STUDIES ON TILLAGE SYSTEM AND WEED MANAGEMENT PRACTICES IN UPLAND RICE (*Oryza sativa* L.) AND THEIR RESIDUAL EFFECT ON SUNFLOWER (*Helianthus annuus* L.)

Thesis

submitted to

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in

Agronomy

by

TAKHELMAYUM MALEMNGANBI

Admn. No. Ph- 294/19 Regn. No. Ph.D./AGR/00331

Department of Agronomy
School of Agricultural Sciences
Nagaland University, Medziphema Campus – 797 106
Nagaland

2024

Affectionately

Dedicated

To My

Beloved Family

&

Friends

DECLARATION

I, **Takhelmayum Malemnganbi,** 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 had not been submitted by me for any research degree in any other university/institute.

This is being submitted to SAS, Nagaland University for the degree of Doctor of Philosophy in Agronomy.

Date:

Place: Medziphema

…………………………..

(TAKHELMAYUM MALEMNGANBI)

(A.P. SINGH)
Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences
Medziphema – 797 106, Nagaland

Dr. A. P. Singh
Asso. Professor
Department of Agronomy

CERTIFICATE – I

This is to certify that the thesis entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuuns* L.)"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in the discipline of Agronomy, is the record of research work carried out by Takhelmayum Malemnganbi, Registration No. Ph.D./AGR/00331, under my personal supervision and guidance.

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

Date :
Place : Medziphema

(A. P. SINGH)
Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences
Medziphema – 797 106, Nagaland

CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRONOMY

This is to certify that the thesis entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuuns* L.)"** submitted by **TAKHELMAYUM MALEMNGANBI**, Admission No. Ph- 294/19, Registration No. Ph.D./AGR/00331, to the Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agronomy has been examined by the Advisory Board and External examiner on

The performance of the student has been found **Satisfactory/Unsatisfactory.**

Members	**Signature**
1. Dr. A. P. Singh (Supervisor & Convener)	……………………..
2. Prof. Debashish Sen (External Examiner)	……………………..
3. Pro-Vice-Chancellors' nominee	……………………..
4. Prof. L. Tongpang Longkumer	……………………..
5. Dr. Debika Nongmaithem	……………………..
6. Prof. Y. K. Sharma	……………………..
7. Prof. Manoj Dutta	……………………..

Head
Department of Agronomy

Dean
School of Agricultural Sciences

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Date: (Takhelmayum Malemnganbi)

Place: *Medziphema*

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LIST OF ABBREVIATIONS AND SYMBOLS

@	At the rate of
&	And
a.i.	Active Ingredient
BCR	Benefit Cost ratio
cc	Cubic centimetre
CD (p=0.05)	Critical difference at 5 per cent probability
cm	Centimetre
CV	Co-Efficient of Variation
DAS	Day after sowing
df	Degree of freedom
^{o}C	Degree Celsius
EC	Emulsifiable concentrate
et al.	*et allia* (and others/ co-workers)
etc.	Etcetera
fb	Followed by
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
ha	Hectare
HI	Harvest index
i.e.	Id est (that is)
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
L	Liter
m	Meter
m^2	Square meter

Max.	Maximum
Min.	Minimum
MOP	Muriate of Potash
msl	Mean sea level
mt	Million tonnes
N	Nitrogen
NS	Non Significant
No.	Number
NU	Nagaland University
K	Potassium
P	Phosphorus
%	Percentage
$^{-1}$ or /	Per
pH	Potential of Hydrogen
ha^{-1}	Per hectare
kg^{-1}	Per kilogram
L^{-1}	Per liter
q	Quintal
₹	Rupees
RDF	Recommended Dose of Fertilizers
R.H.	Relative Humidity
SC	Soluble concentrate
SEm (±)	Standard Error of Mean
Sl. No.	Serial Number
SOV	Source of Variation
SS	Sum of Square
sp., spp.	species (singular and plural)
SSP	Single Superphosphate

t ha^{-1}	Tonnes per hectare
viz.	Videlicet (namely)
wt.	Weight
WCE	Weed control efficiency
WP	Wettable powder

ABSTRACT

A field experiment entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)"** was conducted at the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema campus during the *Kharif* and *Rabi* seasons of 2021-2022 and 2022-2023. The experiment was laid out in split-plot design (SPD) with three tillage systems *viz*., T_1: zero tillage, T_2: minimum tillage and T_3: conventional tillage in the main plot and six weed management practices *viz*., W_1: stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS, W_2: pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (PE), W_3: stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (PE) *fb* cyhalofop-butyl @ 90 g ha^{-1} (PoE) at 25 DAS, W_4: pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS, W_5: weed free and W_6: weedy check in the sub-plot and were replicated thrice. The dominant weed flora present in the field were *Cynadon dactylon* L., *Digitaria sanguinalis* L., *Eleusine indica* L., *Cyperus iria* L., *Ageratum conyzoides* L., *Alternanthera sessiles* L., *Borreria latifolia* (Aubl.) K. Schum., *Borreria ocymoides* L., *Mollugo pentaphylla* L., *Lindernia crustacea* L. and *Sida cordifolia* L. The most dominant weed species found in the experimental field was *Borreria latifolia* (Aubl.) K. Schum with the highest importance value index (IVI) was 82.40%, 47.60% and 51.56% at 30, 60 and 90 DAS respectively throughout the cropping season. The pooled data result revealed that conventional tillage system recorded the minimum weed population (15.47, 13.01 and 7.60 m^{-2}), weed dry weight (8.62,13.21 and 11.00 g m^{-2}) at 30, 60 and 90 DAS, weed index (11.16%) and highest weed control efficiency (72.27%). It also recorded the highest plant height (77.80 cm), number of tillers m^{-2} (233.92), dry matter accumulation (13.22 g plant^{-1}), chlorophyll content (36.60 micro mol m^{-2}), leaf area index (1.87), length of panicle (17.87 cm), number of panicles m^{-2} (216.73), weight of panicle (2.15 g), number of grains panicle^{-1} (85.99), number of filled grains panicle^{-1} (70.84), grain yield (4086.57 kg ha^{-1}), straw yield (5844.14 kg ha^{-1}) and harvest index (40.96%).

It also recorded significantly maximum nutrient uptake by crops and minimum nutrient depletion by weeds. With respect to weed management practices, application of pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS recorded the lowest weed population (11.27, 8.38 and 4.79 m^{-2}), weed dry weight (6.62, 9.00 and 8.04 g m^{-2}) at 30, 60 and 90 DAS, weed index (2.20%), nutrient depletion by weeds and highest weed control efficiency (98.97%), nutrient uptake by crop as compared to other herbicidal treatment. It also recorded the highest growth parameters, yield attributes, grain yield (4588.91 kg ha^{-1}) and harvest index (27.31%). The highest cost of cultivation was recorded in conventional tillage system and stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (PE) *fb* cyhalofop-butyl @ 90 g ha^{-1} (PoE) at 25 DAS. In terms of gross returns, conventional tillage system and application of pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS recorded the highest gross returns (₹ 96709.57 ha^{-1}). Zero tillage system and application of pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS recorded the maximum net returns (₹ 59835.20 ha^{-1}) and B:C ratio (1.70). The maximum total output energy (139601.39 MJ ha^{-1}) and energy use efficiency (7.58%) were recorded in conventional tillage system and application of pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS. The result further revealed that there was no significant residual effect of the rice crop treatments on growth and yield attributes of the succeeding crop sunflower, only tillage system gave significant effect on seed yield and number of seeds head^{-1}. Thus, from the present investigation, it can be concluded that zero tillage with application of pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS found to be the best for minimizing weed growth and maximizing the yield, net returns and B:C ratio as compared to other treatments and hence, economically profitable.

Keywords: Bispyribac sodium, Cyhalofop-butyl, Energy use efficiency, Pyrazosulfuron-ethyl, Rice, Stale seedbed.

CHAPTER I

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.), the humble foodgrains that feeds the world, is one of the prominent staple food grains among the cereal crops feeding more than 3 billion people providing 50-80 % daily calorie intake (Choudhary *et al*., 2011, Juraimi *et al*., 2011). Worldwide, countries in Asia contributes more than 90 % of the total world's rice area and production. The significance of this crop in the context of global food security can be assessed by the fact that it provides more than 50% of the global staple food and accounts 20% of the dietary energy supply, with wheat and maize contributing the remaining 19% and 5% respectively (Schatz *et al*., 2014). It has moulded the culture, diets and economic of thousands of millions of people. More than 50% of the population particularly in developing nations, depends on it for sustenance through providing them essential food, calories and protein (Bhargaw *et al*., 2023). India is the second leading country in the world next to China cultivating in an area of 47.00 million hectares with annual production reaching 132.00 million tonnes and productivity of 4.20 tonnes per hectare (Foreign agricultural service, U.S department of agriculture, 2023-2024). In Nagaland, rice is the dominant food grain and staple diet with 86 % of cultivable area under *jhum* and terrace rice cultivation system. Rice is mainly grown throughout the state as transplanted or direct seeded in lowland and upland rainfed conditions. *Jhum* rice cultivation accounts an area of 90740 hectares with production of 180570 metric tonnes while wet transplanting rice cultivation accounts an area of 128070 hectares with production of 370380 metric tonnes (Government of Nagaland, 2022).

Rice cultivation is done under diverse ecologies varying from transplanted, wet-seeded, dry seeded as irrigated or rainfed upland and lowland. Transplanting or conventional method is done by transplanting seedlings into puddled field and kept the soil flooded during most of the crop growing period.

This establishment method and is labour intensive, time and energy consuming, requires large amount of water which are becoming scarce and expensive. Here, direct seeding method has become one of the desirable methods of rice cultivation which may be either wet or dry direct seeding. Wet seeding is done by sowing sprouted seeds on well puddled soil either by drum seeder or broadcasting. On the other hand, dry seeding involves the sowing of seeds on well prepared, well-drained non-puddled, non-flooded and aerobic soil conditions with optimum moisture level for proper seed germination. In addition to requiring less labour, time, energy, irrigation water, direct seeded rice also reduces emission of greenhouse gases, avoids transplanting shocks, reduces production cost and ensures healthy growth of the subsequent crop with timely sowing and hence germination (Kaur and Singh, 2017). Direct-seeded rice (DSR) cultivation requires only 34% of the total man power requirement and lowers the cost by 29% of the transplanted rice (Saravanane *et al*., 2021). Direct seeding upland rice is becoming more popular as a substitute of transplanted rice among the rice growers if the crops are properly managed (Sharma *et al*., 2007).

Tillage practices are one of the integral parts of crop husbandry for obtaining ideal conditions for seed germination, seedling establishment and crop growth. Tillage plays a crucial role for sustainable crop production and well known to be a traditional means for weed management. It has a significant effect on the crop productivity due to the emergence, density and distribution of weed seed in the soil. Vertical distribution of weed seeds in the soil is affected by different tillage system (Chauhan *et al*., 2006), and this may again affect the relative abundance of weed species in the field (Froud-Williams *et al*., 1981). When planting of crop is delayed, primary tillage can control annual weeds to some extend by allowing them to germinate early before the final tillage operation. While shallow tillage prior to crop emergence and tillage after crop establishment aid in the removal and inhibition of annual and perennial weeds (Singh *et al*., 2016a). Zero tillage is an extreme form of minimum tillage, where primary tillage is completely avoided and secondary tillage is confined only to seedbed preparation where seeds will be sown by drills or manually. While minimum tillage system is another tillage system where primary tillage is not involved and secondary tillage is carried out for the preparation of seedbed. Sowing of crop under zero tillage with standing crop residue with proper application of herbicides in proper combination or in sequence results in lower weed population and higher crop yield than the conventional method (Sharma and Singh, 2012). Under zero tillage system, organic wastes or crop residue presence on the soil surface helps in suppressing weeds. Tillage not only helps in weed management but also affects herbicide degradation. Conventional tillage system requires the intervention of soil with heavy machinery for ploughing, harrowing, planking and levelling for seedbed preparation. Conventional tillage practices may sceptically cause soil deterioration, loss of soil organic matter that might affected the soil productivity and fertility. Adoption of DSR with minimum or zero tillage will conserve the soil and water and ensures sustainable crop production. It also lowers the cost as well as energy to sustain the productivity and better earnings for the farmers.

