of green manures through cowpea @ 4 t ha<sup>-1</sup> manifested increased soil moisture content over all the treatments in the sub plot with accumulated SMC of (38.03%) subsequently followed by treatment SMC of (37.90%) marked in the treatment G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) and G<sub>2</sub> (green manures through cowpea @ 4 t ha<sup>-1</sup>) with SMC of (37.19%). The least performing treatment in relating to SMC in the cultivated soil obtained where no green manures were added (G<sub>0</sub>) with 31.21% soil moisture content. This demonstrated a growth of SMC by 21.85%, 21.43% and 19.16% in the treatments G<sub>4</sub>, G<sub>6</sub> and G<sub>2</sub> respectively as compared to G<sub>0</sub>. The analysis of SMC in next year of cultivation (2023) provided a growth of soil moisture by 21.87%, 21.55% and 19.25% under the following treatment of G<sub>4</sub> (38.11%), G<sub>6</sub> (38.01%) and G<sub>2</sub> (37.29%) respectively in contrast to G<sub>0</sub> (31.27%). Analysis of data from the pooled table of 2022 and 2023 disclosed trends in SMC where incorporation of green manures through (G<sub>4</sub>) with 38.07% moisture content elevated the SMC by 21.86%, G<sub>6</sub> (37.95%) by 21.47% and G<sub>2</sub> (37.24%) by 19.20% contrary to the findings of G<sub>0</sub> (31.24%) soil moisture content. Integration of green manures into the soil help in better soil moisture retention by improving the soil structure, water holding capacity, reduces runoff and soil erosion and aeration of the soil. The investigation revealed that the incorporation of green manures increased the soil moisture content judiciously especially when it was incorporated without any nitrogen supplements. Soil compaction and bulk density was reduced which resulted in more moisture conservation. C/N ratio of the soil was also marked at 20 which indicated lower bulk density (Mosavi *et al.*, 2010).

#### **4.1.17.2.3 Interaction effect**

The merging of tillage and green manures and the outcomes generated by their interaction on soil moisture status at 30 days after sowing (DAS) is provided in detail in the Table 4.8(b) and portrayed graphically in Fig 4.18(b). The interaction of varied aspects of tillage and diverse concentration of green manure treatment seemed to increase the soil moisture content (SMC) during the two year of field study as evident by the results of the treatment combination. In the first year of research,



treatment combination  $T_M G_4$  (minimum tillage + green manures through cowpea @ 4 t ha<sup>-1</sup>) with SMC of 38.33% proved to be the most obliging interaction among all the combinations, followed by the treatment combination of  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with 37.97% SMC and  $T_C G_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with SMC of 37.83% respectively. The minimal contribution to soil moisture content (SMC) came from the combination of  $T_C G_0$  (conventional tillage + control) concentrating SMC of 31.08%. With this evidence it was clear that  $T_M G_4$ ,  $T_M G_6$  and  $T_C G_6$  as compared to  $T_C G_0$  boosted the soil moisture content in the first year by 23.32%, 22.16% and 21.71% respectively. Similar observations were also detailed in the subsequent year (2023) of analysis, where an upsurge of soil moisture content (SMC) by 23.23%, 55.66% and 55.55% concerning  $T_M G_4$ ,  $T_M G_6$  and  $T_C G_6$  was computed contrary to the finding from the treatment combination of  $T_C G_0$  with of SMC (31.11%). The pooled average provided similar trend where  $T_M G_4$  (38.40%),  $T_M G_6$  (38.04%) and  $T_C G_6$  (37.87%) of soil moisture content revealed an elevated SMC of 23.47%, 22.21% and 21.76% respectively, relative to the least effective combination  $T_C G_0$  (31.10%).

#### **4.1.17.3 Soil moisture status at 90 Days After Sowing (DAS)**

Soil moisture content procured from the analysis of the two-year research and its interaction as impacted from the inclusion of tillage and green manuring is detailed in Table 4.8(a) and 4.8(b) and systematically presented in Fig 4.17(c) and 4.18(c).

##### **4.1.17.3.1 Effect of tillage on soil moisture status at 90 (DAS)**

The effect of tillage operations included in the experimentation conducted for two consecutive years under maize cultivation and its impact on soil moisture content at 90 DAS is provided in Table 4.8(a) and Fig 4.17(c). Minimum tillage ( $T_M$ ) procuring soil moisture content of 34.67% was marked to be superior over conventional tillage ( $T_C$ ) which was at 34.21%, presenting 1.34% increase SMC in  $T_M$  over  $T_C$ , in the initial year and by 1.42% in the second year involving the soil

moisture content (SMC) obtained from the inclusion ( $T_M$ ) minimum tillage having soil moisture content (SMC) of 34.79% computed over ( $T_C$ ) conventional tillage accumulating soil moisture content (SMC) of 34.30%. Pooled average of 2022 and 2023 mirrored the findings from the first and second year where ( $T_M$ ) minimum tillage with accumulated soil moisture content (SMC) of 34.73% was marked to be superior over the soil moisture content (SMC) obtained from indulging ( $T_M$ ) with 34.26%, revealing an increase of SMC by 1.37% adopting minimum tillage over conventional tillage. Modiba *et al.* (2024) reported that minimum tillage as compared to conventional tillage revealed a significant increase in soil moisture content as compared to conventional tillage especially due to the depth of ploughing involved. The study also concludes that appropriate tillage practice can immensely increase the ability of soil to hold more moisture which in turn will help the crop to increase its yield and yield attributes. The consequences of this investigation are in line with the outcomes received from the studies of (Lampurlanes *et al.*, 2016 and Ma *et al.*, 2008).

#### **4.1.17.3.2 Effect of green manuring on soil moisture status at 90 (DAS)**

The response of soil moisture content (SMC) at 90 days after sowing (DAS) as influenced by the incorporation of green manures at varying concentration for the two-year investigation its pooled average is noted in Table 4.8(a) and graphically mentioned in Fig 17(c). Varying aspects of soil moisture content was observed under different treatment application out of which the standout performance was marked in the sub plot  $G_4$  (green manures through cowpea @ 4 t ha<sup>-1</sup>) where the SMC was at 36.72%, subsequently followed by  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) having SMC of 35.79% and  $G_2$  (green manures through dhaincha @ 4 t ha<sup>-1</sup>) with SMC of 35.53%. The sub plot treatment where nominal soil moisture content was in the treatment where no green manures were provided ( $G_0$ ) having SMC of 30.33%. This resulted surge in SMC involving  $G_4$  by 21.06%,  $G_6$  by 18% and  $G_2$  by 17.14%, respectively as compared to control ( $G_0$ ). The highest soil moisture content (SMC) in the following year (2023) was attained in the sub plot of  $G_4$  (36.84%) SMC, ensued by  $G_6$  (35.91%) and then by  $G_2$  (35.65%), while the

least SMC was attained in the treatment  $G_0$  i.e. control (30.37%). The pooled average recorded data after the analysis indicated a elevated rise in SMC in the treatment concerning  $G_4$  (36.78%), followed by  $G_6$  (35.85%) and  $G_2$  (35.59%) while the least efficient treatment in SMC contribution in the pooled average was in  $G_0$  (30.35%). This signified an upsurge of SMC by 21.18%, 18.12% and 17.26% in  $G_4$ ,  $G_6$  and  $G_2$  respectively in relation to  $G_0$ . Hasan *et al.* (2014) in their observation expressed that cowpea as a green manure supplement acted as a source for more moisture conservation particularly in areas or region where there is scarcity of water. Runoff and percolation of water was reduced with green manure application resulting into greater moisture conservation. Cultivation of wheat was profoundly elevated as the green manure maintained the supply of essential nutrients, preventing run off, reducing soil compaction and ultimately helping in growth and yield of wheat.

#### 4.1.17.3.3 Interaction effect

The formation and transformation of soil moisture content (SMC) status of the soil in the two-year successive investigation (2022 and 2023) experimented on maize (*Zea mays* L.) involving tillage and green manuring and the outcomes their interaction effect is reflected in Table 4.8(b) and Fig 4.18(c).  $T_M G_4$  i.e. minimum tillage + green manures through cowpea @ 4 t ha<sup>-1</sup> having soil moisture build-up of 37.28% was the most outstanding combination observed in SMC at 90 days after sowing (DAS). The second and third best was followed in the treatment combinations  $T_C G_4$  i.e. conventional tillage + green manures through cowpea @ 4 t ha<sup>-1</sup> with SMC (36.16%) and  $T_M G_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> containing soil moisture content (SMC) of 35.84%, respectively. The smallest contribution to SMC came from the treatment combination of  $T_C G_0$  (conventional tillage + control) where the SMC was noted at 30.26%. These findings led to a discussion to the exposure of SMC contributions of the best performing combinations from the interaction section where  $T_M G_4$  computed to increase the SMC by 23.19% followed by  $T_C G_4$  with 19.49% and  $T_M G_6$  contributed 18.44% SMC, respectively as contrasted to  $T_C G_0$  which was the least efficient treatment combination, computed from the first year analysis. The

succeeding year (2023), unveiled the contribution of  $T_M G_4$  (37.42%) which was the highest, followed by  $T_C G_4$  (36.27%) and  $T_M G_6$  (35.97%) and the least influential treatment combination concerning SMC was in  $T_C G_0$  (30.28%). The pooled average of 2022 and 2023 disclosed similar outcome where  $T_M G_4$  contributed the most SMC amongst all the treatment combination (37.35%) followed by  $T_C G_4$  (36.21%) and  $T_M G_6$  (35.90%) whereas the least prominent combination was in  $T_C G_0$  (30.27%). Computing the most efficient treatment combination to the least it was revealed that an increase of 23.38% in  $T_M G_4$ , 19.62% in  $T_C G_4$  and 18.59% in  $T_M G_6$  in contrary to  $T_C G_0$ .

#### **4.1.17.4 Soil moisture status at 120 Days After Sowing (DAS)**

The details of the analysis on soil moisture content (SMC) of the two-year consecutive investigation including its pooled average as influenced by the indulgence of tillage and green manuring including their interaction is systematically presented in Table 4.8(a) and 4.8(b) and visually depicted in Fig 4.17(d) and 4.18(d).

##### **4.1.17.4.1 Effect of tillage on soil moisture status at 120 (DAS)**

The specifications of the readings acknowledged from the analysis conducted for two years on soil moisture content (SMC) status and its pooled readings as influenced by minimum and conventional tillage operations are conveyed in Table 4.8(a) and expressed in graphical form in Fig 17(d). Tillage operation *via* minimum tillage ( $T_M$ ) increased the soil moisture content in both the years of study (2022 and 2023) with respect to conventional tillage ( $T_C$ ) system. During the first year (2022), the soil moisture content in ( $T_M$ ) was marked at 32.60% while in ( $T_C$ ) it was 32.32% which conveyed a rise of 0.86%. In the second year of study, an upsurge of soil moisture content (SMC) involving tillage practice ( $T_M$ ) which rendered 32.69% SMC, as for conventional tillage ( $T_C$ ) which was manifested at 32.39%. Analysis from the result obtained from the pooled average conveyed similar pattern where ( $T_M$ ) minimum tillage exhibited increase of SMC opposed to ( $T_C$ ) conventional tillage. ( $T_M$ ) possessing SMC of 32.65% as compared to ( $T_C$ ) with 32.35% of SMC, increased the amount of moisture content by 0.92%. Abdullah (2014) stated in his

two years' study on different types of tillage that minimum tillage with residue management as compared to conventional tillage plays an eminent role in conserving soil moisture. 26% increase in soil moisture content was observed with the implementation of minimum tillage as compared to conventional tillage. Minimum tillage which involves less disturbance and the incorporation of residue helps the soil by acting as a much tend to conserve moisture better than the implementation of conventional tillage. The result was parallel with the outcomes of the research conducted by Sharma *et al.* (2014).

#### **4.1.17.4.2 Effect of green manuring on soil moisture status at 120 (DAS)**

The impact contributed by the addition of green manuring through dhaincha and cowpea at different concentration and its influence on soil moisture content (SMC) at 120 days after sowing (DAS) is provided in Table 4.8(a) and Fig 17(d). Soil moisture content status received boosted values with the inclusion of G<sub>4</sub> (green manures through cowpea @ 4 t ha<sup>-1</sup>) marked at 35.17% followed by 33.51% in both G<sub>2</sub> (green manures through dhaincha @ 4 t ha<sup>-1</sup>) and G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>). The least effective sub plot treat was in G<sub>0</sub> (control) with 28.13% SMC, in the initial year (2022). In the following year (2023), the values of SMC recorded from G<sub>4</sub> was 35.26% which was the most influential treatment, followed by G<sub>6</sub> (33.61%) and G<sub>2</sub> (33.60), while SMC of 28.18% was obtained in G<sub>0</sub> *i.e.* control which was the least influential of all the sub plot treatment. An escalation of SMC by 25.12%, 19.26% and 19.23% in G<sub>4</sub>, G<sub>6</sub> and G<sub>2</sub>, respectively was received in contrary to G<sub>0</sub>. The increase in soil moisture content (SMC) was also observed in pooled average analysis *via* the green manure application in the soil. An amplification of soil moisture by 25.07% in G<sub>4</sub>, 19.21% in G<sub>6</sub> and 19.18% in G<sub>2</sub> was noted in comparison to G<sub>0</sub>.

#### **4.1.17.4.3 Interaction effect**

The merging of tillage operations like minimum and conventional tillage with green manures like dhaincha and cowpea in varying proportion and their interaction effect concerning to soil moisture content at 120 days after sowing (DAS) is

summarized in Table 4.8(b) and represented graphically in Fig 4.18(d) for discussion. The initial year of cultivation (2022) presented escalated soil moisture in the treatment combination of  $T_MG_4$  i.e. minimum tillage + green manures through cowpea @ 4 t ha<sup>-1</sup> having SMC of 35.73%, subsequently followed by  $T_CG_4$  i.e. conventional tillage + green manures through cowpea @ 4 t ha<sup>-1</sup>, accumulating SMC of 34.61% and  $T_MG_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (33.60%) SMC. The least influential SMC was noticed in the treatment combination  $T_CG_0$  i.e. conventional tillage + control, having SMC (28.10%). These findings when computed and contrasted conveyed an escalated soil moisture content in the treatment combinations of 27.15% in  $T_MG_4$ , 23.16% in  $T_CG_4$  and 19.57% in  $T_MG_6$ , contrary to the data recorded in  $T_CG_0$ . In the following year (2023),  $T_MG_4$  (35.83%) was marked to be the highest contributor of soil moisture content (SMC) amongst all the treatment combinations, which was then followed by  $T_CG_4$  (34.68%) and  $T_MG_6$  (33.70%) whilst the least was in  $T_CG_0$  (28.16%). The analysis of the following data led to the conclusion that an augmentation in SMC by 27.23%, 23.15% and 19.67%, respectively in  $T_MG_4$ ,  $T_CG_4$  and  $T_MG_6$  was perceived in relation to  $T_CG_0$ . Escalation of soil moisture content was observed the most in the treatment combination of  $T_MG_4$  (35.78%), subsequently by  $T_CG_4$  (34.64%) and  $T_MG_6$  (33.65%) and the least effective treatment combination was in  $T_CG_0$  (28.13%) which accounted for gain in soil moisture content (SMC) by 27.19%, 23.14% and 19.62%, respectively.

Sharma *et al.* (2010) and Wang *et al.*, (2023a) outlined in their research that treatments or mulching with green manuring crops like sunnhemp and leucaena improved soil moisture retention by 1.15-2.29% as compared to bare or fallow treated plots. Harvest as well as overall development of maize crop was significantly improved with the application of green manures. Sunnhemp or leucaena enhanced the yield of maize by about 10.20% individually and by 27.90% when applied together in the soil.

**Table 4.8 (a): Effect of tillage and green manuring on soil moisture content at 30, 60, 90 and 120 Days After Sowing**

| Treatments            | Soil moisture content (%) |       |        |        |       |        |        |       |        |         |       |        |
|-----------------------|---------------------------|-------|--------|--------|-------|--------|--------|-------|--------|---------|-------|--------|
|                       | 30 DAS                    |       |        | 60 DAS |       |        | 90 DAS |       |        | 120 DAS |       |        |
|                       | 2022                      | 2023  | Pooled | 2022   | 2023  | Pooled | 2022   | 2023  | Pooled | 2022    | 2023  | Pooled |
| <b>Tillage</b>        |                           |       |        |        |       |        |        |       |        |         |       |        |
| <b>T<sub>M</sub></b>  | 35.59                     | 35.72 | 35.66  | 36.31  | 36.44 | 36.38  | 34.67  | 34.79 | 34.73  | 32.60   | 32.69 | 32.65  |
| <b>T<sub>C</sub></b>  | 35.36                     | 35.43 | 35.40  | 36.21  | 36.29 | 36.25  | 34.21  | 34.30 | 34.26  | 32.32   | 32.39 | 32.35  |
| <b>SEm ±</b>          | 0.003                     | 0.001 | 0.002  | 0.001  | 0.001 | 0.001  | 0.005  | 0.003 | 0.003  | 0.003   | 0.001 | 0.002  |
| <b>CD at 5%</b>       | 0.018                     | 0.009 | 0.007  | 0.009  | 0.004 | 0.003  | 0.029  | 0.020 | 0.011  | 0.017   | 0.009 | 0.006  |
| <b>CV</b>             | 0.039                     | 0.019 | 0.030  | 0.019  | 0.007 | 0.014  | 0.063  | 0.045 | 0.055  | 0.039   | 0.021 | 0.031  |
| <b>Green manuring</b> |                           |       |        |        |       |        |        |       |        |         |       |        |
| <b>G<sub>0</sub></b>  | 31.32                     | 31.33 | 31.32  | 31.21  | 31.27 | 31.24  | 30.33  | 30.37 | 30.35  | 28.13   | 28.18 | 28.15  |
| <b>G<sub>1</sub></b>  | 35.52                     | 35.65 | 35.58  | 36.53  | 36.64 | 36.58  | 33.89  | 34.01 | 33.95  | 32.08   | 32.16 | 32.12  |
| <b>G<sub>2</sub></b>  | 36.68                     | 36.78 | 36.73  | 37.19  | 37.29 | 37.24  | 35.53  | 35.65 | 35.59  | 33.51   | 33.60 | 33.55  |
| <b>G<sub>3</sub></b>  | 35.21                     | 35.31 | 35.26  | 36.23  | 36.35 | 36.29  | 34.16  | 34.27 | 34.22  | 32.33   | 32.41 | 32.37  |
| <b>G<sub>4</sub></b>  | 37.01                     | 37.12 | 37.06  | 38.03  | 38.11 | 38.07  | 36.72  | 36.84 | 36.78  | 35.17   | 35.26 | 35.21  |
| <b>G<sub>5</sub></b>  | 35.74                     | 35.85 | 35.79  | 36.76  | 36.86 | 36.81  | 34.68  | 34.80 | 34.74  | 32.49   | 32.58 | 32.54  |
| <b>G<sub>6</sub></b>  | 36.87                     | 37.02 | 36.95  | 37.90  | 38.01 | 37.95  | 35.79  | 35.91 | 35.85  | 33.51   | 33.61 | 33.56  |
| <b>SEm ±</b>          | 0.009                     | 0.008 | 0.006  | 0.009  | 0.009 | 0.006  | 0.009  | 0.009 | 0.007  | 0.009   | 0.009 | 0.006  |
| <b>CD @ 5%</b>        | 0.026                     | 0.023 | 0.017  | 0.026  | 0.027 | 0.018  | 0.027  | 0.028 | 0.019  | 0.027   | 0.026 | 0.018  |
| <b>CV</b>             | 0.062                     | 0.055 | 0.059  | 0.061  | 0.062 | 0.062  | 0.065  | 0.067 | 0.066  | 0.070   | 0.066 | 0.068  |

**Table 4.8 (b): Interaction effect of tillage and green manuring on soil moisture content at 30, 60, 90 and 120 Days After Sowing**

| Treatments                        | Soil moisture content (%) |       |        |        |       |        |        |       |        |         |       |        |
|-----------------------------------|---------------------------|-------|--------|--------|-------|--------|--------|-------|--------|---------|-------|--------|
|                                   | 30 DAS                    |       |        | 60 DAS |       |        | 90 DAS |       |        | 120 DAS |       |        |
|                                   | 2022                      | 2023  | Pooled | 2022   | 2023  | Pooled | 2022   | 2023  | Pooled | 2022    | 2023  | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 31.45                     | 31.50 | 31.47  | 31.35  | 31.42 | 31.39  | 30.40  | 30.45 | 30.43  | 28.16   | 28.19 | 28.18  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 35.63                     | 35.77 | 35.70  | 36.63  | 36.77 | 36.70  | 34.58  | 34.71 | 34.65  | 32.32   | 32.41 | 32.37  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 36.73                     | 36.85 | 36.79  | 36.75  | 36.89 | 36.82  | 35.63  | 35.76 | 35.70  | 33.53   | 33.64 | 33.59  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 35.26                     | 35.37 | 35.32  | 36.29  | 36.44 | 36.36  | 34.21  | 34.32 | 34.27  | 32.30   | 32.38 | 32.34  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 37.32                     | 37.49 | 37.40  | 38.33  | 38.47 | 38.40  | 37.28  | 37.42 | 37.35  | 35.73   | 35.83 | 35.78  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 35.84                     | 35.97 | 35.91  | 36.87  | 36.98 | 36.93  | 34.77  | 34.92 | 34.85  | 32.56   | 32.69 | 32.63  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 36.93                     | 37.12 | 37.03  | 37.97  | 38.10 | 38.04  | 35.84  | 35.97 | 35.90  | 33.60   | 33.70 | 33.65  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 31.20                     | 31.15 | 31.18  | 31.08  | 31.11 | 31.10  | 30.26  | 30.28 | 30.27  | 28.10   | 28.16 | 28.13  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 35.41                     | 35.52 | 35.47  | 36.42  | 36.52 | 36.47  | 33.21  | 33.31 | 33.26  | 31.83   | 31.91 | 31.87  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 36.62                     | 36.70 | 36.66  | 37.62  | 37.70 | 37.66  | 35.43  | 35.54 | 35.48  | 33.49   | 33.55 | 33.52  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 35.16                     | 35.25 | 35.21  | 36.18  | 36.27 | 36.22  | 34.12  | 34.22 | 34.17  | 32.36   | 32.44 | 32.40  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 36.70                     | 36.75 | 36.73  | 37.74  | 37.75 | 37.74  | 36.16  | 36.27 | 36.21  | 34.61   | 34.68 | 34.64  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 35.63                     | 35.73 | 35.68  | 36.64  | 36.73 | 36.69  | 34.58  | 34.67 | 34.63  | 32.42   | 32.48 | 32.45  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 36.81                     | 36.92 | 36.87  | 37.83  | 37.92 | 37.87  | 35.73  | 35.85 | 35.79  | 33.43   | 33.52 | 33.47  |
| <b>SEm ±</b>                      | 0.013                     | 0.011 | 0.009  | 0.013  | 0.013 | 0.009  | 0.013  | 0.013 | 0.009  | 0.013   | 0.012 | 0.009  |
| <b>CD at 5%</b>                   | 0.037                     | 0.033 | 0.024  | 0.037  | 0.038 | 0.026  | 0.038  | 0.039 | 0.027  | 0.038   | 0.036 | 0.026  |



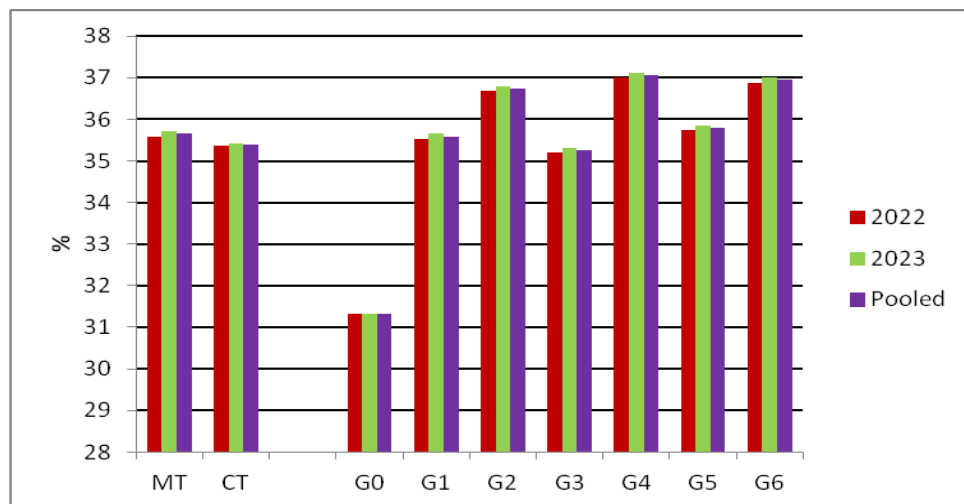


Fig. 4.17(a): Effect of tillage and green manuring on soil moisture content at 30 DAS

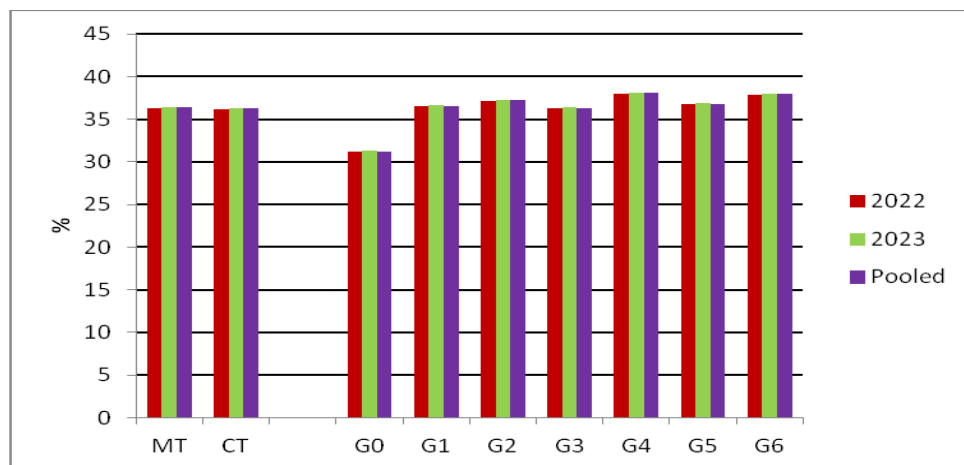


Fig. 4.17(b): Effect of tillage and green manuring on soil moisture content at 60 DAS

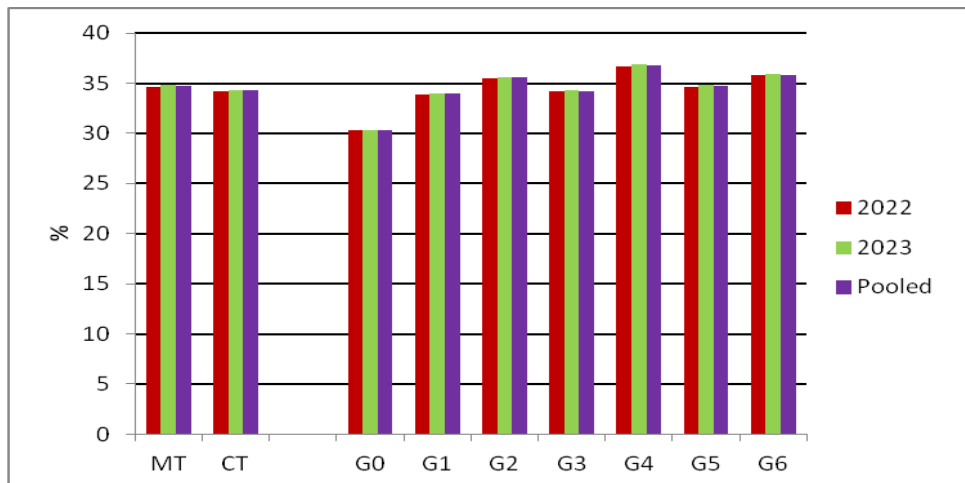


Fig. 4.17(c): Effect of tillage and green manuring on soil moisture content at 90 DAS

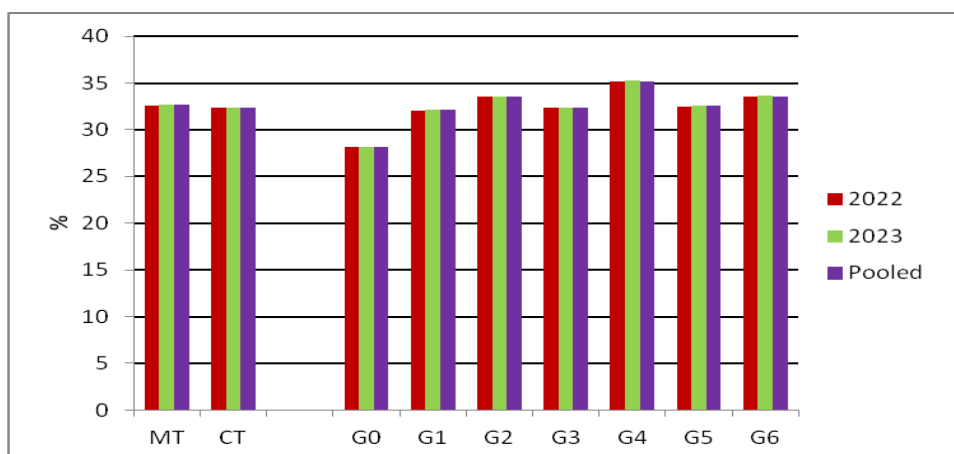


Fig. 4.17(d): Effect of tillage and green manuring on soil moisture content at 120 DAS

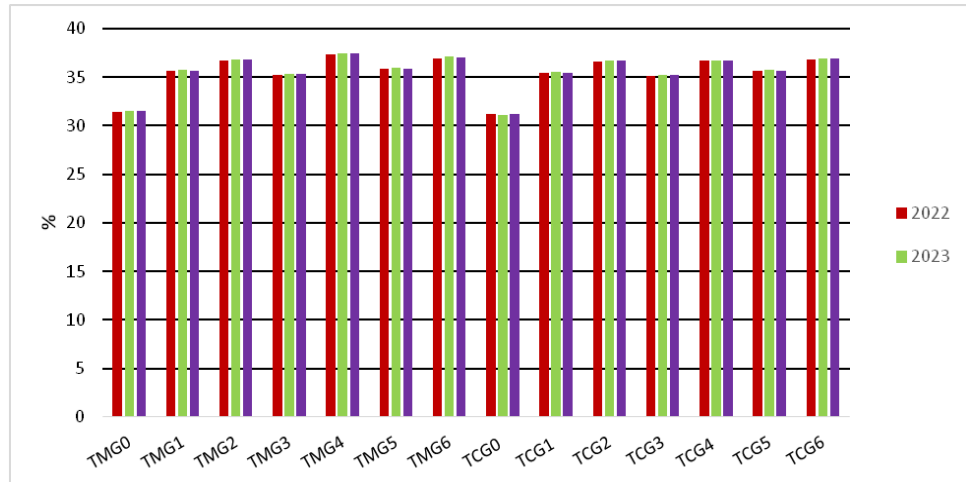


Fig. 4.18(a): Interaction effect of tillage and green manuring on soil moisture content at 30 DAS

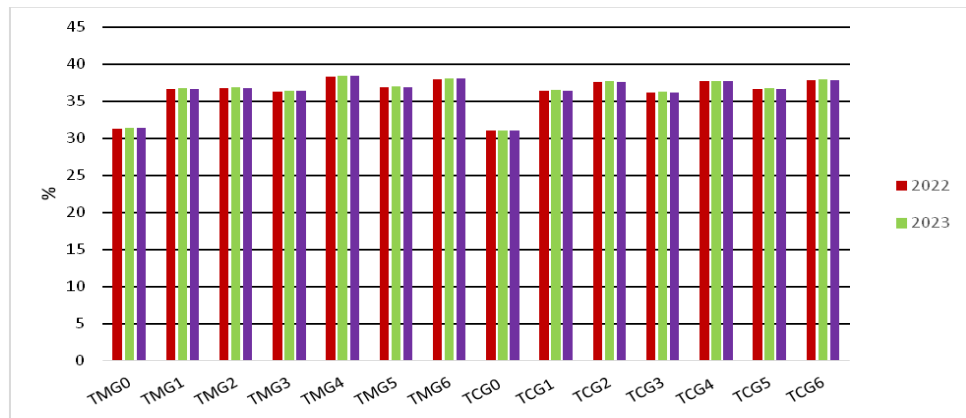


Fig. 4.18(b): Interaction effect of tillage and green manuring on soil moisture content at 60 DAS

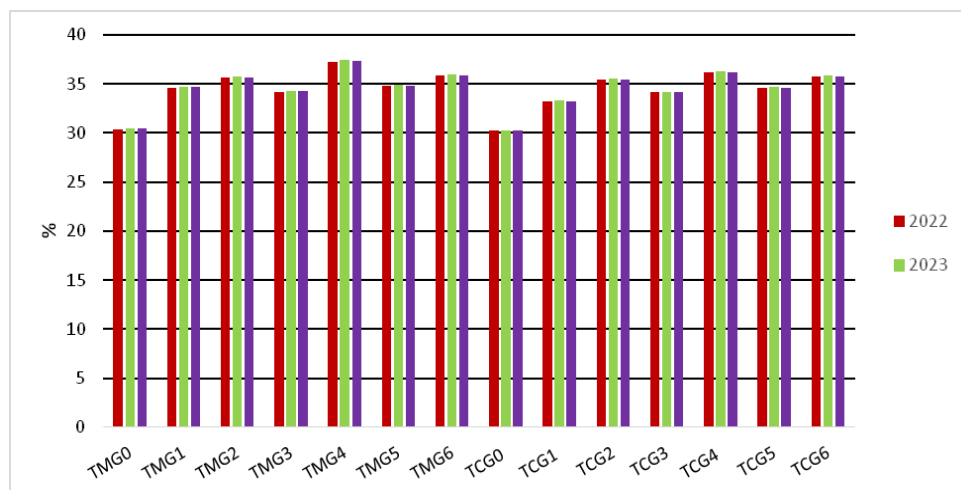


Fig. 4.18(c): Interaction effect of tillage and green manuring on soil moisture content at 90 DAS

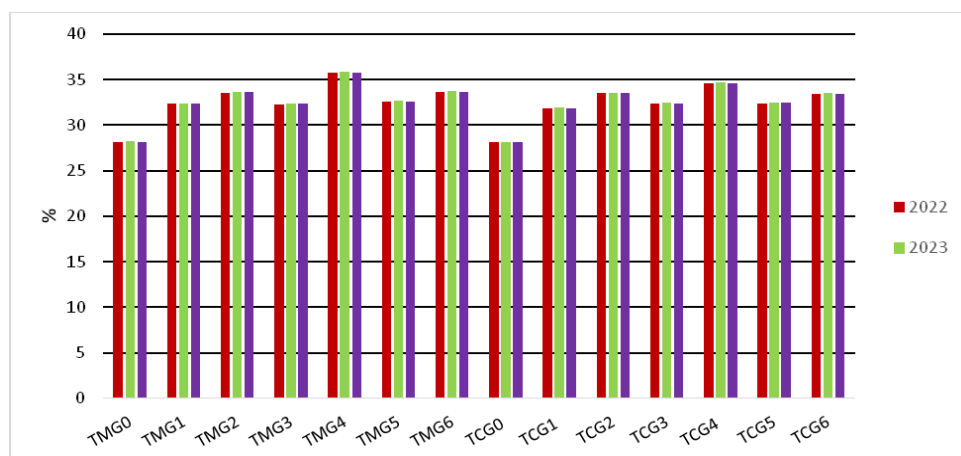


Fig. 4.18(d): Interaction effect of tillage and green manuring on soil moisture content at 120 DAS

## **4.2 Effect of tillage and green manuring on growth, yield attributes and yield of maize**

The numerous attributes concerning the performance of maize crop as impacted by the implementing tillage practices and incorporating green manures at varied amount on crop growth, yield attributes and yield parameters like plant height at (30 DAS, 60 DAS, 90 DAS and at harvest), number of cobs per plant, length of cob, seeds per cob, grain and stover yield is thoroughly discussed in this segment, by the findings received *via* the application of appropriate statistical method.