Successful rice production depends on various factors which influences its growth, development and yield and it may vary to different location and environment. Among the various production factors, weeds are the major yield limiting biotic constraint that reduce crop yield by 30-80% and competes for the natural resources *i.e.*, nutrients, water, light and space interfering all the activities involved in the field throughout the crop growing period (Saravanane *et al*., 2021). The extent of losses due to weeds may vary with the cultural methods, rice cultivars, associated weed species and their density and duration of competition. Among any different system of rice cultivation, weed infestation is more severe under direct seeded rice cultivation with a yield loss up to 90 % (Gaire *et al*., 2013). It is due to the synchronous emergence of competitive weeds and due to seedling size advantage of the crop to suppress the weed seedlings which is again aided by absence of standing water to suppress weeds at the time of seedling emergence. The risk of yield losses due to weeds is more in direct seeded rice than in transplanted rice (Rao *et al*., 2007 and Matloob *et al*., 2015). Weed management in DSR system is more challenging than transplanted rice due to the diversity of weed species and the severity of the infestation (Chauhan, 2013).

In dry DSR, uncontrolled weeds reduced the crop yield by 96% and in wet DSR, by 61% (Rathika *et al*., 2020). Delay in weed control will result in increased weed biomass which is inversely correlated with crop yield (Saravanane *et al*., 2021). Weed density and biomass were almost double as in case of aerobic rice field than those in conventional transplanted rice at 35 and 75 DAS/T (Mahajan *et al*., 2009). So, weed control is a must under any system of rice cultivation. Use of any single weed management approach cannot attain effective season-long and sustainable weed control because of variation in dormancy and wide diversity of growth habits of weeds (Chauhan, 2012). Traditionally, hand weeding, a physical method for weed removal is an easy and eco-friendly method but it is a tedious, greatly labour intensive and expensive method and hence is not considered as an economically viable option. Efficient weed management through adoption of various economically viable weed control measures will be the only option to attain the optimal rice production and productivity. Chemical weed control (herbicide) is the most effective single tool towards weed management if use judiciously according to the given guidelines all around the world. Herbicide with variable mode of action can efficiently control weeds. Selection of appropriate herbicide for specific crop for the specific situation is prerequisite for effective weed control and better yield. Time of application, its dose, methods and herbicide selectivity are to be considered carefully before its application to crops. Continuous dependence on a particular herbicide or different herbicide with same mode of action may cause illicit environmental hazards, unintentional injuries to any non- target vegetation and especially development of herbicide resistant weed species. Hence, combination of herbicides with different modes of action is highly recommendable. Thus, sequential combine application of pre and post emergence herbicides with different modes of action resulted in effect broad spectrum control of diverse weeds. The various herbicides found to effectively control the diverse weed species in DSR include pendimethalin that selectively control annual grasses and certain BLWs and pyrazosulfuron-ethyl which is a broad spectrum systemic as pre emergence and bispyribac- sodium, a broad spectrum systemic that control grasses, sedges and BLWs and cyhalofop-butyl, a selective herbicide that control grasses as post emergence herbicides. Apart from the chemical control, integration of various agronomic measures as alternative way for better weed control as none of the single weed control measures can result in perfect control of diverse weed species.

Among the agronomic measures, stale seedbed (SSB) or false seedbed technique is one of the effective weed control measures based on the principle of flushing out germinated weed seeds prior to the sowing of crops, and depleting the weed seed bank in the surface layer of soil, thereby reducing crop weed competition during crop period. This practice is mainly done in areas of upland, dryland and rainfed rice ecosystem. Here, false seedbeds are prepared several days, weeks or months before sowing of the crop, allowing weed seeds to germinate and emerge, and eliminated by either pre-planting shallow tillage or by spraying of non- selective post emergence herbicides. This is one of the cultural methods which is efficient enough to reduce the weed seed bank, ecologically sound, economically feasible, acceptable to users and environmentally friendly. For this technique to be successful, we should consider several factors like duration of stale seed bed, seedbed preparation methods, method of killing emerged weeds, weed species and prevailing environmental conditions (temperature during the stale seed bed period). SSB effectively control those weed species that are present in the top-soil layer, have initial low dormancy and requires light for germination. It was reported that stale seed bed combined with herbicide (paraquat/ glyphosate) and zero till results in better weed control (Singh *et al*., 2016a). Stale seed bed method with glyphosate @ 1 kg ha^{-1} recorded significantly reduced weed density and dry biomass, better performance of growth and yield attributes in dry direct seeded rice than shallow tillage (Singh, 2013). Stale seedbed method with application of bispyribac-sodium @ 250 ml ha^{-1} as POE at 15 DAS recorded the highest net profit (₹ 34689.5 ha^{-1}) and benefit cost ratio of 1.40 under direct seeded rice system (Sangra *et al*., 2018). In India, adoption of SSB combined with consecutive herbicide applications after one and two irrigations decreased weed density by 44-68% and 77-85%, respectively, compared to a control (Saravanane *et al*., 2021).

Thus, for effective, long-lasting, and sustainable weed control in upland rice, a combination of several weed management techniques preventive and herbicidal is required (Ravikiran *et al*., 2019). Furthermore, the performance of direct seeded rice is affected by the major inputs of proper tillage practices and weed control measures (Dolma, 2017).

Hence, keeping in view of the above points, the present investigation entitled, "**Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)**" was taken up with the following objectives:

1. To study the effect of tillage system and weed management practices on the growth and yield of upland rice.
2. To study the effect of tillage system and weed management practices on weed dynamics.
3. To evaluate the residual effect of different treatments in sunflower.
4. To work out the economics of the treatment

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A brief relevant literature pertaining to the present research work entitled **“Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)”** has been critically reviewed and presented in this chapter under the following sub-headings:

2.1 Weed flora in rice ecosystem

2.2 Importance value index (IVI) of rice

2.3 Effect of tillage on weeds

2.4 Effect of tillage on growth, yield attributes and yield of rice

2.5 Effect of stale seed bed on rice

2.6 Effect of stale seed bed on weeds

2.7 Effect of herbicides on rice and weeds

2.8 Effect of tillage and weed management on energy analysis

2.9 Residual effect of tillage and weed management on succeeding crop

2.10 Economic analysis

2.1 Weed flora in direct seeded rice ecosystem

Singh and Singh (2012) reported that the major weed flora infesting the rice field were *Cynodon dactylon* (9.25%), *Echinochloa colona* (24.5%), *Echinochloa crusgalli* (14.2%), *Leptochloa chinensis* among grasses; *Commelina benghalensis* (4.54%), *Physalis minima, Phyllanthus fraternus* (13.9%), *Euphorbia hirta, Trianthema monogyna, Chorchorus olitorius*(6.8%), *Eclipta alba* (2.1%) among broad-leaved weeds; *Cyperus iria* (13.2%), *Cyperus difformis* and *Fimbristylis miliaceae* among sedges.

Longkumer and Singh (2013) from their field experiment observed that *Ageratum conyzoides*, *Axonopus compressus*, *Borreria hispida*, *Cyperus rotundus*, *Dactylactenium aegyptium*, *Digitaria sanguinalis*, *Eleusine indica*, *Euphorbia hirta*, *Imperata cylindrica*, *Mikania micrantha*, *Mimosa pudica* and *Setaria glauca* were the predominant weed species in upland direct seeded rice.

Madhukumar *et al.* (2013) reported that *Echinochloa colona*, *Digitaria marginata, Eleusine indica*, *Cynodon dactylon*, *Chloris barbata and Dactylactenium aegyptium* were the dominant grass species; *Ageratum conyzoides,Protulaca oleracea*, *Commelina benghalensis*, *Spilanthus acmella*, *Acanthosperum hispidum*, *Mollugo disticha*, *Phyllanthus niruri*, *Stachytarpheta indica*, *Celosia argentia*, *Parthenium hysterophorus* and *Aeschynomene indica* were the most dominant broad leaved weeds and among the sedges *Cyperus rotundus* was dominant in the experimental field of aerobic rice.

Dadsena *et al.* (2014) observed about 24 different species of weeds of 11 different families in the experimental field. The most dominant weed species were *Digitaria ciliaris*, *Cyperus rotundus*, *Cyperus esculentus*, *Eleusine indica*, *Cynodon dactylon*, *Echinochloa colona*, *Ludwigia parviflora*, *Ageratum conyzoides* and *Oldenlandia corymbosa*.

Raghavendra *et al*. (2015) conducted an experiment to ascertain the efficacy of different weed management practices on growth and yield of direct wet seeded rice (DWSR) sown through drum seeder and reported that the dominant weed flora associated with experimental field were *Echinochloa colona*, *Echinochloa crusgalli*, *Denebra arabica*, *Dactylectanium aegypticum*, *Cynodon dactylon* in grasses; *Cyperus difformis* in sedges and *Ammania baccifera*, *Eclipta alba* and *Ludwigia parviflora* in broad-leaved weeds.

Singh *et al*. (2017) reported that the dominant weed species found in the experimental field were *Echinochloa glabrescens, Leptochloa chinensis, Cyperus difformis, Cyperus rotundus, Ecliptaalba* and *Ammania baccifera* in direct seeded rice when experiment was done to study the performance of sequential application of herbicides on weed flora in direct seeded rice at Kaul (Kaithal) Haryana.

Hemalatha *et al*. (2017) carried out an experiment to evaluate the influence of different weed management practices on nutrient uptake by rice and weeds as in dry-seeded rice and reported that eleven weed species belonging to seven different families were recorded in the experimental field. Among them, *Echinochloa colona*, *Echinochloa crusgalli* and *Cynodon dactylon* were grasses, *Cyperus rotundus*, *Cyperus difformis*, *Fimbristylis miliaceae* were sedges while, *Eclipta alba*, *Ludwigia parviflora*, *Ammania baccifera*, *Euphorbia hirta*, *Trianthema portulacastrum* were broad-leaved weeds. However, *Echinochloa colona* and *Echinochloa crusgalli* among grasses, *Cyperus rotundus* among sedges and *Eclipta alba* and *Ludwigia parviflora* among broad-leaved were dominant throughout the crop growth period.

Choudhary *et al.* (2018) observed that the major weeds infesting in dry DSR during experiment were grasses like *Cynodon dactylon*, *Echinochloa colona, Setaria glauca*, *Paspalum scrobiculatum* and Paragrass, broad-leaf weeds like *Melochia corchorifolia*, *Aeschynomene indica*, *Polygonum hydropiper* and *Commenlina diffusa* and sedges like *Cyperus iria* and *Fimbristylis miliaceae*, etc.

Sunil *et al.* (2018) reported that major weed species associated with aerobic rice were *Phyllanthus niruri, Aegeratum conyzoides, Celosia argentia L., Mimosa pudica, Protulaca oleraceae L., Aeschynomene indica, Spilanthus acmella* Murray not (L.) L., *Alternanthera sessilis* L., *Emilia sonchifolia* (L.) DC. ExWight and *Eclipta prostrata* (L.) among broad leaved weeds;

Echinochloa colonam L*., Dactyloctenium aegyptium* (L.) Willd*., Panicum repens* L*., Eleusine indica* (L.) Gaertn*., Cynodon dactylon* (L.) Pers. *and Digitaria marginata* L. among narrow leaved weeds and *Cyperus rotundus* L*., Cyperus iria* L. *and Fimbristylis miliaceae* (L.) Vahl., among sedges.