### **4.2.1 Plant height**

The status of plant height at 30 DAS, 60 DAS, 90 DAS and at harvest, of the experimented crop following the two-year investigation on the topic entitled “Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)” is meticulously analyzed and provided in Table 4.9(a) and 4.9(b) and portrayed in detail in Fig 4.19(a), 4.19(b), 4.19(c), 4.19(d) and Fig 4.20(a), 4.20(b), 4.20(c) and 4.20(d).

#### **4.2.1.1 Plant height at 30 Days After Sowing (DAS)**

The response of plant height at 30 DAS upon the inclusion of minimum and conventional tillage practices and incorporating green manures at varied amount following the two-year analysis, its pooled average data and interaction is thoroughly examined and disclosed in Table 4.9(a) and 4.9(b) and summarized visually in Fig 4.19(a) and 4.20(a).

##### **4.2.1.1.1 Effect of tillage on plant height at 30 DAS**

Table 4.9(a) and Fig 4.19(a) elaborates the details received for the investigative years (2022 and 2023) as well as from the pooled average segment of the analysis. The increase of plant height at 30 days after sowing (DAS) leaned toward plots where ( $T_M$ ) minimum tillage operation was provided as opposed to ( $T_C$ ) conventional tillage. The increment in plant height in ( $T_M$ ) with 32.64 cm was 0.36%

higher than that acknowledged in ( $T_C$ ) having 32.52 cm, in the first year. Indulgence of minimum tillage (32.75 cm) in the second year of study revealed escalation of plant height at 30 DAS by 0.42% in contrary to plant height received from conventional tillage (32.61 cm). The analysis from the findings of the pooled data disclosed an enhancement in plant height at 30 DAS by 0.42% following ( $M_T$ ) minimum tillage (32.70 cm) in contrast to ( $C_T$ ) conventional tillage (32.56 cm). Minimum tillage operation may lead to better soil moisture enhancement and organic matter accumulation as opposed to conventional tillage methods. This may help the soil to enhance the overall soil nutrient accumulation especially NPK content of the soil which directly impact the growth and development of the crop. Sonnad *et al.* (2024) and Sepat *et al.* (2024) stated in their investigation that the implementation of minimum tillage significantly increases plant height of maize, signifying more complimentary growing conditions. Ensuring a suitable blend of tillage practices and nutrient management is crucial for optimizing maize height and achieving peak productivity in yield of the crop.

#### **4.2.1.1.2 Effect of green manuring on plant height at 30 DAS**

The accumulated data received from the investigation executed in the year 2022 and 2023 concerning plant height at 30 days after sowing (DAS) as directed by green manure application is compiled and outlined in Table 4.9(a) and visually schematically in Fig 4.19(a). The first year of experimentation delivered escalated plant height at 30 DAS with the integration of  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) which comprised plant height of 35.67 cm and was proclaimed the most effective sub plot treatment, subsequently followed by  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) with accumulated plant height of 34.82 cm and  $G_4$  (green manuring through cowpea 4 t ha<sup>-1</sup>) with plant height noted at 33.53 cm. The lowest plant height was summed up in the sub plot treatment  $G_0$  (control) with acquired plant height was 26.38 cm. Computing the mentioned plant height report it was ascertained that an elevation in plant height by 35.21% in  $G_6$ , 31.99% in  $G_2$  and 27.10% in  $G_4$  in relation to  $G_0$  was recorded. The registered highest plant height at 30 DAS in the second year (2023) of investigation was attained in the sub

plot treatment of  $G_6$  (35.81 cm) followed sequentially by  $G_2$  (34.97 cm) and  $G_4$  (33.66 cm) while the least influential sub plot treatment was marked in  $G_0$  (26.28 cm) which disclosed escalation of plant height at 30 DAS by 36.26%, 33.06% and 28.06%, respectively. The pooled average findings revealed parallel outcomes where of  $G_6$  (35.74 cm) subsequently by  $G_2$  (34.89 cm) and  $G_4$  (33.60 cm) elevated the height of plant in 30 DAS by 35.73%, 32.51% and 27.61% as compared to ( $G_0$ ) with acquired plant height of (26.33 cm). Better growth and development of crops can be observed with the incorporation of green manures as it not only enhances both the physical and chemical aspects of the soil. Nutrients like NPK are provided by added green manures which are absorbed by the plants in their growth and development.

#### **4.2.1.1.3 Interaction effect**

The acquired results and outcomes received for plant height at 30 DAS, through the interaction between tillage practices and integration of green manures in the two-year research with their pooled average is summarized in Table 4.9(b) and depicted in Fig 4.20(a). Treatment combination  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) achieved the highest plant height at 30 DAS (35.70 cm), followed by  $T_CG_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with plant height of 35.65 cm and  $T_MG_2$  (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) having 34.91 cm. These variables were obtained from the first year of investigation. In the subsequent year (2023), treatment combination  $T_MG_6$  (35.86 cm),  $T_CG_6$  (35.76 cm) and  $T_MG_2$  (35.05 cm) delivered positive outcomes in relation to plant height at 30 DAS, whereas the least influential was in  $T_CG_0$  (26.16 cm). Escalation of plant height by 37.07%, 36.69% and 33.98% was obtained in  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$ , respectively in contrary to  $T_CG_0$ . Pooled analysis of 2022 and 2023 highlighted upsurge of plant height in the treatment combination involving  $T_MG_6$  (35.78 cm) followed by  $T_CG_6$  (35.70 cm) and  $T_MG_2$  (34.98 cm) while the least influential was noted in  $T_CG_0$  (26.22 cm), presenting a rise in plant height at 30 DAS by 36.46%, 36.15% and 33.40%, respectively.

Pattanaik *et al.* (2020) and Kumar *et al.* (2023) in their study found that maize grown with in-situ green manuring, particularly with a nitrogen application of 150 kg ha<sup>-1</sup>, exhibited a significant enhance in plant height, reaching 289.30 cm. This treatment outperformed all other methods, indicating the positive effect of green manures on maize growth. These findings suggest that combining green manures with optimal nitrogen levels can greatly enhance maize yield and yield attributes.

#### **4.2.1.2 Plant height at 60 Days After Sowing (DAS)**

The introduction of tillage operations like minimum and conventional tillage practices and merging it with green manures like dhaincha and cowpea in various proportion and its impact on plant height at 60 DAS during the two-year experimental trial and its interaction is systematically examined and provided in Table 4.9(a) and 4.9(b) and visually portrayed in Fig 4.19(b) and 4.20(b)

##### **4.2.1.2.1 Effect of tillage on plant height at 60 DAS**

The growth and development of maize plant as directed by the implementation and integration of tillage practices like minimum and conventional tillage system in the two-year field study conducted during the *kharif* seasons of 2022 and 2023 and its pooled table is enumerated in Table 4.9(a) and plotted Fig 4.19(b). Integration of (T<sub>M</sub>) minimum tillage in relation to (C<sub>T</sub>) conventional tillage practices tended to improve the plant growth as evident by the finding obtained from the analysis for both the year of cultivation. In 2022, the recorded plant height at 60 DAS concerning (T<sub>M</sub>) was 81.45 cm while (T<sub>C</sub>) was at 81.29 cm. In 2023, higher plant height was also noted with the adoption of (T<sub>M</sub>) having 81.52 cm followed by (T<sub>C</sub>) at 81.34 cm, presenting an upsurge of 0.22% involving (T<sub>M</sub>). Pooled aggregate mean of 2022 and 2023 exhibited similar trend where (T<sub>M</sub>) minimum tillage with plant height of (81.49 cm) was superior to that of (C<sub>T</sub>) conventional tillage (81.32 cm) by 0.20%. Induction of only primary tillage operation may help the soil to maintain the structure more judiciously than conventional tillage practices. Less soil erosion means accumulation of nutrients may be more especially nitrogen which directly affects the plant height and overall development of the crop. Liu *et al.* (2023)



reported that about 20.2% increase in plant height of maize was observed with the implementation of minimum tillage as compared to conventional shallow mould board ploughing. Plants under the minimum tillage system exhibited rapid height gains early in the growing season, which later plateau underscoring that this practice notably enhances maize growth and development. Comparable outcomes were also reported in the investigation carried out by De Vita *et al.* (2007).

#### **4.2.1.2.2 Effect of green manuring on plant height at 60 DAS**

The documented outcomes of plant height at 60 DAS incorporating green manures in the soil during the two-year field study and its pooled aggregate is provided in Table 4.9(a) and exhibited in Fig 4.19(b). A clear indication of enhancement of plant height was distinguished in the initial year (2022) with the addition of green manures. The sub plot with the treatment G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with 85.22 cm, delivered the peak performance in terms of plant height at 60 DAS, followed by G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) with 83.32 cm and G<sub>5</sub> (green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) with 82.95 cm plant height and the least proficient sub plot was obtained in treatment G<sub>0</sub> (control) with 75.23 cm plant height. These consequences led to an elevated plant height by 13.27% in G<sub>6</sub>, 10.75% in G<sub>2</sub> and 10.26% in G<sub>5</sub>, respectively in contrary to G<sub>0</sub>. The succeeding year of cultivation of maize crop led to augment in plant height involving G<sub>6</sub> (85.32 cm) accompanied by G<sub>2</sub> (83.42 cm) and G<sub>5</sub> (83.02 cm) while the least proficient treatment was in G<sub>0</sub> (75.16 cm). The pooled analysis record revealed resembling outcomes from that of first and second year where the most prominent treatment impacting plant height was found in the treatment involving G<sub>6</sub> (85.27 cm) trailed by G<sub>2</sub> (83.37 cm) and G<sub>5</sub> (82.97 cm) whereas G<sub>0</sub> (75.19 cm) presented the lowest efficiency in the development of plant height. An escalation of plant height by 13.40%, 10.87% and 10.34%, respectively involving G<sub>6</sub>, G<sub>2</sub> and G<sub>5</sub> was computed as compared to G<sub>0</sub>. It fixes the nutrient supply and efficiency especially available nitrogen and phosphorus, which is directly linked with plant development. The overall soil health and crop yield is improved with the addition of green manures into

the soil. *Crotalaria juncea* application as a green manure, enhanced shoots development and plant height in maize. The study indicated that the high nitrogen content in *Crotalaria* was crucial in promoting shoot growth. Furthermore, *Tithonia diversifolia* contributed to improved root development, supported plant height by increasing nutrient and water uptake. The collective use of inorganic fertilizers further augmented the positive effect of green manures on shoot growth, facilitating enhanced overall plant establishment (Sangakkara *et al.*, 2004 and Dong *et al.*, 2024).

#### 4.2.1.2.3 Interaction effect

The computed results of the interaction between adopted tillage practices and amount and configuration of green manures applied following the findings obtained from the statistical analysis are systematically disclosed in Table 4.9(b) and Fig 4.20(b). The treatment combination  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) having retained plant height of 85.25 cm was considered the most influential combination, succeeded by  $T_C G_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) where the plant height attained 85.18 cm and  $T_M G_2$  (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) with acquired plant height of 83.39 cm whereas the least efficient plant height was noted in  $T_C G_0$  *i.e.* control with 75.08 cm plant height. These outcomes presented increase in plant height by 13.54%, 13.45% and 11.06%, respectively in the initial year of field study. During the succeeding year (2023), a notable enhancement in plant height was acquired in  $T_M G_6$  (85.40 cm),  $T_C G_6$  (85.24 cm) and  $T_M G_2$  (83.51 cm) while the least influential was in  $T_C G_0$  (75.04 cm). Following these findings an upsurge of 13.80%, 13.59% and 11.28% in plant height was obtained, respectively computing  $T_M G_6$ ,  $T_C G_6$  and  $T_M G_2$  against  $T_C G_0$ . Parallel results were also obtained in the pooled analysis where  $T_M G_6$  (85.33 cm),  $T_C G_6$  (85.21 cm) and  $T_M G_2$  (83.45 cm) in contrary to  $T_C G_0$  (75.06 cm) escalated the plant height by 13.68%, 13.52% and 11.17%, respectively.

#### **4.2.1.3 Plant height at 90 Days After Sowing (DAS)**

The noted plant height at 90 days after sowing (DAS) as obtained after the statistical analysis of the data received in the two-year investigation in 2022 and 2023, their pooled average and interaction of treatments is highlighted in Table 4.9(a) and 4.9(b) and schematically portrayed in Fig 4.19(c) and 4.20(c).

##### **4.2.1.3.1 Effect of tillage on plant height at 90 DAS**

The acquired plant height at 90 days after sowing (DAS) as impacted by implementing tillage operations (minimum and conventional tillage) is outlined in Table 4.9(a) and illustrated in Fig 4.19(c). Observations from the analysis of the plant height at 90 DAS following input of tillage operation conveys the findings that ( $T_M$ ) minimum tillage with plant height of (183.18 cm) was dominant over ( $C_T$ ) conventional tillage (182.80 cm) by 0.20% in the initial year of field study. Persistent to the initial year, the following year also offered similar trend where ( $T_M$ ) minimum tillage with plant height (183.52 cm) was found 0.25% better than ( $C_T$ ) conventional tillage (183.05 cm). Examination of the statistical data received in the pooled average disclosed that 0.22% gain in plant height was ascertained computing ( $T_M$ ) minimum tillage with plant height of (183.35 cm) and ( $C_T$ ) conventional tillage having plant height measured at (182.93 cm). Minimum tillage (MT) impacted the height of tobacco plants (*Nicotiana tabacum*), notably extending the duration of the vegetative growth phase. At harvest, MT showed significantly taller stems than conventional tillage (CT) practices (Orlando *et al.*, 2011 and Islam *et al.*, 2014).

##### **4.2.1.3.2 Effect of green manuring on plant height at 90 DAS**

Impact of green manures (dhaincha and cowpea) integration into the soil at different concentration on plant height at 90 DAS over two years and its pooled average is exhibited in Table 4.9(a) and illustrated in Fig 4.19(c). The most impact on plant height was received with the application of  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with plant height of (186.69 cm), followed by  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) (185.12 cm) and  $G_5$

(green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) with (184.57 cm) plant height. The lowest performing treatment under the sub plot was at G<sub>0</sub> *i.e.* control with (176.21 cm). The increase outcome of 5.94%, 5.05% and 4.74% were acquired in G<sub>6</sub>, G<sub>2</sub> and G<sub>5</sub> in comparison to G<sub>0</sub>, in the initial year of investigation (2022). The second year data of plant height acquired after 90 DAS are as follows. The highest plant height was obtained in the sub plot treatment G<sub>6</sub> (186.92 cm), followed by G<sub>2</sub> (185.54 cm) and G<sub>5</sub> (185.09 cm) and the least influential sub plot treatment was in G<sub>0</sub> (176.15 cm). In the pooled average records, the most impacted sub plot treatment with the addition of green manures was in G<sub>6</sub> (186.80 cm), subsequently by G<sub>2</sub> (185.33 cm) and G<sub>5</sub> (184.83 cm) whereas the least effective treatment was notable in the treatment G<sub>0</sub> (176.18 cm), this observation obtained in the pooled data of 2022 and 2023 presented escalated plant height by 6.02% involving (G<sub>6</sub>), 5.19% in (G<sub>2</sub>) and 4.90% in (G<sub>5</sub>), in relation to the readings noted from G<sub>0</sub>.

#### 4.2.1.3.3 Interaction effect

The readings noted *via* the implementation of tillage and application of green manures and its interaction as obtained in the two year (2022 and 2023) analysis and its pooled observations is discussed in detail in the Table 4.9(b) and Fig 20(c). T<sub>M</sub>G<sub>6</sub> (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with attained plant height of (187.23 cm) was perceived to be the most important treatment combination in the initial year (2022) of field study, thereafter by T<sub>C</sub>G<sub>6</sub> *i.e.* conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> with plant height (186.14 cm) and T<sub>M</sub>G<sub>2</sub> *i.e.* minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup> attaining plant height (185.19 cm). The least contributing treatment combination was attained in T<sub>C</sub>G<sub>0</sub> *i.e.* conventional tillage + control, with plant height (176.11 cm). Escalation in height of the maize plant amounting to 6.31%, 5.69% and 5.15% was measured as compared to T<sub>C</sub>G<sub>0</sub>. The succeeding year of cultivation unveiled that T<sub>M</sub>G<sub>6</sub> with measuring plant height of (187.58 cm) was identified as the best interaction among all treatment combination for plant height at 90 DAS, followed by T<sub>C</sub>G<sub>6</sub> (186.27 cm) and T<sub>M</sub>G<sub>2</sub> (185.70 cm)

whereas the least was noted in  $T_CG_0$  (176.05 cm) computing rise in plant height by 6.54%, 5.80% and 5.48% adopting  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$ , respectively. The most vital combination in the pooled average findings were in  $T_MG_6$  (187.40),  $T_CG_6$  (186.21 cm) and  $T_MG_2$  (185.44 cm) and the least was in  $T_CG_0$  (176.08 cm), contributing elevated plant height by 6.42%, 5.75% and 5.31%, respectively in plant height.

Arantes *et al.* (2016) in their study revealed that sole maize planting as compared to intercropping maize with perennial green manures did not show significantly change in plant height. Plant height, stem diameter, and related traits, remained unaltered by the addition of green manures. However, the highest plant population was recorded when green manures were introduced at the V4 growth stage of maize, possibly due to improved soil moisture conservation. These results were in line with the outcomes received in the study conducted by Song *et al.* (2024).

#### **4.2.1.4 Plant height at harvest**

The measured plant height at harvest as persuaded by the implementation of varied tillage practices like minimum and conventional tillage, their pooled average data and their interaction received after two consecutive years of study is systematically provided in Table 4.9(a) and 4.9(b) and visually highlighted in Fig 4.19(d) and 4.20(d).

##### **4.2.1.4.1 Effect of tillage on plant height at harvest**

The effect of integrating minimum and conventional tillage practices and its influence on plant height of maize at harvest during the two-year investigation and the pooled average received is given in Table 4.9(a) and depicted graphically in Fig 4.19(d). The most influenced tillage practice in relation to plant height of maize in both the years of cultivation was obtained in ( $T_M$ ) minimum tillage acquiring (181.46 cm) in the first year (2022) and (181.50 cm) in the succeeding year (2023), while the least influential tillage practice was in ( $C_T$ ) conventional tillage (181.15 cm) in 2022 and (181.18 cm) in 2023. This unveiled the per cent increase of plant height at

harvest adopting ( $M_T$ ) by 0.17% for both the year 2022 and 2023, respectively in contrary to ( $T_C$ ). Comparable result was obtained in pooled average where ( $T_M$ ) minimum tillage containing plant height of (181.48 cm) furnished higher plant height as compared to ( $T_C$ ) conventional tillage where the attained plant height at harvest was recorded at (181.16 cm). Boomsma *et al.* (2010) claimed that minimum or no-till practices had a significant impact on crop yield, plant population and plant height at 4 and 8 weeks after sowing. Although overall plant height may not reliably indicate yield in no-till systems, superior variability in plant height at 4 weeks after planting was linked to abridged relative yields in incessant maize under no-till conditions. Parallel findings were also noted in the study conducted by Xu *et al.* (2019).

#### **4.2.1.4.2 Effect of green manuring on plant height at harvest**

The enhancement of green manures on the growth and development of maize crop at harvest in the two-year evaluation and its pooled average is briefly summarized in the Table 4.9(a) and Fig 4.19(d). Incorporation of green manures such as dhaincha and cowpea improves the growth of maize crop as evident by the outcomes received from the initial year of analysis (2022) where the most influencing treatment under sub plot was observed in  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) achieving plant height of (184.67 cm), thereafter by  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) acquiring plant height of (183.50 cm) and  $G_5$  (green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) attaining plant height of (182.95 cm). An amplification of plant height at harvest of 2.23%, 2.36% and 2.36% was marked respectively *via* the introduction of  $G_6$ ,  $G_2$  and  $G_5$ , in contrary to  $G_0$  (control) which obtain plant height measuring (175.22 cm). Enhancement of plant height was also observed following the addition of green manures in the succeeding year (2023) of crop cultivation where the acquired outcomes were  $G_6$  (184.82 cm),  $G_2$  (183.40 cm) and  $G_5$  (182.99 cm) were noted as the most outstanding performers while the least influential was in the treatment  $G_0$  (175.16 cm). These finding from the second year of cultivation disclosed the per cent increase adopting green manures by 5.51%, 4.70% and 4.47%, respectively computing  $G_6$ ,  $G_2$  and  $G_5$ , in relation to the outcomes obtained

implementing  $G_0$ . An escalation in plant height at harvest was also acquired integrating green manures in the pooled average of 2022 and 2023. Increase in plant height inducing  $G_6$  (184.74 cm),  $G_2$  (183.45 cm) and  $G_5$  (182.97 cm) up surged the plant height of maize by 5.45%, 4.71% and 4.44%, respectively in contrary to  $G_0$  (175.19 cm) which was the least effective treatment in the sub plot of the pooled average. Plants that acquired 5 t ha<sup>-1</sup> of green manure showed the tallest height, measuring 60.7 cm. This is significantly superior to the control plots height of 52.76 cm. This demonstrates that green manure has a positive effect on the growth of soybean plants. The results suggest that application of green manure can improve growth attributes, which may lead to elevated soybean yields in the Mount Cameroon Region (Egbe *et al.*, 2022).

#### 4.2.1.4.3 Interaction effect

The interaction effect of tillage and green manuring on plant height of maize at harvest for the two-year field exploration and its pooled outcomes of the two year (2022 and 2023) is tabulated in Table 4.9(b) and represented graphically in Fig 4.20(d). The most influential treatment combination of the initial year (2022) was attained in  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with plant height marked at (185.23 cm), thereafter in  $T_CG_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) maintaining plant height of (184.10 cm) and  $T_CG_2$  (conventional tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) having (183.76 cm) plant height at harvest. The treatment combination  $T_CG_0$  (conventional tillage + control) performed the worst maintaining plant height computing (175.08 cm). The upsurge of plant height at harvest by 5.79%, 5.15% and 4.95% was noted following  $T_MG_6$ ,  $T_CG_6$  and  $T_CG_2$ , respectively as compared to  $T_CG_0$ . In the succeeding year (2023), the best interaction was noted in the combinations of  $T_MG_6$  (185.38 cm), followed by  $T_CG_6$  (184.25 cm) and  $T_MG_5$  (183.50 cm). An escalation by 5.85%, 5.21% and 4.84%, respectively was attained in plant height at harvest comparing the most influential treatment combination  $T_MG_6$  (185.30 cm), followed by  $T_CG_6$  (184.18 cm) and  $T_CG_2$  (183.53 cm) in contrary to  $T_CG_0$  (175.05 cm) which was identified as the

least efficient treatment combination obtained in the pooled analysis of 2022 and 2023.



**Table 4.9 (a): Effect of tillage and green manuring on plant height at 30 DAS, 60 DAS, 90 DAS and at harvest**

| Treatment            | Plant height (cm) |       |        |        |       |        |        |        |        |            |        |        |
|----------------------|-------------------|-------|--------|--------|-------|--------|--------|--------|--------|------------|--------|--------|
|                      | 30 DAS            |       |        | 60 DAS |       |        | 90 DAS |        |        | At harvest |        |        |
|                      | 2022              | 2023  | Pooled | 2022   | 2023  | Pooled | 2022   | 2023   | Pooled | 2022       | 2023   | Pooled |
| Tillage              |                   |       |        |        |       |        |        |        |        |            |        |        |
| <b>T<sub>M</sub></b> | 32.64             | 32.75 | 32.70  | 81.45  | 81.52 | 81.49  | 183.18 | 183.52 | 183.35 | 181.46     | 181.50 | 181.48 |
| <b>T<sub>C</sub></b> | 32.52             | 32.61 | 32.56  | 81.29  | 81.34 | 81.32  | 182.80 | 183.05 | 182.93 | 181.15     | 181.18 | 181.16 |
| <b>SEm ±</b>         | 0.006             | 0.005 | 0.004  | 0.002  | 0.004 | 0.002  | 0.005  | 0.010  | 0.006  | 0.003      | 0.003  | 0.002  |
| <b>CD at 5%</b>      | 0.036             | 0.031 | 0.015  | 0.011  | 0.021 | 0.008  | 0.031  | 0.061  | 0.022  | 0.020      | 0.016  | 0.008  |
| <b>CV</b>            | 0.083             | 0.071 | 0.077  | 0.010  | 0.020 | 0.016  | 0.013  | 0.025  | 0.020  | 0.008      | 0.007  | 0.008  |
| Green manuring       |                   |       |        |        |       |        |        |        |        |            |        |        |
| <b>G<sub>0</sub></b> | 26.38             | 26.28 | 26.33  | 75.23  | 75.16 | 75.19  | 176.21 | 176.15 | 176.18 | 175.22     | 175.16 | 175.19 |
| <b>G<sub>1</sub></b> | 32.03             | 32.16 | 32.10  | 80.07  | 80.15 | 80.11  | 181.78 | 182.19 | 181.98 | 179.82     | 180.09 | 179.95 |
| <b>G<sub>2</sub></b> | 34.82             | 34.97 | 34.89  | 83.32  | 83.42 | 83.37  | 185.12 | 185.54 | 185.33 | 183.50     | 183.40 | 183.45 |
| <b>G<sub>3</sub></b> | 32.76             | 32.89 | 32.83  | 80.24  | 80.30 | 80.27  | 182.20 | 182.41 | 182.31 | 180.48     | 180.30 | 180.39 |
| <b>G<sub>4</sub></b> | 33.53             | 33.66 | 33.60  | 82.59  | 82.67 | 82.63  | 184.37 | 184.73 | 184.55 | 182.53     | 182.64 | 182.58 |
| <b>G<sub>5</sub></b> | 32.88             | 32.97 | 32.93  | 82.92  | 83.02 | 82.97  | 184.57 | 185.09 | 184.83 | 182.95     | 182.99 | 182.97 |
| <b>G<sub>6</sub></b> | 35.67             | 35.81 | 35.74  | 85.22  | 85.32 | 85.27  | 186.69 | 186.92 | 186.80 | 184.67     | 184.82 | 184.74 |
| <b>SEm ±</b>         | 0.017             | 0.016 | 0.012  | 0.014  | 0.012 | 0.009  | 0.010  | 0.010  | 0.007  | 0.015      | 0.011  | 0.009  |
| <b>CD @ 5%</b>       | 0.049             | 0.047 | 0.033  | 0.042  | 0.035 | 0.026  | 0.030  | 0.029  | 0.020  | 0.044      | 0.033  | 0.027  |
| <b>CV</b>            | 0.125             | 0.122 | 0.124  | 0.043  | 0.036 | 0.040  | 0.014  | 0.013  | 0.014  | 0.021      | 0.015  | 0.018  |

**Table 4.9 (b): Interaction effect of tillage and green manuring on plant height at 30 DAS, 60 DAS, 90 DAS and at harvest**

| Treatment                         | Plant height (cm) |       |        |        |       |        |        |        |        |            |        |        |
|-----------------------------------|-------------------|-------|--------|--------|-------|--------|--------|--------|--------|------------|--------|--------|
|                                   | 30 DAS            |       |        | 60 DAS |       |        | 90 DAS |        |        | At harvest |        |        |
|                                   | 2022              | 2023  | Pooled | 2022   | 2023  | Pooled | 2022   | 2023   | Pooled | 2022       | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 26.48             | 26.39 | 26.44  | 75.38  | 75.28 | 75.33  | 176.30 | 176.24 | 176.27 | 175.36     | 175.30 | 175.33 |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 32.14             | 32.20 | 32.17  | 80.22  | 80.32 | 80.27  | 182.10 | 182.43 | 182.26 | 180.16     | 180.22 | 180.19 |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 34.91             | 35.05 | 34.98  | 83.39  | 83.51 | 83.45  | 185.19 | 185.70 | 185.44 | 183.23     | 183.50 | 183.36 |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 32.77             | 32.92 | 32.85  | 80.29  | 80.34 | 80.32  | 182.31 | 182.54 | 182.43 | 180.76     | 180.34 | 180.55 |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 33.58             | 33.76 | 33.67  | 82.67  | 82.75 | 82.71  | 184.49 | 184.93 | 184.71 | 182.52     | 182.73 | 182.63 |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 32.93             | 33.06 | 33.00  | 82.95  | 83.08 | 83.02  | 184.67 | 185.25 | 184.96 | 182.98     | 183.05 | 183.02 |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 35.70             | 35.86 | 35.78  | 85.25  | 85.40 | 85.33  | 187.23 | 187.58 | 187.40 | 185.23     | 185.38 | 185.30 |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 26.27             | 26.16 | 26.22  | 75.08  | 75.04 | 75.06  | 176.11 | 176.05 | 176.08 | 175.08     | 175.01 | 175.05 |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 31.93             | 32.12 | 32.02  | 79.93  | 79.98 | 79.95  | 181.46 | 181.95 | 181.71 | 179.47     | 179.95 | 179.71 |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 34.72             | 34.89 | 34.81  | 83.26  | 83.32 | 83.29  | 185.05 | 185.37 | 185.21 | 183.76     | 183.29 | 183.53 |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 32.75             | 32.86 | 32.81  | 80.19  | 80.27 | 80.23  | 182.10 | 182.27 | 182.18 | 180.20     | 180.25 | 180.22 |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 33.48             | 33.56 | 33.52  | 82.51  | 82.59 | 82.55  | 184.26 | 184.54 | 184.40 | 182.54     | 182.55 | 182.54 |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 32.83             | 32.89 | 32.86  | 82.89  | 82.96 | 82.92  | 184.47 | 184.92 | 184.70 | 182.92     | 182.92 | 182.92 |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 35.65             | 35.76 | 35.70  | 85.18  | 85.24 | 85.21  | 186.14 | 186.27 | 186.21 | 184.10     | 184.25 | 184.18 |
| <b>SEm ±</b>                      | 0.024             | 0.023 | 0.016  | 0.020  | 0.017 | 0.013  | 0.015  | 0.014  | 0.010  | 0.022      | 0.016  | 0.013  |
| <b>CD at 5%</b>                   | 0.069             | 0.067 | 0.047  | 0.059  | 0.049 | 0.037  | 0.043  | 0.041  | 0.029  | 0.063      | 0.047  | 0.038  |

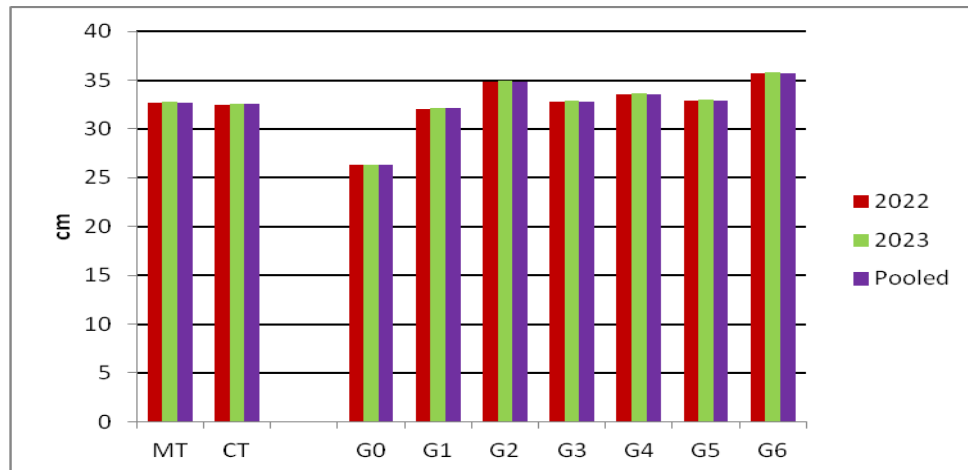


Fig. 4.19(a): Effect of tillage and green manuring on plant height at 30 DAS

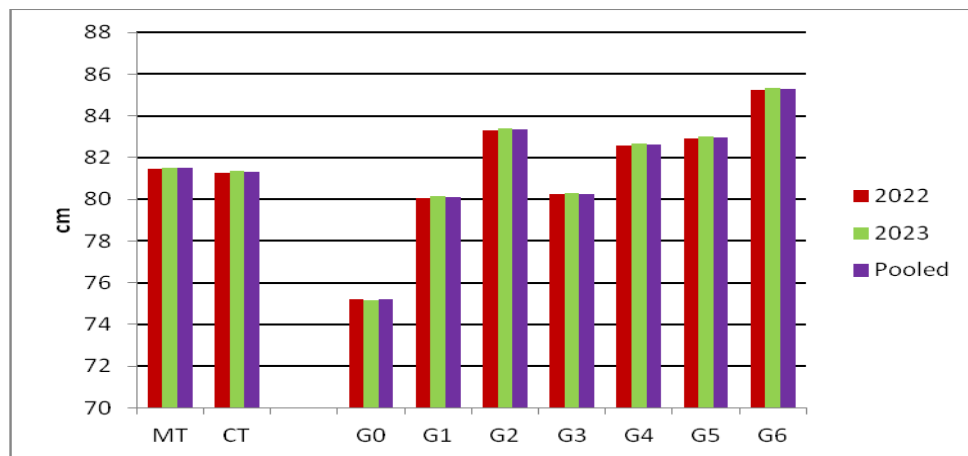


Fig. 4.19(b): Effect of tillage and green manuring on plant height at 60 DAS

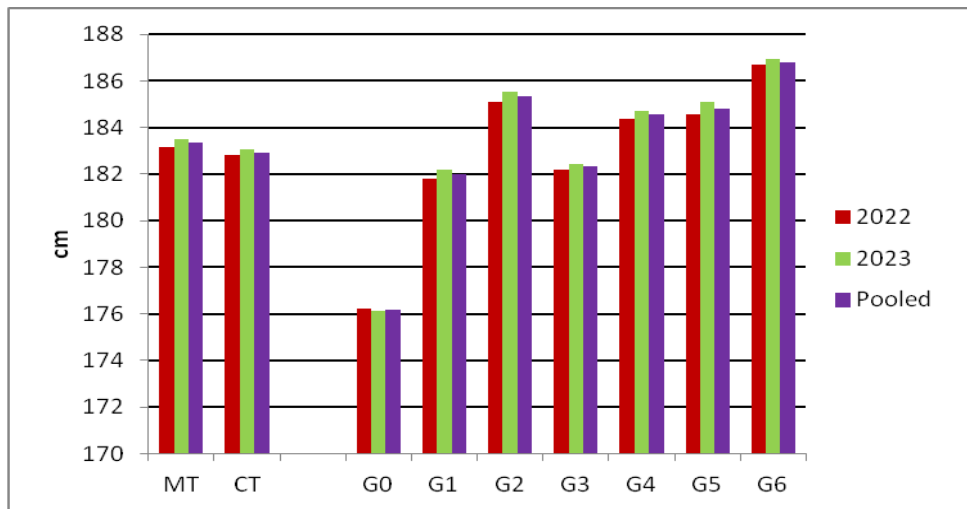


Fig. 4.19(c): Effect of tillage and green manuring on plant height at 90 DAS

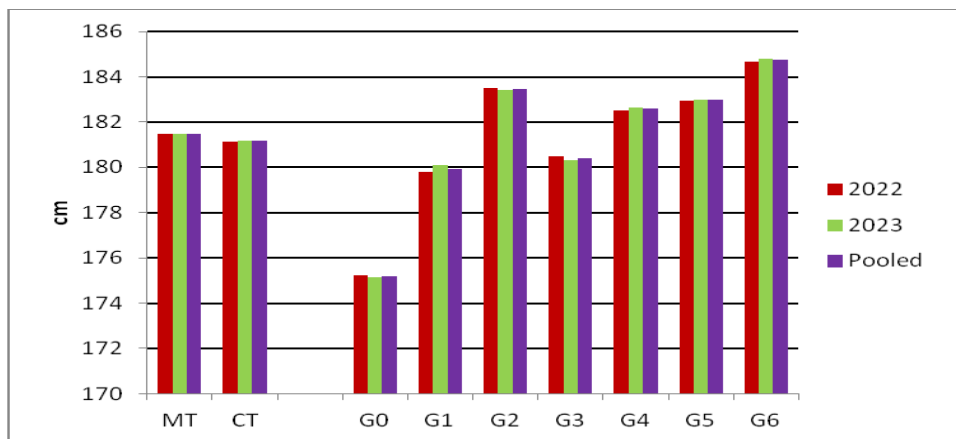


Fig. 4.19(d): Effect of tillage and green manuring on plant height at harvest

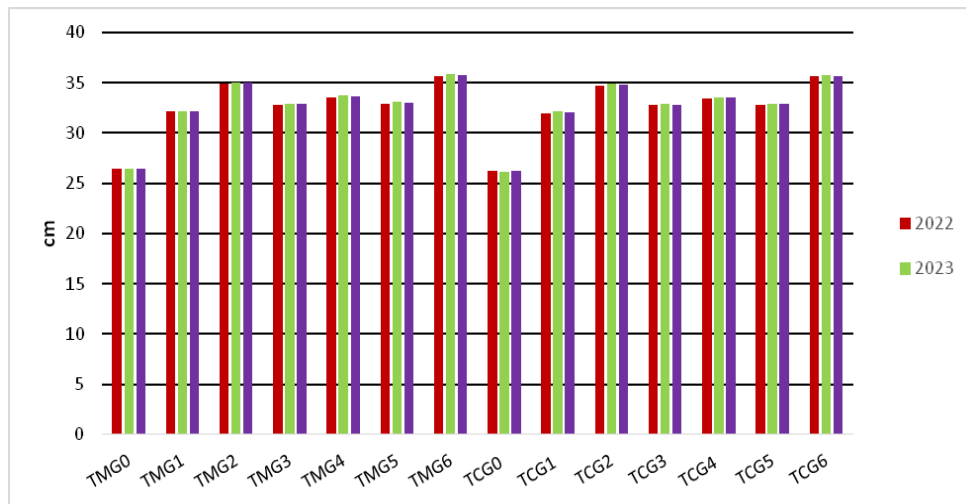


Fig. 4.20(a): Interaction effect of tillage and green manuring on plant height at 30 DAS

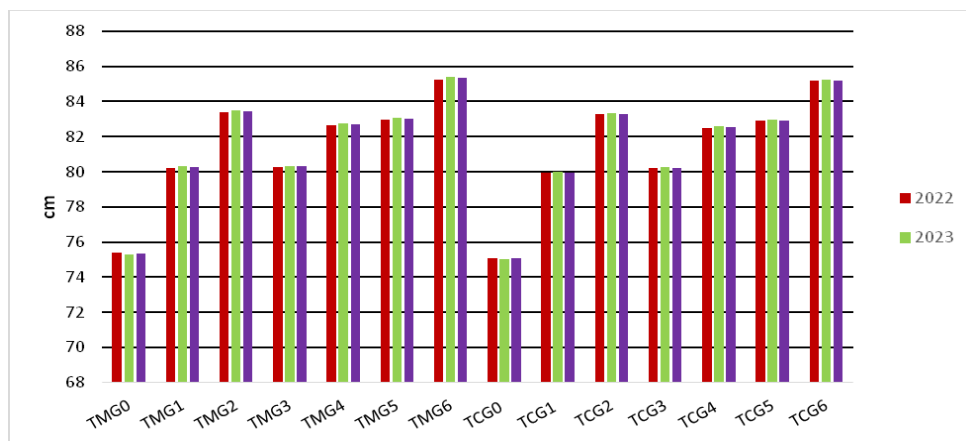


Fig. 4.20(b): Interaction effect of tillage and green manuring on plant height at 60 DAS

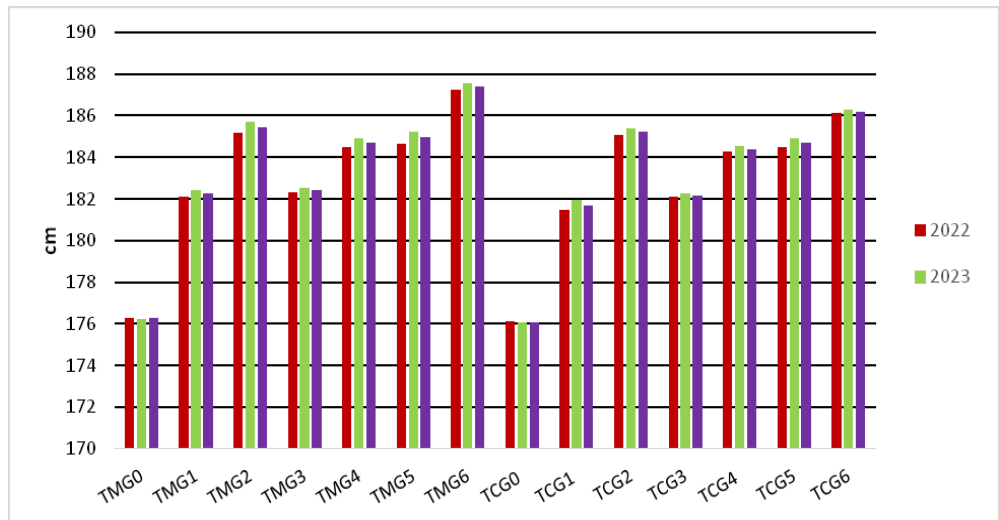


Fig. 4.20(c): Interaction effect of tillage and green manuring on plant height at 90 DAS

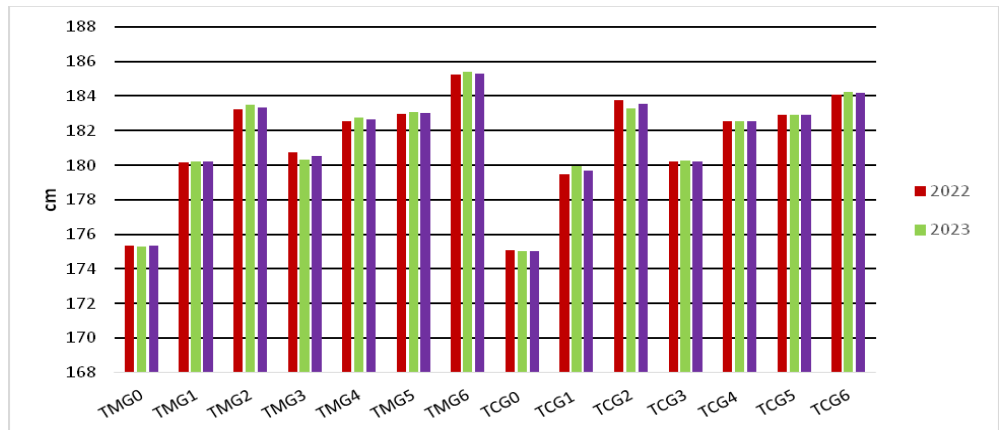


Fig. 4.20(d): Interaction effect of tillage and green manuring on plant height at harvest

#### **4.2.2 Number of cobs per plant**

The number of cobs per plant procured from the investigation conducted for two years on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize and its interaction as impacted from the introduction of minimum and conventional tillage systems and incorporation of green manures like dhaincha and cowpea at varied proportion is provided in Table 4.10(a) and 4.10(b) and systematically illustrated in Fig 4.21(a) and 4.21(b).

##### **4.2.2.1 Effect of tillage on number of cobs per plant**

Different tillage operations like minimum and conventional tillage, its impact on the development of maize cobs and their count is reflected in Table 4.10(a) and Fig 4.21(a). The count of maize cobs in minimum tillage ( $T_M$ ) was superior over both the years of study as well as the pooled result in contrary to conventional tillage ( $T_C$ ). In the initial year (2022), a mean of 1.49 cobs was obtained introducing minimum tillage ( $T_M$ ) while in conventional tillage ( $T_C$ ) the cob count was 1.36, presenting an increase of 9.55% whereas in the second year the cob tally in ( $T_M$ ) acquiring 1.64 cobs rose to 23.30% in contrary to the cob count in plants obtained from ( $T_C$ ) having 1.33 cobs. The pooled analysis of 2022 and 2023 unveiled a 15.55% elevation in cobs tally implementing minimum tillage (1.56) number of cobs in contrast to number of cobs received *via* conventional tillage (1.35). Appropriate tillage implementation enhances vital soil properties like soil moisture and bulk density. These soil properties are crucial for development of maize plant and its yield components. For example, Mould board plough increases the soil temperature and helps in germination of seeds and its establishment which supports the plant for better crop stand and ultimately superior cob formation (Shevchenko *et al.*, 2024) which was also supported by Parangi *et al.* (2023).

##### **4.2.2.2 Effect of green manuring on number of cobs per plant**

The varied data affiliated with number of cobs per plant *via* the inclusion of green manures at varied proportion is vigilantly documented in Table 4.10(a) and

visually exemplified in Fig 4.21(a). Incorporation of green manures had an encouraging impact on the development of cobs in maize plant in the first year of study.  $G_6$  i.e. green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ , was the most impactful sub plot treatment having cob count of (1.57), followed by the treatment  $G_2$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$ ) and  $G_5$  green manuring through dhaincha  $1 \text{ t ha}^{-1}$  and cowpea  $1 \text{ t ha}^{-1}$  @  $2 \text{ t ha}^{-1}$ ) where the cob count in both the treatment was marked at (1.50). The least effective treatment in the progress of cobs was seen in  $G_0$  (control) where the mean cob was noted at (1.13). The applied treatment unveiled an upsurge of cobs in maize plant by 38.93% in  $G_6$  and 32.74% in  $G_2$  and  $G_5$  in contrary to  $G_0$ . The succeeding year (2023) revealed escalation of cob figures adopting  $G_6$  (1.60) and  $G_2$  (1.60) by 45.45% and  $G_4$  (1.57) and  $G_5$  (1.57) by 42.72% as compared to  $G_0$  (1.10) marked as the least influential treatment in the development of cob count up. Similarly, in the pooled mean of 2022 and 2023, improvement in cob numbers were observed in the treatment  $G_6$  (1.58) which gave the highest cob average, followed by  $G_2$  (1.55) and  $G_5$  (1.53), whereas the least was noted in  $G_0$  (1.12), presenting an elevated increase in number of cobs per plant by 41.07%, 38.39% and 36.60%, respectively in  $G_6$ ,  $G_2$  and  $G_5$  in relation to  $G_0$ . Increase in maize yield up to  $3000 \text{ kg ha}^{-1}$  was observed with the incorporation of green manures like pea and dhaincha. Green manure helps in increasing the cob count and seed production which ultimately increases the yield of the crop (Balazs *et al.*, 2024).

#### 4.2.2.3 Interaction effect

The compiled fact and figures obtained from the interaction of adopted tillage practices and added green manures in the two-year field research and its pooled mean records are methodically included in Table 4.10(b) and depicted in Fig 4.21(b). An ascending trend in number of cobs per plant in the base year (2022) was observed in the treatment combination consisting of  $T_M G_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) where the cobs were numbered to (1.73), subsequently followed by the treatment combination  $T_M G_2$  (minimum tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) and  $T_M G_5$  (minimum tillage + green manuring through dhaincha  $1 \text{ t ha}^{-1}$  and cowpea  $1 \text{ t ha}^{-1}$  @  $2 \text{ t ha}^{-1}$ )



with cobs totaled at (1.53). Least performing interaction was perceived in the combination  $T_CG_0$  (conventional tillage + control) noted at (1.07). This acquired outcomes disclosed increased number of cobs per plant amounting to 61.68% adopting  $T_MG_6$  and 42.99% embracing  $T_MG_2$  and  $T_MG_5$ , in contrast to  $T_CG_0$ . An upsurge of number of cobs per plant was attained in the interaction of treatments  $T_MG_6$  (1.80) trailing by  $T_MG_2$  (1.73) and  $T_MG_4$  (1.73) while the least effective was in  $T_CG_0$  (1.00) indicating a rise of 80% in  $T_MG_6$  and 73% in  $T_MG_2$  and  $T_MG_4$ . The mean pooled outcomes from the two-year investigation disclose escalated results where  $T_MG_6$  (1.77) and  $T_MG_2$  (1.63) in contrary to  $T_CG_0$  (1.03) amounted to upsurge the number of cobs per plant by 71.48% and 58.25%, respectively.

#### **4.2.3 Length of cob**

The inferences received during the cultivation of maize in the two-year investigation and the impact of merging tillage and green manuring systems and practices on the growth and development concerning the cob length is systematically provided in Table 4.10(a) and 4.10(b) and depicted visually in Fig 4.22(a) and 4.22(b).

##### **4.2.3.1 Effect of tillage on length of cob**

The enhancement and influence of tillage practices like minimum and conventional tillage on the observed length of cob for both the year of cultivation (2022 and 2023) including the pooled mean average is analytically described in Table 4.10(a) and portrayed in Fig 4.22(a). During the preliminary year of crop study the acquired cob length was comprehended to be higher in ( $T_M$ ) minimum tillage attaining (18.31 cm) in relation to ( $T_C$ ) conventional tillage where it was (18.24 cm) providing 0.38% increase integrating ( $T_M$ ) whereas in the second year an elevation of 0.54% length of cob was detected figuring minimum tillage (18.35 cm) to that of conventional tillage (18.25). The mean average of 2022 and 2023 disclosed an upsurge of cob length by 0.43% integrating ( $T_M$ ) having cob length (18.33 cm) in contrary to ( $T_C$ ) with cob length of (18.25 cm). Mustapha *et al.* (2024) outlined that explicit tillage practices develop soil structure and soil moisture retention capacity

which plays a crucial role in enhancing better plant development. Root development, nutrient efficiency and moisture uptake by the plant is also improved. Consequently, crop shows better growth and improved cob formation in maize and increase yield of maize seeds.

#### **4.2.3.2 Effect of green manuring on length of cob**

The diverse configuration and proportion of green manures added and its influence on the length of maize cobs over two years of intense cropping and its pooled mean is disclosed in Table 4.10(a) and graphically represented in Fig 4.22(a). Superior length of cob was premeditated in the sub plot treatment  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) having cob length of (18.84 cm) followed by  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) where the attained cob length was (18.60 cm) and  $G_5$  (green manuring through dhaincha  $1 \text{ t ha}^{-1}$  and cowpea  $1 \text{ t ha}^{-1}$  @  $2 \text{ t ha}^{-1}$ ) acquiring cob length of (18.21 cm). The least effective treatment was in the treatment of  $G_0$  i.e. control (17.77 cm) presenting an amplified growth of cob length in  $G_2$  by 6.02%,  $G_6$  by 4.67% and  $G_5$  by 2.47%, respectively. In the successive year (2023), the most effective treatment of the sub plot attained a cob length of 18.86 cm which was in  $G_2$ , consequently followed by  $G_6$  with 18.65 cm and  $G_1$  and  $G_5$  with 18.24 cm of cob length, whereas the lowest cob length was in the sub plot treatment of  $G_0$  (17.73 cm). The mean of 2022 and 2023 conveyed an augment of cob length by 6.19%, 4.90% and 2.70% respectively in the treatment comprising of  $G_2$  (18.85 cm),  $G_6$  (18.62 cm) and  $G_5$  (18.23 cm) as compared to  $G_0$  with noted cob length of (17.75 cm). Opier *et al.* (2024) outlined in their study that Green manuring @  $20 \text{ t ha}^{-1}$  increases the cob length of sweet corn (*Zea mays saccharata* L.) significantly. Green manuring + NPK compound fertilizer also known as phonska was instrumental in enhancing yield and yield attributes of maize like plant height, cob development. This study concludes that the combination of balanced fertilization is essential for the overall development of maize crop. These findings were parallel to the findings of (Ashritha and Debbarma, 2022).

#### 4.2.3.3 Interaction effect

The contribution of minimum and conventional tillage practices and green manures at varied fractions and its attributes towards their interaction in the two-year study and its pooled average data is meticulously briefed in Table 4.10(b) and portrayed in Fig 22(b). The treatments combination which conveyed the most influenced in relation to cob length was noted in  $T_MG_2$  (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) with cob length of (18.93 cm), trailed by  $T_CG_2$  (conventional tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) acquiring cob length of (18.75 cm) and  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) attaining cob length of (18.66 cm), while the lowest cob length was in the treatment combination  $T_CG_0$  (conventional tillage + control) achieving length of cob marked at (17.73 cm). This outcomes of the initial year of study disclosed increase in cob length in better performing combinations like  $T_MG_2$  by 6.76%,  $T_CG_2$  by 5.75% and  $T_MG_6$  by 5.24%, respectively in comparison to the length of cob received in  $T_CG_0$ . Augmentation of length of cob was also marked in the interaction of  $T_MG_2$  (18.98 cm) by 7.35%,  $T_CG_2$  (18.75 cm) by 6.05% and  $T_MG_6$  (18.70 cm) by 5.76%, in contrary to  $T_CG_0$  with (17.68 cm) of cob length. The pooled aggregated mean of 2022 and 2023 unveiled significant improvement in the treatment combinations of  $T_MG_2$  which was noted as the most influenced combination presenting (18.95 cm) cob length, subsequently followed by  $T_CG_2$  (18.75 cm) and  $T_MG_6$  (18.68 cm) whereas the least effective was in the treatment combination  $T_CG_0$  with (17.70 cm), this provided escalated rise in cob length by 7.06%, 5.92% and 5.53% in  $T_MG_2$ ,  $T_CG_2$  and  $T_MG_6$  in contrast to  $T_CG_0$ .

#### 4.2.4 Number of grains per cob

The details obtained from the inclusion of tillage operations and the green manures incorporated in different amount and its impact on the number of grains per cob for the two-year analysis and its interaction of treatment combinations is briefed for discussion in Table 4.10(a) and 4.10(b) and visually depicted for validation in Fig 4.23(a) and 4.23(b).

#### 4.2.4.1 Effect of tillage on number of grains per cob

The details of the research and its findings pertaining to the number of grains per cob as impacted by the adoption of varied tillage practices like minimum and conventional tillage for the two year of thorough investigation and the aggregate pooled mean of 2022 and 2023 is presented in Table 4.10(a) and portrayed in Fig 4.23(a). The number of grains per cob was observed to be performing much superior with the integration of ( $T_M$ ) minimum tillage (338.25) as compared to the count of seeds obtained in ( $T_C$ ) conventional tillage (338.02), presenting upsurge of grains of maize by 0.06% in ( $T_M$ ) in contrary to ( $T_C$ ). In the succeeding year the higher grains were noted in the section of minimum tillage (338.30) in contrast to conventional tillage (338.08). Aggregate mean of 2022 and 2023 disclosed a rise in grain count of maize following the implementation of ( $T_M$ ) minimum tillage (338.27) as compared to ( $T_C$ ) conventional tillage (338.05). Sun *et al.* (2023) and Tuti *et al.* (2022) expressed that the use of staggered planting system with strip rotary tillage in maize cultivation especially high density plantation improves the structure of the soil and canopy of the plant. It also reduces the bulk density of the soil and increases root dry weight by 51.26% and grain yield by 25.44%. This advocates that seed filling and cob development of maize is directly related to the physical aspects of the soil.

#### 4.2.4.2 Effect of green manuring on number of grains per cob

The consequences of green manure application *via* dhaincha and cowpea on the number of grains per cob on cultivated maize observed in the two-year analysis and its pooled average is briefly explained in Table 4.10(a) and portrayed in Fig 4.23(a). An intensified grain count in the first year (2022) was accounted with the use green manure treatments like  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) computing 357.68 grains per cob,  $G_5$  (green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) (353.64) and  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) (352.39). Sub plot treatment which numbered the least count of grains was computed in  $G_0$  (control) acquiring grains count by (280.24), these outcomes exhibited rise of 27.63%, 26.19% and 25.74% in  $G_6$ ,  $G_5$  and  $G_2$  in contrast to  $G_0$ . In the succeeding year of cultivation (2023), peak number of

grains were determined in the sub plot treatments  $G_6$  (357.81) followed by  $G_5$  (353.74) and  $G_2$  (352.50), while the least influential treatment was accounted in  $G_0$  (280.03). A rise of 27.77% utilizing  $G_6$ , 26.32% via  $G_5$  and 25.87% through  $G_2$  was summarized. The mean aggregate of the two-year field study divulged the discoveries of the incorporated green manures on the grain development in the cultivated maize crop.  $G_6$  (357.75) was outlined the utmost contributing treatment in developing the grain count, followed by  $G_5$  (353.69) and  $G_2$  (352.44) providing a rise of grain count in cob by 27.70%, 26.25% and 25.80%, respectively in relation to  $G_0$  (280.14).

#### 4.2.4.3 Interaction effect

The interaction effect received from the amalgamation of tillage practices and green manure incorporation on the number of grains per cob in the two-year cultivation of maize and its mean aggregates is provided for discussion in Table 4.10(b) and Fig 4.23(b). The findings from the first year research conducted in 2022 provided the facts where the treatment combination  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with grain count (357.89) attained the peak contributor in the development of grains in maize cobs, subsequently followed by  $T_CG_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) acquiring grain count of (357.47) and  $T_MG_5$  (minimum tillage + green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) accumulating (353.70) grains of maize. This results from the initial year unveiled an escalation in maize grain count by 27.88% in  $T_MG_6$ , 27.73% in  $T_CG_6$  and 26.38% in  $T_MG_5$  in contrary to the least influential treatment combination  $T_CG_0$  having grain count of (279.86). The succeeding year (2023), reported parallel consequences where  $T_MG_6$  (358.03),  $T_CG_6$  (357.59) and  $T_MG_5$  (353.81) in contrary to  $T_CG_0$  (279.69) elevated the seed count in cobs by 28%, 27.85% and 26.50%, correspondingly. An escalation of grain count was visible in the mean aggregate of outcomes from 2022 and 2023 pooled where the treatment combination  $T_MG_6$  (357.96) increased the seed count by 27.94%,  $T_CG_6$  (353.53) by 26.35% and  $T_MG_5$  (353.76) by 26.44%, in contrast to  $T_CG_0$  (279.78) which was the least effective treatment combination in the pooled mean.

Kucerik *et al.* (2024) and Xu *et al.* (2017) in their investigation stated that the use of green manures in a diverse range of cover crops can increase the biomass production of maize. It was reported that incorporation of mustard as a green manure improved the plant growth attributes. Biomass yield was also improved by 18.4 g plant<sup>-1</sup> as compared to control which was at 8.6 g plant<sup>-1</sup>. This shows that the use of green manures particularly mustard not only improves soil properties but also enhances the overall productivity of maize.

**Table 4.10 (a): Effect of tillage and green manuring on number of cobs per plant, length of cob and number of grains per cob**

| Treatment             | Number of cobs per plant |        |        | Length of cob (cm) |       |        | Number of grains per cob |        |        |
|-----------------------|--------------------------|--------|--------|--------------------|-------|--------|--------------------------|--------|--------|
|                       | 2022                     | 2023   | Pooled | 2022               | 2023  | Pooled | 2022                     | 2023   | Pooled |
| <b>Tillage</b>        |                          |        |        |                    |       |        |                          |        |        |
| <b>T<sub>M</sub></b>  | 1.49                     | 1.64   | 1.56   | 18.31              | 18.35 | 18.33  | 338.25                   | 338.30 | 338.27 |
| <b>T<sub>C</sub></b>  | 1.36                     | 1.33   | 1.35   | 18.24              | 18.25 | 18.25  | 338.02                   | 338.08 | 338.05 |
| <b>SEm ±</b>          | 0.018                    | 0.044  | 0.024  | 0.011              | 0.012 | 0.008  | 0.007                    | 0.005  | 0.004  |
| <b>CD at 5%</b>       | 0.108                    | 0.269  | 0.093  | 0.065              | 0.075 | 0.032  | 0.043                    | 0.033  | 0.017  |
| <b>CV</b>             | 5.735                    | 13.621 | 10.607 | 0.268              | 0.310 | 0.290  | 0.009                    | 0.007  | 0.008  |
| <b>Green manuring</b> |                          |        |        |                    |       |        |                          |        |        |
| <b>G<sub>0</sub></b>  | 1.13                     | 1.10   | 1.12   | 17.77              | 17.73 | 17.75  | 280.24                   | 280.03 | 280.14 |
| <b>G<sub>1</sub></b>  | 1.40                     | 1.47   | 1.43   | 18.20              | 18.24 | 18.22  | 320.21                   | 320.28 | 320.24 |
| <b>G<sub>2</sub></b>  | 1.50                     | 1.60   | 1.55   | 18.84              | 18.86 | 18.85  | 352.39                   | 352.50 | 352.44 |
| <b>G<sub>3</sub></b>  | 1.40                     | 1.50   | 1.45   | 18.14              | 18.19 | 18.17  | 352.07                   | 352.17 | 352.12 |
| <b>G<sub>4</sub></b>  | 1.47                     | 1.57   | 1.52   | 18.17              | 18.20 | 18.18  | 350.71                   | 350.80 | 350.76 |
| <b>G<sub>5</sub></b>  | 1.50                     | 1.57   | 1.53   | 18.21              | 18.24 | 18.23  | 353.64                   | 353.74 | 353.69 |
| <b>G<sub>6</sub></b>  | 1.57                     | 1.60   | 1.58   | 18.60              | 18.65 | 18.62  | 357.68                   | 357.81 | 357.75 |
| <b>SEm ±</b>          | 0.087                    | 0.091  | 0.063  | 0.017              | 0.018 | 0.013  | 0.027                    | 0.017  | 0.016  |
| <b>CD @ 5%</b>        | 0.254                    | 0.266  | 0.179  | 0.051              | 0.053 | 0.036  | 0.078                    | 0.050  | 0.045  |
| <b>CV</b>             | 14.991                   | 15.003 | 15.000 | 0.233              | 0.243 | 0.238  | 0.019                    | 0.013  | 0.016  |

**Table 4.10 (b): Interaction effect of tillage and green manuring on number of cobs per plant, length of cob and number of grains per cob**

| Treatments                        | Number of cobs per plant |       |        | Length of cob (cm) |       |        | Number of grains per cob |        |        |
|-----------------------------------|--------------------------|-------|--------|--------------------|-------|--------|--------------------------|--------|--------|
|                                   | 2022                     | 2023  | Pooled | 2022               | 2023  | Pooled | 2022                     | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 1.20                     | 1.20  | 1.20   | 17.81              | 17.79 | 17.80  | 280.62                   | 280.36 | 280.49 |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 1.47                     | 1.67  | 1.57   | 18.24              | 18.29 | 18.27  | 320.22                   | 320.26 | 320.24 |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 1.53                     | 1.73  | 1.63   | 18.93              | 18.98 | 18.95  | 352.38                   | 352.53 | 352.45 |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 1.47                     | 1.67  | 1.57   | 18.15              | 18.22 | 18.19  | 352.08                   | 352.19 | 352.14 |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 1.47                     | 1.73  | 1.60   | 18.16              | 18.19 | 18.18  | 350.82                   | 350.92 | 350.87 |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 1.53                     | 1.67  | 1.60   | 18.22              | 18.27 | 18.25  | 353.70                   | 353.81 | 353.76 |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 1.73                     | 1.80  | 1.77   | 18.66              | 18.70 | 18.68  | 357.89                   | 358.03 | 357.96 |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 1.07                     | 1.00  | 1.03   | 17.73              | 17.68 | 17.70  | 279.86                   | 279.69 | 279.78 |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 1.33                     | 1.27  | 1.30   | 18.15              | 18.18 | 18.17  | 320.19                   | 320.31 | 320.25 |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 1.47                     | 1.47  | 1.47   | 18.75              | 18.75 | 18.75  | 352.39                   | 352.47 | 352.43 |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 1.33                     | 1.33  | 1.33   | 18.13              | 18.17 | 18.15  | 352.05                   | 352.14 | 352.10 |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 1.47                     | 1.40  | 1.43   | 18.18              | 18.20 | 18.19  | 350.60                   | 350.68 | 350.64 |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 1.47                     | 1.47  | 1.47   | 18.20              | 18.21 | 18.21  | 353.58                   | 353.67 | 350.63 |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 1.40                     | 1.40  | 1.40   | 18.53              | 18.59 | 18.56  | 357.47                   | 357.59 | 353.53 |
| <b>SEm ±</b>                      | 0.123                    | 0.129 | 0.089  | 0.025              | 0.026 | 0.018  | 0.038                    | 0.024  | 0.022  |
| <b>CD at 5%</b>                   | NS                       | NS    | NS     | 0.072              | 0.075 | 0.051  | 0.110                    | 0.071  | 0.064  |



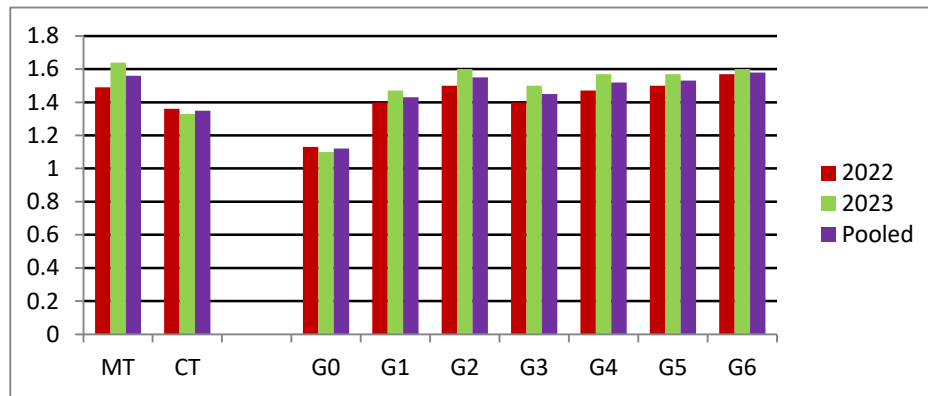


Fig. 4.21(a): Effect of tillage and green manuring on number of cobs per plant

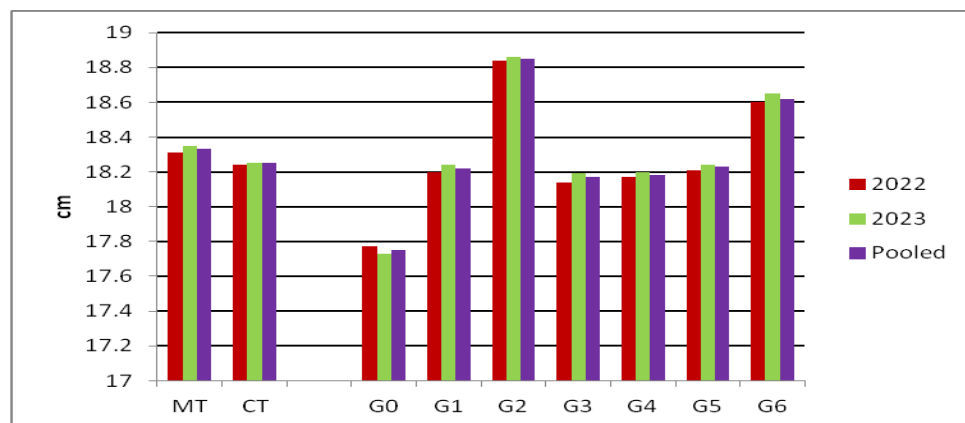


Fig. 4.22(a): Effect of tillage and green manuring on length of cob

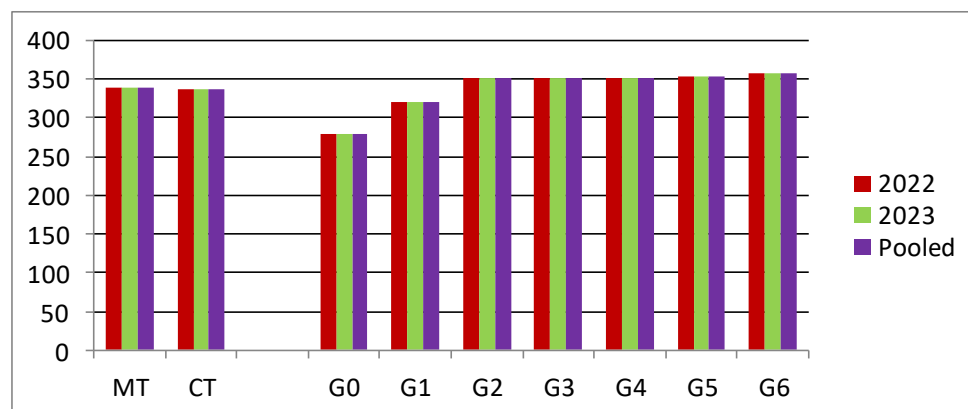


Fig. 4.23(a): Effect of tillage and green manuring on number of grains per cob

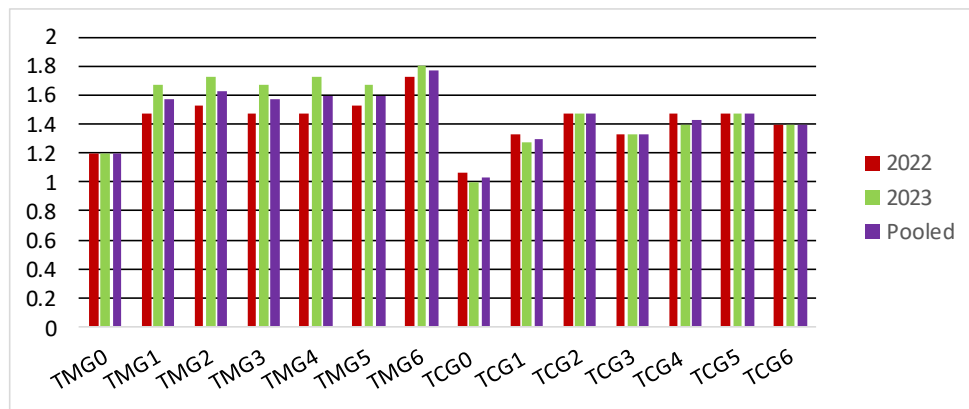


Fig. 4.21(b): Interaction effect of tillage and green manuring on number of cobs per plant

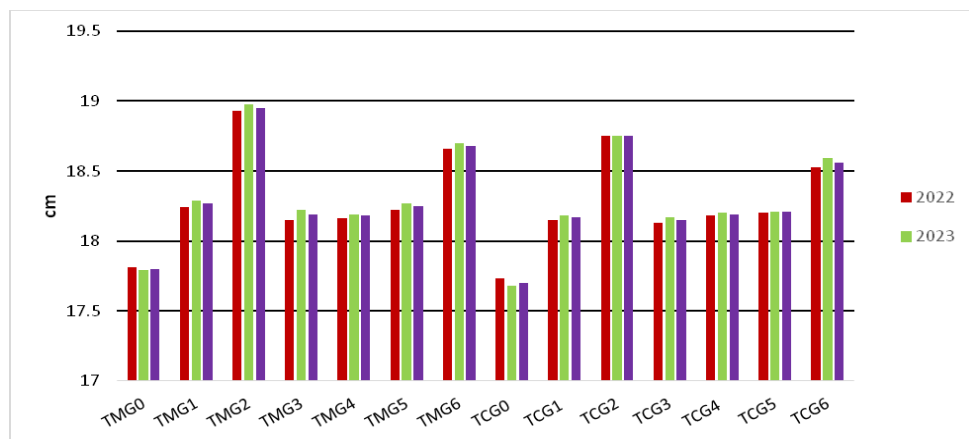


Fig. 4.22(b): Interaction effect of tillage and green manuring on length of cob

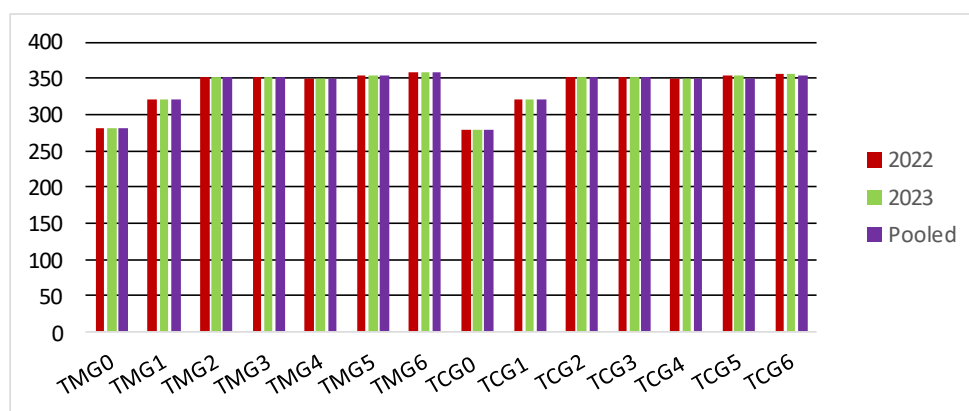


Fig. 4.23(b): Interaction effect of tillage and green manuring on number of grains per cob

#### 4.2.5 Seed yield

The facts delivered in Table 4.11(a) and 4.11(b) and Fig 4.24(a) and 4.24(b) meticulously summarizes the outcomes of seed yield of maize for two years' analysis and the interaction of treatment combinations *via* tillage and green manuring.