Yogananda *et al*. (2019) conducted research to study the efficacy of sequential application of herbicides on weed density, weed dry weight, yield and economics of dry direct-seeded rice under Cauvery command area of Karnataka, Mandya. The study revealed that the predominant weed flora associated with dry direct-seeded rice were *Cynodon dactylon* L. (Bermuda grass), *Dinebra retroflexa* (Vahl) Panz. (Viper grass), *Echinochloa colonum* L. (barnyard grass), *Panicum repens* L. (quack grass) and *Digiteria sanguinalis* L. (large crab grass) among grasses; *Ageratum conyzoides* L. (Billygoat weed), *Digera arvensis* L. (false amaranth), *Physalis minima* L. (native gooseberry), *Commelina benghalensis* L. (benghal dayflower), *Abutilon indicum* L. (Indian mallow), *Portulaca oleracea* L. (common purslane), *Parthenium hysterophorus* L. (congress grasss) and *Trianthema portulacastrum* L. (desert horse purslane) among broad-leaved weeds (BLW); and *Cyperus rotundus* L. (purple nut sedge) and *Cyperus iria* L. (rice flat sedge) among sedges.

Jat *et al*. (2019) reported that the major weed flora present in the experimental fields was categorized into grassy weeds [*Echinochloa colona* (L.) Link., *Leptochloa chinensis* (L.) Nees, *Brachiaria reptans* (L.) C.A. Gardner & C.E. Hubb, *Eragrostis tenella var. japonica* (Thunb.) and *Panicum repens* L.; broadleaf weeds (*Physalis minima* L., *Digera arvensis* (L.) Mart., *Celosia argentea* L., *Caesulia axillaris* Roxb. and *Phyllanthus niruri* L. and sedges (*Cyperus rotundus* L. and *Fimbristylis miliacea* (L.) Vahl.]. Weeds like *C. rotundus*, *F. miliacea*, *L. chinensis* L. and *Cynodon dactylon* (L.) Pers. dominated in DSR, and *E. colona* in PTPR while conducting an experiment to evaluate integrated weed management options that included transplanted rice under puddled and unpuddled conditions, zero till DSR with or without residue retention and cover crops, zero till transplanted rice (ZTTPR); different combination of herbicides with or without cover crops.

Nagarjun *et al*. (2019) found out that the predominant category of weed observed in the experimental field which conducting a field trial to study the effect of different herbicide combinations and weed management methods on yield, energetics and economics of dry direct-seeded rice was broad leaved followed by grasses and sedges. Among the weed species, the densities of *Cyperus rotundus*, *Cynodon dactylon*, *Digitaria marginata*, *Ageratum conyzoides*, *Commelina benghalensis* and *Alternenthra sessilis* were more than other weed species.

Soujanya *et al*. (2020) conducted an experiment and reported that weed flora observed in the experimental plot were *Trianthema portulacastram*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Digera arvensis*, *Corchorus capsularis*, among broad leaved weeds. *Echinocloa colona* was the dominant weed among grasses and *Cyperus rotundus* was the major sedge. The broad leaved weeds were dominant weeds compared to grasses and sedges.

Choudhary and Dixit (2021) evaluated the sequential applications of pre- and post-emergence herbicides for broad-spectrum weed management options in dry direct-seeded rice where the study revealed that the common weed species found at the study site comprised sedges, for instance, *Cyperus iria* (L.), *Cyperus compressus* (L.), *Cyperus rotundus* (L.), *Fimbristylis miliacea* (L.), and important grasses such as *Digitaria ciliaris* (Retz.) Koel, *Echinochloa colona* (L.) Link., *Dactyloctenium aegyptium* (L.) Willd., *Eleusine indica* (L.) Gaertn. *Leptochloa chinensis* and major broad-leaved weeds like *Celosia argentea*, *Alternanthera sessilis*, *Physalis minima*, *Ageratum conyzoides*, *Ludwigia octavalis*, *Protulaca oleracea*, *Phyllanthus niruri* (L.).

Malik *et al*. (2021) also observed similar type of weed flora in DSR under lateritic soil of West Bengal where it was found that the experimental field was infested with 14 weed species, out of which *Digitaria sanguinalis*, *Echinochloa colona* was the most predominant among Grasses, Alternanthera sessilis, *Heydiotis corymbosa*, *Spilanthes acmella*, *Ludwigia parviflora*, *Cyanotis axillaris*, *Hydrolea zelylanica* among broadleaved and *Cyperus iria* and *Cyperus compressus* among sedges.

Sen *et al*. (2021) carried out a field experiment to evaluate the combinations of pre-emergence (~PE) and post-emergence (~PoE) herbicides as sequential applications, and their impacts on weeds, crops, economics, water productivity, and major nutrients-use efficiencies in dry direct-seeded rice. The weed species in the experimental field were *Echinochloa colona* (L.) Link., *Echinochloa crusgalli* (L.) Beauv., *Leptochloa chinensis* (L.) Nees., *Dactyloctenium aegyptium* (L.) Willd./Beauv., *Digitaria sanguinalis* (L.) Scop. (Grassy weeds); *Eclipta alba* L., *Digera arvensis* Forsk., *Trianthema portulacastrum* L. (Broad-leaved weeds); and *Cyperus rotundus* L., *Cyperus iria* L. (Sedges). *Echinochloa crusgalli* and *Eclipta alba* were more dominant weeds.

Jaiswal and Duary (2023) reported that direct-seeded rice was infested with *Digitaria sanguinalis* (L.) Scop., *Echinochloa colona* (L.) Link, *Paspalum notatum* Flüggé among the grasses; *Eclipta alba* (L.), *Spilanthes calva* DC., *Ludwigia parviflora* (Jacq.) Raven, *Alternanthera philoxeroides* (Mart.) Griseb. and *Oldenlandia corymbosa* (L.) among broad-leaved; *Cyperus iria* (L.) and *Fimbristylis miliacea* (L.) Vahl among sedges and *Cyanotis axillaris* D. Don ex Sweet (monocot).

Kokilam *et al*. (2023) conducted an experiment on the tittle weed dynamics and productivity of direct wet seeded rice under different weed management practices. The result showed that the weed flora of the experimental field was composite in nature consisting of grasses, sedges and broad-leaved weeds

(BLW). The major grassy weeds were *Echinochloa crusgalli* (L.), *Echinochloa colona* (L.) and *Cynodon dactylon* (L.) and common sedges included *Cyperus rotundus* (L.) and *Cyperus iria* (L.). Among the BLW, *Eclipta alba* (L.) and *Ammania baccifera* (L.) were the dominant species in direct wet seeded rice ecosystem.

Toppo *et al*. (2023) carried out an investigation to study effect of sowing time and weed management practices on weed dynamics, productivity and economics of direct-seeded rice and revealed that *Echinochloa colona* among grasses, *Commelina benghalensis* and *Alternanthera sessilis* among broad leaved and *Cyperus rotundus* among sedges were predominant weed species in the experimental site during both the years.

Paul *et al*. (2023) conducted a field experiment to evaluate the application of pre-emergence, early post-emergence and post-emergence herbicides using drone and knapsack sprayer to assess the weed control efficiency in direct-seeded rice and found that the experimental site was dominanted with weed flora consisted of *Echinochloa colona*, *Echinochola crugalli*, *Leptochloa chinensis*, *Cyperus difformis*, *Bergia capensis*, *Ludwigia parviflora* in both seasons. *Monochoria vaginalis* was found in *kharif* season and *Ammannia baccifera* and *Eclipta alba* were found in *rabi* season.

Puniya *et al*. (2023) carried out an investigation to study the sequential application of herbicides for weed management in direct-seeded basmati rice. The experimental field was dominated by *Echinochloa* spp. and *Digitaria sanguinalis* amongst grassy weeds; *Caesulia axillaris* and *Physalis minima* amongst broad-leaved weeds and *Cyperus difformis* and *Cyperus iria* amongst sedges. Beside these major weeds, *Commelina benghalensis*, *Cucumis* spp., *Euphorbia* spp. and *Dactyloctenium aegyptium* were recorded as other weeds.

Bagale and Sah (2024) evaluated the effect of weed management practices on weeds in spring rice and observed that the experimental field was among the

8 most prominent weeds identified, 3 were BLW (*Sphenoclea zeylanica*, *Ammannia coccinea*, and *Ludwigia perennis* belonging to family *Sphenocleaceae*, *Lathyraceae*, and *Onagraceae*, respectively), 3 were grasses (*Echinocloa colona*, *Echinocloa crusgalli* and *Digitaria sanguinalis* belonging to family *Poaceae*), and 2 were sedges (*Cyperus iria* and *Fimbrystylis miliacea* belonging to family *Cyperaceae*).

2.2 Importance value index of rice

Sinha (2017) conducted an experiment to study of biodiversity and to assess the phytosociological studies of weed species under direct dry seeded rice system. It was revealed that the highest IVI value was recorded with *Echinocloa colona*, *Cyperus iria* and *Cyperus flavidus* indicating the most dominant among the observed weed community. The lowest IVI values represented by *Cyanodon dactylon*, *Digitaria sanguinalis*, *Eclipta prostrata*, *Ipomea aquatica* reflects that they are the rarest species in the weed community. Thus, *Echinocloa colona* was the dominant weed species of the concerned study site. The IVI value ranged between 1.2 to 45.4%.

Kavitha *et al*. (2018) carried out a field trial to evaluate the phytosociological study of weeds and to estimate the dominant of weed flora in low land rice eco-system under varying climatic condition and concluded that *Cyperus rotundus* was the predominant weed species with highest important value index (IVI) of 45.50 and 45.63 per cent, respectively.

Haris *et al*. (2019) conducted an experiment to analyze the community structure of weed rice in 8-week-old and revealed that the highest important value index (IVI) was *Echinochloa colonum* (L) Link and the lowest were *Leptochloa chinensis* (L.) Nees, *Cyperus sanguinolentus* Vahl, *Portulaca oleracea* L and *Physalis angulata* L.

Sah *et al*. (2020) carried out a field trial to investigate weed flora diversity in rice crop during *Kharif* season of 2020-21 in four development blocks and concluded that Importance Value Index (IVI) of *Monochoria vaginalis* was 44.53 and 44.45 at Naraini and Mahua blocks, respectively. While, IVI value of *Scirpus muritimus* was 85.78 at Badokhar Khurd and IVI value of *Caesulia axillaris* at Baberu block was 40.96.

Kastanja *et al*. (2021) carried out an investigation aimed at examining the weed diversity in upland rice area and revealed that there are 21 weed species of 11 families. Weed's Importance Value Index (IVI) at station 1 was *Borreria laevis* (Lamk), *Brachiaria mutica* (Forsk.) Stapf, *Borreria latifolia* (Aubl.) K. Sch., and *Phyllanthus niruri* L., while the dominant weeds at station 2 were *Paspalum commersonii* Lamk (IVI 6.93) and *Ottochloa nodosa* (IVI 4.82), and at stations 3 and 4 the highest was *Imperata cylindrica* Beauv, (IVI 38.16 and 35.81).

Kaushal *et al*. (2023) conducted a field study to to find out the most important and dominant weeds in direct seeded rice cultivation of village Kureli, block Takhatpur Bilaspur district Chhattisgarh. Results revealed that on the basis of importance value index the most dominant weeds were *Echinochloa colona* (L.) Link , *Cyperus iria* L. *Paspalum scrobiculatum* L., *Cyperus difformis* L., *Alternanthera tenella* Colla *Fimbristylis miliacea* (L.) Vahl, *Ischaemum rugosum* Salisb, *Cynodon dactylon* (L.) Pers., *Ammannia baccifera* L. and *Ludwigia perennis* Burm.f. in the study area.

2.3 Effect of tillage practices on weeds

Govindan and Chinnusamy (2014), reported higher weed density and dry weight in zero tillage system while significantly lower total weed density, weed seed count recorded in transplanted rice with conventional tillage.

Upasani *et al.* (2014) reported that tillage methods significantly affected the population and dry matter of weeds in rice. Continuous conventional tillage in rice recorded 65.32 % reduction in weed population 30 and 60 days after sowing (DAS), respectively, than the continuous zero tillage.