##### 4.2.5.1 Effect of tillage on seed yield

The outcomes received from varied tillage (minimum and conventional tillage) implementation in the two-year field investigation and the mean aggregate of both the years of cropping (2022 and 2023) is precisely outlined in Table 4.11(a) and accurately illustrated in Fig 4.24(a). Minimum tillage ( $T_M$ ) outperformed conventional tillage ( $T_C$ ) in the base year (2022) generating more seed yield cultivating maize. Minimum tillage ( $T_M$ ) (5585 kg ha<sup>-1</sup>) recorded higher seed yield amounting to 0.16% more than that noted in ( $T_C$ ) conventional tillage (5575.57 kg ha<sup>-1</sup>). In the second year (2023), minimum tillage (5584.95 kg ha<sup>-1</sup>) accumulated more seed yield of cultivated maize than conventional tillage (5575.59 kg ha<sup>-1</sup>). Similarly, in the pooled aggregate of 2022 and 2023, higher seed yield was observed adopting ( $T_M$ ) minimum tillage (5584.98 kg ha<sup>-1</sup>) than ( $T_C$ ) conventional tillage (5575.58 kg ha<sup>-1</sup>). Minimum tillage improves the soil structure, enhances the moisture retention capabilities of the soil, increased organic matter and reduces nutrient loss due to excessive tillage operation which may lead to better grain yield in crops. Mtyobile and Mhlontlo, (2021) asserted that significant augmentation of maize yield was observed with the implementation of minimum tillage (MT) in a research carried out in South Africa. An increase from 2.3 t ha<sup>-1</sup> to 4.78 t ha<sup>-1</sup> was observed under minimum tillage. Conventional tillage averaged relatively lower yield of about 4.16 t ha<sup>-1</sup> as compared to other tillage practices. The results were in line with the outcomes of the research conducted by Shah *et al.* (2014).

##### 4.2.5.2 Effect of green manuring on seed yield

Assorted data associated to seed yield obtained by the inclusion of green manures into the soil and its effect on the overall yield contribution over both the

years of cultivation and its pooled aggregate mean is outlined in Table 4.11(a) and represented visually in Fig 4.24(a). The application of green manure treatment in the sub plot of  $G_6$  i.e. green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> (5692.42 kg ha<sup>-1</sup>), was evident in improving the seed yield the most, trailed by  $G_2$  i.e. green manuring through dhaincha 4 t ha<sup>-1</sup> (5646.46 kg ha<sup>-1</sup>) and by  $G_4$  i.e. green manuring through cowpea 4 t ha<sup>-1</sup> (5618.67 kg ha<sup>-1</sup>), whereas the least effective treatment was in  $G_0$  (5367.21 kg ha<sup>-1</sup>). These outcomes in the initial year reflected an increase of 6.05%, 5.20% and 4.68% embracing  $G_6$ ,  $G_2$  and  $G_4$ , respectively in contrary to  $G_0$ . The subsequent year (2023) of cropping maize, delivered elevated results where enhanced seed yield was acquired implementing green manure viz.  $G_6$  (5692.54 kg ha<sup>-1</sup>) followed by  $G_2$  (5646.58 kg ha<sup>-1</sup>) and  $G_4$  (5618.76 kg ha<sup>-1</sup>), indicating a rise of 6.07%, 5.22% and 4.70%, respectively as compared to  $G_0$  (5366.43 kg ha<sup>-1</sup>). The pooled mean aggregate of 2022 and 2023 disclosed similar pattern of green manure attribution in seed yield.  $G_6$  (5692.48 kg ha<sup>-1</sup>), trailed by  $G_2$  (5646.52 kg ha<sup>-1</sup>) and  $G_4$  (5618.71 kg ha<sup>-1</sup>) in contrary to  $G_0$  (5366.82 kg ha<sup>-1</sup>) presented a rise of 6.06%, 5.21% and 4.69%, respectively in seed yield of maize. Green manures may aid nutrient use efficiency especially macronutrients like NPK which directly enhances the crop yield and development. The microbial activity may be improved which maintains the overall soil health and improves the rhizospheric zone of the crop and may help the crop nutrient absorption capacity.

#### 4.2.5.3 Interaction effect

The interaction of treatments concerning minimum and conventional tillage practices and altered alignment of green manures and its influences on seed yield of maize is provided in Table 4.11(b) and illustrated in Fig 24(b). Treatment combination  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) outperformed all the treatment combinations in the initial year (2022) of cropping in relation to seed yield noting (5696.07 kg ha<sup>-1</sup>), followed by  $T_C G_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) having seed yield (5688.76 kg ha<sup>-1</sup>) and  $T_M G_2$  i.e.

minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) marking seed yield of (5650.06 kg ha<sup>-1</sup>), whereas the least persuasive treatment combination was noted in T<sub>C</sub>G<sub>0</sub> (conventional tillage + control) with (5359.58 kg ha<sup>-1</sup>) of maize seed yield. This presented rise of seed yield by 6.27%, 6.14% and 5.41% adopting T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>2</sub> against T<sub>C</sub>G<sub>0</sub>, respectively. Similar pattern of escalation of seed yield with the incorporation of green manures were also seen in the second year (2023) where T<sub>M</sub>G<sub>6</sub> (5696.25 kg ha<sup>-1</sup>), T<sub>C</sub>G<sub>6</sub> (5688.84 kg ha<sup>-1</sup>) and T<sub>M</sub>G<sub>2</sub> (5650.22 kg ha<sup>-1</sup>) presented increase of seed yield by 6.28%, 6.14% and 5.42%, respectively computing with T<sub>C</sub>G<sub>0</sub> (5359.27 kg ha<sup>-1</sup>). Correspondingly in the pooled aggregates of 2022 and 2023, an upsurge of 6.28%, 6.14% and 5.42%, respectively in seed yield of maize was marked with the implementation of T<sub>M</sub>G<sub>6</sub> (5696.16 kg ha<sup>-1</sup>), T<sub>C</sub>G<sub>6</sub> (5688.80 kg ha<sup>-1</sup>) and T<sub>M</sub>G<sub>2</sub> (5650.14 kg ha<sup>-1</sup>) in contrary to T<sub>C</sub>G<sub>0</sub> (5359.43 kg ha<sup>-1</sup>).

A research conducted in the Northern China Plains revealed that the yield of spring maize boosted by 5.38% to 11.68% with the incorporation of green manures as compared to common traditional winter fallow practices. Maize yield was at its peak with the augment of optimized nitrogen application with 14,312.2 kg ha<sup>-1</sup>. This shows the capacity of green manuring to enhance maize growth and productivity and limit the use of synthetic fertilizers (Su *et al.*, 2022) and (Sharma *et al.*, 2018).

#### **4.2.6 Stover yield**

The yield of maize stover marked by the use of minimum and conventional tillage operations with green manure conducted for two years on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.). The pooled aggregate data and the interactions of different treatment combinations is provided for deliberation in Table 4.11(a) and 4.11(b) and Fig 4.25(a) and 4.25(b).

##### **4.2.6.1 Effect of tillage on stover yield**

Varied aspects of results obtained from the analysis as influenced by tillage methods employed for two years (2022 and 2023) and its pooled mean is given for

consideration in Table 4.11(a) and portrayed in Fig 4.25(a). ( $T_M$ ) minimum tillage ( $7386.74 \text{ kg ha}^{-1}$ ) produced higher stover in the first year (2022) than ( $C_T$ ) conventional tillage ( $7365.05 \text{ kg ha}^{-1}$ ), displaying 0.29% growth. In the subsequent year, progression in stover yield was marked utilizing ( $T_M$ ) minimum tillage ( $7386.93 \text{ kg ha}^{-1}$ ) in comparison to stover yield received in ( $T_C$ ) conventional tillage ( $7365.48 \text{ kg ha}^{-1}$ ). Parallel to 2022 and 2023, elevation of stover production was obtained *via* minimum tillage ( $7386.84 \text{ kg ha}^{-1}$ ) in relation to conventional tillage ( $7365.26 \text{ kg ha}^{-1}$ ). Minimum tillage may retain more biomass on the soil surface which helps the soil to reduce nutrient and soil loss. This improves the crop to absorb the nutrient more judiciously enhancing the overall growth and development of the plant leading to better stover production. Studies involving various tillage practices revealed that incorporation of crop residues into the soil irrespective of treatment involving microbial agent improved the growth and stover yield of maize crop when compared with outcomes under conventional tillage practices. This concludes that suitable tillage practices and crop residue management is essential for better crop establishment and its yield components in maize (Naveen *et al.*, 2023). These outcomes were supported by (Xu *et al.*, 2022 and Leghari *et al.*, 2017).

#### 4.2.6.2 Effect of green manuring on stover yield

Impact of added green manures on the two-year research conducted on maize crop and the pooled aggregates received *via* the investigation is noted for discussion in Table 4.11(a) and visually outlined in Fig 4.25(a). The most persuasive sub plot treatments were noticeable in  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) with stover yield of ( $7537.73 \text{ kg ha}^{-1}$ ),  $G_4$  (green manuring through cowpea  $4 \text{ t ha}^{-1}$ ) procuring ( $7516.32 \text{ kg ha}^{-1}$ ) of stover yield and  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) acquiring ( $7417.96 \text{ kg ha}^{-1}$ ) while the least prominent treatment amongst all the sub plot was distinguished in  $G_0$  (control) with stover yield of ( $7219.73 \text{ kg ha}^{-1}$ ), disclosing escalation in stover yield by 4.40%, 4.10% and 2.74%, respectively computed against  $G_0$ . An upsurge of 4.42%, 4.14% and 2.76%, involving  $G_6$  ( $7538.08 \text{ kg ha}^{-1}$ ),  $G_4$  ( $7518.06 \text{ kg ha}^{-1}$ ) and  $G_2$  ( $7418.24 \text{ kg ha}^{-1}$ ) was also recorded in contrast to  $G_0$  ( $7218.76 \text{ kg ha}^{-1}$ ) in the succeeding year of

cropping (2023). A surge in stover yield of maize implementing green manures was prominent in the pooled aggregate table where 4.41%, 4.12% and 2.75% increase in stover yield was obtained computing  $G_6$  (7537.90 kg ha<sup>-1</sup>),  $G_4$  (7517.19 kg ha<sup>-1</sup>) and  $G_2$  (7418.10 kg ha<sup>-1</sup>) against the findings of  $G_0$  (7219.25 kg ha<sup>-1</sup>). Green manures provide adequate nutrient supply especially N and P which help the crop growth and development. It enriches the soil with organic matter, improves the soil structure and biology, conserves moisture and reduces fertilizer dependency, overall benefitting the crop biomass production. Acs *et al.* (2024) and Zhang *et al.* (2025b) reported in their findings that enrichment of soil properties better crop growth and sustainable development in yield and yield attributes were observed with the use of green manures. The improvement in soil subsequently led to an increase in crop performance resulting in higher yield and better stover production in maize plantation.

#### 4.2.6.3 Interaction effect

Diverse data received following the research conducted for two consecutive years in the *kharif* seasons of 2022 and 2023 on the stover yield of maize crop and how the interaction of tillage and green manures inclusion influenced the performance of stover production with its pooled aggregate is systematically outlined in Table 4.11(b) and graphically represented in Fig 4.25(b). The interaction  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) was the most prominent combination concerning the stover production of maize (7550.34 kg ha<sup>-1</sup>) in the initial year of cropping (2022) followed by the treatment combination  $T_CG_6$  (conventional tillage + green manuring through dhaincha 1 t ha<sup>-1</sup> and cowpea 1 t ha<sup>-1</sup> @ 2 t ha<sup>-1</sup>) acquiring stover yield of (7525.12 kg ha<sup>-1</sup>) and  $T_MG_4$  (minimum tillage + green manuring through cowpea 4 t ha<sup>-1</sup>) procuring (7521.69 kg ha<sup>-1</sup>) stover produce. The least effective treatment combination concerning stover yield in the first year of investigation was marked in  $T_CG_0$  (conventional tillage + control) with (7179.87 kg ha<sup>-1</sup>). These outcomes in the initial year offered a growth of stover production by 5.15% through the integration of  $T_MG_6$ , 4.80% involving  $T_CG_6$  and 4.76% by  $T_MG_4$  in contrary to  $T_CG_0$ . The second

year produced up surged stover yield where a rise of 5.18%, 4.83% and 4.78% was acquired through the computation of  $T_MG_6$  (7550.82 kg ha<sup>-1</sup>),  $T_CG_6$  (7525.34 kg ha<sup>-1</sup>) and  $T_MG_4$  (7521.89 kg ha<sup>-1</sup>) in relation to  $T_CG_0$  (7178.32 kg ha<sup>-1</sup>). Pooled aggregate mean of 2022 and 2023 revealed higher stover production in the treatment combination  $T_MG_6$  (7550.58 kg ha<sup>-1</sup>) subsequently followed by  $T_CG_6$  (7525.23 kg ha<sup>-1</sup>) and  $T_MG_4$  (7521.79 kg ha<sup>-1</sup>) whereas the least influential treatment combination was found in  $T_CG_0$  (7179.10 kg ha<sup>-1</sup>), displaying a progression in stover yield by 5.17% in  $T_MG_6$ , 4.82% in  $T_CG_6$  and 4.77% in  $T_MG_4$  in contrary to  $T_CG_0$ .



**Table 4.11 (a): Effect of tillage and green manuring on number of seed yield and stover yield of maize**

| Treatment             | Seed yield<br>(kg ha <sup>-1</sup> ) |         |         | Stover yield<br>(kg ha <sup>-1</sup> ) |         |         |
|-----------------------|--------------------------------------|---------|---------|----------------------------------------|---------|---------|
|                       | 2022                                 | 2023    | Pooled  | 2022                                   | 2023    | Pooled  |
| <b>Tillage</b>        |                                      |         |         |                                        |         |         |
| <b>T<sub>M</sub></b>  | 5585.00                              | 5584.95 | 5584.98 | 7386.74                                | 7386.93 | 7386.84 |
| <b>T<sub>C</sub></b>  | 5575.57                              | 5575.59 | 5575.58 | 7365.05                                | 7365.48 | 7365.26 |
| <b>SEm ±</b>          | 0.051                                | 0.052   | 0.036   | 0.094                                  | 0.435   | 0.223   |
| <b>CD at 5%</b>       | 0.309                                | 0.318   | 0.143   | 0.572                                  | 2.648   | 0.874   |
| <b>CV</b>             | 0.004                                | 0.004   | 0.004   | 0.006                                  | 0.027   | 0.020   |
| <b>Green manuring</b> |                                      |         |         |                                        |         |         |
| <b>G<sub>0</sub></b>  | 5367.21                              | 5366.43 | 5366.82 | 7219.73                                | 7218.76 | 7219.25 |
| <b>G<sub>1</sub></b>  | 5586.40                              | 5586.51 | 5586.45 | 7311.10                                | 7311.39 | 7311.24 |
| <b>G<sub>2</sub></b>  | 5646.46                              | 5646.58 | 5646.52 | 7417.96                                | 7418.24 | 7418.10 |
| <b>G<sub>3</sub></b>  | 5556.86                              | 5556.97 | 5556.91 | 7309.15                                | 7309.37 | 7309.26 |
| <b>G<sub>4</sub></b>  | 5618.67                              | 5618.76 | 5618.71 | 7516.32                                | 7518.06 | 7517.19 |
| <b>G<sub>5</sub></b>  | 5593.99                              | 5594.11 | 5594.05 | 7319.29                                | 7319.54 | 7319.42 |
| <b>G<sub>6</sub></b>  | 5692.42                              | 5692.54 | 5692.48 | 7537.73                                | 7538.08 | 7537.90 |
| <b>SEm ±</b>          | 0.254                                | 0.238   | 0.174   | 0.825                                  | 0.973   | 0.638   |
| <b>CD @ 5%</b>        | 0.741                                | 0.695   | 0.495   | 2.408                                  | 2.840   | 1.814   |
| <b>CV</b>             | 0.011                                | 0.010   | 0.011   | 0.027                                  | 0.032   | 0.030   |

**Table 4.11 (b): Interaction effect of tillage and green manuring on number of seed yield and stover yield of maize**

| Treatments                        | Seed yield<br>(kg ha <sup>-1</sup> ) |         |         | Stover yield<br>(kg ha <sup>-1</sup> ) |         |         |
|-----------------------------------|--------------------------------------|---------|---------|----------------------------------------|---------|---------|
|                                   | 2022                                 | 2023    | Pooled  | 2022                                   | 2023    | Pooled  |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 5374.83                              | 5373.58 | 5374.21 | 7259.59                                | 7259.20 | 7259.40 |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 5590.66                              | 5590.83 | 5590.75 | 7313.43                                | 7313.74 | 7313.59 |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 5650.06                              | 5650.22 | 5650.14 | 7422.86                                | 7423.20 | 7423.03 |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 5560.97                              | 5561.12 | 5561.04 | 7313.00                                | 7313.20 | 7313.10 |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 5624.96                              | 5625.06 | 5625.01 | 7521.69                                | 7521.89 | 7521.79 |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 5597.46                              | 5597.61 | 5597.54 | 7326.29                                | 7326.49 | 7326.39 |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 5696.07                              | 5696.25 | 5696.16 | 7550.34                                | 7550.82 | 7550.58 |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 5359.58                              | 5359.27 | 5359.43 | 7179.87                                | 7178.32 | 7179.10 |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 5582.13                              | 5582.19 | 5582.16 | 7308.77                                | 7309.03 | 7308.90 |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 5642.86                              | 5642.94 | 5642.90 | 7413.05                                | 7413.28 | 7413.16 |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 5552.74                              | 5552.82 | 5552.78 | 7305.30                                | 7305.54 | 7305.42 |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 5612.38                              | 5612.46 | 5612.42 | 7510.95                                | 7514.24 | 7512.60 |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 5590.52                              | 5590.60 | 5590.56 | 7312.29                                | 7312.59 | 7312.44 |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 5688.76                              | 5688.84 | 5688.80 | 7525.12                                | 7525.34 | 7525.23 |
| <b>SEm ±</b>                      | 0.359                                | 0.337   | 0.246   | 1.167                                  | 1.376   | 0.902   |
| <b>CD at 5%</b>                   | 1.047                                | 0.982   | 0.699   | 3.406                                  | 4.017   | 2.565   |

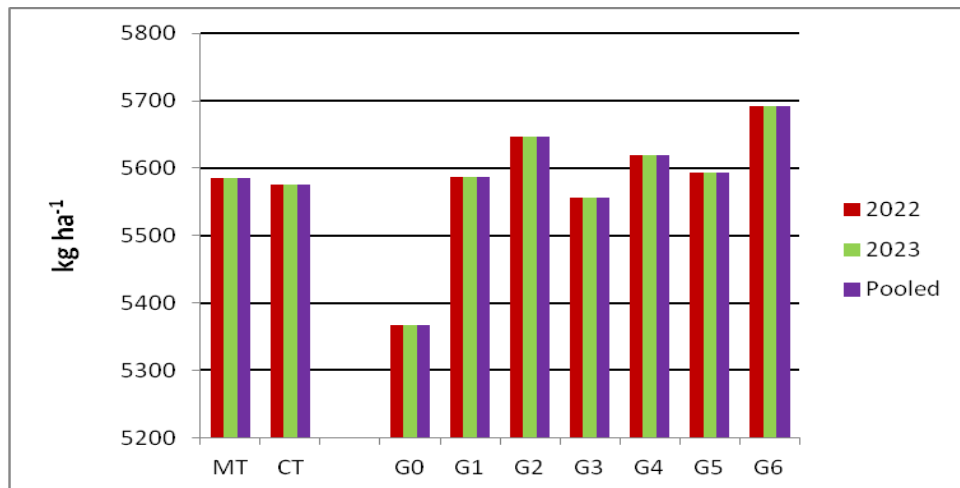


Fig. 4.24(a): Effect of tillage and green manuring on seed yield

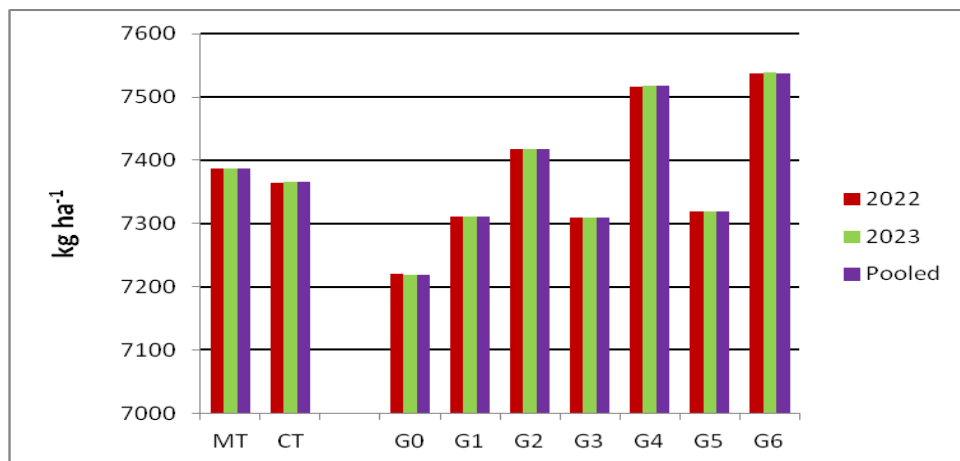


Fig. 4.25(a): Effect of tillage and green manuring on stover yield

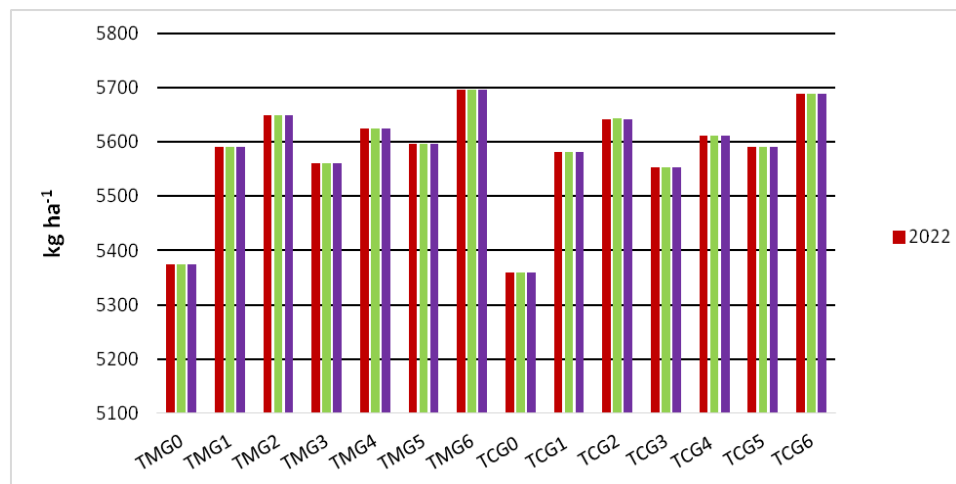


Fig. 4.24(b): Interaction effect of tillage and green manuring on seed yield

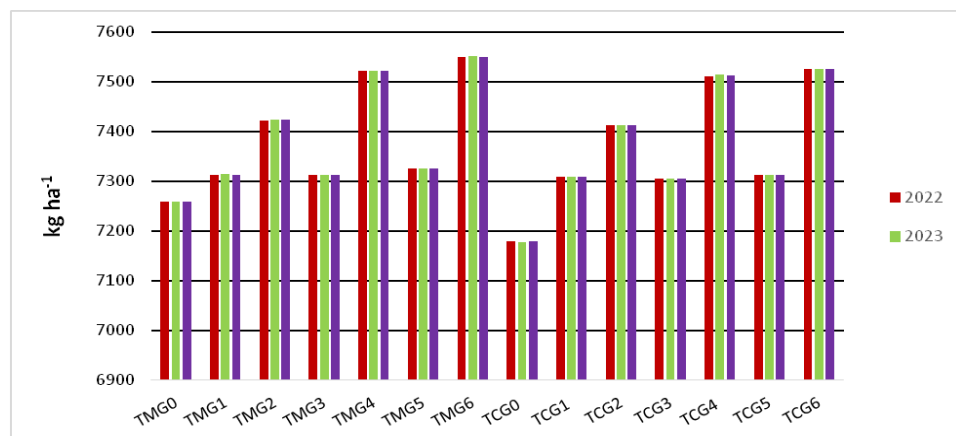


Fig. 4.25(b): Interaction effect of tillage and green manuring on stover yield

### **4.3 Effect of tillage and green manuring on quality attributes of maize**

The precise data obtained *via* the application of appropriate statistical method on quality attributes of maize seeds like protein content, carbohydrate content, oil content and ash content of maize grains received after the two-year investigation as directed by tillage and green manuring is summarized in this segment of discussion evident with appropriate tables and figures.

#### **4.3.1 Protein content**

The findings of protein content of maize seeds from the two-year consecutive investigation as directed by the implementation of tillage operations like minimum and conventional tillage and through the application of green manures *via* dhaincha and cowpea at varied proportion is thoroughly defined in Table 4.12(a) and 4.12(b) and visually depicted in Fig 4.26(a) and 4.26(b).

##### **4.3.1.1 Effect of tillage on protein content**

The outlined results of protein content of maize seeds as obtained by the introduction of tillage practices (minimum and conventional tillage) in the two-year analysis and its pooled mean is systematically noted in Table 4.12(a) and portrayed in Fig 4.26(a). Minimum tillage ( $T_M$ ) with assimilated protein content of (9.15%) was marked to be higher than that received from conventional tillage ( $T_C$ ) which was manifested at (9.02%), giving 1.44% increase of protein content in ( $T_M$ ) than ( $T_C$ ). These outcomes were documented from the initial year research (2022). The second year of investigation (2023), disclosed elevated protein content in minimum tillage (9.27%) to that of conventional tillage (9.15%) giving a rise of 1.31% *via* minimum tillage implementation. Pooled analysis mean data unveiled an escalation of protein content by 1.43% concerning ( $T_M$ ) minimum tillage with acquired data of (9.21%) protein content in contrary to ( $T_C$ ) conventional tillage with protein content of (9.08%). Tillage practices considerably increase the protein content in maize and soybean seeds. The overall grain yield of both the crop was increased with the implementation of reduced tillage than that of intensive tillage systems (Spoljar *et*

*al.*, 2009). These outcomes were identical to the findings of (Simic *et al.*, 2020 and Yue *et al.*, 2022).

#### 4.3.1.2 Effect of green manuring on protein content

The influence of dhaincha and cowpea as green manure treatments provided in the soil over two years and its impact on protein content of maize seed is manifested in Table 4.12(a) and exhibited in Fig 4.26(a). The sub plot consisting of green manuring treatment  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) exhibited peak protein content of (9.57%) was outlined as the most prominent treatment in the sub plot, subsequently followed by  $G_4$  (green manuring through cowpea 4 t ha<sup>-1</sup>) obtaining protein content of (9.37%) and  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) with (9.24%), while the least persuasive sub plot treatment was marked in  $G_0$  (control) having protein content of (8.02%). An escalation of protein content by 19.32%, 16.83% and 15.21%, was computed concerning  $G_6$ ,  $G_4$  and  $G_2$ , respectively in contrary to  $G_0$ . An elevated rise of protein content by 22.89%, 19.24% and 17.98% was observed in the succeeding year (2023) via  $G_6$  (9.77%),  $G_4$  (9.48%) and  $G_2$  (9.38%) in comparison to  $G_0$  (7.95%). The pooled analysis outcomes unveiled similar findings to 2022 and 2023 where  $G_6$  (9.67%) increased the protein content by 21.17%,  $G_4$  (9.42%) by 18.04% and  $G_2$  (9.31%) by 16.66%, respectively as contrasted to the treatment  $G_0$  (7.98%).

#### 4.3.1.3 Interaction effect

The assorted results of protein content of maize seeds obtained through the interaction of varied tillage practices and different proportion of green manures over two-year investigation and its pooled mean findings are determined in Table 4.12(b) and Fig 4.26(b), respectively. In the preliminary year of study (2022), noticeable growth of protein content was obtained in the treatment combination  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) attaining protein content (9.60%), followed by  $T_C G_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) acquiring protein content (9.54%) and  $T_M G_4$  (minimum tillage + green manuring through

cowpea 4 t ha<sup>-1</sup>) with protein content (9.41%) and the least influential was in T<sub>C</sub>G<sub>0</sub> (conventional tillage + control) with noted protein content of (7.83%). An increase of 22.60%, 21.83% and 20.17% was observed in T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>4</sub>, respectively in relation to T<sub>C</sub>G<sub>0</sub>, in the year 2022. In the second year of investigation, an upsurge of protein content of 25.93%, 24.77% and 21.43%, was noted in T<sub>M</sub>G<sub>6</sub> with protein content of (9.81%), T<sub>C</sub>G<sub>6</sub> with (9.72%) and T<sub>M</sub>G<sub>4</sub> with (9.46%), respectively was perceived in contrary to T<sub>C</sub>G<sub>0</sub> having protein content of (7.79%). Pooled average mean of the year 2022 and 2023 disclosed escalation of protein content in the treatment combination T<sub>M</sub>G<sub>6</sub> (9.71%), T<sub>C</sub>G<sub>6</sub> (9.63%) and T<sub>M</sub>G<sub>4</sub> (9.43%), whereas the least effective interaction was noted in the treatment combination T<sub>C</sub>G<sub>0</sub> (7.81%), these findings offered a intensification of protein content by 24.32%, 23.30% and 20.74% via T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>4</sub> in comparison to T<sub>C</sub>G<sub>0</sub>.

Wanniang and Singh (2020) in their study found out that multiple studies have supported the use of green manures under maize cultivation which increased the yield by 22% and quality of maize as compared to sole maize. Enhancement in nutrient composition and uptake were also improved with the increase in yield and protein content in maize kernels. Similar outcomes were also reported by Bekeko, (2014) where the application of green manures not only improved the maize seeds in various factors but also rejuvenated the soil which in turn enhances the crop performance.

#### **4.3.2 Carbohydrate content**

The carbohydrate content of the maize seeds obtained from the two-year investigation on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.) including their interaction is shown in Table 4.12(a) and 4.12(b) and Fig 4.27(a) and 4.27(b).

##### **4.3.2.1 Effect of tillage on carbohydrate content**

The influence caused by the implementation of tillage practices on the carbohydrate content of maize seed during the two-year analysis and the pooled

aggregate mean of 2022 and 2023 is offered as evidence of the findings in Table 4.12(a) and Fig 4.27(a). The varied outcomes received from the investigation of the first year (2022) validates that ( $T_M$ ) minimum tillage with acquired carbohydrate content of (74.64%) was 0.13% higher than that of carbohydrate content noted from implementing ( $T_C$ ) conventional tillage (74.54%). The second year (2023) specified elevation of carbohydrate content in maize seed with the incorporation of minimum tillage (74.69%) in relation to conventional tillage (74.56%) offering a growth of 0.17%. Pooled average outcomes of 2022 and 2023 highlighted increased carbohydrate content implementing minimum tillage (74.67%) whereby escalation of 0.16% carbohydrate content was noted in contrary to conventional tillage (74.55%). Pedo *et al.*, (2008) in their findings mentioned that production of maize silage and improvement in carbohydrate content in maize seeds were observed and was significantly dependent in various tillage methods employed. The study was comparable with the investigation of Rezende *et al.* (2015) where appropriate agronomic practice also improved the concentration of vital carbohydrate fractions, starch and other non-fiber carbohydrate. These components are very essential for better digestibility and enhancement of energy content in silage.

#### **4.3.2.2 Effect of green manuring on carbohydrate content**

Table 4.12(a) and Fig 4.27(a) summarizes the outcomes obtained from the study conducted on maize crop for two years involving green manuring treatments viz. dhaincha and cowpea at varied fractions and its persuasion on the carbohydrate content of yielded maize seeds. The initial year observed development of carbohydrate on maize seed via the treatment  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) with (75.49%) carbohydrate content, followed by  $G_6$  i.e. green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> with attained carbohydrate content of (75.18%) and  $G_4$  (green manuring through cowpea 4 t ha<sup>-1</sup>) having accumulated (74.99%) carbohydrate content.  $G_0$  (control) acquired the least carbohydrate content amongst all treatment in the sub plot accumulating (73.21%). An upsurge of carbohydrate content of maize seed by 3.11%, 2.69% and 2.43% was elucidated assessing  $G_2$ ,  $G_6$  and  $G_4$  against  $G_0$ . The performance of  $G_2$  (75.57%) was



the most remarkable improving carbohydrate content pertaining to all the treatments in the sub plot, subsequently followed by  $G_6$  (75.25%) and  $G_4$  (75.02%) indication 3.30%, 2.87% and 2.55% upsurge in carbohydrate content in contrary to  $G_0$  (73.15%). Furthermore, in the pooled aggregate mean of 2022 and 2023 highlighted rise in carbohydrate content by 3.21%, 2.77% and 2.50% *via* the computation of sub plot treatment  $G_2$  (75.53%),  $G_6$  (75.21%) and  $G_4$  (75.01%) alongside  $G_0$  (73.18%). Plantations involving incorporation of leguminous biomass in maize cultivation resulted in increase of sugar and carbohydrate in maize seeds, showing a significant influence on the carbohydrate composition of maize seeds. The quality of maize seed was substantial with the involvement of biomass incorporation as compared to sole cropping (Marques *et al.*, 2018 and Dai *et al.*, 2014).

#### 4.3.2.3 Interaction effect

The convergence of minimum and conventional tillage practices along with green manure application at diverse rate and its impact on the carbohydrate content of the maize seeds over two years of investigation and its pooled average is exhibited in Table 4.12(b) and highlighted in 4.27(b). Improvement of carbohydrate content in maize seed was highly observable with the implementation of treatment combination  $T_MG_2$  (minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>) which accumulated (75.53%) carbohydrate marking the most persuasive treatment, subsequently by  $T_CG_2$  (conventional tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>) with carbohydrate content of (75.45%) and  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) where carbohydrate content was marked at (75.22%). The least contribution to carbohydrate was noted in the treatment combination  $T_CG_0$  (conventional tillage + control) having (73.10%) carbohydrate. Computing the values received after appropriate analysis it was highlighted that an escalation of carbohydrate content by 3.32% in  $T_MG_2$ , 3.21% in  $T_CG_2$  and 2.90% in  $T_MG_6$  in contrary to  $T_CG_0$  was distinguished in the first year. In the succeeding year, development of carbohydrate was noticeable following the treatment combinations  $T_MG_2$  (75.64%), followed by  $T_CG_2$  (75.49%) and  $T_MG_6$  (75.28%), while the least carbohydrate content was marked in the treatment

combination of  $T_C G_0$  (73.03%). The data received from the pooled average table unveiled an elevation of carbohydrate content in maize seed by 3.44%, 3.28% and 2.98% computing  $T_M G_2$  (75.59%),  $T_C G_2$  (75.47) and  $T_M G_6$  (75.25%) against the values obtained from  $T_C G_0$  (73.07%).

### 4.3.3 Oil content

The oil content obtained from the maize seed following the investigation conducted over two years integrating two factors *i.e.* tillage and green manuring on soil including their interaction and pooled analysis of the year 2022 and 2023 is presented in Table 4.12(a) and 4.12(b) and Fig 4.28(a) and 4.28(b).

#### 4.3.3.1 Effect of tillage on oil content

Impact of tillage practices on oil content accumulation of maize seeds over two years of rigorous investigation in the *kharif* seasons of 2022 and 2023, its findings and their pooled mean is carefully outlined in Table 4.12(a) and the data are graphically represented in Fig 4.28(a). Concentration of oil content with the implementation of minimum tillage ( $T_M$ ) was more than that obtained from conventional tillage practices ( $T_C$ ). Integration of minimum tillage (3.48%) led to 0.86% more oil content than conventional tillage (3.45%) in 2022. Higher oil build-up was also observed in minimum tillage (3.50%) than conventional tillage practice (3.48%) in the following year (2023). An upsurge of 0.57% oil content was attained employing ( $T_M$ ) minimum tillage (3.49%) in contrary to ( $T_C$ ) conventional tillage (3.47%) in the pooled aggregate mean of 2022 and 2023. Nassir *et al.* (2024) in their findings outlined that reduced tillage as compared to intensive tillage was found to be more suitable for improving the quality of seeds including oil content in maize. Intensive tillage practice hinders the soil by making it more compact which may lead to plants inability to penetrate the soil for root development. Yield components of maize as well as other quality related aspects of maize seeds may be hampered if appropriate tillage methods are not employed. This study was at par with the investigation of Burak *et al.* (2021).

#### 4.3.3.2 Effect of green manuring on oil content

Introduction of green manuring through dhaincha and cowpea into the soil and its effect on oil build-up in maize seed over two years' analysis and its pooled average mean data are systematically highlighted in Table 4.12(a) and Fig 4.28(a). With the incorporation of green manures into the soil, development of oil content of maize seed revived. Peak oil content was obtained in the sub plot treatment  $G_2$  (green manuring through dhaincha @ 4 t ha<sup>-1</sup>) with (3.69%) followed by  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with oil content of (3.57%) and  $G_4$  (green manuring through cowpea @ 4 t ha<sup>-1</sup>) acquiring oil content of (3.45%). The least contributing sub plot treatment in the process of oil accumulation in maize seed was found in  $G_0$  (control) with (3.34%) oil content. Growth of oil content by 10.47%, 6.88% and 3.29% was summarized computing oil content noted in  $G_2$ ,  $G_6$  and  $G_4$ , respectively in relation to  $G_0$ . In the subsequent year, higher oil content was noted in the treatment  $G_2$  (3.73%),  $G_6$  (3.60%) and  $G_4$  (3.47%) whereas lower oil in maize seed over all the treatment was in the sub plot  $G_0$  (3.32%). Rise of 12.34% in  $G_2$ , 8.43% in  $G_6$  and 4.51% in  $G_4$ , in oil concentration was highlighted as compared to  $G_0$  in the second year. Pooled aggregate obtained from 2022 and 2023 exhibited similar trend where an escalation of 11.41% in  $G_2$  (3.71%), 7.50% in  $G_6$  (3.58%) and 3.90% in  $G_4$  (3.46%) was analyzed in relation to  $G_0$  (3.33%). Katral *et al.* (2024) and Li *et al.* (2013) declared that oil composition of maize with specific genotypes demonstrate elevated concentration of oil 3.4% to 6.8% which may be optimized further by involving certain agronomic practices like green manure incorporation in the soil as it may provide the essential nutrients and make the soil sustainable in the long run.

#### 4.3.3.3 Interaction effect

The merging of tillage and green manure, its influence on oil production on maize seeds over two years of detailed investigation conducted including the pooled average of varied treatment combinations is provided in Table 4.12(b) and accurately displayed in Fig 4.28(b). The combination of  $T_M G_2$  i.e. minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>) executed the best performance in terms of oil

development in maize seed amounting to (3.70%), subsequently by  $T_CG_2$  *i.e.* conventional tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>) accumulating (3.67%) and  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) which acquired oil content of (3.59%). These findings from the first year resulted in escalation of oil content in maize seed by 11.44%, 10.54% and 8.13%, respectively in contrary to  $T_CG_0$  having (3.32%) maize seed oil content in the initial year (2022). Higher amount of oil was also noted in the second year utilizing  $T_MG_2$  (3.74%),  $T_CG_2$  (3.72%) and  $T_MG_6$  (3.61%), while the least influential treatment combination was noted in  $T_CG_0$  having (3.30%) maize seed oil content, offering 13.33%, 12.72% and 9.39% increase, respectively as compared to the least  $T_CG_0$ . Joint aggregate mean of 2022 and 2023 exhibited the rise of oil content by 12.38%, 11.48% and 8.76%, respectively analyzing  $T_MG_2$  (3.72%),  $T_CG_2$  (3.69%) and  $T_MG_6$  (3.60%) against  $T_CG_0$  (3.31%).

#### **4.3.4 Ash content**

The ash content of maize seeds as inclined by the incorporation of tillage and through the integration of green manuring respectively in 2022 and 2023 and their pooled average data is deliberated in this part of discussion. Facts and findings are provided in Table 4.12(a) and 4.12(b) and represented in Fig 4.29(a) and Fig 4.29(b).

##### **4.3.4.1 Effect of tillage on ash content**

The consequences of employing suitable tillage actions like minimum and conventional tillage in maintaining ash content in maize seeds is provided for scrutiny in Table 4.12(a) and depicted in Fig 4.29(a). Superior ash concentration in maize seeds was identified in ( $T_M$ ) minimum tillage (1.20%) that ( $T_C$ ) conventional tillage (1.18%) in the first year of crop cultivation, indicating 1.69% rise in ash accumulation in maize seed through minimum tillage adoption. In the second year (2023) cultivated maize seed obtained from the research field received more response from maintaining ash concentration in maize seeds *via* ( $T_M$ ) minimum tillage giving 2.52% more ash from maize seeds compared to ( $T_M$ ). Ash accumulation in maize seeds were more integrating minimum tillage (1.21%) as opposed to conventional

tillage (1.18%), specifying 2.54% more ash exploiting minimum tillage. Kabiri *et al.* (2016) outlined that minimum tillage (MT) combined with residue incorporation resulted in an increase in ash content in canola seeds. The biochemical configuration of canola seed improved with minimum tillage practice as compared to sole cropping. Protein, oil and mineral composition of maize also improved under minimum tillage.

#### **4.3.4.2 Effect of green manuring on ash content**

The impact facilitated by the augmentation of green manures through dhaincha and cowpea at diverse quantity and its persuasion on ash content of maize seeds is furnished in Table 4.12(a) and Fig 4.29(a). Trends led by the addition of green manures into the soil and its influence on ash concentration through various sub plot treatments clearly indicate the dominance of treatments like G<sub>6</sub> (1.26%), G<sub>2</sub> (1.23%) and G<sub>4</sub> (1.21%) where higher ash accumulation was observed, while G<sub>0</sub> *i.e.* control highlighted just (1.12%) of ash content marking the least influential treatment in the sub plot. This provided a significant increase in ash concentration following G<sub>6</sub> by 12.50%, G<sub>2</sub> by 9.82% and G<sub>4</sub> by 8.03%, respectively in relation to G<sub>0</sub>. Vast development of ash in maize seeds were marked with the adoption of green manure sub plot treatment like G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) with ash content of (1.28%), subsequently followed by G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) having (1.25%) ash accumulation and G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) acquiring ash of (1.22%). An upsurge of 16.36%, 13.63% and 10.90% was noticeable computing G<sub>6</sub>, G<sub>2</sub> and G<sub>4</sub> in contrary to G<sub>0</sub> (1.10%). Furthermore, the pooled mean outcomes highlighted escalation of ash content in maize seed involving G<sub>6</sub> (1.27%) by 14.41%, G<sub>2</sub> (1.24%) by 11.71% and G<sub>4</sub> (1.21) by 9% in comparison to G<sub>0</sub> (1.11%).

#### **4.3.4.3 Interaction effect**

The interaction of assorted tillage and green manuring aspects implemented into the soil and the response of this merger on the ash content of maize seed is systematically highlighted in Table 4.12(b) and exhibited 4.29(b). Varied assortment

of treatment combination and its contribution towards ash accumulation is demonstrated as evident from the data table where  $T_CG_6$  (conventional tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) obtained the most ash (1.27%) amongst all treatments, followed by  $T_MG_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) with (1.26%) and  $T_MG_2$  (minimum tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) attaining ash of (1.24%), additionally lower ash content was acquired in the treatment combination  $T_CG_0$  (conventional tillage + control) having (1.11%) ash. A rise in ash content of 14.41%, 13.51% and 11.71% was noted respectively involving  $T_CG_6$ ,  $T_MG_6$  and  $T_MG_2$  as compared to  $T_CG_0$ . In the subsequent year  $T_MG_6$  (1.30%) was marked the most influential and effective combination maintaining ash content, followed by  $T_CG_6$  (1.27%), and  $T_MG_2$  (1.26%) as compared to  $T_CG_0$  (1.09%). These outcomes revealed elevated ash concentration of 19.26%, 16.51% and 15.59%, respectively concerning  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$  in relation to  $T_CG_0$ . Mean table of 2022 and 2023 disclosed comparable trend to that of second year of cultivation where  $T_MG_6$  (1.28%),  $T_CG_6$  (1.27%) and  $T_MG_2$  (1.25%) as compared to  $T_CG_0$  (1.10%) provided increase of 16.36%, 15.45% and 13.63%, in ash content, respectively.

Platace *et al.* (2015) highlighted that addition of soil amendments and type and application of fertilizers and other agronomic practices enhanced the ash content of different grasses. Cubars and Poisa, (2017) also declared similar findings where organic amendments as compared to inorganic fertilizers performed significantly better in improving the ash content. Better biomass production was observed with the input of organic than inorganic fertilizers.

**Table 4.12 (a): Effect of tillage and green manuring on protein content, carbohydrate content, oil content and ash content of maize seed**

| Treatment            | Protein content (%) |        |        | Carbohydrate content (%) |        |        | Oil content (%) |        |        | Ash content (%) |        |        |
|----------------------|---------------------|--------|--------|--------------------------|--------|--------|-----------------|--------|--------|-----------------|--------|--------|
|                      | 2022                | 2023   | Pooled | 2022                     | 2023   | Pooled | 2022            | 2023   | Pooled | 2022            | 2023   | Pooled |
| Tillage              |                     |        |        |                          |        |        |                 |        |        |                 |        |        |
| <b>T<sub>M</sub></b> | 9.15                | 9.27   | 9.21   | 74.64                    | 74.69  | 74.67  | 3.48            | 3.50   | 3.49   | 1.20            | 1.22   | 1.21   |
| <b>T<sub>C</sub></b> | 9.02                | 9.15   | 9.08   | 74.54                    | 74.56  | 74.55  | 3.45            | 3.48   | 3.47   | 1.18            | 1.19   | 1.18   |
| <b>SEm ±</b>         | 0.0115              | 0.0178 | 0.0106 | 0.0071                   | 0.0066 | 0.0048 | 0.0010          | 0.0019 | 0.0011 | 0.0012          | 0.0003 | 0.0006 |
| <b>CD at 5%</b>      | 0.0700              | 0.1080 | 0.0415 | 0.0430                   | 0.0400 | 0.0190 | 0.0061          | 0.0114 | 0.0042 | 0.0071          | 0.0020 | 0.0024 |
| <b>CV</b>            | 0.5806              | 0.8835 | 0.7496 | 0.0434                   | 0.0404 | 0.0419 | 0.1335          | 0.2462 | 0.1984 | 0.4486          | 0.1285 | 0.3289 |
| Green manuring       |                     |        |        |                          |        |        |                 |        |        |                 |        |        |
| <b>G<sub>0</sub></b> | 8.02                | 7.95   | 7.98   | 73.21                    | 73.15  | 73.18  | 3.34            | 3.32   | 3.33   | 1.12            | 1.10   | 1.11   |
| <b>G<sub>1</sub></b> | 9.15                | 9.29   | 9.22   | 74.45                    | 74.49  | 74.47  | 3.42            | 3.44   | 3.43   | 1.17            | 1.18   | 1.18   |
| <b>G<sub>2</sub></b> | 9.24                | 9.38   | 9.31   | 75.49                    | 75.57  | 75.53  | 3.69            | 3.73   | 3.71   | 1.23            | 1.25   | 1.24   |
| <b>G<sub>3</sub></b> | 9.11                | 9.30   | 9.21   | 74.30                    | 74.35  | 74.32  | 3.40            | 3.42   | 3.41   | 1.16            | 1.17   | 1.17   |
| <b>G<sub>4</sub></b> | 9.37                | 9.48   | 9.42   | 74.99                    | 75.02  | 75.01  | 3.45            | 3.47   | 3.46   | 1.21            | 1.22   | 1.21   |
| <b>G<sub>5</sub></b> | 9.12                | 9.31   | 9.22   | 74.50                    | 74.54  | 74.52  | 3.42            | 3.45   | 3.43   | 1.19            | 1.21   | 1.20   |
| <b>G<sub>6</sub></b> | 9.57                | 9.77   | 9.67   | 75.18                    | 75.25  | 75.21  | 3.57            | 3.60   | 3.58   | 1.26            | 1.28   | 1.27   |
| <b>SEm ±</b>         | 0.0346              | 0.0305 | 0.0230 | 0.0144                   | 0.0222 | 0.0132 | 0.0097          | 0.0094 | 0.0067 | 0.0037          | 0.0037 | 0.0026 |
| <b>CD @ 5%</b>       | 0.1009              | 0.0890 | 0.0655 | 0.0420                   | 0.0648 | 0.0376 | 0.0282          | 0.0273 | 0.0191 | 0.0107          | 0.0107 | 0.0074 |
| <b>CV</b>            | 0.9320              | 0.8107 | 0.8726 | 0.0473                   | 0.0728 | 0.0614 | 0.6837          | 0.6565 | 0.6701 | 0.7532          | 0.7493 | 0.7512 |

**Table 4.12 (b): Interaction effect of tillage and green manuring on protein content, carbohydrate content, oil content and ash content of maize seed**

| Treatment                         | Protein content (%) |        |        | Carbohydrate content (%) |        |        | Oil content (%) |        |        | Ash content (%) |        |        |
|-----------------------------------|---------------------|--------|--------|--------------------------|--------|--------|-----------------|--------|--------|-----------------|--------|--------|
|                                   | 2022                | 2023   | Pooled | 2022                     | 2023   | Pooled | 2022            | 2023   | Pooled | 2022            | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 8.21                | 8.11   | 8.16   | 73.32                    | 73.28  | 73.30  | 3.35            | 3.34   | 3.35   | 1.12            | 1.11   | 1.12   |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 9.20                | 9.35   | 9.28   | 74.48                    | 74.52  | 74.50  | 3.42            | 3.45   | 3.43   | 1.19            | 1.21   | 1.20   |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 9.33                | 9.48   | 9.40   | 75.53                    | 75.64  | 75.59  | 3.70            | 3.74   | 3.72   | 1.24            | 1.26   | 1.25   |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 9.12                | 9.33   | 9.23   | 74.33                    | 74.38  | 74.36  | 3.41            | 3.42   | 3.42   | 1.18            | 1.19   | 1.18   |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 9.41                | 9.46   | 9.43   | 75.05                    | 75.13  | 75.09  | 3.46            | 3.48   | 3.47   | 1.21            | 1.23   | 1.22   |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 9.16                | 9.35   | 9.26   | 74.55                    | 74.60  | 74.58  | 3.44            | 3.46   | 3.45   | 1.20            | 1.22   | 1.21   |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 9.60                | 9.81   | 9.71   | 75.22                    | 75.28  | 75.25  | 3.59            | 3.61   | 3.60   | 1.26            | 1.30   | 1.28   |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 7.83                | 7.79   | 7.81   | 73.10                    | 73.03  | 73.07  | 3.32            | 3.30   | 3.31   | 1.11            | 1.09   | 1.10   |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 9.10                | 9.23   | 9.16   | 74.41                    | 74.45  | 74.43  | 3.41            | 3.43   | 3.42   | 1.16            | 1.16   | 1.16   |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 9.14                | 9.29   | 9.22   | 75.45                    | 75.49  | 75.47  | 3.67            | 3.72   | 3.69   | 1.22            | 1.23   | 1.22   |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 9.10                | 9.27   | 9.19   | 74.27                    | 74.31  | 74.29  | 3.38            | 3.42   | 3.40   | 1.14            | 1.15   | 1.15   |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 9.33                | 9.50   | 9.41   | 74.94                    | 74.92  | 74.93  | 3.43            | 3.46   | 3.45   | 1.20            | 1.21   | 1.21   |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 9.08                | 9.27   | 9.17   | 74.45                    | 74.49  | 74.47  | 3.40            | 3.43   | 3.42   | 1.18            | 1.19   | 1.19   |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 9.54                | 9.72   | 9.63   | 75.14                    | 75.21  | 75.18  | 3.55            | 3.59   | 3.57   | 1.27            | 1.27   | 1.27   |
| <b>SEm ±</b>                      | 0.0489              | 0.0431 | 0.0326 | 0.0204                   | 0.0314 | 0.0187 | 0.0137          | 0.0132 | 0.0095 | 0.0052          | 0.0052 | 0.0037 |
| <b>CD at 5%</b>                   | 0.1426              | 0.1258 | 0.0927 | 0.0594                   | 0.0916 | 0.0532 | 0.0399          | 0.0386 | 0.0271 | 0.0151          | 0.0152 | 0.0104 |



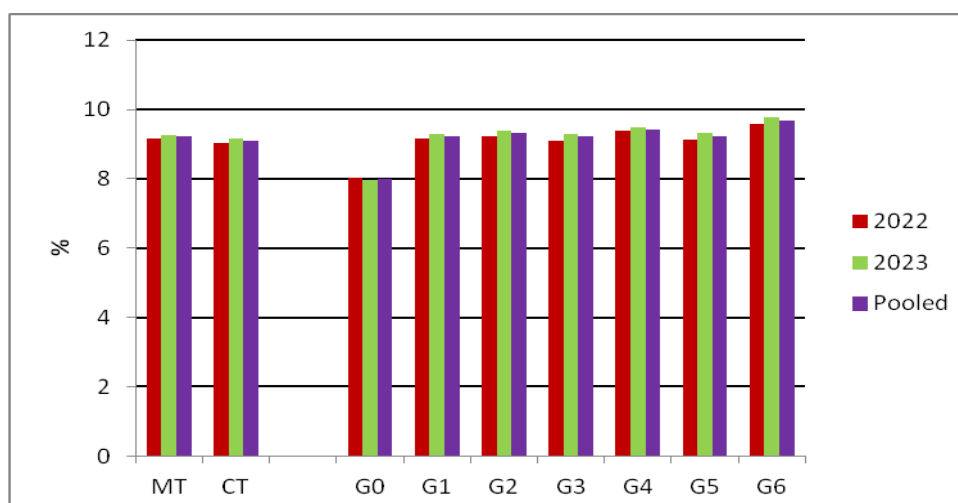


Fig. 4.26(a): Effect of tillage and green manuring on protein content

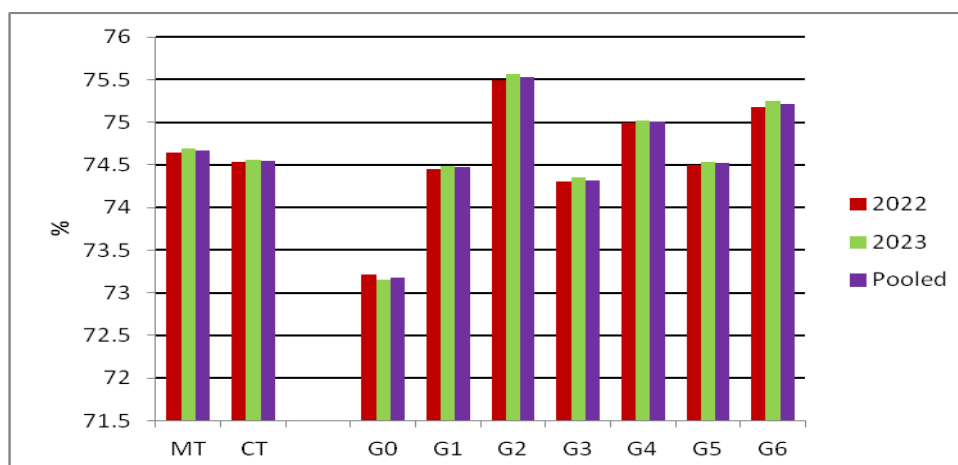


Fig. 4.27(a): Effect of tillage and green manuring on carbohydrate content

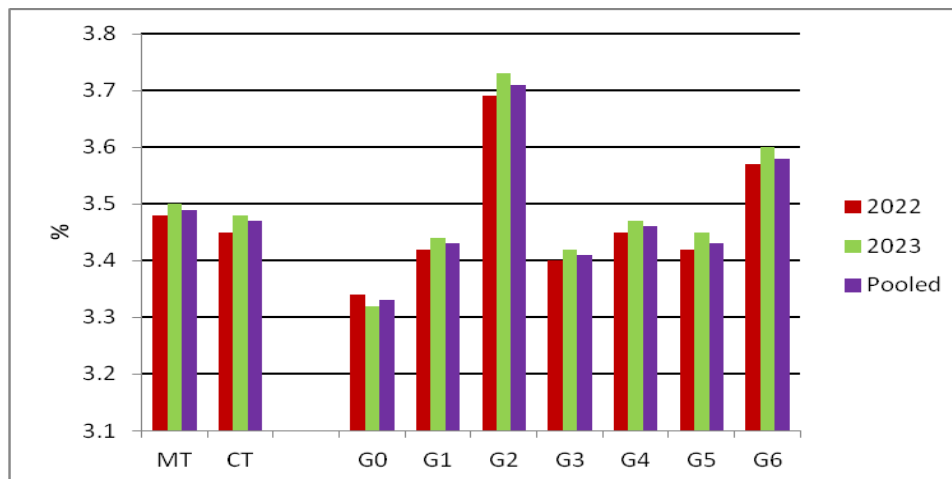


Fig. 4.28(a): Effect of tillage and green manuring on oil content

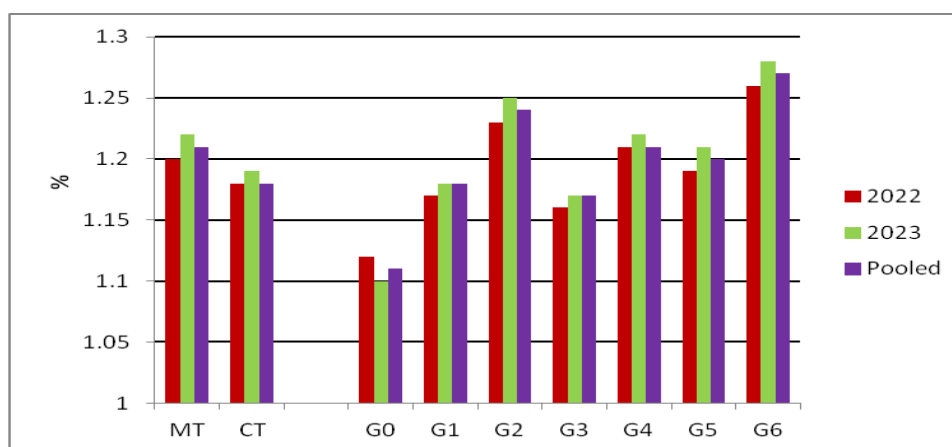


Fig. 4.29(a): Effect of tillage and green manuring on ash content

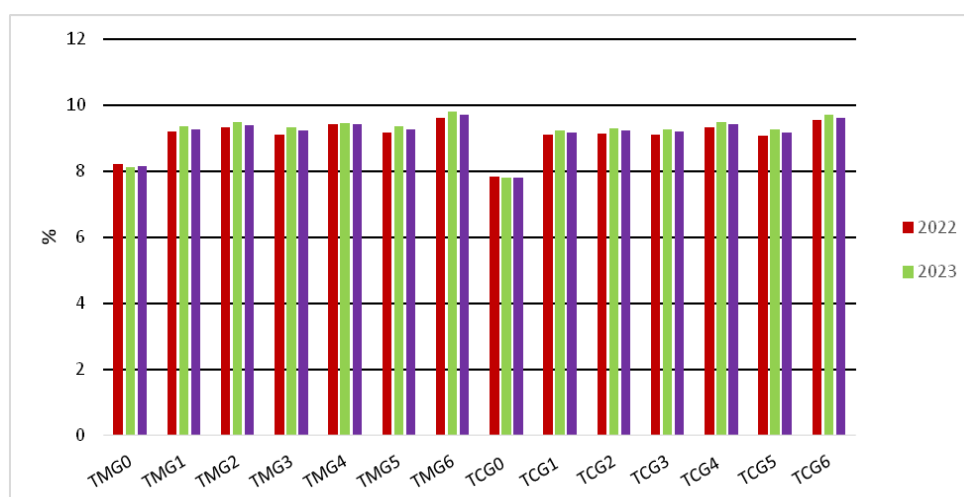


Fig. 4.26(b): Interaction effect of tillage and green manuring on protein content

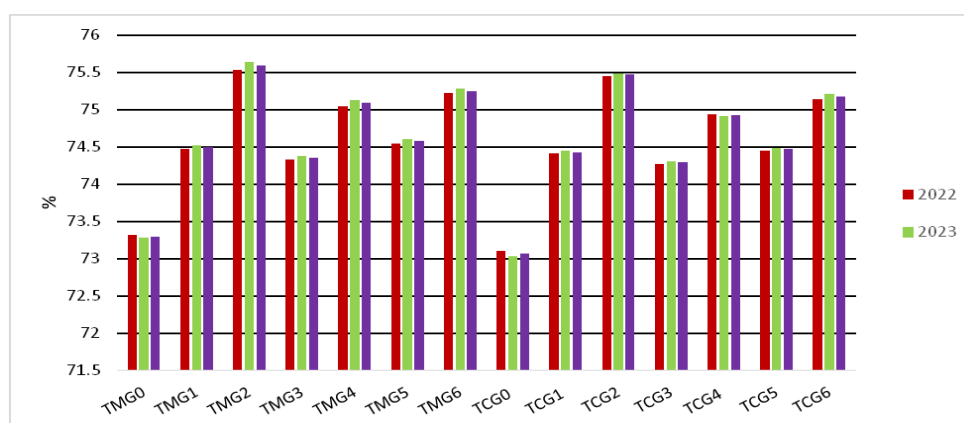


Fig. 4.27(b): Interaction effect of tillage and green manuring on carbohydrate content

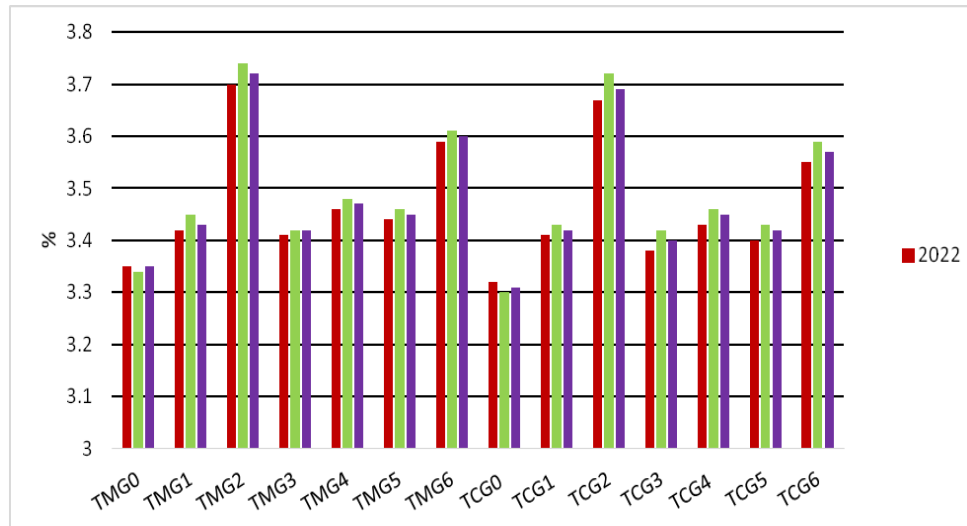


Fig. 4.28(b): Interaction effect of tillage and green manuring on oil content

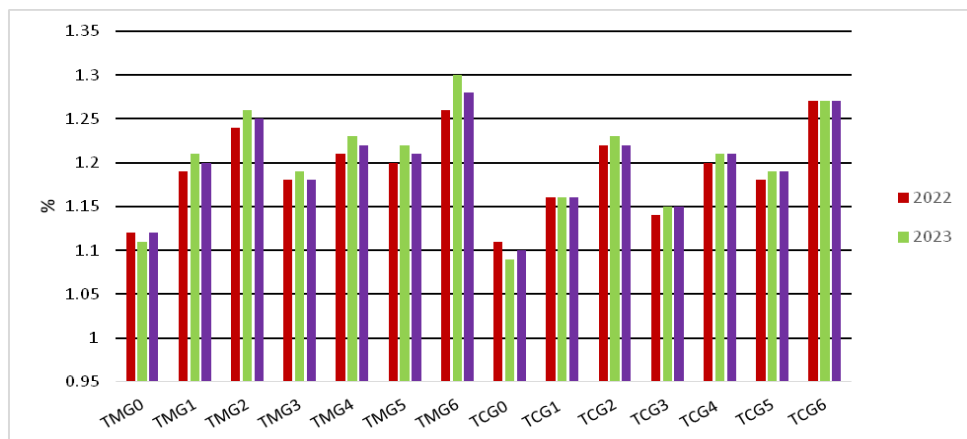


Fig. 4.29(b): Interaction effect of tillage and green manuring on ash content

#### **4.4 Effect of tillage and green manuring on plant analysis**

The acquired nutrient content and uptake of the maize seed and stover obtained after the completion of the experimentation for two consecutive years *i.e.* 2022 and 2023 on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.) in the experimental farm of Department of Soil and Water Conservation, Nagaland University, School of Agricultural Sciences. The data received over both the years including their pooled average and interaction between tillage and green manuring is precisely presented in Table 4.14(a) and 4.14(b), 4.15(a) and 4.15(b), 4.16(a) and 4.16(b), 4.17(a) and 4.17(b), respectively.

##### **4.4.1 Nutrient content of maize seed and stover**

The appropriate results and findings acquired on nitrogen, phosphorus and potassium content of maize seed and stover as impacted by different tillage practices employed and incorporation of green manures into the soil over both the years of the experimental trail, their pooled aggregate mean including their interaction effect is provided in Table 4.13(a), 4.13(b) and 4.14(a) and 4.14(b), respectively.

##### **4.4.1.1 Nitrogen content of maize seed and stover**

The outcomes pertaining to nitrogen content of maize seed and stover received after the analysis of samples for both the years of study, their pooled aggregate mean and interaction effect are explicitly noted in Table 4.13(a) and 4.13(b), respectively.