Singh *et al.* (2014) reported that zero tillage resulted in higher weed densities of most of the weed species studied. Tillage treatment did not affect biomass accumulation of sedges and grasses, while broadleaved weeds had higher biomass under zero tillage.

Banjara *et al.* (2017) concluded that significantly lowest weed density, biomass and weed growth rate across all the growth stages under zero tillage (ZT) direct drilling of seeds and fertilizers at 2 days after harvesting (DAH) of rice as compare to other tillage practices.

Surin *et al.* (2019) revealed from the study that conventional tilled rice after conventional tilled wheat had a greater number of total weeds (537.6, 321.6 and 199.7 m^{-2} at 30, 60 and 90 DAS respectively) and interestingly less total weed dry matter (53.5, 46.7 and 33.3 g m^{-2} at 30, 60 and 90 DAS, respectively) than rice grown after zero tilled wheat.

Marasini *et al.* (2020) performed an experiment to evaluate tillage methods and weed management practices on weed dynamics and yield of DDSR. The result revealed that the weed density at each observation was not influenced by tillage methods, and was found to be higher in zero tillage while the total weed dry weight was influenced by different tillage system. At 30 DAS weed dry weight at zero tillage was significantly higher but at 15, 45 and 60 DAS weed dry weight was not influenced by tillage methods but the weed dry weight was found to be higher in zero tillage.

Mishra *et al.* (2022) executed a field trial to assess the effect of different tillage intensities and crop rotations on the weed population dynamics in rice-based cropping systems. The result obtained from the trial showed that conventional tillage in rice-maize crop rotation had the minimum total weed density (352 m^{-2}) whereas reduced tillage with 30% anchored crop residue in rice-wheat rotation had the maximum total density (2049 m^{-2}) and dry matter of weeds (270.6 g m^{-2}). The minimum total weed dry matter (187.6 g m^{-2}) was recorded with RT +30% anchored crop residue in rice-maize rotation.

Sapre *et al.* (2022) conducted an experiment to evaluate the effect of tillage and weed management on weed dynamics and yield of rice in rice-wheat-greengram cropping system in vertisols of central India. Results showed that the maximum weed density and biomass were found with zero tillage in rice in the presence of *Sesbania* (S) and greengram residues (ZT+ S+ GG); under zero tillage in rice in the presence of *Sesbania* and green gram residues-zero tillage in wheat in the presence of rice residues- zero tillage in greengram in the presence of wheat residues system while the minimum was recorded with conventional tillage was done in transplanted rice under CT(TPR)-CT(W)-fallow system and it also recorded the highest weed control efficiency.

2.4 Effect of tillage practices on growth, yield attributes and yield of rice

Ujoh and Ujoh (2014) in a study to find out which tillage methods and practices performed better for higher growth and yield of rice, recorded that zero tillage (ZT) had the highest average plant height of 78.8 cm, 16 numbers of tillers produced and higher grain yield of 1500 kg ha^{-1} under granular applied fertilizers.

Singh *et al.* (2014) reported that zero tillage resulted in higher weed densities of most of the weed species studied. Result showed that grain yield was significantly higher in the conventional tillage system (2.40–3.32 t ha^{-1}), because of lesser weed pressure, than in zero tillage (2.08–2.73 t ha^{-1}). It also recorded the highest number of tillers m^{-2} as well as biological yield during both the years.

Upasani *et al.* (2014) revealed that different tillage sequences and weed-control methods had a significant effect on yield and yield-attributing parameters. Effective tillers (266 m^{-2}), grains $panicle^{-1}$ (48), 1000-seed weight (23.60 g), grain yield (1.96 t ha^{-1}) and straw yield (2.86 t ha^{-1}) were maximum in CT-CT (conventional tillage-conventional tillage) sequence.

Surin *et al.* (2019) concluded that conventionally tilled rice produced 14.6%higher productive tillers; 3.0 % higher panicle length; 9.3 % higher filled grain; resulting 25.5 % higher grain (3.0 t ha^{-1}) and 27.9 % higher straw yield (4.2 t ha^{-1}) compared to zero tilled rice (2.4 t ha^{-1} grain and 3.2 t ha^{-1} straw).

Mukherjee (2019) performed an experiment to evaluate the effect of various crop establishment methods and herbicides on growth and yield of rice. Study concluded that highest plant height, number of tillers per hill, effective tillers m^{-2}, test weight and straw yield were obtained with conventional till rice.

Marasini *et al.* (2020) performed an experiment to evaluate tillage methods and weed management practices on weed dynamics and yield of DDSR and observed that grains per panicle (157) in conventional tillage were significantly higher and between tillage methods, conventional method had produced higher grain yield even though there was no significant influence of tillage methods on grain yield of rice.

Pandey and Kandel (2020) reported that tillage system significantly affected effective tiller number in individual years where conventional tillage (CT) system had significantly more effective tillers than in zero tillage (ZT) system with higher grain yield (4.8 t ha^{-1}) of rice than ZT (4.4 t ha^{-1}). While panicle (ear-head) length (21.9 cm), number of grains $panicle^{-1}$ (133.8) and weight of 1000 grain $panicle^{-1}$ (21.6 g) were significantly higher in zero tillage.

Saini *et al*. (2022) carried out an experiment to study the effect of different tillage system and varieties on yield of rice. It was found that conventional tillage recorded taller plants (124.50 cm), higher dry matter accumulation (858.49 gm^{-2}), higher value of absolute growth rate, crop growth rate and relative growth rate which was followed by minimum tillage without residue. It also concluded that significantly greater number of grains $panicle^{-1}$ and panicle length were recorded in conventional tillage while minimum tillage with residue retention recorded lower values of number of grains per panicle and panicle length. In terms of yield, conventional tillage produced much higher grain yield, straw yield, and biological yield and was at par with minimum tillage without residue.

2.5 Effect of stale seedbed on weeds

Sindhu *et al*. (2010) concluded that adoption of stale seedbed either 7 days or 14 days significantly control grasses during the first year and greatly reduced their number during the second year. It had also same effect on the broadleaf weeds but no significant effect was observed on the number and dry weight of sedges at 20 DAS between normal seedbed and stale seedbed plots.

Ameena (2015) conducted a trial and stale seedbed treatments with weed killers resulted in reduction in weedy rice plant density to the tune of 39.83% to 63.72% during first year and 58.27 to 76.99% during second year.

Sangra *et al.* (2018) performed an experiment and revealed that significantly lower weed intensity (3.89 m^{-2}) was recorded under bispyribac sodium salt @ 250 ml a.i. ha^{-1} POE at 15 DAS + 1 Hand weeding at 30 DAS followed by stale seed bed technique followed by bispyribac sodium salt @ 250 ml a.i. ha^{-1} POE at 15 DAS and bispyribac sodium salt @ 250 ml a.i. ha^{-1} POE at 15 DAS registered reduce the weed density.

Singh *et al.* (2018) revealed that at sowing both stale seedbed with glyphosate @ 1 kg ha^{-1} and stale seedbed with shallow (5 cm) tillage significantly decreased the viable seedbank of *Echinochloa colona* and *Dactyloctenium aegyptium* by 25-30 % of that without a stale seedbed. At 20 DAS, both the stale seedbed methods had 22- 51 % lower density of *Cyperus* *rotundus* and 42- 67 % less grass weeds than rice sown without stale seedbed. After harvest both the stale seedbed treatments had a significantly lower seedbank than that without a stale seedbed by 13-33 %.

Habimana *et al.* (2019) reported that under aerobic rice cultivation, stale seedbed technique *fb* bispyribac sodium 10 % SC at 30 ml ha^{-1} *a.i.* as early PoE with one IC at 40 DAS recorded significantly lower weed count and lower weed dry weight at 30 DAS (11.50 and 0.53 gm^{-2}), 60 DAS (31.33 and 8.61 g m^{-2}) and at 90 DAS (38.33 and 28.0 gm^{-2}) and lowest weed index (3.80 %) followed by straw mulch at 6 tonnes per hectare *fb* bispyribac sodium 10% SC at 30 ml per hectare *a.i.* as PoE at 30 DAS (15.67 and 0.71 gm^{-2}), 60 DAS (35.33 and 9.86 gm^{-2}) and at 90 DAS (42.17 and 30.00 gm^{-2}) and weed index (4.14 %).

Ravikiran *et al.* (2019) from the study revealed that stale seedbed method recorded significantly lower weed population, total weed dry weight and higher weed control efficiency compared to no SSB (conventional) method at 30 and 60 DAS.

Senthilkumar *et al.* (2019) executed an experiment on stale seed bed techniques as successful weed management practice and reported that in dry direct seeded condition stale seed bed using glyphosate application @ 1 kg ha^{-1} was more effective in reducing the weed density and it recorded higher grain yield and B: C ratio than SSB using shallow tillage.

Bana *et al.* (2020) performed weed control and rice yield stability studies across diverse tillage and crop establishment systems under on-farm environments. The results obtained from the study revealed that DSR with residue (DSRR) coupled with pretilachlor as pre-emergence (PE) @ 0.75 kg ha^{-1} followed by bispyribac-sodium as post-emergence (POE) @ 0.025 kg ha^{-1} (PretBis) or cyhalofop butyl @ 0.060 kg ha^{-1} (PretCy) resulted in rice grain yield (5.38 t ha^{-1} and 5.33 t ha^{-1}) statistically at par with transplanted rice (TPR)-PretBis (5.30 t ha^{-1}) and TPR-PretCy (5.21 t ha^{-1}).

Dilipkumar *et al.* (2022) conducted an investigation to investigate the integration effects of pretilachlor, oxadiazon, and dimethenamid with or without glyphosate in a stale seedbed method to control weedy rice in wet-seeded rice. Results observed from the study showed that stale seedbed with glyphosate treatment conferred a greater reduction in weedy rice density and dry weight when compared to that observed in a stale seedbed without glyphosate. A stale seedbed with glyphosate increased rice dry weight by 11%, density by 6%, and grain yield by 7% compared to the rates observed under non-glyphosate treatment.

2.6 Effect of stale seedbed on crop

Sindhu *et al.* (2010) reported that stale seedbed technique brought about an increase in grain and straw yields than normal seedbed. The result revealed that during the two year experiment, higher grain yield of 7213 and 7157 kg ha-1 was produced by stale seedbed for 14 days, followed by stale seedbed for 7 days (6860 and 7052 kg ha-1).

Ameena (2015) reported that stale seedbed coupled with glyphosate application followed by wet ploughing the field and wet seeding recorded the lowest weedy rice population and highest rice yields of 1.70 and 1.71 t ha-1 during both the years.

Sangra *et al.* (2018) performed an experiment to evaluate the different weed management practice on growth and yield attributing characters of rice under direct seeded rice system. Result showed that among the weed control practices, Stale seed bed technique followed by bispyribac sodium salt @ 250 ml ha^{-1}. POE at 15 DAS was found the best for obtaining higher net profit (₹ ha^{-1} 34689.5) and benefit: cost ratio (1.40) in different weed management practices under direct seeded rice system.

Habimana *et al.* (2019) revealed that stale seedbed technique fb bispyribac sodium 10 % SC at 30 ml per hectare *a.i.* as early PoE with one IC at 40 DAS recorded the highest plant height (59.17 cm), panicle length (24.98 cm), productive tillers (41.58 hill^{-1}), total dry matter (151.30 g plant^{-1}), test weight (26.12 g), grain yield (5838 kg ha^{-1}), straw yield (9904 kg ha^{-1}), net return (₹ 61,782 ha^{-1}) and B: C ratio (2.54).

Ravikiran *et al.* (2019) concluded that stale seedbed method recorded higher panicle length (272.1 cm), spikelets per panicle (77.83), panicle per cent filled grains (84.99 %), thousand grain weight (27.44 g), grain yield (2.90 t ha^{-1}), compared to no stale seedbed method (conventional).

Dilipkumar *et al.* (2022) conducted an investigation to study the integration effects of pretilachlor, oxadiazon, and dimethenamid with or without glyphosate in a stale seedbed method to control weedy rice in wet-seeded rice. It was concluded that stale seedbed with glyphosate increased rice dry weight by 11%, density by 6%, and grain yield by 7% compared to the rates observed under non-glyphosate treatment.

2.7 Effect of chemical herbicides on crop and weeds

Walia *et al.* (2012) reported that pendimethalin 0.75 kg ha^{-1}applied as pre-emergence combined with bispyribac-sodium 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} as post-emergence resulted in yields that were 61.7 and 42.1% greater than pendimethalin 0.75 kg ha^{-1} applied alone.

Kumar *et al.* (2012) conducted a research trial to find out the most effective weed control method under different sowing dates in direct-seeded unpuddled rice and concluded that pendimethalin 1.0 kg ha^{-1} + anilophos 0.4 kg ha^{-1} applied as pre-emergence gave significantly higher grain yield than other weed control treatments due to more number of tillers per metre row length, 1000-grain weight and highest weed control efficiency (73 and 75%) during both the years of study.

Bhurer *et al.* (2013) concluded that among the weed control practices, application of pendimethalin (1 kg *a.i* ha^{-1}) *fb* 2,4-D @1 kg *a.i.* ha^{-1} at 25 and hand weeding 45 days after sowing was found the best for obtaining higher yield and weed control efficiency in DDSR. Among the herbicidal treatments, the use of pre-emergence pendimethalin 1 kg *a.i.* ha^{-1} *fb* 2,4-D 1 kg *a.i.* ha^{-1} at 25 DAS *fb* hand weeding 45 DAS produced maximum number of panicles per square meter (423.1 and 294.6), panicle weight (1.42 and 1.92 g), filled grains $panicle^{-1}$ (70 and 69), 1000 grain weight (24.89 and 21.68 gm), grain yield (4982 and 4061 kg ha^{-1}) and straw yield (6662 and 5499 kg ha^{-1}) in 2010 and 2011 respectively which were comparable to that of weed free treatment. Among herbicides, pre-emergence pendimethalin 1 kg *a.i.* ha^{-1} *fb* 2,4-D 1 kg *a.i.* ha^{-1} at 25 *fb* hand weeding 45 DAS yielded the minimum dry weed weight and weed density as compared to others.

Mahajan and Chauhan (2013) conducted an experiment to evaluate the efficacy of pre- emergence (pendimethalin and pyrazosulfuron) and post-emergence herbicides (bispyribac, penoxsulam, and azimsulfuron) applied either alone or in a sequence for weed control in dry-seeded fine rice cv. 'Punjab Mehak 1'. Results indicated that bispyribac sodium alone as post- emergence reduced the weed density by 52% and weed dry weight by 50%, whereas sequential application of pendimethalin *fb* bispyribac sodium had controlled 92% of weed density and 93% of weed dry weight. Result also revealed that the highest number of grains $panicle^{-1}$ (112) and number of panicles m^{-2} (261) and grain yield (4.99 t ha^{-1}) was recorded with the sequential application of pendimethalin @ 750 g a.i. ha^{-1} PRE followed by bispyribac-sodium @ 25 g a.i. ha^{-1} POST.

Nayak *et al.* (2014) reported that among different weed management practices, pre- emergence application of pendimethalin followed by post-emergence application of bispyribac-sodium or pre- emergence application of anilofos followed by post-emergence application of 2, 4-D sodium salt recorded significantly lower weed population (59.9 m^{-2}) at 20 DAS and highest weed control efficiency of 46.4 %.

Das *et al*. (2015) revealed that that post-emergence application of bispyribac sodium 10 % SC @ 30 g *a.i.* ha^{-1} followed by @ 25 g *a.i.* ha^{-1} gave significantly lower total weed density, weed dry weight and higher weed control efficiency at all the stages.

Mahajan and Chauhan (2015) carried out field experiments to study weed control in response to tank mixtures of herbicides currently applied in DSR in South Asia. Results revealed that sequential application of pendimethalin *fb* azimsulfuron, bispyribac, or fenoxaprop provided better weed control than the single application of any of these herbicides with highest weed control efficiency (98%) recorded with the tank mixture of azimsulfuron plus bispyribac plus fenoxaprop which was similar to the grain yield in the plots treated with the tank mix of pendimethalin (applied as pre-emergence) *fb* bispyribac sodium.

Kaur and Singh (2015) conducted a field experiment to study the bio-efficacy of different herbicides in direct-seeded rice. Result revealed that significantly lowest weed dry matter and highest weed control efficiency (100%) recorded with sequential application of pendimethalin @ 0.75 kg ha^{-1} and bispyribac sodium @ 0.025 kg ha^{-1}. The highest crop dry matter accumulation (1257.0 g m^{-2}), number of grains $panicle^{-1}$ (84.8), number of effective tillers m^{-2} (291.3) and grain yield (5.56 t ha^{-1}) were recorded with the same treatment as compared to the other herbicidal treatments. The highest net profit and B:C ratio (1.38) were realized from sequential application of pendimethalin and bispyribac sodium.

Kumaran *et al*. (2015) carried out an investigation to evaluate the herbicide (bispyribac sodium 10% SC) on weed control and their nutrient management in direct seeded lowland rice and revealed that early post emergence application of bispyribac sodium 10% SC 40 g ha^{-1} recorded lowest total weed density, lowest nitrogen, phosphorus and potassium removal by weeds, higher weed control efficiency, highest grain yield (5058 kg ha^{-1}) and harvest index (0.59). Different weed management practices imposed on rice crop did not affect the germination of succeeding green gram.

Raghavendra *et al*. (2015) conducted an experiment to ascertain the efficacy of different weed management practices on growth and yield of direct wet seeded rice (DWSR) sown through drum seeder. Based on the result, it was reported that among the herbicides bispyribac sodium @ 25 g *a.i.* ha^{-1} at 25 DAS as post emergence not only reduced population (2.89 No. m^{-2}) and dry weight of weeds (3.43 g m^{-2}) with high weed control efficiency at 60 and 90 DAS (82.48 and 71.29%) but also increased the grain yield (5367 kg ha^{-1}) of rice with the concomitant increase in the yield attributes (number of panicles per meter square, panicle length and filled grains per panicle 489, 21.28 cm and 103 respectively).

Kaur and Singh (2016) conducted a field experiment to study the effect of various establishment methods and weed-control treatments on weeds, crop growth, yield attributes and yield of rice (*Oryza sativa* L.). Based on the study, it was revealed that the maximum grain yield (6.7 t ha^{-1}) was recorded under weed-free treatment which was statistically at par with sequential use of pendimethalin 0.75 kg ha^{-1} with bispyribac 0.025 kg ha^{-1} (6.6 t ha^{-1}) or azimsulfuron 0.02 kg ha^{-1} (6.5 t ha^{-1}). Among the herbicide treatment, sequential use of pendimethalin 0.75 kg ha^{-1} with bispyribac 0.025 kg ha^{-1} recorded maximum plant height (96.0 cm), tillers m^{-2} (303.9), effective $tillers^{-2}$ (286.6), grain $panicle^{-1}$ (95.0) and lowest weed biomass.

Kumari *et al*. (2016) reported that pendimethalin 750 g ha^{-1} *fb* bispyribac 25 g ha^{-1}recorded significantly higher grain yield of 54.02 q ha^{-1} than pendimethalin (44.94 q ha^{-1}) and bispyribac (35.86 q ha^{-1}) alone because of less weed density and dry matter of grasses, sedges and broadleaf weeds. Interaction effect of rice + BM of *Sesbania* (4 WAS) with pendimethalin 750 g ha^{-1} *fb* bispyribac 25 g ha^{-1}recorded significantly higher growth parameters, yield attributes and grain yield of rice (59.68 q ha^{-1}) as compared to rest of the treatment combination.

Rana *et al.* (2016) carried out a research trial to evaluate the efficacy of herbicide combinations for weed management on weeds, crop and economics in direct-seeded rice. Result revealed that pendimethalin *fb* bispyribac *fb* manual weeding recorded the lowest weed density, dry weight, weed index and highest grain yield during the three years of the experimentation.

Singh *et al.* (2016b) conducted a field trial at Madhuban and Taraori in Karnal district of Haryana to evaluate pre-emergence (PRE) and post-emergence (POST) herbicides for providing feasible and economically viable weed management options to farmers for predominant scented dry seeded rice varieties. The result revealed that maximum weed biomass reduction was observed with the sequential application of pendimethalin PRE *fb* bispyribac-sodium *fb* azimsulfuron POST at 45 DAS (22.5 and 7.6 g m^{-2}) at Madhuban and Taraori. Application of bispyribac-sodium after pendimethalin PRE provided significantly higher returns over variable cost (1744) and B:C (4.0) at Taraori.

Soren *et al.* (2017) carried out a field trial to study the bio-efficacy and phytotoxicity of Bispyribac Sodium 10% SC on direct seeded rice cv. IET 9947 in West Bengal. Based on the experimentation, it was found that post-emergence application of bispyribac sodium 10% SC @ 30 g a.i. ha^{-1} followed by @ 20 g a.i. ha^{-1} gave significantly lower total weed density, weed dry weight and higher weed control efficiency at all the stages. Considering net production value (NPV), application of bispyribac sodium 10% SC @ 30 g a.i. ha^{-1} can be recommended to the farming community.

Yogananda *et al.* (2017) conducted an investigation to study the effect of weed management practices in wet direct-seeded rice (*Oryza sativa* L.). Result revealed that pre-emergence application of bensulfuron-methyl + pretilachlor GR at 660 g ha^{-1} *fb* bispyribac-sodium at 25 g ha^{-1} at 20 DAS significantly reduced weed growth and recorded the higher grain yield (4.80 t ha^{-1}) and it was at par with sequential application of pendimethalin at 1.0 kg ha^{-1} *fb* postemergence application of bispyribac-sodium, pre-emergence application of bensulfuron-methyl + pretilachlor, application of pendimethalin as pre-emergence *fb* 1 HW. Uncontrolled weed growth caused 55.2% reduction in seed yield of wet seeded rice.

Baghel *et al.* (2018) carried out a study to evaluate the effects of weed control options on weed interference, microbial activity and direct-seeded rice productivity in a conservation agriculture-based rice–wheat cropping system. Study revealed that the sequential applications of pendimethalin @ 1.5 kg ha^{-1} *fb* bispyribac-Na @ 25 g ha^{-1} at 25 DAS/ DAT resulted in better control of weeds and higher weed-control efficiency (WCE), but this combination with 1 hand-weeding (HW) at 45 DAS resulted as the best resulted in significantly higher grain, straw and total biological yields of rice followed by applications of pendimethalin @ 1.5 kg ha^{-1} *fb* bispyribac-Na @ 25 g ha^{-1}.

Dhanapal *et al.* (2018) conducted a field trial to study the effect of various weed management practices on weed density, weed dry weight, yield and economics of direct seeded rice. Result from the study revealed that among the various treatments, three hand weeding (20, 40 and 60 DAS) recorded significantly higher rice grain (4.04 t ha^{-1} and 3.64 t ha^{-1}) and straw (6.3 t ha^{-1} and 6.52 t ha^{-1}) yields in both the years of the study and it was at par with pendimethalin 1.0 kg ha^{-1} at 2 DAS *fb* bispyribac sodium 25 g ha^{-1} *fb* manual weeding (3.87 t ha^{-1}, 6.0 t ha^{-1} and 3.5 t ha^{-1} and 6.4 t ha^{-1} respectively).

Rolaniya *et al.* (2018) carried out an experiment to study the influence of irrigation scheduling and weed management practices on weed density and performance of dry direct seeded rice and revealed that the applications of pendimethalin 1 kg a.i. ha^{-1} at 3 DAS followed by bispyribac sodium 25 g a.i. ha^{-1} at 25 DAS effectively controlled weed of all the species. It also recorded higher panicle length (25.43 cm), test weight (24.08 g), tiller density produce (363.14) and similar yield (6.32 t ha^{-1}) as weed free (6.67 t ha^{-1}).