##### **4.4.1.1.1 Effect of tillage on nitrogen content of maize seed and stover**

The varied aspect of nitrogen content of seed and stover as influenced by minimum and conventional tillage operations is outlined in Table 4.13(a). With respect to nitrogen content in maize seed, higher concentration of nitrogen was noticeable with the adoption of ( $T_M$ ) minimum tillage (1.46%) as opposed to ( $T_C$ ) conventional tillage (1.44%), indicating a rise of 1.38% using ( $T_M$ ) in the initial year

(2022). In the following year, an escalation of 1.36% was marked with the implementation of minimum tillage (1.48%) in relation to conventional tillage (1.46%). Minimum tillage (1.47%) plot in the pooled aggregate plot increased the nitrogen content of seed by 1.37% in contrary to conventional tillage with nitrogen content of (1.45%). Sime and Aune (2016) suggested in their investigation that increase in nutrient composition of maize seeds were observed with the implementation of minimum tillage. Minimum tillage helps the soil to enhance its moisture and establish a good soil structure which helps the plant to be more productive. Root development and increase in nutrient availability was also observed with the implementation of minimum tillage. These results were substantiated by Li *et al.* (2023) and Batyrbek *et al.* (2022) where N content in seeds were much improved under reduced tillage system rather than excessive tillage practices.

Likewise, for nitrogen content of maize stover in the initial year (2022), the findings with the adoption of minimum tillage (1.25%) was more substantial than that of outcomes received from conventional tillage (1.24%) indicating 0.80% increase whereas in the second year a rise of 1.61% was computed following (T<sub>M</sub>) with (1.26%) and (T<sub>C</sub>) with (1.24%) nitrogen content in stover. Pooled outcomes of 2022 and 2023 resulted considerable rise of nitrogen content in stover with the employment of minimum tillage (1.26%) in contrary to conventional tillage (1.24%). Nyamwange *et al.* (2021) and Nigussie *et al.* (2021) outlined that the implementation of appropriate tillage method which involves less disturbance to the soil like minimum tillage enhances the available nitrogen and soil microbial biomass carbon in comparison to conventional tillage system. Which in turn help the crops to absorb more nitrogen and overall productivity of the crop.

#### **4.4.1.1.2 Effect of green manuring on nitrogen content of maize seed and stover**

Table 4.13(a) provides the evidence of data received on nitrogen content of maize seed and stover as impacted by the induction of varied green manure application into the experimental soil over two years of field study in the year 2022 and 2023 including the pooled mean. Integration of green manures following the configuration of G<sub>6</sub> *i.e.* green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup>

@ 4 t ha<sup>-1</sup> acquiring (1.53%) nitrogen content in seed was marked as the most influential treatment among all the other treatment in the sub plot, followed by G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) with (1.50%), N content in seed and the treatment G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) amounted to (1.48%) nitrogen content of maize seed. The least persuasive treatment was in G<sub>0</sub> i.e. control (1.28%), N content of seed. The aforementioned outcomes obtained from the first year study (2022) revealed escalation of N content of maize seeds by 19.53% involving G<sub>6</sub>, 17.18% concerning G<sub>4</sub> and 15.62% in G<sub>2</sub>, in relation to G<sub>0</sub>. Correspondingly, in the second year of investigation, an upsurge of N content of maize seed by 21.87%, 18.75% and 17.18% was evident with the implementation of G<sub>6</sub> (1.56%), G<sub>4</sub> (1.52%) and G<sub>2</sub> (1.50%), respectively in contrary to G<sub>0</sub> (1.28%). The result received from the pooled analysis mean table of 2022 and 2023 provided substantial evidence where G<sub>6</sub> (1.55%) followed by G<sub>4</sub> (1.51%) and G<sub>2</sub> (1.49%) was noted the peak performing treatment over all the others in the sub plot, while the least persuasive treatment was noted in G<sub>0</sub> having (1.28%) nitrogen content of maize seed computing a rise of 21.09%, 17.96% and 16.40%, respectively. Hu *et al.* (2023) in their findings stated that the nitrogen content in seed and N uptake was significantly improved with the incorporation of green manures. The N uptake in seed varied from 93.10 to 129.3 kg ha<sup>-1</sup> with the incorporation of green manures. This suggest that the incorporation of green manures enriches the soil with organic carbon, improves soil structure and maintains the microbial activity enriching the soil nitrogen mineralization making it efficiently available to the plants, which tends to increase its accumulation in the seed.

In the instance of nitrogen content of maize stover, treatment G<sub>6</sub> i.e. green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, was highlighted the peak performing sub plot treatment with N content of stover marked at (1.32%), subsequently followed by G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) having (1.27%), nitrogen content in maize stover and G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) where the N content of stover was at (1.26%). As compared to the findings of G<sub>0</sub> (1.17%) an increase of 12.82%, 8.54% and 7.69% was recorded in G<sub>6</sub>, G<sub>4</sub> and G<sub>2</sub> in the first year of field study (2022). The successive year of investigation

resulted comparable result where  $G_6$  (1.34%) followed by  $G_4$  (1.28%) and  $G_2$  (1.27%) specified a growth of N content in stover of 17.54%, 12.28% and 11.40% respectively, in contrary to  $G_0$  (1.14%). The mean aggregate findings of 2022 and 2023 highlighted escalated outcomes in  $G_6$  (1.33%) followed by  $G_4$  (1.28%) and  $G_2$  (1.27%) while the least persuasive treatment was obtained in  $G_0$  with (1.16%) nitrogen content of stover. Computing the results obtained from the pooled table it was noticed that upsurge of N content in stover adopting green manures were 14.65%, 10.34% and 9.48%, respectively in relation to  $G_0$ . Yang *et al.* (2018) outlined in their research that the amount of mineral nitrogen and dissolved organic nitrogen saw an increase with the application of green manures. It also increases the N content and uptake in maize stover by enhancing different forms of nitrogen. The overall productivity and dry matter accumulation is boosted with the incorporation of green manures. Evidences of these outcomes were confirmed by the studies conducted by Li *et al.* (2024).

#### 4.4.1.1.3 Interaction effect

The impact of tillage operations like minimum and conventional tillage aspects and integration of green manures involving dhaincha and cowpea in varied rate on the nitrogen content of maize seed and stover for two consecutive years including the pooled aggregate mean of both the years is systematically stated in Table 4.13(b). Maximum nitrogen content in seed was distinguished in the treatment combination  $T_MG_6$  *i.e.* minimum tillage combined with green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> possessing (1.54%) trailed by  $T_CG_6$  (conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) bearing N content of seed (1.53%), however the least N content was analysed in the treatment combination  $T_CG_0$  (conventional tillage + control) exhibiting N content of (1.25%). This shows an augment in N content of maize seed of 23.20% and 22.4% *via*  $T_MG_6$  and  $T_CG_6$  respectively as opposed to  $T_CG_0$ . In the following year, superior N content of maize seed were interpreted in the treatment combination  $T_MG_6$  (1.57%) and  $T_CG_6$  (1.56%) displaying a peak rise of nitrogen content of maize seed by 25.60% and 24.80%, respectively in relation to  $T_CG_0$ .



(1.25%). A boost in N content of seed in the pooled aggregate table was scrutinized with the adoption of  $T_MG_6$  (1.55%) and  $T_CG_6$  (1.54%) whereas the least influential treatment combination was achieved in  $T_CG_0$  (1.25%). A rise of N content of seed by 24% and 23.20% was distinguished in  $T_MG_6$  and  $T_CG_6$ , respectively in contrary to  $T_CG_0$ .

Pertaining to N content of maize stover, the treatment combination  $T_MG_6$  (1.33%),  $T_CG_6$  (1.31%) and  $T_MG_4$  (1.28%) maintained the peak performing treatment combinations in the initial year of study (2022), conversely  $T_CG_0$  (1.15%) conveyed the least effective combination concerning N content in stover. These findings revealed upsurge of N content in stover by implementing  $T_MG_6$  by 15.65%,  $T_CG_6$  by 13.91% and  $T_MG_4$  by 11.30%, as compared to  $T_CG_0$ . Likewise, in the second year study (2023) escalated values of nitrogen content in stover was seen in the combinations  $T_MG_6$  (1.35%),  $T_CG_6$  (1.33%) and  $T_MG_4$  (1.29%) and the most inferior combination was marked in  $T_CG_0$  (1.10%), presenting a rise of N content of stover by 22.72%, 20.90% and 17.27%, respectively in contrast to  $T_CG_0$ . Pooled aggregate revealed 18.58%, 16.81% and 14.15%, increase in N content of maize stover adopting treatment combination  $T_MG_6$  (1.34%),  $T_CG_6$  (1.32%) and  $T_MG_4$  (1.29%), in contrary to  $T_CG_0$  (1.13%).

#### **4.4.1.2 Phosphorus content of maize seed and stover**

The assorted outcomes received through the implementation of tillage operations and green manure treatment over two years of rigorous experiment, the pooled average and the interaction between tillage and green manures is manifest systematically in Table 4.13(a) and 4.13(b).

##### **4.4.1.2.1 Effect of tillage on phosphorus content of maize seed and stover**

The verdicts referring to phosphorus content of maize seed and stover for the two-year study (2022 and 2023) and the pooled mean received as effected by tillage operations involved in the experimental field is offered precisely in Table 4.13(a). Tillage operation especially ( $T_M$ ) minimum tillage (0.24%) reported to with higher

concentration of P content in seed in relation to (T<sub>C</sub>) conventional tillage (0.23%), declaring a rise of 4.34% concerning (T<sub>M</sub>) in the primary year (2022). Likewise, in the succeeding year (2023), a progression of 8.69% in phosphorus content in seed was determined involving (T<sub>M</sub>) minimum tillage (0.25%) and (C<sub>T</sub>) conventional tillage (0.23%). Data received from the pooled analysis table also displayed similar outcomes of the initial year where (T<sub>M</sub>) minimum tillage with the obtained value of P content of (0.24%) was 4.34% more than that obtained from (T<sub>C</sub>) conventional tillage (0.23%). Singh *et al.* (2018) concluded that the phytic acid is present in maize seed which is also considered as the most important phosphorus base. Phytic acid makes up to 80% of maize seed total phosphorus content and about 1.50% of maize dry weight. Forms and type of tillage operations may influence the seed quality and production. As compared to excessive tillage, minimum tillage which contributes less soil disturbance may be more beneficial to improve the quality of seed. These results were confirmed by the study conducted by Saeed *et al.* (2017).

Concerning to the outcomes acquired for the phosphorus content of maize stover for the initial year (2022), it can be briefed that (T<sub>M</sub>) minimum tillage with the analyzed value of (0.19%) P content of stover exhibited 11.76% higher values of phosphorus in comparison to (T<sub>C</sub>) conventional tillage (0.17%). In the subsequent year of field study (2023), the bearing potential of (T<sub>M</sub>) minimum tillage (0.20%) of P content was 5.26% more than (T<sub>M</sub>) minimum tillage (0.19%). Pooled result of 2022 and 2023 also demonstrated comparable outcome the first and second year of experimentation, where 5.55% boost of phosphorus content in maize stover was obtained computing (T<sub>M</sub>) minimum tillage (0.19%) and (T<sub>C</sub>) conventional tillage (0.18%). Duminda *et al.* (2018) commented that the phosphorus availability, content in crop and its uptake varies across different soil types. The physical condition of soil is key to availability of phosphorus to the plants, soils where minimal disturbance is present tends to be more phosphorus available to the plants as compared to soil where the physical condition is weakened, which was also confirmed in the investigation conducted by Freitas, (2022).

#### 4.4.1.2.2 Effect of green manuring on phosphorus content of maize seed and stover

Results pertaining to phosphorus content of maize seed and stover as influenced by the incorporation of green manures into the cultivated soil during the *kharif* seasons of 2022 and 2023 are concisely represented in Table 4.13(a) for reference. The green manuring treatment of  $G_1$  i.e. green manuring through dhaincha @ 2 t ha<sup>-1</sup> and  $G_6$  i.e. green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, exhibited higher P content of maize seed (0.25%) than any other treatment in the sub plot, followed by  $G_2$  (green manuring through dhaincha @ 4 t ha<sup>-1</sup>) with the noted phosphorus content of (0.24%). The least influential treatment was marked in the sub plot  $G_0$  (control) acquiring P content of (0.22%). Computing the most effective treatment with the least influential, following the results obtained through appropriate statistical method application in the initial year it was concluded that  $G_1$  and  $G_6$  escalated the P concentration by 13.63% and  $G_2$  by 9.09%, respectively in contrary to the values received from  $G_0$ . The field study from the second year also disclosed upsurge of P accumulation of maize seed in the sub plot treatment of  $G_6$  (0.26%) and  $G_2$  (0.25%) whereas the least persuasive sub plot treatment was noted in  $G_0$  (0.22%), which showed 18.18% and 13.63% increase of P content in seed in the treatment  $G_6$  and  $G_2$  as compared to  $G_0$ . The joint mean of 2022 and 2023 reported higher P content in maize seed in the sub plot treatment  $G_6$  (0.25%) and the least in  $G_0$  (0.22%), exhibiting 13.63% rise in P content with the implementation of  $G_6$  over  $G_0$ . An increase of 300% in phosphorus content and uptake in maize seed was observed with the incorporation of green manure via *Arachis pinto* mixed with natural phosphate. Phosphorus availability was significantly influenced with the synergy of both the applied components improving the growth and yield components of maize (Medeiros *et al.*, 2019) and was also outlined in the research performed by Lee *et al.* (2020).

With reference to the outcomes of P content in maize stover, the treatment  $G_6$  (0.21%) and  $G_2$  (0.19%) delivered higher P concentration than all other treatments in the initial year (2022). An augment of P content in maize stover by 31.25% and

18.75%, respectively was obtained computing the values received from  $G_6$  and  $G_2$  against  $G_0$  (0.16%), in the primary year of investigation. Elevated P content of maize stover was also noted in the succeeding year involving  $G_6$  (0.23%) and  $G_2$  (0.22%) where P concentration of 53.33% and 46.66%, respectively was computed in contrary to the P content of stover observed in  $G_0$  (0.15%). In the pooled analysis of data obtained from the first and second year of investigation it was found that integration of  $G_6$  (0.22%) and  $G_2$  (0.20%) as opposed to  $G_0$  (0.15%) up surged the phosphorus concentration of maize stover by 46.66% and 33.33%, respectively. Gu *et al.* (2023) and Nguyen *et al.* (2024) in their studies highlighted that the improvement in soil microbial biomass carbon and nutrient cycling was observed with the addition of green manures which turns the soil to be better to accumulate and disseminate available phosphorus to the plants. Green manure addition not only enriches the soil quality and fertility but also to better nutrient content and uptake in the plant biomass.

#### 4.4.1.2.3 Interaction effect

The impact of tillage and green manuring interaction in relation to phosphorus content in seed and stover over two years of investigation and its pooled aggregate mean data received is concisely given in Table 4.13(b) for discussion. In the initial year the treatment combination  $T_M G_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup> demonstrated as the most efficient treatment combination concerning P content of maize seed (0.26%) while P concentration of maize seed was seen to be lowest in the treatment combination  $T_C G_0$  (conventional tillage + control) attaining (0.21%). This showed an escalation of P concentration by 23.80% in  $T_M G_6$  over  $T_C G_0$ . In the succeeding year (2023) P content of seed augmented to 27.27% concerning in  $T_M G_6$  (0.28%) in contrary to  $T_C G_0$  (0.22%). The pooled aggregate mean of 2022 and 2023 also revealed parallel outcomes where a rise of 28.57% P content in maize seed was accounted for computing the values of phosphorus content in  $T_M G_6$  (0.27%) and  $T_C G_0$  (0.21%).

In relation to phosphorus content of maize stover, the treatment combinations  $T_MG_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, having P content of (0.22%),  $T_MG_2$  i.e. minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>, acquiring P content of (0.21%) and  $T_CG_6$  i.e. conventional tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, signifying the P content by (0.20%) were considered as the most dominant combinations maintaining superior phosphorus concentration of maize stover over all the treatment combination in the initial year (2022). Least inconsequential treatment combination was denoted in  $T_CG_0$  with P content of (0.15%). These outcomes exhibited an upsurge of 46.66%, 40% and 33.33% P content in  $T_MG_6$ ,  $T_MG_2$  and  $T_CG_6$ , respectively in contrary to  $T_CG_0$ . Likewise, in the second year field study the P content in maize stover was signified higher in the combinations  $T_MG_6$  with (0.25%) followed by  $T_MG_2$  and  $T_CG_3$  with P content of (0.22%), respectively reflecting a rise of 78.57% in  $T_MG_6$  and 57.14% in  $T_MG_2$  and  $T_CG_3$ , correspondingly in contrary to  $T_CG_0$  (0.14%). Growth of phosphorus content in maize stover was noticeable in the pooled aggregate involving the treatment combinations  $T_MG_6$  (0.24%) followed by  $T_MG_2$  and  $T_CG_6$  acquiring (0.21%) of P content in stover. Minimal impact was perceptible in the combination  $T_CG_0$  having P content of (0.15%). Computing the most influential with the least it was evident that an escalation of 60% involving  $T_MG_6$  and 40% concerning  $T_MG_2$  and  $T_CG_6$  was determined in relation to  $T_CG_0$ .

#### **4.4.1.3 Potassium content of maize seed and stover**

The potassium content of maize seed and stover as directed by the combination between tillage and green manuring cultivating maize (*Zea mays* L.) is accessible in Table 4.14(a) and 4.14(b) and their details regarding the two-year investigation and pooled mean analysis and their interactions are presented below.

##### **4.4.1.3.1 Effect of tillage on potassium content of maize seed and stover**

Distinct results and conclusion drawn after the two consecutive year of investigation involving tillage operations like minimum and conventional tillage

interventions and the consequences pertaining to the potassium content of maize seed and stover is enumerated concisely in Table 4.14(a). Augmented result concerning to potassium content of maize seed was observed with the employment of ( $T_M$ ) minimum tillage (0.44%) than ( $T_C$ ) conventional tillage (0.43%) by 2.32% in the primary year of experimentation (2022). Similarly, in the subsequent year K content of maize seed rose to 4.54% involving minimum tillage (0.46%) in relation to conventional tillage (0.44%). Meanwhile an upsurge of K content by 4.65% concerning the values received from implementing minimum tillage (0.45%) in contrary to conventional tillage (0.43%). Jha *et al.* (2023) in their study discovered that reduced tillage method increases the water soluble potassium, exchangeable and non-exchangeable potassium, K content and uptake in seed under maize-chickpea cropping system. This result indicates the competence of reduced tillage practice and its role in improving nutrient composition and dissemination to soil and plant.

In the context of potassium content of maize stover, no changes in the potassium content values were observed in the initial year integrating minimum and conventional tillage systems. Meanwhile in the second year of study, 0.75% increase in K content of maize stover was noted implementing minimum tillage operation (1.33%) in relation to conventional tillage (1.32%). The pooled analysis of both the years combined (2022 and 2023), exhibited rise of K content in maize stover by 0.76% involving minimum tillage having (1.32%) potassium content of maize stover in comparison to conventional tillage system with (1.31%), K content of maize stover. Deubel *et al.* (2011) expressed that adoption of reduced tillage practice or zero tillage as compared to conventional tillage practices increases the exchangeable, non-exchangeable and water soluble potassium in the soil which helps the plant to absorb the nutrients efficiently. The disturbance of soil is minimal with the incorporation of reduced tillage operation, which helps the plant to enhance its yield and yield attributes.

#### **4.4.1.3.2 Effect of green manuring on potassium content of maize seed and stover**

Data and outcomes of the two-year experimentation conducted on maize crop in the *kharif* seasons of 2022 and 2023 and the impact induced by the addition of different proportion of dhaincha and cowpea incorporated into the soil including the pooled aggregate mean of both the years of study is specified in Table 4.14(a) for discussion. Green manure application through G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>), G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) and G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) performed excellent in maintaining the K content of obtained maize seeds in the initial year of investigation. Growth of K content of seed by 27.50% utilizing G<sub>2</sub>, 17.50% in G<sub>6</sub> and 7.50% in G<sub>4</sub> was accounted concerning to the worst performing treatment of the sub plot G<sub>0</sub> (0.40%) in the first year. The succeeding cultivation of maize crop presented elevated increase of K content in seed adopting green manure treatment of G<sub>2</sub> (0.52%) followed by G<sub>6</sub> (0.50%) and G<sub>4</sub> (0.46%) by 33.33%, 28.20% and 17.94%, respectively in comparison to G<sub>0</sub> with (0.39%) of K concentration. Escalated values of K accumulation of 33.33%, 23.07% and 12.82% was distinguished implementing the sub plot treatments of G<sub>2</sub> (0.52%), G<sub>6</sub> (0.48%) and G<sub>4</sub> (0.44%) in computation with the K content values received from the least influential treatment G<sub>0</sub> (0.39%) in the pooled average records compiled from the findings of 2022 and 2023. Research indicates that potassium is one of the key macronutrient for crop. It helps to better crop growth, yield components and nutrient composition and uptake. Green manuring sole or combined with inorganic fertilizer boosted the maize performance by increasing the ability to absorb nutrients (Asante-Badu *et al.*, 2020) and was supported by the study of Singh *et al.* (2023b).

In the case of acquired potassium content of maize stover, elevated amount of K content of stover was measured following the sub plot treatment G<sub>6</sub> (1.38%) and G<sub>2</sub> (1.34%) over all the other treatments applied. G<sub>6</sub> produced a rise of K content in maize stover by 12.19% and G<sub>2</sub> was at 8.94% in relation to the least contributing treatment concerning K content in stover G<sub>0</sub> (1.23%). In the succeeding year *i.e.* 2023, the most contribution towards K accumulation on maize stover was accounted in the sub plot treatments G<sub>6</sub> (1.41%) followed by G<sub>3</sub> (1.36%) and G<sub>2</sub> (1.35%) whereas G<sub>0</sub> (1.22%) was distinguished as the marginal contributor towards K

concentration. Contrasting the aforementioned points, it can be concluded that with the adoption of  $G_6$  an upsurge of K content of 15.57% was observed subsequently utilising  $G_3$  it was 11.47% and for  $G_2$  it was 10.65% in comparison to values obtained in  $G_0$ . An escalation of K accumulation of maize stover by 55.65%, 99.99% and 66.36%, respectively was calculated comparing and contrasting the K content values of  $G_6$  (1.39%),  $G_2$  (1.34%) and  $G_3$  (1.33%) against the minimal contributing treatment in the pooled aggregate table  $G_0$  (1.22%). Organic manures like FYM and green manures significantly boost the potassium content and uptake by the plant. It maintains steady supply of nutrients, in an environment friendly way ensuring that the plants absorb the nutrients. It rejuvenates the plant in its growth, better physiological stand and overall productivity of the maize crop (Chaudhary *et al.*, 2017 and Patil *et al.*, 2017).

#### **4.4.1.3.3 Interaction effect**

The influence of tillage practices involved, manipulating the soil physical conditions and whereby adding green manures, incorporated before the maize seeds were sown (for proper decomposition) in the experimental field and their interactions over two years of rigorous investigation on potassium content of maize seed and stover is systematically included in Table 4.14(b). The treatment combination  $T_M G_2$  (minimum tillage combined with green manuring through dhaincha 4 t ha<sup>-1</sup>) was signified as the most important interaction where higher amount of K accumulation of maize seeds (0.52%) was exhibited amongst all treatment combination in the first year of field study. The next in order was the combination  $T_C G_2$  (minimum tillage merged green manuring through dhaincha 4 t ha<sup>-1</sup>) and  $T_M G_6$  i.e. minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>, procuring K content of 0.51% and 0.49%, respectively.  $T_C G_0$  i.e. conventional tillage + control portrayed the least contributing combination acquiring only (0.40%) potassium content of seed. Rise in K content deploying  $T_M G_2$ ,  $T_C G_2$  and  $T_M G_6$  in contrast to  $T_C G_0$  was highlighted at 30%, 27.50% and 22.50%, respectively in the preliminary year of experimentation. The second year of investigation resulted in the following conclusion. Potassium content of maize seed was accounted to be higher in the



combination  $T_MG_2$  (0.53%) followed by  $T_MG_6$  (0.52%) and  $T_CG_2$  (0.51%) while minimal contribution towards the buildup of K content was reported in the treatment combination  $T_CG_0$  (0.39%), displaying a growth of 35.89% involving  $T_MG_2$ , 33.33% relating and 30.76% using  $T_CG_2$  in contrary to  $T_CG_0$ . Meanwhile in the pooled aggregates data for 2022 and 2023 combined displayed the following outcomes. Soaring concentration of potassium of maize seed by 35.89%, 30.76% and 28.20% was indicated computing the K content of  $T_MG_2$  (0.53%),  $T_CG_2$  (0.51%) and  $T_MG_6$  (0.50%) against  $T_CG_0$  (0.39%).

In the perspective of potassium content in maize stover, superior K accumulation was maintained by the treatment combination  $T_MG_6$  having K content marked at (1.40%) subsequently followed by the interaction of  $T_CG_6$  where K content of maize seed attained (1.36%) and  $T_MG_2$  with (1.35%). An escalation of K content by 13.82%, 10.56% and 9.75% was noticeable concerning  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$ , respectively in relation to  $T_CG_0$  (1.23%) in the initial year of investigation. Concerning the second year higher K content was accumulated introducing the treatment combinations  $T_MG_6$  having K content of maize stover (1.42%) by 17.35%,  $T_CG_6$  (1.40%) by 15.70% and  $T_MG_2$  (1.36%) by 12.39% respectively computing the data received from  $T_CG_0$  (1.21%). Up surged potassium content of maize stover was also noticed in the treatment combination of  $T_MG_6$  (1.41%),  $T_CG_6$  (1.38%) and  $T_MG_2$  (1.35%) by 15.57%, 13.11% and 10.65%, respectively in comparison to the least influential treatment combination of the pooled average  $T_CG_0$  (1.22%).

**Table 4.13 (a): Effect of tillage and green manuring on nitrogen content and phosphorus content of maize seed and stover**

| Treatments            | Nitrogen content (%) |        |        |        |        |        | Phosphorus content (%) |        |        |        |        |        |
|-----------------------|----------------------|--------|--------|--------|--------|--------|------------------------|--------|--------|--------|--------|--------|
|                       | Seed                 |        |        | Stover |        |        | Seed                   |        |        | Stover |        |        |
|                       | 2022                 | 2023   | Pooled | 2022   | 2023   | Pooled | 2022                   | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>Tillage</b>        |                      |        |        |        |        |        |                        |        |        |        |        |        |
| <b>T<sub>M</sub></b>  | 1.46                 | 1.48   | 1.47   | 1.25   | 1.26   | 1.26   | 0.24                   | 0.25   | 0.24   | 0.19   | 0.20   | 0.19   |
| <b>T<sub>C</sub></b>  | 1.44                 | 1.46   | 1.45   | 1.24   | 1.24   | 1.24   | 0.23                   | 0.23   | 0.23   | 0.17   | 0.19   | 0.18   |
| <b>SEm ±</b>          | 0.0019               | 0.0032 | 0.0019 | 0.0026 | 0.0015 | 0.0015 | 0.0028                 | 0.0021 | 0.0017 | 0.0015 | 0.0003 | 0.0008 |
| <b>CD at 5%</b>       | 0.0114               | 0.0198 | 0.0074 | 0.0160 | 0.0089 | 0.0059 | NS                     | 0.0128 | 0.0068 | 0.0089 | 0.0020 | 0.0030 |
| <b>CV</b>             | 0.5909               | 1.0090 | 0.8297 | 0.9684 | 0.5365 | 0.7813 | 5.4240                 | 4.0271 | 4.7585 | 3.7219 | 0.7942 | 2.6024 |
| <b>Green manuring</b> |                      |        |        |        |        |        |                        |        |        |        |        |        |
| <b>G<sub>0</sub></b>  | 1.28                 | 1.28   | 1.28   | 1.17   | 1.14   | 1.16   | 0.22                   | 0.22   | 0.22   | 0.16   | 0.15   | 0.15   |
| <b>G<sub>1</sub></b>  | 1.47                 | 1.49   | 1.48   | 1.22   | 1.24   | 1.23   | 0.25                   | 0.24   | 0.24   | 0.17   | 0.17   | 0.17   |
| <b>G<sub>2</sub></b>  | 1.48                 | 1.50   | 1.49   | 1.26   | 1.27   | 1.27   | 0.24                   | 0.25   | 0.24   | 0.19   | 0.22   | 0.20   |
| <b>G<sub>3</sub></b>  | 1.46                 | 1.49   | 1.47   | 1.23   | 1.24   | 1.23   | 0.23                   | 0.24   | 0.23   | 0.18   | 0.21   | 0.19   |
| <b>G<sub>4</sub></b>  | 1.50                 | 1.52   | 1.51   | 1.27   | 1.28   | 1.28   | 0.23                   | 0.24   | 0.24   | 0.18   | 0.20   | 0.19   |
| <b>G<sub>5</sub></b>  | 1.46                 | 1.49   | 1.48   | 1.24   | 1.26   | 1.25   | 0.23                   | 0.23   | 0.23   | 0.17   | 0.19   | 0.18   |
| <b>G<sub>6</sub></b>  | 1.53                 | 1.56   | 1.55   | 1.32   | 1.34   | 1.33   | 0.25                   | 0.26   | 0.25   | 0.21   | 0.23   | 0.22   |
| <b>SEm ±</b>          | 0.0056               | 0.0061 | 0.0041 | 0.0043 | 0.0057 | 0.0036 | 0.0024                 | 0.0029 | 0.0019 | 0.0042 | 0.0037 | 0.0028 |
| <b>CD @ 5%</b>        | 0.0162               | 0.0179 | 0.0118 | 0.0126 | 0.0165 | 0.0101 | 0.0069                 | 0.0084 | 0.0053 | 0.0122 | 0.0107 | 0.0079 |
| <b>CV</b>             | 0.9374               | 1.0180 | 0.9791 | 0.8485 | 1.1078 | 0.9877 | 2.4794                 | 2.9315 | 2.7213 | 5.6852 | 4.6310 | 5.1503 |

**Table 4.13 (b): Interaction effect of tillage and green manuring on nitrogen content and phosphorus content of maize seed and stover**

| Treatments                        | Nitrogen content (%) |        |        |        |        |        | Phosphorus content (%) |        |        |        |        |        |
|-----------------------------------|----------------------|--------|--------|--------|--------|--------|------------------------|--------|--------|--------|--------|--------|
|                                   | Seed                 |        |        | Stover |        |        | Seed                   |        |        | Stover |        |        |
|                                   | 2022                 | 2023   | Pooled | 2022   | 2023   | Pooled | 2022                   | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 1.31                 | 1.31   | 1.31   | 1.20   | 1.18   | 1.19   | 0.22                   | 0.22   | 0.22   | 0.16   | 0.15   | 0.16   |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 1.47                 | 1.50   | 1.49   | 1.23   | 1.24   | 1.23   | 0.25                   | 0.24   | 0.25   | 0.16   | 0.18   | 0.17   |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 1.49                 | 1.52   | 1.51   | 1.26   | 1.28   | 1.27   | 0.25                   | 0.25   | 0.25   | 0.21   | 0.22   | 0.21   |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 1.46                 | 1.49   | 1.48   | 1.23   | 1.24   | 1.23   | 0.23                   | 0.25   | 0.24   | 0.18   | 0.19   | 0.18   |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 1.51                 | 1.51   | 1.51   | 1.28   | 1.29   | 1.29   | 0.24                   | 0.25   | 0.24   | 0.19   | 0.20   | 0.20   |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 1.47                 | 1.50   | 1.48   | 1.25   | 1.26   | 1.25   | 0.23                   | 0.24   | 0.24   | 0.18   | 0.20   | 0.19   |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 1.54                 | 1.57   | 1.55   | 1.33   | 1.35   | 1.34   | 0.26                   | 0.28   | 0.27   | 0.22   | 0.25   | 0.24   |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 1.25                 | 1.25   | 1.25   | 1.15   | 1.10   | 1.13   | 0.21                   | 0.22   | 0.21   | 0.15   | 0.14   | 0.15   |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 1.46                 | 1.48   | 1.47   | 1.21   | 1.24   | 1.23   | 0.24                   | 0.25   | 0.24   | 0.17   | 0.17   | 0.17   |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 1.46                 | 1.49   | 1.48   | 1.26   | 1.27   | 1.26   | 0.23                   | 0.24   | 0.23   | 0.17   | 0.21   | 0.19   |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 1.46                 | 1.48   | 1.47   | 1.23   | 1.24   | 1.23   | 0.22                   | 0.23   | 0.22   | 0.18   | 0.22   | 0.20   |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 1.49                 | 1.52   | 1.51   | 1.27   | 1.28   | 1.27   | 0.23                   | 0.24   | 0.23   | 0.17   | 0.20   | 0.19   |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 1.45                 | 1.48   | 1.47   | 1.24   | 1.25   | 1.24   | 0.22                   | 0.22   | 0.22   | 0.17   | 0.18   | 0.18   |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 1.53                 | 1.56   | 1.54   | 1.31   | 1.33   | 1.32   | 0.24                   | 0.23   | 0.24   | 0.20   | 0.21   | 0.21   |
| <b>SEm ±</b>                      | 0.0079               | 0.0087 | 0.0059 | 0.0061 | 0.0080 | 0.0050 | 0.0033                 | 0.0040 | 0.0026 | 0.0059 | 0.0052 | 0.0039 |
| <b>CD at 5%</b>                   | 0.0230               | 0.0253 | 0.0166 | 0.0178 | 0.0234 | 0.0143 | NS                     | 0.0118 | 0.0075 | 0.0173 | 0.0152 | 0.0112 |

**Table 4.14 (a): Effect of tillage and green manuring on potassium content of maize seed and stover**

| Treatment             | Potassium content (%) |        |        |        |        |        |
|-----------------------|-----------------------|--------|--------|--------|--------|--------|
|                       | Seed                  |        |        | Stover |        |        |
|                       | 2022                  | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>Tillage</b>        |                       |        |        |        |        |        |
| <b>T<sub>M</sub></b>  | 0.44                  | 0.46   | 0.45   | 1.30   | 1.33   | 1.32   |
| <b>T<sub>C</sub></b>  | 0.43                  | 0.44   | 0.43   | 1.30   | 1.32   | 1.31   |
| <b>SEm ±</b>          | 0.0032                | 0.0029 | 0.0022 | 0.0060 | 0.0044 | 0.0037 |
| <b>CD at 5%</b>       | NS                    | NS     | 0.0085 | NS     | NS     | NS     |
| <b>CV</b>             | 2.3838                | 2.9988 | 3.1916 | 2.1077 | 1.5139 | 1.8298 |
| <b>Green manuring</b> |                       |        |        |        |        |        |
| <b>G<sub>0</sub></b>  | 0.40                  | 0.39   | 0.39   | 1.23   | 1.22   | 1.22   |
| <b>G<sub>1</sub></b>  | 0.41                  | 0.43   | 0.42   | 1.25   | 1.29   | 1.27   |
| <b>G<sub>2</sub></b>  | 0.51                  | 0.52   | 0.52   | 1.34   | 1.35   | 1.34   |
| <b>G<sub>3</sub></b>  | 0.40                  | 0.42   | 0.41   | 1.31   | 1.36   | 1.33   |
| <b>G<sub>4</sub></b>  | 0.43                  | 0.46   | 0.44   | 1.31   | 1.33   | 1.32   |
| <b>G<sub>5</sub></b>  | 0.42                  | 0.43   | 0.43   | 1.30   | 1.33   | 1.31   |
| <b>G<sub>6</sub></b>  | 0.47                  | 0.50   | 0.48   | 1.38   | 1.41   | 1.39   |
| <b>SEm ±</b>          | 0.0044                | 0.0039 | 0.0029 | 0.0065 | 0.0064 | 0.0046 |
| <b>CD @ 5%</b>        | 0.0128                | 0.0113 | 0.0083 | 0.0190 | 0.0188 | 0.0130 |
| <b>CV</b>             | 2.4618                | 2.1205 | 2.2925 | 1.2226 | 1.1895 | 1.2059 |

**Table 4.14 (b): Interaction effect of tillage and green manuring on potassium content of maize seed and stover**

| Treatments                        | Potassium content (%) |        |        |        |        |        |
|-----------------------------------|-----------------------|--------|--------|--------|--------|--------|
|                                   | Seed                  |        |        | Stover |        |        |
|                                   | 2022                  | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 0.41                  | 0.39   | 0.40   | 1.23   | 1.22   | 1.23   |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 0.41                  | 0.43   | 0.42   | 1.24   | 1.28   | 1.26   |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 0.52                  | 0.53   | 0.53   | 1.35   | 1.36   | 1.35   |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 0.41                  | 0.43   | 0.42   | 1.31   | 1.35   | 1.33   |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 0.44                  | 0.47   | 0.46   | 1.31   | 1.33   | 1.32   |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 0.42                  | 0.43   | 0.43   | 1.30   | 1.33   | 1.32   |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 0.49                  | 0.52   | 0.50   | 1.40   | 1.42   | 1.41   |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 0.40                  | 0.39   | 0.39   | 1.23   | 1.21   | 1.22   |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 0.41                  | 0.43   | 0.42   | 1.26   | 1.29   | 1.28   |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 0.51                  | 0.51   | 0.51   | 1.34   | 1.33   | 1.34   |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 0.39                  | 0.41   | 0.40   | 1.31   | 1.36   | 1.33   |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 0.41                  | 0.44   | 0.43   | 1.31   | 1.34   | 1.32   |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 0.42                  | 0.43   | 0.43   | 1.29   | 1.33   | 1.31   |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 0.045                 | 0.48   | 0.47   | 1.36   | 1.40   | 1.38   |
| <b>SEm ±</b>                      | 0.0062                | 0.0055 | 0.0041 | 0.0092 | 0.0091 | 0.0065 |
| <b>CD at 5%</b>                   | 0.0180                | 0.0160 | 0.0118 | NS     | NS     | NS     |

#### **4.4.2 Nutrient uptake of maize seed and stover**

The proper observations and records accumulated from the two-year experimental trail undertaken in 2022 and 2023 on nitrogen, phosphorus and potassium uptake of maize seed and stover as influenced by varied tillage system implemented and the inclusion of green manures through dhaincha and cowpea at varied rates, their pooled mean and the interaction effect is systematically highlighted in Table 4.15(a), 4.15(b) and 4.16(a) and 4.16(b).