Usman *et al.* (2018) carried out an experiment to study the comparative bio-efficacy of different weedicides and cultural practices against grasses, sedges and broad-leaf weeds in direct seeded rice. Study revealed that pre-emergence application of pendimethalin along with spray of fenoxaprop-p-ethyl and bispyribac sodium at 22 DAS lowered down the weed population at maximum from 125 m^{-2} to 11.50 m^{-2} as compared to rest of the treatments. Likewise, one stale bed technique with spray of glyphosate 15-20 days before seeding and bispyribac sodium at 22 DAS decreased the weed density from 130.5 m^{-2} to 17.20 m^{-2} in the observed field areas.

Nagarjun *et al*. (2019) conducted a field trial to study the effect of different herbicide combinations and weed management methods on yield, energetics and economics of dry direct-seeded rice and concluded that effective control of weeds was observed at 90 DAS with application of bensulfuron-methyl + pretilachlor (60 + 600 g ha^{-1}) as pre-emergence *fb* bispyribac sodium (25 g ha^{-1}) at 25 DAS recording reduced weed density and dry weight due to broader spectrum of effective herbicides on major weed flora apart from hand weeding.

Dangol *et al.* (2020) reported that the plot treated with bispyribac sodium 10 % SC recorded a significantly higher number of effective tillers m^{-2} and grains $panicle^{-1}$ at 90 DAS while it recorded the lowest weed density (9.17 weeds m^{-2}) at 60 DAS and was found statistically superior in terms of grain yield (6.97 tons ha^{-1}), straw yield (7.78 tons ha^{-1}) and harvest index (47.29 %).

Marasini *et al.* (2020) performed an experiment to evaluate tillage methods and weed management practices on weed dynamics and yield of DDSR and revealed that higher grain yield of DDSR were obtained with application of pendimethalin *fb* hand weeding (3,742 kg ha^{-1}); pendimethalin *fb* bispyribac-Na (3,552 kg ha^{-1}), and pendimethalin *fb* tank mixture application of bispyribac-Na and ethoxysulfuron (3,638 kg ha^{-1}).

Pavithra *et al.* (2021) conducted a field experiment to evaluate the weed management efficacy of sequential application of pendimethalin and bispyribac-sodium in aerobic rice. *Echinochloa colona* (28.1%), *Ludwigia abyssinica* (28%) and *Cyperus difformis* (19.8%) among grasses, broad-leaved weeds and sedges, respectively were the predominant in the experimental field. Among the weed control treatments, pendimethalin 1.0 kg ha^{-1} at 3 DAS *fb* bispyribac-sodium 30 g ha^{-1} at 30 DAS was found to be effective recording lowest weed density and biomass and superior growth attributes, yield attributes and yield of rice (4.86 t ha^{-1}).

Choudhary and Dixit (2021) conducted an experiment to evaluate the sequential applications of pre- and post-emergence herbicides for broad-spectrum weed management options in dry direct-seeded rice. Based on the result, it was revealed that sequential application of pendimethalin @ 1000 g ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} is recommended along with need-based application of post-emergence herbicides (fenoxaprop @ 60 g ha^{-1} + chlorimuron + metasulfuron @ 4 g ha^{-1}) or one hand weeding resulted in lowest weed density, weed dry weight, improve the weed control efficiency and provides economically higher productivity resulting from higher number of panicle m^{-2}, grains $panicle^{-1}$ and grain yield in DDSR.

Naganjali *et al.* (2021) conducted a field trial to evaluate the effect of nutrient and weed management under semi dry rice in sandy clay loam soil. Based on the study, it was revealed that under weed management sub plots, bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4- D 80 WP 0.5 kg ha^{-1}) + HW at 50 DAS enhanced grain (4845 kg ha^{-1}), straw output (5436 $kgha^{-1}$) and harvest index (47.1%).

Mitra *et al*. (2022) conducted an experiment to study the efficacy of pre- and post-emergence herbicide combinations on weed control in no-till mechanically transplanted rice. Based on the result it was revealed that among the herbicidal treatments, the combination of bispyribac-sodium (10%SP) + pyrazosulfuron (10%WP) was found to be the most effective in controlling all weed flora at both 35 and 55 DAT. The sequential application of pendimethalin (pre-emergence) followed bispyribac-sodium + pyrazosulfuron (post-emergence) resulted in significantly higher rice grain yield (4.4 t-ha^{-1}) and relative gross-margin (417 USD-ha^{-1}) than all other treatments. Maximum WCE (e.g. 78.85% and 74.62% at 35 and 55 DAT, respectively) was achieved with the sequential application of any of the three pre-emergence herbicides followed by bispyribac + pyrazosulfuron as a post-emergence herbicide.

Shah *et al*. (2021) performed a field trial to assess the effect of various combinations of herbicides mixture under seedbed preparation to evaluate different attributes of weed control efficiencies (WCE) coupled with grain yield and economics of DDSR. The result of the experiments revealed lower weed intensity (WI) and higher weed control efficiency (WCE), net return and benefit-cost (B:C) ratio with pendimethalin *fb* tank mixture of bispyribac sodium and ethoxysulfuron in both the years. Grain yield was significantly higher with weed free treatment followed by pendimethalin *fb* tank mixture of bispyribac sodium and ethoxysulfuron in both the years due to higher WCE and lower WI which resulted in better growth and development of DDSR.

Jaiswal and Duray (2023) conducted an experiment to evaluate the impact of different tillage and herbicides on the nutrient removal by weeds and productivity of direct-seeded rice (DSR) and the result showed that sequential application of oxadiargyl *fb* fexoxaprop-p-ethyl + ethoxysulfuron, oxadiargyl *fb* penoxsulam + cyhalofop-butyl, oxadiargyl *fb* bispyribac-sodium and pendimethalin fb bispyribac sodium recorded the lowest total weed biomass.

Toppo *et al*. (2023) carried out a field trial to study effect of sowing time and weed management practices on weed dynamics, productivity and economics of direct-seeded rice. The results revealed that late sowing of DSR on 20th July and post emergence application of bispyribac sodium 25 g ha^{-1} had lesser weed density; weed dry weight and higher weed control efficiency (56.42% and 66.19%) among all other treatments.

Swain *et al*. (2023) conducted an experiment to study the effect of fertility levels and weed management practices on weed dynamics, yield and economics of transplanted rice. The study revealed that the post emergence application of bispyribac sodium @ 25 g ha^{-1} recorded significantly lower number of weed population due to the intrinsic efficiency of herbicide and was found to be more efficient and recorded reduction in weed dry weight (1.17, 1.56, 1.72 and 0.91 g m^{-2} at 30, 50, 70 DAT and harvest, respectively) and registered maximum weed control efficiency (90.83% and 92.13% at 30 and 50 DAT respectively) than all other treatments because of least dry matter production of the weeds over weed check treatment. It further concluded that significantly higher grain (3.22 t ha^{-1}), straw yield (4.35 t ha^{-1}) and higher harvest index of 42.48% were also registered with post emergence application of bispyribac sodium @ 25 g ha^{-1}.

Paul *et al*. (2023) conducted a field experiment on the title drone-based herbicide application for energy saving, higher weed control and economics in direct-seeded rice (Oryza sativa). Study demonstrated that drone application of pre-emergence pretilachlor followed by post-emergence bispyribac sodium significantly reduced the weed density, weed dry weight and recorded the highest grain and straw yields in DSR and application of pretilachlor followed by bispyribac sodium through drone might be recommended to obtain higher productivity with more remunerative energy and income in direct-seeded rice.

Pant *et al*. (2023) carried out to evaluate the effect of herbicide application on weed density and yield of wet-direct seeded spring rice. Results observed from the study showed that among all sequential application, pendimethalin *fb* bispyribac sodium (119.3 m^{-2} and 124.33 m^{-2}) and butachlor *fb* bispyribac sodium (129.3 m^{-2} and 148.0 m^{-2}) were better and reduced weed density higher than other sequential application at 30 DAS and 90 DAS, whereas at 60 DAS, the highest reduction in total weed density was observed in pretilachlor *fb* 2,4-D EE (90.0 m^{-2}) and butachlor *fb* bispyribac sodium (93.0 m^{-2}). The highest number of effective tillers m^{-2}, grains $panicle^{-1}$ and grain yield were observed in sequential application of pendimethalin followed by bispyribac sodium and was statistically similar with weed free plot. Significantly lower weed index was obtained in pendimethalin *fb* bispyribac sodium.

Puniya *et al*. (2023) carried out and investigation to study the sequential application of herbicides for weed management in direct-seeded basmati rice. Result from the study revealed that significantly lowest weed density and biomass and highest weed control efficiency was noticed in pendimethalin 1000 g ha^{-1} as PE *fb* bispyribac-sodium 25 g ha^{-1} at 25 DAS herbicidal treatment. It also recorded the highest grain yield (2.67 t ha^{-1} and 2.57 t ha^{-1}) and straw yield (5.52 t ha^{-1} and 5.48 t ha^{-1}) which was also found to be statistically at par with pretilachlor 600 g ha^{-1} as pre-emergence *fb* penoxsulam + cyhalofop-butyl 150 g ha^{-1} at 25 DAS for both grain yield (2.45 t ha^{-1} and 2.39 t ha^{-1}) and straw yield (4.91 t ha^{-1} and 4.86 t ha^{-1}).

2.8 Effect of tillage and weed management on energy analysis

Mishra and Singh (2011) carried out a field experiment to study the effect of tillage and weed control on weed dynamics, productivity and energy-use efficiency of various oilseeds and pulses grown in rice (*Oryza sativa* L.)-based systems. Results revealed that pre-emergence application of pendimethalin 1.0 kg ha^{-1} significantly reduced the dry biomass of all weeds except common vetch. It further outlined that the total operational energy input was higher in conventional tillage than zero tillage due to consumption of higher energy in field preparation and the maximum energy productivity was obtained under zero tillage in all the crops due to energy saving in field preparation. Use of pendimethalin for weed control enhanced the output energy in all the crops.

Kaur and Singh (2016) conducted a field experiment to study the effect of various establishment methods and weed-control treatments on weeds, crop growth, yield attributes and yield of rice (*Oryza sativa* L.) and revealed that energy-use efficiency (5.37) and energy productivity (0.37 kg MJ^{-1}) were more with sequential application of pendimethalin 0.75 kg ha^{-1} *fb* bispyribac 0.025 kg ha^{-1}.

Lal *et al*. (2016) carried out an experiment to assess the energy budgeting of weed management in soybean cultivation and revealed that sequential application of pendimethalin 750 g ha^{-1} PE *fb* imazethapyr 100 g ha^{-1} at 20 DAS was found to be the most energy efficient weed management strategy and had maximum value of total output energy (71.90 x 10^{3} MJ ha^{-1}) and net energy returns (62.32 x 10^{3} MJ ha^{-1}).

Kumar *et al*. (2017) conducted a field experiment to find out the effect of different tillage practices and weed management practices on energy analysis (input-output) of wheat. The result revealed that energy consumption in terms of energy input was recorded maximum under conventional tillage with weed free situation (21704 MJ ha^{-1}) and the lowest energy input was recorded under zero tillage with weedy (19021 MJ ha^{-1}) which was followed by zero tillage with sulfosulfuron 25 g ha^{-1}. Energy output, net energy return and energy use efficiency were maximum in case of zero tillage plots closely followed by application of pinoxaden 50 g ha^{-1} *fb* MSM 4 g ha^{-1}, readymix application of clodinofop 60 g + MSM 4 g ha^{-1} and clodinofop 60 g *fb* MSM 4 g ha^{-1}.

Nagarjun *et al*. (2019) conducted a field experiment to study the effect of different herbicide combinations and weed management methods on yield, energetics and economics of dry direct-seeded rice. It was concluded that among the various herbicide combinations, sequential application of bensulfuron-methyl + pretilachlor as pre-emergence *fb* bispyribac-sodium was found to be the most energy and economically efficient weed management strategy in dry direct-seeded rice and had maximum value of total output energy (169090 MJ ha^{-1}), net energy returns (157444 MJ ha^{-1}), energy use efficiency (14.52), net returns (₹ 59,276 ha^{-1}) and benefit: cost ratio (2.93).

Gerhard and Hans-Peter (2021) conducted a field trial to investigate the energy efficiency of four tillage systems (mouldboard plough, deep conservation tillage, shallow conservation tillage and no-tillage) for sugar beet and soybean production, taking fuel consumption, total energy input (made up of both direct and indirect inputs), crop yield, energy output, net-energy output, energy intensity and energy use efficiency into account. The result revealed that the total energy input was for both crops highest with mouldboard plough and deep conservation tillage and lowest with no-tillage.

Naganjali *et al*. (2021) conducted a field trial to evaluate the effect of nutrient and weed management under semi dry rice in sandy clay loam soil. Result from the study revealed that among weed management practices higher input energy (27915 MJ ha^{-1}) was expended in bispyribac sodium 10 SC 25 g ha^{-1} (early PoE) *fb* fenoxaprop-p-ethyl 62.5 g ha^{-1} + 2, 4- D 80 WP 0.5 kg ha^{-1}) at 35- 40 DAS. While bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4-D 80 WP 0.5 kg ha^{-1} + HW at 50 DAS, resulted in the highest energy output (146458 MJ ha^{-1}), net energy (118895 MJ ha^{-1}), energy use efficiency (5.33%) and energy productivity (0.18 Kg MJ^{-1}).

Acharya *et al*. (2022) to assess the input energy requirements and output energy production of establishment methods and weed management in rice and revealed that among herbicidal treatments, application of oxadiargyl @ 90 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop @ 135 g ha^{-1} (PoE) produced highest output energy (142655 MJ ha^{-1}), the highest energy use efficiency (11.89) and energy profitability (10.89), which was at par with hand weeding twice and oxadiargyl @ 90 g ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} + fenoxaprop @ 56 g ha^{-1} (PoE) with energy output of 137926 MJ ha^{-1}.

2.9 Residual effect on the subsequent crop

Rabiee *et al.* (2011) conducted a trial to evaluate the effects of tillage systems and rice residue management on yield components, grain and oil yields of rapeseed (*Brassica napus* L.) as second crop in paddy fields. Based on the study it was found that tillage systems showed significant effect on grain and oil yields, biological yield, harvest index, plant density and silique number per plant. No tillage system with residue recorded the lowest grain and oil yields. Minimum tillage system (2033 kg ha^{-1}) and conventional tillage (2255 kg ha^{-1}) showed no significant difference for grain yield, however, they were significantly different from no tillage system (1455kg ha^{-1}). Results also showed that despite the higher grain yield in conventional tillage system, minimum tillage system with and without residue had relative advantages due to reducing the costs of tillage operations.

Zahan *et al.* (2016) observed from the field experiment to evaluate the residual effect of rice herbicides (pendimethalin, pyrazosulfuron-ethyl, butachlor, pretilachlor, orthosulfamuron, acetochlor + bensulfuron methyl, butachlor + propanil and 2,4-D amine) on the succeeding crops viz. wheat, lentil and sunflower by following bioassay technique. The results showed that seedling germination of all these succeeding crops in the herbicide treated plots did not differ significantly from those of weedy and hand weeded control plots.

Moreover, leaf chlorophyll content, seedling shoot length and dry matter of wheat, lentil and sunflower were not adversely affected by any of the herbicide treatments imposed in *aman* rice. It was concluded that herbicides used in unpuddled transplanted *aman* rice had no residual effect on the germination and leaf chlorophyll content, seedling shoot length and dry matter of the succeeding wheat, lentil and sunflower crops.

Raj and Syriac (2017) carried out the bioassay studies to assess the residual effect of herbicide mixture, bipyribac-sodium + metamifop 14% SE in soil with indicator plant. The effect of different concentrations of herbicide mixture, on shoot length, root length, shoot fresh and dry weight of cucumber, sunflower and maize were observed. Overall, as the concentration of herbicide mixture increased, there was decreased in the growth parameters in the tested crops.

Teja and Duary (2018) carried out a field trial to study the effect of tillage and weed management practices on weed growth and productivity of yellow mustard in direct-seeded rice- yellow mustard - greengram cropping system. Results from the study revealed that conservational tillage (zero tillage + residue) along with recommended herbicide (pendimethalin at 0.75 kg ha^{-1}) + one hand weeding (HW) recorded the lower values of total weed density (6.20 and 6.43 m^{-2}) and dry weight (1.22 and 1.42 g m^{-2}) and higher values of seed yield (1.20 and 1.46 t ha^{-1}), number of siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and test weight in first and second year, respectively. Furthermore, in second year, conservational tillage even with recommended herbicide alone registered at par values of total weed density and dry weight with conventional tillage + recommended herbicide + 1 HW and it also recorded 10.2% higher seed yield than conventional tillage + recommended herbicide + 1 HW.

Kalita *et al.* (2023) conducted an experiment to study the performance of Indian mustard under tillage and weed management in rice (*Oryza sativa*)-based cropping sequence. Results obtained from the study revealed that seed, stover and oil yield of Indian mustard were increased in the year round minimum tillage with rice residue retention by 35.97, 23.41 and 38.90%, respectively due to higher crop growth characteristics and yield attributes as compared to conventional tillage.

2.10 Economics

Upasani *et al.* (2014) revealed that continuous conventional tillage sequence in rice and wheat recorded the maximum gross return (₹ 57,607 ha^{-1}), net return (₹ 28,446 ha^{-1}).

Das *et al.* (2015) reported that highest NPV (net production value) was noted under bispyribac sodium 10% SC @ 20 g ha^{-1} (pooled NPV = 2.76) owing to higher seed yield and comparatively lower cost under this treatment.

Kaur and Singh (2016) conducted a field experiment to study the effect of various establishment methods and weed-control treatments on weeds, crop growth, yield attributes and yield of rice and revealed that sequential application of pre- and post-emergence herbicides resulted in more benefit: cost ratio (1.66) and energy output: input ratio (5.32).

Singh *et al.* (2016b) conducted a field trial to evaluate pre-emergence and post-emergence herbicides for providing feasible and economically viable weed management options to farmers for predominant scented dry seeded rice varieties and revealed that application of bispyribac-sodium after pendimethalin pre-emergence provided significantly higher return over variable cost (₹ 1744) and B:C (4.0) at Taraori.

Chakraborti *et al.* (2017) conducted an experiment to study the effect of weed management practices on nutrient uptake by direct seeded upland rice and reported that the pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} at 2 DAS + bispyribac-sodium at 25 g ha^{-1} at 20 DAS recorded the highest net returns and return per rupee invested.

Yogananda *et al.* (2017) reported from the study of effect of weed management practices in wet direct-seeded rice that pre-emergence application of bensulfuron-methyl + pretilachlor GR at 660 g ha^{-1} *fb* bispyribac-sodium at 25 g ha^{-1} at 20 DAS significantly recorded the higher net monetary returns (₹ 25631 ha^{-1}) and B: C ratio (1.62) which was at par with pre-emergence application of pendimethalin at 1.0 kg ha^{-1} *fb* postemergence application of bispyribac-sodium, pre-emergence application of bensulfuron-methyl + pretilachlor, application of pendimethalin as pre-emergence *fb* 1 HW.

Baghel *et al.* (2018) from the study to evaluate the effects of weed control options in a conservation agriculture-based rice–wheat cropping system revealed that the pre emergence application of pendimethalin 1.0 kg ha^{-1} *fb* bispyribac sodium 25 g ha^{-1} recorded the highest net benefit: cost ratio (1.08 and 1.25) as compared to other weed control practices during both the years.

Dhanapal *et al.* (2018) conducted a field trial to study the effect of various weed management practices on weed density, weed dry weight, yield and economics of direct seeded rice and observed that higher net returns and benefit: cost ratio of ₹ 28965 and 2.0 and ₹ 41402 and 2.4, respectively were obtained with pendimethalin 1.0 kg ha^{-1} *fb* bispyribac sodium 25 g ha^{-1} as postemergence with manual weeding.

Dhakal *et al.* (2019) carried out an experiment on integrated weed management in direct-seeded rice: dynamics and economics to identify the most effective and economical method of managing weeds in DSR and concluded that net return and B:C ratio close to 2 (1.94) were greater with application of pendimethalin followed by bispyribac-sodium than that followed by one hand weeding and other weed control treatments.

Ravikiran *et al.* (2019) revealed that stale seedbed method recorded highest net income (₹ 27,848/- ha^{-1}) and B: C ratio (1.48) compared to no stale seedbed method (conventional).

Mukherjee (2019) performed an experiment to evaluate the effect of various crop establishment methods and herbicides on growth and yield of rice and concluded that the maximum net return (₹ ha^{-1}) and benefit: cost ratio were obtained with conventional till direct seeded rice.

Dangol *et al.* (2020) concluded that for the economic analysis, the post-emergence herbicide bispyribac sodium was beneficial as compared to other weed management practices in terms of gross returns, net returns and B: C ratio (1.41).

Bhargaw and Roy (2020) conducted a field experiment to study the influence of integrated weed management practices on nutrients uptake by crop and weed under dry direct seeded rice and concluded that the highest benefit-cost ratio of 1.0 was recorded from Pendimethalin @ 1 kg ha^{-1} at 0-2 days after sowing followed by bispyribac-Na @ 25 g ha^{-1} at 20 days after sowing which was statistically at par with pendimethalin @ 1 kg ha^{-1} at 0-2 days after sowing followed by 2, 4-D Na salt @ 0.5 kg ha^{-1} at 20 days after sowing followed by one hand weeding at 40 days after sowing (0.97).

Shah *et al*. (2021) performed a field trial to assess the effect of various combinations of herbicides mixture under seedbed preparation to evaluate different attributes of weed control efficiencies (WCE) coupled with grain yield and economics of DDSR and concluded that pendimethalin *fb* tank mixture of bispyribac sodium and ethoxysulfuron recorded significantly highest net return which was statistically at par with weed free treatment and highest B:C ratio.

Swain *et al*. (2023) conducted an experiment to study the effect of fertility levels and weed management practices on weed dynamics, yield and economics of transplanted rice. Result obtained from the study revealed that the combined influence of 100% RDF with post emergence application of bispyribac sodium @ 25 g ha^{-1} achieved higher net return (₹ 31, 746 ha^{-1}) and return per rupee investment (1.81).

Puniya *et al*. (2023) from the study of sequential application of herbicides for weed management in direct-seeded basmati rice reported that pendimethalin 1000 g ha^{-1} as PE *fb* bispyribac-sodium 25 g ha^{-1} at 25 DAS resulted in numerically higher gross returns (₹ 111874 ha^{-1} and ₹ 107909 ha^{-1}), net return (₹ 82267 ha^{-1} and ₹ 77002 ha^{-1}), and benefit: cost ratio (2.78 and 3.49) followed by pretilachlor 600 g ha^{-1} during both years of the study.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The field experiment entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)"** was conducted at the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema campus during the *Kharif* and *Rabi* season of 2021-2022 and 2022-2023. Details of the experimental materials used and the research methodologies adopted during the period of experimentation are described in this chapter.

3.1 General information

3.1.1 Experimental site

The experimental field is geographically located at 25˚ 45′ 43″ N latitude and 95˚ 53′ 04″ E longitude at an altitude of 310 m above the mean sea level (MSL). The site comes under Mid Tropical Hill (AZ52).

3.1.2 Climatic and weather conditions during the experiment period

Climatologically, Medziphema falls under sub-tropical climatic zone and is subjected to extreme of weather conditions *i.e.*, extremely hot summer and cold winter. The region lies in humid sub- tropical region with an average rainfall ranging from 2000-2500 mm annually. The rainy season usually starts from April and extends up to the end of September. The mean temperature varied from 21-33.3˚C during summer while minimum temperature seldom goes down to 8˚C in winter owing to high atmospheric humidity.