##### **4.4.2.1 Nitrogen uptake of maize seed and stover**

The assorted aspects of nitrogen uptake by maize seed and stover as impacted by tillage and green manuring effects in 2022 and 2023 and their pooled average is judiciously represented in Table 4.15(a) and 4.15(b).

##### **4.4.2.1.1 Effect of tillage on nitrogen uptake of maize seed and stover**

The results summarized for nitrogen uptake of maize seed and stover following two years' rigorous study undertaken on the topic entitled effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.) in the *kharif* seasons of 2022 and 2023 and how the tillage practices in particular influences the outcomes of the investigation is meticulously offered in Table 4.15(a). Following the cultivation of crop in the first year, seed samples were prepared and analyzed for the determination of N content of maize seed where it was observed that ( $T_M$ ) minimum tillage ( $81.83 \text{ kg ha}^{-1}$ ) produced higher N uptake in seed in plots where ( $T_C$ ) conventional tillage ( $80.55 \text{ kg ha}^{-1}$ ) was employed by 1.58%. ( $T_M$ ) also performed better than ( $T_C$ ) in the second year improving the N uptake by 1.50% received from computing the values of minimum tillage ( $82.99 \text{ kg ha}^{-1}$ ) to that of conventional tillage system ( $81.76 \text{ kg ha}^{-1}$ ). The pooled average mean of both the years indicated an escalation of 1.55% N uptake of maize seed concerning to minimum tillage ( $82.41 \text{ kg ha}^{-1}$ ) in contrary to conventional tillage integrated plots ( $81.15 \text{ kg ha}^{-1}$ ). Gotosa *et al.* (2021) declared that with the implementation of reduced tillage (RT) the nitrogen uptake in seed rose to twice to that of conventional

tillage (CT) practices. Increase from 8 to 60 kg ha<sup>-1</sup> was observed with the use of reduced tillage as compared to conventional tillage. The rise in nitrogen recovery efficiency was also observed from 5% to 40% under reduced tillage. Reduced tillage enhanced the recovery of applied N showing the benefits of this tillage practices. The outcomes of this result was approved by the findings of Kane *et al.* (2015) where it was concluded that minimum tillage methods may increase the overall nitrogen content of soil and plants.

In relation to nitrogen uptake of maize stover, integration of minimum tillage systems (92.58 kg ha<sup>-1</sup>) meticulously increased the N uptake capability of maize stover indicating a rise of 1.62% over conventional tillage adopted plots (91.10 kg ha<sup>-1</sup>) in the primary year of experimental trial. N uptake of maize stover was in the succeeding year was comparable to the outcomes of the first year where (T<sub>M</sub>) minimum tillage with N uptake of stover resulted to (93.40 kg ha<sup>-1</sup>) which was 1.92% higher than the calculated values achieved from (T<sub>C</sub>) conventional tillage (91.64 kg ha<sup>-1</sup>). Nitrogen uptake in maize plant notably increased with the induction of reduced tillage practices like chisel and minimum tillage practices as relative to conventional tillage. Minimum tillage employed with split fertilizer application stimulated the crop growth and productivity, increasing the nutrient composition and uptake by the seed and plant (Wasaya *et al.*, 2018). Comparable findings were noted in the pooled analysis table concerning N uptake of maize stover where 1.77% higher analyzed value of N uptake was marked following the computation of outcomes received from (T<sub>M</sub>) minimum tillage (92.99 kg ha<sup>-1</sup>) in relation to (T<sub>C</sub>) conventional tillage operation (91.37 kg ha<sup>-1</sup>).

#### **4.4.2.1.2 Effect of green manuring on nitrogen uptake of maize seed and stover**

Data pertaining to the nitrogen uptake of maize seed and stover following the investigation conducted over two years and the influence generated by the application of green manures into the soil is portrayed in Table 4.15(a) for reference. Application of green manures at varied amount tended to revitalize the nitrogen uptake by the plant during the study conducted in the first year of cropping. Sub plot treatments G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t

ha<sup>-1</sup>) having N uptake value of (87.17 kg ha<sup>-1</sup>) signified the highest contributor towards the growth of nitrogen in maize seed, subsequently followed by the treatment G<sub>4</sub> (green manuring through cowpea 4 t ha<sup>-1</sup>) with N uptake of (84.28 kg ha<sup>-1</sup>) and G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) with N uptake of (83.47 kg ha<sup>-1</sup>). The most minimal increment towards N uptake in maize seed was seen in the sub plot treatment G<sub>0</sub> (control) where the acquired N uptake was marked at (68.88 kg ha<sup>-1</sup>). Augmentation of N uptake in maize seed at 22.22%, 55.55% and 66.65% was noted in G<sub>6</sub>, G<sub>4</sub> and G<sub>2</sub>, correspondingly was maintained in contrast with the N uptake retained in G<sub>0</sub>. The subsequent year of the trail disclosed the input of sub plot treat G<sub>6</sub> (88.90 kg ha<sup>-1</sup>) marking the highest contributory in the N uptake of maize seeds, the second came from the treatment G<sub>4</sub> (85.22 kg ha<sup>-1</sup>) and the third from G<sub>2</sub> where the obtained N uptake was noted at (84.79 kg ha<sup>-1</sup>). The least influential sub plot treatment concerning N uptake in maize seed was distinguished in G<sub>0</sub> (68.60 kg ha<sup>-1</sup>). These findings depicted growth of N uptake in maize seed of 29.59% in G<sub>0</sub>, 24.22% involving G<sub>4</sub> and 23.60% exploiting G<sub>2</sub>, in contrary to the values of G<sub>0</sub>. Akbarian *et al.* (2021) revealed in their findings that the nitrogen absorption capacity of planted maize crop remarkably improved with the incorporation of green manures. N uptake in maize plant and seed was significantly enhanced applying green manures. Joint mean of pooled 2022 and 2023 revealed escalated growth of N uptake of seed where the input G<sub>6</sub> resulted the most effective contributing (88.04 kg ha<sup>-1</sup>) subsequently followed by G<sub>4</sub> and G<sub>2</sub> amounting to (84.75 kg ha<sup>-1</sup>) and (84.13 kg ha<sup>-1</sup>) of N uptake, respectively. These outcomes generated a rise of N uptake in maize seed following the sub plot G<sub>6</sub> by 28.07%, G<sub>4</sub> by 23.29% and G<sub>2</sub> by 22.38%, in relation to G<sub>0</sub> (68.74 kg ha<sup>-1</sup>).

The outlook of N uptake of maize stover as influenced by green manure applications are as follows. In the primary year (2022), nitrogen uptake of maize stover obtain from the first year experimentation unveiled escalated data involving the sub plot treatment G<sub>6</sub> (99.25 kg ha<sup>-1</sup>) followed by G<sub>4</sub> (95.71 kg ha<sup>-1</sup>) and G<sub>2</sub> (93.47 kg ha<sup>-1</sup>) while the least influential treatment was found in the treatment G<sub>0</sub> (84.72 kg ha<sup>-1</sup>). These aforementioned points obtained in the first year presented elevated N uptake of maize stover by 17.15%, 12.97% and 10.32%, respectively in



comparison to  $G_0$ . In relation to the data obtained in the subsequent year, rise of N uptake of maize seed of 22.66%, 16.87% and 14.42% was noticed in  $G_6$  (101.26 kg ha<sup>-1</sup>),  $G_4$  (96.48 kg ha<sup>-1</sup>) and  $G_2$  (94.46 kg ha<sup>-1</sup>) in contrary to the values of  $G_0$  (82.55 kg ha<sup>-1</sup>). Combined mean of 2022 and 2023 data disclosed higher values of nitrogen content of maize stover in the sub plot  $G_6$  having accumulated (100.26 kg ha<sup>-1</sup>) followed by the treatment  $G_4$  maintaining N uptake by (96.10 kg ha<sup>-1</sup>) and  $G_2$  with N uptake of (93.96 kg ha<sup>-1</sup>). In comparison to  $G_0$  (83.64 kg ha<sup>-1</sup>) the N uptake involving the treatment  $G_6$ ,  $G_4$  and  $G_2$  rose by 19.87%, 14.89% and 12.33%, respectively. Rani *et al.* (2021) stated that dhaincha as a green manure resulted in the highest nitrogen uptake by the cultivated maize plant in contrast to other treatments. Green manuring through dhaincha applied with 100% RDF proved to be the most beneficial combination amongst all treatment combination. The nutrient absorption capacity and efficiency of the crop was enhanced with the addition of green manures, improving overall development of the crop. The consequences of these findings were also highlighted in the investigation conducted by Gao *et al.* (2024) where green manure application helped the overall development of the crop as well as the maintenance of soil health.

#### 4.4.2.1.3 Interaction effect

The interaction between the merger of tillage system (minimum and conventional tillage) and green manuring (dhaincha and cowpea) at varied proportion and its influences on the nitrogen uptake of seed and stover including the pooled findings of 2022 and 2023 is concisely offered in Table 4.15(b). In the primary year of investigation, the treatment combination involving  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) resulted the most contributing combination concerning N uptake in maize seed whereby (87.50 kg ha<sup>-1</sup>) was marked, subsequently followed by the treatment combination  $T_C G_6$  (conventional tillage merged with green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) acquiring N uptake of (86.84 kg ha<sup>-1</sup>) and  $T_M G_4$  (minimum tillage + green manuring through cowpea 4 t ha<sup>-1</sup>) having N uptake amounted to (84.74 kg ha<sup>-1</sup>). The variables obtained showed substantial effectiveness

implementing the treatments  $T_MG_6$  by 30.26%,  $T_CG_6$  by 29.28% and  $T_MG_4$  by 26.15%, pertaining to the least operative treatment combination *i.e.*  $T_CG_0$  (conventional tillage + control) procuring N uptake value of ( $67.17 \text{ kg ha}^{-1}$ ). In the successive year (2023), the treatment combination concerning  $T_MG_6$  ( $89.24 \text{ kg ha}^{-1}$ ) manifested the most robust efficiency in sustaining the N uptake of maize seed, thereafter the treatment  $T_CG_6$  ( $88.56 \text{ kg ha}^{-1}$ ) and the combination  $T_MG_2$  ( $85.69 \text{ kg ha}^{-1}$ ). The most inferior outcome was noted in the treatment combination  $T_CG_0$  having N uptake of ( $66.81 \text{ kg ha}^{-1}$ ). Computing the acquired results from the second year it was pronounced that a growth of 33.57%, 32.55% and 28.25% was marked in  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_2$  in evaluation to  $T_CG_0$ . Joint pooled mean of 2022 and 2023, highlighted escalation of N uptake of maize seed by the combination  $T_MG_6$  ( $88.37 \text{ kg ha}^{-1}$ ) by 31.91%,  $T_CG_6$  ( $87.70 \text{ kg ha}^{-1}$ ) by 30.91% and  $T_MG_2$  ( $85.03 \text{ kg ha}^{-1}$ ) by 26.92% in comparison to  $T_CG_0$  ( $66.99 \text{ kg ha}^{-1}$ ).

With regards to the nitrogen content in maize stover, the following assumptions can be drawn. The interaction of treatments  $T_MG_6$  ( $100.17 \text{ kg ha}^{-1}$ ) followed by  $T_CG_6$  ( $98.33 \text{ kg ha}^{-1}$ ) and  $T_MG_4$  ( $96.28 \text{ kg ha}^{-1}$ ) rendered higher impact towards the accumulation of N uptake values in the initial year, whereas the treatment combination  $T_CG_0$  ( $82.33 \text{ kg ha}^{-1}$ ) portrayed the worst efficiency concerning N uptake of maize stover. Pertaining to this finding in the primary year, computing the best and the worst performing interaction it was depicted that upsurge of N uptake of 21.66%, 19.43% and 16.94%, involving  $T_MG_6$ ,  $T_CG_6$  and  $T_MG_4$ , respectively was noted in contrary to the combination  $T_CG_0$ . A growth of N uptake of 29.02%, 26.69% and 22.51%, correspondingly was marked in the second year of study trail conducted in 2023, comparing the values distinguished in  $T_MG_6$  ( $102.19 \text{ kg ha}^{-1}$ ),  $T_CG_6$  ( $100.34 \text{ kg ha}^{-1}$ ) and  $T_MG_4$  ( $97.03 \text{ kg ha}^{-1}$ ) in relation to  $T_CG_0$  ( $79.20 \text{ kg ha}^{-1}$ ). Joint aggregate mean outcomes of the two-year experimental trail unveiled the efficiency potential of the treatment combination relating to  $T_MG_6$  ( $101.18 \text{ kg ha}^{-1}$ ) followed by  $T_CG_6$  ( $99.33 \text{ kg ha}^{-1}$ ) and  $T_MG_4$  ( $96.66 \text{ kg ha}^{-1}$ ) exhibited higher values concerning to N uptake in maize stover. In relation to these abovementioned findings it was clear that an escalated outcomes of N uptake of 25.26%, 22.97% and 19.67%

was computed in  $T_M G_6$ ,  $T_C G_6$  and  $T_M G_4$ , respectively in contrary to the findings of  $T_C G_0$  ( $80.77 \text{ kg ha}^{-1}$ ).

#### **4.4.2.2 Phosphorus uptake of maize seed and stover**

The compiled spectrum of evidences obtained on phosphorus uptake of maize seed and stover as altered by adopting minimum and conventional tillage systems and the integration of green manures over two years' rigorous experimentation and their interaction is enumerated in Table 4.15(a) and 4.15(b).

##### **4.4.2.2.1 Effect of tillage on phosphorus uptake of maize seed and stover**

The various observations and outcomes recorded on phosphorus uptake by maize seed and plant as influenced by tillage systems integrated in the study field for the two-year experimentation and the pooled average retrieved is highlighted in Table 4.15(a) for reference. The performance of phosphorus uptake of maize seed peaked with the implementation of ( $T_M$ ) minimum tillage ( $13.44 \text{ kg ha}^{-1}$ ) than the performance of ( $T_C$ ) conventional tillage ( $12.57 \text{ kg ha}^{-1}$ ) in the initial year of investigation demonstrating a boost of 6.92% P uptake adopting ( $T_M$ ) as evident from the data's seen in the provided reference table. The second year of the field study, indicated an intensification of P uptake ability following ( $T_M$ ) minimum tillage ( $13.52 \text{ kg ha}^{-1}$ ) rather than the integration of ( $T_C$ ) conventional tillage ( $12.91 \text{ kg ha}^{-1}$ ) portraying a rise of 4.72%. Joint mean of the two years' experimental trial revealed elevate P uptake of 6.98% involving minimum tillage ( $13.63 \text{ kg ha}^{-1}$ ) in relation to conventional tillage ( $12.74 \text{ kg ha}^{-1}$ ). Wang *et al.* (2023b) reported that the introduction of reduced tillage like minimum tillage or no till in concurrence with cover crops led to prominent influence in microbial phosphorus and readily available phosphorus present in the soil. These may potentially support improved P mineralization, phosphorus uptake and crop performance in maize cropping. The ramifications of these findings were validated in the investigation taken by Anil *et al.* (2022) whereby they found out that reduced tillage operations may induce the plant to absorb more NPK uptake.

In connection to the obtained P uptake of maize stover implementing minimum and conventional tillage systems the following results can be drawn. Higher values of P uptake were noted in the field where minimum tillage operations ( $13.81 \text{ kg ha}^{-1}$ ) were executed delivering a rise of 7.22% in comparison to the plots where conventional tillage system ( $12.88 \text{ kg ha}^{-1}$ ) were enforced, in the primary year (2022) of the trail period. Escalated results were also summarized concerning the adoption of ( $T_M$ ) minimum tillage ( $14.62 \text{ kg ha}^{-1}$ ) in relation to ( $T_C$ ) conventional tillage ( $14.09 \text{ kg ha}^{-1}$ ) displaying a growth of 3.76% in ( $T_M$ ) over ( $T_C$ ), in the succeeding year (2023). Placement of concentrated bands of phosphorus close to soil surface significantly enhanced the phosphorus uptake by crop especially in farming system attributed by no tillage or minimum tillage practices. This type of tillage causes fewer disturbances to the soil and the application of nutrients like phosphorus may improve the availability and its efficiency (Alam *et al.*, 2018). Pooled mean aggregate of two-year comprehensive research detailed the following results. Minimum tillage with the P uptake amounting of ( $14.22 \text{ kg ha}^{-1}$ ) in contrary to the P uptake of maize stover in conventional tillage ( $13.49 \text{ kg ha}^{-1}$ ) up surged the increase per cent by 5.41% in favour of minimum tillage over conventional tillage system.

#### **4.4.2.2.2 Effect of green manuring on phosphorus uptake of maize seed and stover**

The acquired phosphorus uptake of maize seed and stover as impacted by the addition of green manures at varied proportion over two years' robust research and their joint mean is reflected for discussion in Table 4.15(a). With the induction of green manures in the soil the P uptake in maize seed seemed to be more resolute as evident from the treatment  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) where P uptake of maize seed was acknowledged to be the most having ( $14.23 \text{ kg ha}^{-1}$ ), subsequently followed by the treatment  $G_1$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$ ) where the marked values of P uptake was noted at ( $13.69 \text{ kg ha}^{-1}$ ) and thirdly in the sub plot treatment  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) with acquired P uptake of ( $13.36 \text{ kg ha}^{-1}$ ). The minimal influence on P uptake of maize seed occurred in the treatment where no green manures were added ( $G_0$ ) *i.e.*

control having P uptake of (11.54 kg ha<sup>-1</sup>), this resulted in the escalation of P uptake of seed measuring 23.31%, 18.63% and 15.77%, respectively in G<sub>6</sub>, G<sub>1</sub> and G<sub>2</sub> in reference to G<sub>0</sub>, in the initial year of the trail. Likewise, in the second year trail, elevated measurement of P uptake of maize seed was documented in the superior treatments like G<sub>6</sub> (14.52 kg ha<sup>-1</sup>) followed by G<sub>2</sub> (13.83 kg ha<sup>-1</sup>) and G<sub>1</sub> (13.59 kg ha<sup>-1</sup>), whereas the most inferior treatment among all the sub plot treatment was summarized in G<sub>0</sub> having P uptake of (11.81 kg ha<sup>-1</sup>). An upsurge of P uptake by 22.94%, 17.10% and 15.07% was noticeable in the treatments G<sub>6</sub>, G<sub>2</sub> and G<sub>1</sub>, respectively in contrary to the P uptake estimate in G<sub>0</sub>. Leguminous plants such as sunnhemp and dhaincha improves the nutrient composition and uptake by crops. Research indicated that sunnhemp performed notably better than dhaincha in phosphorus uptake by the maize plant (Gutema *et al.*, 2024). Similarly, in the joint pooled mean of both the year disclosed the P uptake estimate of the superior performing sub plot treatment s like G<sub>6</sub> (14.37 kg ha<sup>-1</sup>) by 23.13%, G<sub>1</sub> (13.64 kg ha<sup>-1</sup>) by 16.88% and G<sub>2</sub> (13.60 kg ha<sup>-1</sup>) by 16.53%, respectively in contrary to the P uptake value of G<sub>0</sub> (11.67 kg ha<sup>-1</sup>).

In relation to the P uptake of maize stover received concerning the incorporation of green manures it can be summarized that, a gain of phosphorus uptake of maize stover by 40.68%, 23.27% and 20.55% was obtained computing the P uptake figures of treatment G<sub>6</sub> (16.08 kg ha<sup>-1</sup>), G<sub>2</sub> (14.09 kg ha<sup>-1</sup>) and G<sub>4</sub> (13.78 kg ha<sup>-1</sup>) in relation to G<sub>0</sub> (11.43 kg ha<sup>-1</sup>). Comparable result was also acknowledged in the succeeding year trail where sub plots G<sub>6</sub> (17.34 kg ha<sup>-1</sup>), G<sub>2</sub> (16.07 kg ha<sup>-1</sup>) and G<sub>4</sub> (15.29 kg ha<sup>-1</sup>) in comparison to the least influential sub plot treatment G<sub>0</sub> (10.47 kg ha<sup>-1</sup>) delivered rise of P uptake of maize stover of 65.61%, 53.48% and 46.03%, respectively. Likewise, in the joint mean of 2022 and 2023 parallel outcomes to the first year and second year analysis where growth of P uptake of maize stover of 52.60%, 37.71% and 32.69%, respectively was highlighted in the plot G<sub>6</sub> with the calculated P uptake of stover at (16.71 kg ha<sup>-1</sup>), G<sub>2</sub> at (15.08 kg ha<sup>-1</sup>) and G<sub>4</sub> at (14.53 kg ha<sup>-1</sup>) was noted in comparison to G<sub>0</sub> (10.95 kg ha<sup>-1</sup>) which indicated the least effectiveness amongst all the sub plot treatment. Mweta *et al.* (2007) reported that green manuring *via Gliricidia sepium* may play a pivotal role in enhancing the

phosphorus availability. The decrease in soil sorption capacity may limit the P availability to the plants but with the addition of green manures the availability of P may be more accessible to the crops. *Gliricidia sepium* with inorganic phosphorus amendment showed a synergetic effect providing more nutrient availability and uptake efficiency in maize cropping. These findings were in accordance with the outcome of Logah *et al.*, (2013).

#### 4.4.2.2.3 Interaction effect

The merging of tillage systems involving minimum and conventional tillage with green manures like dhaincha and cowpea at varying proportion and their interaction effect over two years' trial and the obtained joint mean aggregate data in relation to phosphorus uptake of maize seed and stover is systematically articulated in Table 4.15(b), for guidance. Treatment combination  $T_M G_6$  *i.e.* minimum tillage combined with green manuring through dhaincha  $2 \text{ t ha}^{-1}$  + cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ , exhibited the highest contribution of P uptake of maize seed ( $14.62 \text{ kg ha}^{-1}$ ), secondly by the treatment combination  $T_M G_1$  (minimum tillage together with green manuring through dhaincha  $2 \text{ t ha}^{-1}$ ) with P uptake value of ( $14.16 \text{ kg ha}^{-1}$ ) and thirdly by  $T_C G_6$  (conventional tillage combined with green manuring through dhaincha  $2 \text{ t ha}^{-1}$  + cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) having P uptake estimation of ( $13.84 \text{ kg ha}^{-1}$ ), over all the other treatment combinations in the initial year of cultivation of maize crop in the trial period.  $T_C G_0$  *i.e.* conventional tillage system merged with control plot, with the accumulated P uptake value of ( $11.08 \text{ kg ha}^{-1}$ ) was manifested as the least contribution combination. An assessment of data calculating the augment of P uptake per cent of most influenced combinations where an escalation of 31.94%, 27.79% and 24.90% was noted in  $T_M G_6$ ,  $T_M G_1$  and  $T_C G_6$  was computed against the estimates received from  $T_C G_0$ . The subsequent year of experimental trail highlighted the development of phosphorus uptake of maize seeds in the interaction of treatments namely  $T_M G_6$  ( $15.76 \text{ kg ha}^{-1}$ ) followed by  $T_M G_2$  ( $14.31 \text{ kg ha}^{-1}$ ) and  $T_M G_4$  ( $19.55 \text{ kg ha}^{-1}$ ) unveiling an elevation of P uptake per cent of 35.74%, 23.25% and 17.91% in comparison to the minimal influencing upon P uptake of maize seed in the second year study  $T_C G_0$  ( $11.61 \text{ kg ha}^{-1}$ ). Assessment of joint pooled observation of 2022 and

2023 conveyed the findings that treatment  $T_CG_0$  ( $11.34 \text{ kg ha}^{-1}$ ) operated very inadequately in relation to  $T_MG_6$  ( $15.19 \text{ kg ha}^{-1}$ ),  $T_MG_2$  ( $14.13 \text{ kg ha}^{-1}$ ) and  $T_MG_4$  ( $13.69 \text{ kg ha}^{-1}$ ) highlighting an upsurge of P uptake of 33.95%, 24.60% and 20.72% in  $T_MG_6$ ,  $T_MG_2$  and  $T_MG_4$ , respectively in relation to outcomes observed in  $T_CG_0$ .

In accordance to the results obtained for P uptake of maize stover, it was perceived that in the preliminary year of research trial, P uptake of maize stover was detected to be in more amount in the interactions  $T_MG_6$  ( $16.86 \text{ kg ha}^{-1}$ ) thereafter by  $T_MG_2$  ( $15.34 \text{ kg ha}^{-1}$ ) and  $T_CG_6$  ( $15.30 \text{ kg ha}^{-1}$ ) in contrary to  $T_0G_0$  ( $11.01 \text{ kg ha}^{-1}$ ) which marked the least influential amongst all the interaction, exhibiting a rise of P uptake of stover of 53.13% involving  $T_MG_6$ , 39.32% concerning  $T_MG_2$  and 38.96% adopting  $T_CG_6$ , contrasting to  $T_0G_0$ . Amplified P uptake considering all the treatment the best performing interacting was acknowledged in  $T_MG_6$  ( $18.88 \text{ kg ha}^{-1}$ ) having delivered the most contribution in P uptake of maize stover, thereafter by  $T_MG_2$  ( $16.33 \text{ kg ha}^{-1}$ ) and  $T_CG_6$  ( $15.80 \text{ kg ha}^{-1}$ ). An augmentation of P uptake by 87.86%, 62.48% and 57.21% was remarked following the administration of treatments  $T_MG_6$ ,  $T_MG_2$  and  $T_CG_6$ , respectively against the most inferior treatment combination interaction in the subsequent year  $T_CG_0$  ( $10.05 \text{ kg ha}^{-1}$ ). The consolidated table for the two years (2022 and 2023) trial elucidated the following observations. The interactions which up surged the P uptake of maize stover was noticeable in  $T_MG_6$  ( $17.87 \text{ kg ha}^{-1}$ ),  $T_MG_2$  ( $15.84 \text{ kg ha}^{-1}$ ) and  $T_CG_6$  ( $15.55 \text{ kg ha}^{-1}$ ) while the least influence on P uptake of maize stover was perceptible in the treatment combination  $T_CG_0$  ( $10.53 \text{ kg ha}^{-1}$ ). Phosphorus uptake of maize stover in the pooled table displayed escalated growth of 69.70%, 50.42% and 47.67%, implementing treatments  $T_MG_6$ ,  $T_MG_2$  and  $T_CG_6$ , respectively, as compared to the with substandard outcome  $T_CG_0$ , concerning the pooled aggregate data of the investigation.

#### **4.4.2.3 Potassium uptake of maize seed and stover**

Heterogeneous data and results obtained on the parameter potassium uptake of maize seed and stover as characterized by the implementation and incorporation of assorted tillage system and diverse proportion of green manuring introduced in the

experimental field is duly referred in Table 4.16(a) and 4.16(b), respectively for consideration.

#### **4.4.2.3.1 Effect of tillage on potassium uptake of maize seed and stover**

Table 4.16(a) precisely describes and represents the results acquired after analyzing the potassium uptake of maize seed and stover as influenced by varied tillage systems integrated for the two-year maize cultivated research trial field and the pooled aggregate mean of both the year of investigation. More concentration of potassium uptake of maize seed was highlighted in the plots integrated with ( $T_M$ ) minimum tillage system ( $24.79 \text{ kg ha}^{-1}$ ) rather than ( $T_C$ ) conventional tillage ( $23.81 \text{ kg ha}^{-1}$ ) indicating a rise of 4.11% K uptake value in seed, adopting ( $T_M$ ) in the primary year of research experimentation. The succeeding year also leaned towards the outcomes of the initial year where K uptake in minimum tillage ( $25.52 \text{ kg ha}^{-1}$ ) integrated plots exhibited increase of 3.65% in contrary to conventional tillage operated plots ( $24.62 \text{ kg ha}^{-1}$ ). Availability of potassium in the soil notably increased with the implementation of zero and minimum tillage. The uptake of potassium increased in contrast to conventional tillage system. This result was concluded in maize-chickpea cropping system (Kumar *et al.*, 2022) which was also highlighted by (Madar *et al.*, 2020) in their research whereby reduced tillage operation enhanced the nutrient content and uptake of maize-wheat cropping system. The combined mean obtained from the two-year investigation also acknowledges the contribution of ( $T_M$ ) minimum tillage ( $25.15 \text{ kg ha}^{-1}$ ) whereby K uptake of maize seed elevated by up to 3.88% in relation to ( $T_C$ ) conventional tillage system ( $24.21 \text{ kg ha}^{-1}$ ).

Meanwhile the outcomes attained through the analysis of data received after the completion of investigation for potassium uptake in maize stover as persuaded by tillage practices involved is meticulously described below. In the initial year (2022), K uptake of maize stover was distinguished to be increasing with the implementation of ( $T_M$ ) minimum tillage ( $96.42 \text{ kg ha}^{-1}$ ) in contrast to ( $T_C$ ) conventional tillage ( $95.65 \text{ kg ha}^{-1}$ ), whereby escalation of K uptake of stover was accounted for 0.80% concerning ( $T_M$ ). In the second year, an upsurge of K uptake of stover by 0.53% was established following minimum tillage ( $98.04 \text{ kg ha}^{-1}$ ) in contrary to conventional



tillage ( $97.52 \text{ kg ha}^{-1}$ ). Similarly, in the joint mean findings of 2022 and 2023, it was perceived that the integration of minimum tillage ( $97.23 \text{ kg ha}^{-1}$ ) was found to be more profound in sustaining the K uptake of maize stover than the plots implemented with conventional tillage system ( $96.58 \text{ kg ha}^{-1}$ ) by about 0.67%. Costa *et al.* (2009) observed that reduced tillage like no till and minimum tillage as compared to other extensive tillage could be the solution to increase the soil potassium availability and accessibility. Crops may utilize the nutrient more efficiently as the nutrient may be more readily available to the plants.

#### **4.4.2.3.2 Effect of green manuring on potassium uptake of maize seed and stover**

The role played by the incorporation of green manures into the soil as a soil amendment and its influence on potassium uptake of maize seed upon the two years continuous cropping and the outcome pertaining to the investigation is meticulously characterized in Table 4.16(a). In the initial year of research, which was conducted in the year 2022, the treatments where green manures were added performed significantly better than control plots. The sub plot,  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) achieved superior result in potassium uptake of maize seed over all the other sub plot treatment amounting to ( $28.89 \text{ kg ha}^{-1}$ ) of K uptake of maize seed. This treatment was followed by the sub plot treatment ( $G_6$ ) which contained green manuring through dhaincha  $2 \text{ t ha}^{-1}$  + cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ , with K uptake summing up to ( $26.75 \text{ kg ha}^{-1}$ ) and ( $G_4$ ) which comprised of green manuring through cowpea  $4 \text{ t ha}^{-1}$ , totaling to K uptake of maize seed by ( $23.97 \text{ kg ha}^{-1}$ ). The sub plot ( $G_0$ ) where no green manures were added showed inadequate result marking as the subpar amongst the sub plots ( $21.56 \text{ kg ha}^{-1}$ ). Superior potassium uptake in maize seed by 33.33%, 22.22% and 55.55% was estimated in  $G_2$ ,  $G_6$  and  $G_4$ , respectively in relation to  $G_0$ . The following year derived higher K uptake of seed in the treatments containing  $G_2$  ( $29.55 \text{ kg ha}^{-1}$ ) trailed by  $G_6$  ( $28.27 \text{ kg ha}^{-1}$ ) and  $G_4$  ( $25.66 \text{ kg ha}^{-1}$ ) while  $G_0$  amounted to only ( $20.75 \text{ kg ha}^{-1}$ ) K uptake, measured as the least aiding sub plot treatment. Contrasting the superior sub plot treatment with the worst performing treatment in the sub plot, up surged significance of K uptake was noticeable by 42.40% adopting  $G_2$ , 36.24% by using  $G_6$  and 23.66% by implementing  $G_4$ ,

respectively in contrary to  $G_0$ . Combined mean of 2022 and 2023 also delivered comparable outcomes to that of the first and second trail where  $G_2$  (29.22 kg ha<sup>-1</sup>) followed by  $G_6$  (27.51 kg ha<sup>-1</sup>) and  $G_4$  (24.82 kg ha<sup>-1</sup>), noted the best performing treatments in the sub plot. Compared to  $G_0$  (21.15 kg ha<sup>-1</sup>), an elevation of K uptake of maize seed by 38.15%, 30.07% and 17.35%, respectively was conveyed.

Pertaining to the results obtained for potassium uptake of maize stover as inclined by the added green manures, the outcomes received are discussed below. The addition of green manures *via* dhaincha 2 t ha<sup>-1</sup> merged with cowpea 2 t ha<sup>-1</sup> (103.90 kg ha<sup>-1</sup>) furnished outcomes of elevated K uptake of maize stover over all the sub plot treatment in the first year of experimentation. Likewise,  $G_2$  (99.52 kg ha<sup>-1</sup>) and  $G_4$  (98.21 kg ha<sup>-1</sup>) were the next best influential treatment marked in the initial year. The plots where no green manures were added performed very poorly concerning K uptake of stover (88.80 kg ha<sup>-1</sup>). The incorporation of green manures through  $G_6$ ,  $G_2$  and  $G_4$  inclined the K uptake of maize stover by 17%, 12.07% and 10.59%, correspondingly computing and contrasting with plots where green manures were omitted. Similarly, in the subsequent year of investigation (2023), plots where green manures were integrated flourished the K uptake of maize stover, which was evident from the findings of  $G_6$  (106.04 kg ha<sup>-1</sup>),  $G_4$  (102.24 kg ha<sup>-1</sup>) and  $G_2$  (99.78 kg ha<sup>-1</sup>) totaling an escalated K uptake by 20.56%, 16.24% and 13.45%, in contrary to the plots where green manures were absent  $G_0$  (87.95 kg ha<sup>-1</sup>). Green manures plot with reference to  $G_6$  (104.97 kg ha<sup>-1</sup>),  $G_2$  (99.65 kg ha<sup>-1</sup>) and  $G_4$  (99.23 kg ha<sup>-1</sup>) furthermore escalated the K uptake of maize stover in the pooled mean of 2022 and 2023 whereby a rise of 18.77%, 12.75% and 12.27%, respectively was distinguished in comparison to  $G_0$  (88.38 kg ha<sup>-1</sup>).

#### **4.4.2.3.3 Interaction effect**

The convergence of minimum and conventional tillage practices accompanied with green manures at varied amount and its impact on the potassium uptake of maize stover over the two years of investigation and its pooled average is demonstrated in Table 4.16(b), for acknowledgement. Higher K uptake of maize stover was noted in the interactions where tillage operations were conducted and

green manures were applied in the initial year of experimentation. The treatment combination  $T_MG_2$  (minimum tillage merged with dhaincha  $4 \text{ t ha}^{-1}$ ) was the most impactful combination in relation to K uptake of maize seed ( $29.19 \text{ kg ha}^{-1}$ ). The second and third most influential combination was distinguished in  $T_CG_2$  (conventional tillage + dhaincha  $4 \text{ t ha}^{-1}$ ) and  $T_MG_6$  (minimum tillage coupled with dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  i.e. @  $4 \text{ t ha}^{-1}$ ) acquiring K uptake value at  $28.59 \text{ kg ha}^{-1}$  and  $27.72 \text{ kg ha}^{-1}$ . The least impactful treatment combination was noticed in  $T_CG_0$  with K uptake of ( $21.26 \text{ kg ha}^{-1}$ ). These findings portrayed a rise of K uptake in maize seed in the initial year by 37.30%, 34.47% and 30.38% in  $T_MG_2$ ,  $T_CG_2$  and  $T_MG_6$ , respectively in contrary to  $T_CG_0$ . Meanwhile in the succeeding year of field study, Escalated K uptake of maize seed was notable in the combinations  $T_MG_2$  ( $30.13 \text{ kg ha}^{-1}$ ),  $T_MG_6$  ( $29.43 \text{ kg ha}^{-1}$ ) and  $T_CG_2$  ( $28.97 \text{ kg ha}^{-1}$ ), portraying a rise of 45.41%, 42.03% and 39.81%, correspondingly in relation to  $T_CG_0$  ( $20.72 \text{ kg ha}^{-1}$ ). Similarly, in the joint mean of 2022 and 2023 i.e. the two-year investigation period, tillage systems merged with green manures tended to outperform the combinations were only sole tillage operations were integrated and green manures were excluded. The treatment combination like  $T_MG_2$  ( $29.66 \text{ kg ha}^{-1}$ ),  $T_CG_2$  ( $28.78 \text{ kg ha}^{-1}$ ) and  $T_MG_6$  ( $28.58 \text{ kg ha}^{-1}$ ) managed to accumulate more K uptake of maize seed among all the other combinations, while the least persuasive treatment combination was prominent in  $T_CG_0$  ( $20.99 \text{ kg ha}^{-1}$ ). An upsurge of K uptake of maize seed by 41.30%, 37.11% and 36.16% was remarked in the treatments  $T_MG_2$ ,  $T_CG_2$  and  $T_MG_6$ , respectively in comparison to  $T_CG_0$  in the pooled aggregate mean data.

Wen *et al.* (2021) declared that the long- term use of milk vetch and ryegrass as a green manure amendment increased the potassium uptake in red paddy cultivation. It enhanced the potassium absorption by the rice crop and grains and also helped the soil to retain the potassium. This finding concludes that green manures not only improve the soil fertility but also helps in nutrient composition and uptake especially in cereals like rice.

The outcomes received for potassium uptake of maize stover highlights the following results. The initial year study discloses that,  $T_MG_6$  ( $105.45 \text{ kg ha}^{-1}$ ),  $T_CG_6$

(102.34 kg ha<sup>-1</sup>) and T<sub>M</sub>G<sub>2</sub> (99.96 kg ha<sup>-1</sup>) directed more K uptake of maize stover than the other treatment combination in the study period, meanwhile lowest K uptake value was noticed in the treatment combination T<sub>C</sub>G<sub>0</sub> (88.07 kg ha<sup>-1</sup>). Computing the most influential to the least it was summarized that a growth of K uptake of maize stover of 19.73%, 16.20% and 13.50% was noted respectively in T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>2</sub> in comparison to T<sub>C</sub>G<sub>0</sub>. An upsurge of K uptake of maize stover concerning the treatment combination T<sub>M</sub>G<sub>6</sub> (106.97 kg ha<sup>-1</sup>), T<sub>C</sub>G<sub>6</sub> (105.10 kg ha<sup>-1</sup>) and T<sub>M</sub>G<sub>2</sub> (100.71 kg ha<sup>-1</sup>) by 22.81%, 20.66% and 15.62%, respectively in contrary to T<sub>C</sub>G<sub>0</sub> (87.10 kg ha<sup>-1</sup>) was computed in the second year of investigation following the data evident in the provided statistically analyzed table. Following the analysis of the two-year research, the observations recorded for the pooled aggregate revealed the following outcomes. Treatment combination T<sub>M</sub>G<sub>6</sub> with K uptake of maize stover containing (106.21 kg ha<sup>-1</sup>) outperformed all the other combinations marking as the top performing combination, followed by T<sub>C</sub>G<sub>6</sub> with (103.72 kg ha<sup>-1</sup>) and T<sub>M</sub>G<sub>2</sub> acquiring (100.33 kg ha<sup>-1</sup>) of K uptake concentration. In comparison to T<sub>C</sub>G<sub>0</sub> (87.58 kg ha<sup>-1</sup>) which was the least influential treatment combination T<sub>M</sub>G<sub>6</sub>, T<sub>C</sub>G<sub>6</sub> and T<sub>M</sub>G<sub>2</sub> escalated the K uptake of maize stover by 21.27%, 18.42% and 14.55%, respectively concerning the pooled average of 2022 and 2023.

Absorption of potassium from the soil by the plant may be more accessible with the incorporation of various green manures like common vetch and hairy vetch. Vetch is very efficient in accumulating and mobilizing nutrients like potassium with their deep root systems, enhancing nutrient cycling more easily. Subsequent crop rotation is also more beneficial with the plantation and application of common and hairy vetch as it not only provides nutrients but also maintains the soil health and environment (Gabhane *et al.*, 2023). The outcomes of this research were also summarized in the investigation conducted by Kumar *et al.* (2020) where it was highlighted that application of green manures significantly enriched the NPK content and uptake of green gram in the state of Haryana, under coarse textured soil.

**Table 4.15 (a): Effect of tillage and green manuring on nitrogen uptake and phosphorus uptake of maize seed and stover**

| Treatments            | Nitrogen uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        | Phosphorus uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        |
|-----------------------|----------------------------------------|--------|--------|--------|--------|--------|------------------------------------------|--------|--------|--------|--------|--------|
|                       | Seed                                   |        |        | Stover |        |        | Seed                                     |        |        | Stover |        |        |
|                       | 2022                                   | 2023   | Pooled | 2022   | 2023   | Pooled | 2022                                     | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>Tillage</b>        |                                        |        |        |        |        |        |                                          |        |        |        |        |        |
| <b>T<sub>M</sub></b>  | 81.83                                  | 82.99  | 82.41  | 92.58  | 93.40  | 92.99  | 13.44                                    | 13.52  | 13.63  | 13.81  | 14.62  | 14.22  |
| <b>T<sub>C</sub></b>  | 80.55                                  | 81.76  | 81.15  | 91.10  | 91.64  | 91.37  | 12.57                                    | 12.91  | 12.74  | 12.88  | 14.09  | 13.49  |
| <b>SEm ±</b>          | 0.1074                                 | 0.1797 | 0.1047 | 0.1943 | 0.1089 | 0.1114 | 0.1524                                   | 0.1162 | 0.0958 | 0.1088 | 0.0228 | 0.0556 |
| <b>CD at 5%</b>       | 0.6533                                 | 1.0937 | 0.4110 | 1.1821 | 0.6626 | 0.4372 | NS                                       | 0.7068 | 0.3762 | 0.6620 | 0.1388 | 0.2182 |
| <b>CV</b>             | 0.6060                                 | 0.9999 | 0.8295 | 0.9693 | 0.5393 | 0.7828 | 5.3699                                   | 3.9839 | 4.7097 | 3.7360 | 0.7280 | 2.6007 |
| <b>Green manuring</b> |                                        |        |        |        |        |        |                                          |        |        |        |        |        |
| <b>G<sub>0</sub></b>  | 68.88                                  | 68.60  | 68.74  | 84.72  | 82.55  | 83.64  | 11.54                                    | 11.81  | 11.67  | 11.43  | 10.47  | 10.95  |
| <b>G<sub>1</sub></b>  | 81.84                                  | 83.05  | 82.45  | 89.20  | 90.54  | 89.87  | 13.69                                    | 13.59  | 13.64  | 12.19  | 12.55  | 12.37  |
| <b>G<sub>2</sub></b>  | 83.47                                  | 84.79  | 84.13  | 93.47  | 94.46  | 93.96  | 13.36                                    | 13.83  | 13.60  | 14.09  | 16.07  | 15.08  |
| <b>G<sub>3</sub></b>  | 81.03                                  | 82.71  | 81.87  | 89.66  | 90.51  | 90.09  | 12.50                                    | 13.15  | 12.83  | 13.16  | 14.98  | 14.07  |
| <b>G<sub>4</sub></b>  | 84.28                                  | 85.22  | 84.75  | 95.71  | 96.48  | 96.10  | 13.11                                    | 13.58  | 13.34  | 13.78  | 15.29  | 14.53  |
| <b>G<sub>5</sub></b>  | 81.64                                  | 83.35  | 82.50  | 90.88  | 91.86  | 91.37  | 12.59                                    | 13.05  | 12.82  | 12.69  | 13.79  | 13.24  |
| <b>G<sub>6</sub></b>  | 87.17                                  | 88.90  | 88.04  | 99.25  | 101.26 | 100.26 | 14.23                                    | 14.52  | 14.37  | 16.08  | 17.34  | 16.71  |
| <b>SEm ±</b>          | 0.3105                                 | 0.3407 | 0.2305 | 0.3228 | 0.4247 | 0.2667 | 0.1328                                   | 0.1609 | 0.1043 | 0.3100 | 0.2727 | 0.2064 |
| <b>CD @ 5%</b>        | 0.9062                                 | 0.9945 | 0.6554 | 0.9420 | 1.2397 | 0.7584 | 0.3876                                   | 0.4698 | 0.2966 | 0.9050 | 0.7959 | 0.5870 |
| <b>CV</b>             | 0.9367                                 | 1.0132 | 0.9763 | 0.8608 | 1.1244 | 1.0023 | 2.5013                                   | 2.9504 | 2.7414 | 5.6906 | 4.6524 | 5.1632 |

**Table 4.15 (b): Interaction effect of tillage and green manuring on nitrogen uptake and phosphorus uptake of maize seed and stover**

| Treatments                        | Nitrogen uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        | Phosphorus uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        |
|-----------------------------------|----------------------------------------|--------|--------|--------|--------|--------|------------------------------------------|--------|--------|--------|--------|--------|
|                                   | Seed                                   |        |        | Stover |        |        | Seed                                     |        |        | Stover |        |        |
|                                   | 2022                                   | 2023   | Pooled | 2022   | 2023   | Pooled | 2022                                     | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 70.58                                  | 70.39  | 70.49  | 87.12  | 85.90  | 86.51  | 12.00                                    | 12.00  | 12.00  | 11.86  | 10.89  | 11.37  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 82.37                                  | 83.68  | 83.02  | 89.71  | 90.69  | 90.20  | 14.16                                    | 13.42  | 13.79  | 11.95  | 12.92  | 12.43  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 84.37                                  | 85.69  | 85.03  | 93.78  | 95.02  | 94.40  | 13.94                                    | 14.31  | 14.13  | 15.34  | 16.33  | 15.84  |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 81.19                                  | 83.05  | 82.12  | 89.71  | 90.68  | 90.20  | 12.98                                    | 13.72  | 13.35  | 13.16  | 13.65  | 13.41  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 84.74                                  | 85.13  | 84.93  | 96.28  | 97.03  | 96.66  | 13.50                                    | 13.88  | 13.69  | 14.54  | 15.29  | 14.92  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 82.04                                  | 83.78  | 82.91  | 91.33  | 92.31  | 91.82  | 12.87                                    | 13.62  | 13.25  | 12.94  | 14.41  | 13.68  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 87.50                                  | 89.24  | 88.37  | 100.17 | 102.19 | 101.18 | 14.62                                    | 15.76  | 15.19  | 16.86  | 18.88  | 17.87  |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 67.17                                  | 66.81  | 66.99  | 82.33  | 79.20  | 80.77  | 11.08                                    | 11.61  | 11.34  | 11.01  | 10.05  | 10.53  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 81.31                                  | 82.43  | 81.87  | 88.68  | 90.39  | 89.53  | 13.21                                    | 13.77  | 13.49  | 12.42  | 12.18  | 12.30  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 82.57                                  | 83.89  | 83.23  | 93.16  | 93.90  | 93.53  | 12.79                                    | 13.35  | 13.07  | 12.85  | 15.82  | 14.33  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 80.88                                  | 82.37  | 81.62  | 89.61  | 90.35  | 89.98  | 12.03                                    | 12.59  | 12.31  | 13.15  | 16.32  | 14.73  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 83.81                                  | 85.31  | 84.56  | 95.14  | 95.93  | 95.54  | 12.72                                    | 13.28  | 13.00  | 13.02  | 15.28  | 14.15  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 81.25                                  | 82.93  | 82.09  | 90.43  | 91.41  | 90.92  | 12.30                                    | 12.49  | 12.39  | 12.43  | 13.16  | 12.80  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 86.84                                  | 88.56  | 87.70  | 98.33  | 100.34 | 99.33  | 13.84                                    | 13.27  | 13.56  | 15.30  | 15.80  | 15.55  |
| <b>SEm ±</b>                      | 0.4391                                 | 0.4819 | 0.3259 | 0.4564 | 0.6007 | 0.3772 | 0.1878                                   | 0.2276 | 0.1475 | 0.4385 | 0.3856 | 0.2920 |
| <b>CD at 5%</b>                   | 1.2816                                 | 1.4064 | 0.9268 | 1.3323 | 1.7532 | 1.0726 | NS                                       | 0.6644 | 0.4195 | 1.2798 | 1.1255 | 0.8302 |

**Table 4.16 (a): Effect of tillage and green manuring on potassium uptake of maize seed and stover**

| Treatment             | Potassium uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        |
|-----------------------|-----------------------------------------|--------|--------|--------|--------|--------|
|                       | Seed                                    |        |        | Stover |        |        |
|                       | 2022                                    | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>Tillage</b>        |                                         |        |        |        |        |        |
| <b>T<sub>M</sub></b>  | 24.79                                   | 25.52  | 25.15  | 96.42  | 98.04  | 97.23  |
| <b>T<sub>C</sub></b>  | 23.81                                   | 24.62  | 24.21  | 95.65  | 97.52  | 96.58  |
| <b>SEm ±</b>          | 0.1782                                  | 0.1622 | 0.1205 | 0.4411 | 0.3281 | 0.2749 |
| <b>CD at 5%</b>       | 1.0846                                  | 0.9873 | 0.4732 | NS     | NS     | NS     |
| <b>CV</b>             | 3.3616                                  | 2.9662 | 3.1643 | 2.1050 | 1.5377 | 1.8383 |
| <b>Green manuring</b> |                                         |        |        |        |        |        |
| <b>G<sub>0</sub></b>  | 21.56                                   | 20.75  | 21.15  | 88.80  | 87.95  | 88.38  |
| <b>G<sub>1</sub></b>  | 23.09                                   | 23.84  | 23.46  | 91.27  | 93.95  | 92.61  |
| <b>G<sub>2</sub></b>  | 28.89                                   | 29.55  | 29.22  | 99.52  | 99.78  | 99.65  |
| <b>G<sub>3</sub></b>  | 22.23                                   | 23.25  | 22.74  | 95.75  | 99.04  | 97.40  |
| <b>G<sub>4</sub></b>  | 23.97                                   | 25.66  | 24.82  | 98.21  | 100.24 | 99.23  |
| <b>G<sub>5</sub></b>  | 23.59                                   | 24.15  | 23.87  | 94.79  | 97.47  | 96.13  |
| <b>G<sub>6</sub></b>  | 26.75                                   | 28.27  | 27.51  | 103.90 | 106.04 | 104.97 |
| <b>SEm ±</b>          | 0.2444                                  | 0.2167 | 0.1633 | 0.4783 | 0.4730 | 0.3363 |
| <b>CD @ 5%</b>        | 0.7133                                  | 0.6326 | 0.4644 | 1.3959 | 1.3805 | 0.9563 |
| <b>CV</b>             | 2.4637                                  | 2.1179 | 2.2922 | 1.2199 | 1.1848 | 1.2022 |

**Table 4.16 (b): Interaction effect of tillage and green manuring on potassium uptake of maize seed and stover**

| Treatments                        | Potassium uptake (kg ha <sup>-1</sup> ) |        |        |        |        |        |
|-----------------------------------|-----------------------------------------|--------|--------|--------|--------|--------|
|                                   | Seed                                    |        |        | Stover |        |        |
|                                   | 2022                                    | 2023   | Pooled | 2022   | 2023   | Pooled |
| <b>T<sub>M</sub>G<sub>0</sub></b> | 21.86                                   | 20.78  | 21.32  | 89.54  | 88.80  | 89.17  |
| <b>T<sub>M</sub>G<sub>1</sub></b> | 23.11                                   | 23.85  | 23.48  | 90.44  | 93.62  | 92.03  |
| <b>T<sub>M</sub>G<sub>2</sub></b> | 29.19                                   | 30.13  | 29.66  | 99.96  | 100.71 | 100.33 |
| <b>T<sub>M</sub>G<sub>3</sub></b> | 22.99                                   | 23.91  | 23.45  | 95.80  | 98.97  | 97.39  |
| <b>T<sub>M</sub>G<sub>4</sub></b> | 24.94                                   | 26.44  | 25.69  | 98.28  | 99.79  | 99.04  |
| <b>T<sub>M</sub>G<sub>5</sub></b> | 23.70                                   | 24.07  | 23.88  | 95.49  | 97.44  | 96.46  |
| <b>T<sub>M</sub>G<sub>6</sub></b> | 27.72                                   | 29.43  | 28.58  | 105.45 | 106.97 | 106.21 |
| <b>T<sub>C</sub>G<sub>0</sub></b> | 21.26                                   | 20.72  | 20.99  | 88.07  | 87.10  | 87.58  |
| <b>T<sub>C</sub>G<sub>1</sub></b> | 23.07                                   | 23.82  | 23.45  | 92.09  | 94.29  | 93.19  |
| <b>T<sub>C</sub>G<sub>2</sub></b> | 28.59                                   | 28.97  | 28.78  | 99.09  | 98.84  | 98.97  |
| <b>T<sub>C</sub>G<sub>3</sub></b> | 21.47                                   | 22.58  | 22.03  | 95.70  | 99.11  | 97.41  |
| <b>T<sub>C</sub>G<sub>4</sub></b> | 23.01                                   | 24.88  | 23.95  | 98.14  | 100.69 | 99.42  |
| <b>T<sub>C</sub>G<sub>5</sub></b> | 23.48                                   | 24.23  | 23.85  | 94.08  | 97.50  | 95.79  |
| <b>T<sub>C</sub>G<sub>6</sub></b> | 25.79                                   | 27.12  | 26.45  | 102.34 | 105.10 | 103.72 |
| <b>SEm ±</b>                      | 0.3456                                  | 0.3065 | 0.2310 | 0.6764 | 0.6689 | 0.4756 |
| <b>CD at 5%</b>                   | 1.0088                                  | 0.8946 | 0.6568 | NS     | NS     | 1.3524 |



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## **CHAPTER V**

### **SUMMARY AND CONCLUSIONS**

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## SUMMARY AND CONCLUSION

The research entitled “Effect of tillage and green manuring on soil properties for assessing the performance of maize (*Zea mays* L.)”. was carried out during the *kharif* seasons of the year 2022 and 2023 at the experimental farm of the Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus with the purpose of studying and analyzing the effects of tillage and green manuring on soil properties, soil moisture content, growth, yield attributes and yield cultivating maize. The experiment was laid out in split plot design, with the following objectives:

1. To assess the effect of tillage and green manuring on soil properties and soil moisture status
2. To study the effect of tillage and green manuring on quality of maize
3. To evaluate the effect of tillage and green manuring on yield attributes and yield of maize.

The experiment which was laid out in split plot design (SPD) was replicated thrice with fourteen different treatment combinations. The main plot consisted of two tillage system viz., Minimum tillage ( $T_M$ ) and Conventional tillage ( $T_C$ ) and the sub plot comprised of seven different treatments namely Control ( $G_0$ ), Green manuring through dhaincha @ 2 tonnes  $ha^{-1}$  ( $G_1$ ), Green manuring through dhaincha @ 4 tonnes  $ha^{-1}$  ( $G_2$ ), Green manuring through cowpea @ 2 tonnes  $ha^{-1}$  ( $G_3$ ), Green manuring through cowpea @ 4 tonnes  $ha^{-1}$  ( $G_4$ ), Green manuring through dhaincha (1 t  $ha^{-1}$ ) and cowpea (1 t  $ha^{-1}$ ) @ 2 tonnes  $ha^{-1}$  ( $G_5$ ), Green manuring through dhaincha (2 t  $ha^{-1}$ ) and cowpea (2 t  $ha^{-1}$ ) @ 4 tonnes  $ha^{-1}$  ( $G_6$ ). Maize variety RCM-76 with spacing of 60 cm  $\times$  25 cm was sown as a test crop for the experimental trial. The soil of the experimental site was acidic with

medium to high range of organic carbon content, available N, P and K. The maize crop was sowed following the recommended package of practice. The impact of various tillage practices and diverse combination of green manures incorporated on soil properties, soil moisture content, growth, yield attributes and yield, seed quality, nutrient content and uptake by the maize crop during the cropping period and after harvest of the crop were recorded following the standard procedures and analyzed using appropriate statistical methods. The salient findings of the present investigation have been summarized as follows:

### **5.1 Effect of tillage and green manuring on soil properties and soil moisture status**

The soil's physical, chemical and biological properties including soil moisture content was more profound with the implementation of minimum tillage system in contrary to conventional tillage whereas the incorporation of green manures at varied proportion tend to augment the overall performance of the soil properties and soil moisture status.

1. The soil acidity components like soil pH decreased with the implementation of minimum tillage ( $T_M$ ) while the total and exchangeable acidity of the soil managed to increase in minimum tillage ( $T_M$ ) in comparison to conventional tillage practices ( $T_C$ ). Green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  ( $G_6$ ) increased the pH of the soil the most amongst all the sub plot treatment. The treatment combination  $T_C G_6$  (conventional tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) was the most prominent interaction optimizing and maintaining the soil pH. The total and exchangeable acidity of the soil decreased with the implementation of conventional tillage systems ( $T_C$ ) whereby the addition of green manures significantly reduced the acidity factor involving total and exchangeable acidity. The combination  $T_C G_2$  (conventional tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) played an enhanced role in plummeting the total and exchangeable acidity of the soil.

2. The organic carbon content of the soil enhanced and increased with the adoption of conventional tillage ( $T_C$ ) practice in comparison to minimum tillage ( $T_M$ ) whereas the cation exchange capacity of the soil elevated with the inclusion of minimum tillage ( $T_M$ ). Both organic carbon content and cation exchange capacity of the soil augmented with the incorporation of green manures especially in the sub plot treatment of  $G_2$  i.e. green manuring through green manuring through dhaincha  $4 \text{ t ha}^{-1}$ . The organic carbon content of the soil enhances in the treatment combination of  $T_C G_2$  while the cation exchange capacity upsurge in the interaction  $T_M G_2$ .

3. The available N, P and K of the soil performed significantly better in the plots where minimum tillage ( $T_M$ ) was utilized in contrary to conventional tillage ( $T_C$ ). Higher available nitrogen and potassium was recorded in the sub plot treatment involving  $G_6$  while the sub plot  $G_2$  was more pronounced in the augmentation of available phosphorus. Treatment combination  $T_M G_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) developed the available nitrogen of the soil as well as the available potassium. Higher and elevated available K was accounted in the treatment combination of  $T_M G_2$  (minimum tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ).

4. The physical properties of the soil concerning bulk density, water holding capacity, hydraulic conductivity, mean weight diameter and per cent aggregates  $> 0.25 \text{ mm}$  was found to be superior in the main plot of minimum tillage ( $T_M$ ) in comparison to conventional tillage ( $T_C$ ). The particle density of the soil was more articulated in the plots involving conventional tillage system. The sub plot treatment ( $G_6$ ) optimized and increased the bulk density, water holding capacity, hydraulic conductivity, mean weight diameter and percent aggregates  $> 0.25 \text{ mm}$  of the soil over the period of study. The treatment combination involving  $T_M G_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) reduced the bulk density and elevated the water holding capacity, hydraulic conductivity, mean weight diameter and percent aggregates  $> 0.25 \text{ mm}$  of the soil while the particle density of the soil was increased in the interaction of  $T_C G_0$ .

5. The soil biological aspects of the cultivated soil over both the years were prominent in the main plot concerning minimum tillage ( $T_M$ ) over conventional tillage ( $T_C$ ). Up surged soil microbial biomass carbon (SMBC) and soil respiration was observed in the sub plot treatment of  $G_2$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) and the treatment combination  $T_M G_2$  (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>) augmented both the SMBC and soil respiration of the cultivated soil in comparison to all the treatment combination involved.

6. The soil moisture content of the experimental plot during the growing period of the crop was analyzed and the following conclusions are highlighted. The soil moisture content of 30 DAS, 60 DAS, 90 DAS and 120 DAS was observed to be higher in the plots where minimum tillage ( $T_M$ ) operations were implemented. The sub plot treatment involving  $G_4$  (green manuring through cowpea @ 4 t ha<sup>-1</sup>) escalated the soil moisture status of the experimental plot over all the other treatments in 30 DAS, 60 DAS, 90 DAS and 120 DAS of the cropping period. Higher soil moisture content was also observed in the treatment combination of  $T_M G_4$  (minimum tillage + green manuring through cowpea @ 4 t ha<sup>-1</sup>) over all the crop growth period viz., 30, 60, 90 and 120 DAS.

## **5.2 Effect of tillage and green manuring on growth, yield attributes and yield of maize**

1. The growth attributes of plant was profoundly altered by the type of tillage operation incorporated in the trial plots. Minimum tillage ( $T_M$ ) escalated the height of the maize plant in all phases of crop growth i.e. 30, 60, 90 and 120 DAS in comparison to conventional tillage ( $T_C$ ) practices. The application of green manures especially the use of the treatment  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) substantially influenced the plant height of maize over all stage of cropping period. The most impact was highlighted in the interaction of treatments concerning  $T_M G_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) over all the other combinations in relation to improvement in plant height over all the stages of growing period.

2. Yield attributes like number of cobs per plant, length of cob and number of grains per cob was significantly influenced with the adoption of minimum tillage ( $T_M$ ) in contrast to conventional tillage ( $T_C$ ) system of tillage practice. Addition of green manures into the soil also augmented the yield attributes especially the use of treatment  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) where higher number of cobs and grain count was noted. The sub plot treatment concerning  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) was accounted to enhance length of maize cob. The treatment combination of  $T_M G_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) recorded higher number of cobs and grains per cob over all the combinations whereas  $T_M G_2$  (minimum tillage + green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) marked enlarged length of cob amongst all the treatment combinations.

3. The grain and stover yield of the maize crop was noticed to be more significant in the plots where minimum tillage practice was introduced in contrary to conventional tillage practice. Green manure also enhanced the grain and stover yield where higher amount of yield components was observed in the sub plot where green manures especially  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) was implemented.  $T_M G_6$  (minimum tillage + green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) made a substantial contribution concerning the grain and stover yield of the crop.

### **5.3 Effect of tillage and green manuring on quality of maize**

1. The implementation of minimum tillage practices ( $T_C$ ) significantly enhanced the quality of maize seed concerning the protein content, carbohydrate content, oil content and ash content in comparison to conventional tillage ( $T_C$ ). Incorporation of green manures involving  $G_6$  (green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$ ) was noted to increase the protein content and ash content of the maize seeds whereas  $G_2$  (green manuring through dhaincha  $4 \text{ t ha}^{-1}$ ) up surged the carbohydrate content and oil content of the harvested maize seeds. Higher protein content and ash content was observed in the treatment combination  $T_M G_6$  (minimum tillage + green

manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) while carbohydrate content and oil content was noted to be elevated in the interaction involving T<sub>M</sub>G<sub>2</sub> (minimum tillage + green manuring through dhaincha 4 t ha<sup>-1</sup>).

#### **5.4 Effect of tillage and green manuring on nutrient content and uptake of maize seed and stover**

1. Escalated nitrogen, phosphorus and potassium content of maize seed and stover were noticeable with the adoption of minimum tillage (T<sub>M</sub>) in comparison to conventional tillage practices (T<sub>C</sub>). Application of green manures also played an important role in enhancing the N and P content of maize seed and stover particularly with the inclusion of sub plot treatment G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) where higher values of nutrient composition was marked. Potassium content of maize seed was noted to be enhanced with the involvement of G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>), while the K content in stover was marked to be higher in the sub plot treatment G<sub>6</sub>. The treatment combination T<sub>M</sub>G<sub>6</sub> (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) increased the N and P content of maize seed and stover whereas the K content of maize seed was escalated with the inclusion of treatment combination involving T<sub>M</sub>G<sub>2</sub> while the K content in maize stover was marked higher with the adoption of T<sub>M</sub>G<sub>6</sub>.

2. The recorded and analyzed nitrogen, phosphorus and potassium uptake of maize seed revealed that the implementation of minimum tillage (T<sub>M</sub>) improved the N, P and K uptake of the harvested maize seed of the experimental trial in contrary to conventional tillage practices (T<sub>C</sub>). The uptake of N and P in maize seed and stover was more prominent involving the sub plot treatment G<sub>6</sub> (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) whereas the K uptake of maize stover was also marked higher adopting G<sub>6</sub>, while the K uptake of maize seed was higher in the plots where G<sub>2</sub> (green manuring through dhaincha 4 t ha<sup>-1</sup>) was adopted. T<sub>M</sub>G<sub>6</sub> (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) escalated the N and P uptake of maize seed and stover whereas the K uptake of maize

seed was noted to be higher in the treatment combination  $T_MG_2$  (minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>). Higher K uptake of maize stover was noticed in the treatment combination concerning  $T_MG_6$ .

**Considering the outcomes of this research, the following conclusions may be derived**

1. The implementation of minimum tillage enhanced the soil physical, chemical and biological properties over both the years of field study. Crop growth, yield components and yield of maize was highly influenced with the incorporation of minimum tillage practice.
2. The application of green manures greatly improved the soil properties of the experimental field which was noticeable by the performance of the crop. The incorporation of green manures especially with the treatment  $G_6$  (green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>) performed significantly better boosting and sustaining the soil health and fertility, crop growth and productivity of maize crop. The  $G_4$  (green manuring through dhaincha 4 t ha<sup>-1</sup>) eloquently enhanced the soil moisture status of the cultivated soil and can be recommended for improving soil moisture conservation.
3. The treatment combination namely  $T_MG_6$  (minimum tillage + green manuring through dhaincha 2 t ha<sup>-1</sup> and cowpea 2 t ha<sup>-1</sup> @ 4 t ha<sup>-1</sup>),  $T_MG_2$  (minimum tillage + green manuring through dhaincha @ 4 t ha<sup>-1</sup>) and  $T_MG_4$  (minimum tillage + green manuring through cowpea @ 4 t ha<sup>-1</sup>) can be marked as the most important treatment combination sustaining and optimizing adequate responses to the requirements of the soil and the trial crop. Soil health, fertility, moisture status and overall crop performance was greatly enhanced with the incorporation of the above treatment combinations.



### **Recommendations as per the findings obtained**

As per the results obtained over the two-year systematic research and analysis, the implementation of minimum tillage practice combined with green manuring through dhaincha  $2 \text{ t ha}^{-1}$  and cowpea  $2 \text{ t ha}^{-1}$  @  $4 \text{ t ha}^{-1}$  can be recommended, as the soil physical, chemical and biological properties as well as the overall growth and productivity of the maize crop was observed to be significantly enhanced.

### **Future prospects**

The findings of the present investigation highlight the role of tillage and green manuring in improving the soil properties and consequently the performance of maize. The hilly terrain of Nagaland is very susceptible to excessive and unsupervised tillage operations, so utmost care should be focused. Further studies can be emphasized to validate the short and long term effect of tillage and green manuring especially in the different parts of North Eastern Region of India. Pot culture experiments can also be recommended for further understanding of the subject matter. Field trails can be done to comprehend the contribution of nitrogen released from green manures and their symbiotic relationship with nitrogen-fixing bacteria. Locally suitable methods can be introduced to the farmers so that sustainable production of maize can be achieved.

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## **REFERENCES**

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