The detailed meteorological data of different weather parameters recorded during the period of investigation is presented in Table 3.1 and shown graphically in Fig 3.1. The mean weekly maximum and minimum temperature

Table 3.1(a) Mean weekly meteorological data recorded during the cropping season (2021-2022)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
22	33.11	22.94	91.29	61.00	17.40	1	4.4
23	33.56	23.63	91.71	63.14	39.1	1	2.8
24	33	24.79	93.29	75.29	19.5	3	3.8
25	33.01	24.51	93.29	67.43	43.4	4	4.3
26	33	25	92.57	69.14	37.6	1	1.9
27	33.17	24.73	88.86	73.43	19.2	2	2.5
28	32.41	24.69	92.71	70.43	105.7	5	3.9
29	33.69	24.66	94.57	69.57	53.3	2	3.9
30	34.49	24.89	89.57	70.43	74.9	2	6.6
31	32.27	25.1	91.57	78.43	34	3	3.9
32	33.2	24.53	92.86	67.86	25.2	3	3.4
33	32.47	24.93	95.57	77	41.8	2	1.6
34	32.37	24.29	91.86	67.71	7	0	3.2
35	32.31	24.29	92.86	72.86	52.9	4	3.0
36	33.19	24.01	94.57	68.43	49.1	3	6.5
37	33.79	23.94	93.57	67.71	42.2	1	5.8
38	32.11	23.31	94	67.71	13.1	2	5.0
39	33.7	23.77	93.14	66	8.1	2	7.1
40	32.29	23.06	94.29	71.14	5	1	5.0
41	33.89	23.57	91.86	62.86	53.8	2	7.8
42	33.3	23.6	95.43	70.14	69.1	3	5.4
43	29.99	18.97	96.86	71.86	2.1	0	7.2
44	30.03	19.07	95.14	57.86	0	0	7.5
45	29.46	15.24	96	49.14	0	0	8.4
46	28.64	16.39	94.86	54.71	0	0	7.5
47	27.76	13.33	96.43	49.29	0	0	8.0
48	26.90	11.40	95.86	45.71	0.00	0	7.9
49	26.43	15.24	95.14	57.71	8.50	1	5.0
50	25.33	11.60	94.86	51.71	0.00	0	6.7
51	24.91	8.93	95.43	46.71	4.70	1	6.7
52	23.35	9.66	96.50	50.00	3.20	1	6.2
1	24.2	8.5	95	47	0.0	0	7.2
2	24.9	10.3	96	54	14.8	1	5.3
3	22.4	10.6	94	55	3.4	1	4.7
4	20.7	11.4	97	67	16.4	3	2.7
5	19.8	9.5	95	58	2.1	0	3.1
6	21.5	9.7	96	51	30.2	2	6.1
7	24.7	7.2	95	39	0.0	0	8.7
8	24.1	10.6	95	47	18.9	2	5.8
9	26.9	12.7	95	44	5.4	1	7.7
10	31.0	12.4	94	37	0.0	0	8.3

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
11	33.5	15.2	92	37	0.0	0	7.7
12	35.5	17.5	87	32	2.0	0	6.9
13	30.7	19.3	84	57	0.9	0	1.5
14	29.1	19.8	91	69	10.4	2	2.3
15	28.8	19.8	95	78	95.3	3	2.3
16	32.7	19.9	88	62	35.5	3	2.9
17	32.6	20.0	87	61	18.3	1	7.1

Source: ICAR Research Complex for NEH Region, Jharnapani, Nagaland recorded was 29.8˚C and 18.4˚C during the first year of investigation, May 2021-April 2022 while 30.1˚C and 17.9˚C during the second year of investigation, May 2022-April 2023. The mean weekly maximum and minimum relative humidity recorded was 93.4% and 60.2% during the first year, May 2021-April 2022 while 93.0 % and 59.9% during the second year, May 2022- April 2023. The mean weekly sunshine hours during the period of experimentation were 5.3 hrs during the first year, May 2021-April 2022 and 5.4 hrs during the second year, May 2022-April 2023. The average weekly amount of rainfall received during the first and second year, was 22.6 mm and 25.3 mm respectively. Likewise, the average weekly number of rainy days during the period of study was 1.4 and 1.5 days respectively.

3.1.3 Details of the experimental soil condition

The soil of the experimental field was well drained and sandy loam in texture with low available nitrogen, high in available phosphorus and medium in available potassium. To examine the fertility status of the soil, the respective soil samples were collected randomly from the experimental field at a depth of 0-15 cm by soil auger before sowing of the crop. Likewise, five soil samples were collected from each plot after harvesting of the main crop to know the fertility status during both the years of experimentation. The collected soil samples were shade dried, ground and sieved through 2 mm sieve and analyzed for their physical and chemical properties by the standard methods as given in Table 3.2. For determination of bulk density, the soil samples were collected layer wise *viz*. 0-5, 5-15 and 15- 30 cm respectively at three different random spots.

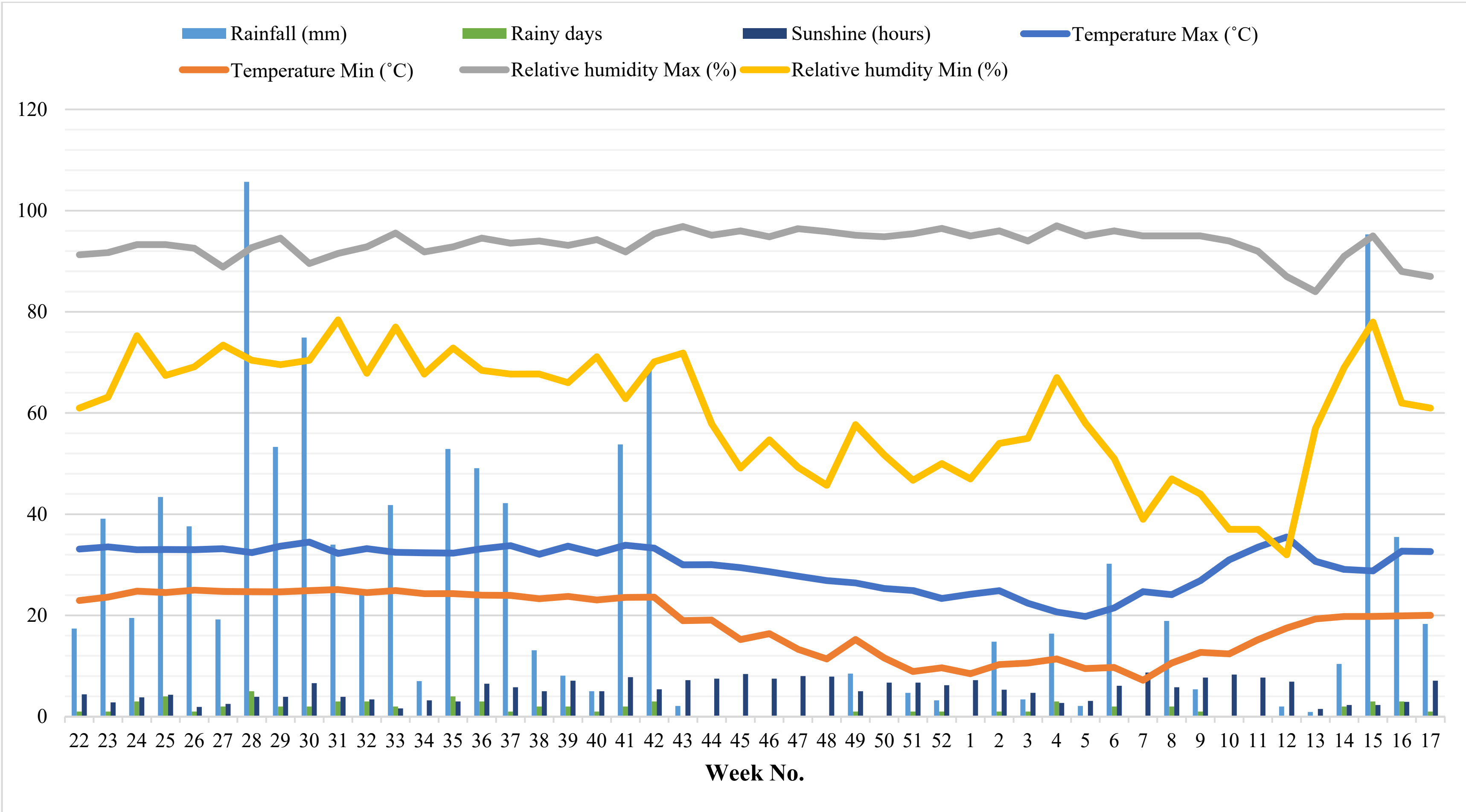


Fig 3.1(a) Meteorological data during the cropping season (2021-2022)

Table 3.1(b) Meteorological data recorded during the cropping season (2022-2023)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
22	33.3	23.3	93	65	22.5	2	4.8
23	33.0	24.0	94	74	51.1	4	2.9
24	30.3	23.3	95	74	46.7	4	1.3
25	31.2	23.4	95	75	34.8	3	1.8
26	33.3	24.9	93	68	9.9	2	4.5
27	34.2	24.7	91	66	77.1	3	7.2
28	34.1	24.5	90	69	22.9	3	6.9
29	33.9	24.5	92	75	135.3	4	3.4
30	31.8	23.2	96	70	135.3	5	3.6
31	33.6	23.9	93	68	48.8	2	3.1
32	33.3	23.9	96	71	114.7	5	5.1
33	33.6	24.2	91	72	27.5	2	6.1
34	34.1	24.5	94	68	64.2	1	4.1
35	32.7	24.3	93	68	9.0	1	4.6
36	33.4	24.4	89	67	21.7	2	4.9
37	31.9	23.5	91	72	42.8	3	4.1
38	33.5	24.0	91	65	15.3	2	5.6
39	32.8	23.2	91	70	81.2	2	6.3
40	31.9	23.5	95	74	31.0	3	4.4
41	31.8	22.7	91	71	2.9	1	5.0
42	30.9	20.6	94	65	19.7	3	5.9
43	28.1	19.9	95	71	41.0	2	4.7
44	29.8	17.1	96	60	0.0	0	8.0
45	29.3	16.7	96	57	0.0	0	8.2
46	27.9	14.6	98	56	0.0	0	8.2
47	27.7	12.8	96	52	0.0	0	8.0
48	27.8	14.3	96	67	0.0	0	7.4
49	27.6	12.0	95	49	0.0	0	8.0
50	26.4	11.3	96	50	0.0	0	7.0
51	25.7	11.0	96	51	0.2	0	6.4
52	22.7	11.2	97	60	15.2	1	3.9
1	23.2	9.2	97	50	0.0	0	6.9
2	25.4	8.8	96	55	0.0	0	6.9
3	22.8	7.0	94	45	0.0	0	5.7
4	24.9	6.9	93	45	0.0	0	6.0
5	27.0	10.4	93	46	0.0	0	6.2
6	25.6	10.2	94	53	0.0	0	3.7
7	26.9	11.0	91	43	0.0	0	5.3

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
8	29.0	15.1	93	51	0.0	0	3.4
9	29.1	11.2	89	39	0.0	0	7.0
10	31.4	13.5	91	38	0.0	0	6.1
11	30.0	15.1	92	53	20.8	1	4.7
12	25.5	16.0	96	65	37.0	3	3.4
13	29.7	16.4	90	54	18.2	2	3.8
14	29.1	16.2	91	51	19.3	3	6.8
15	34.7	16.2	82	37	0.0	0	8.0
16	35.1	19.7	89	50	27.7	1	5.5
17	31.7	18.3	86	59	20.2	2	6.1

Source: ICAR Research Complex for NEH Region, Jharnapani, Nagaland

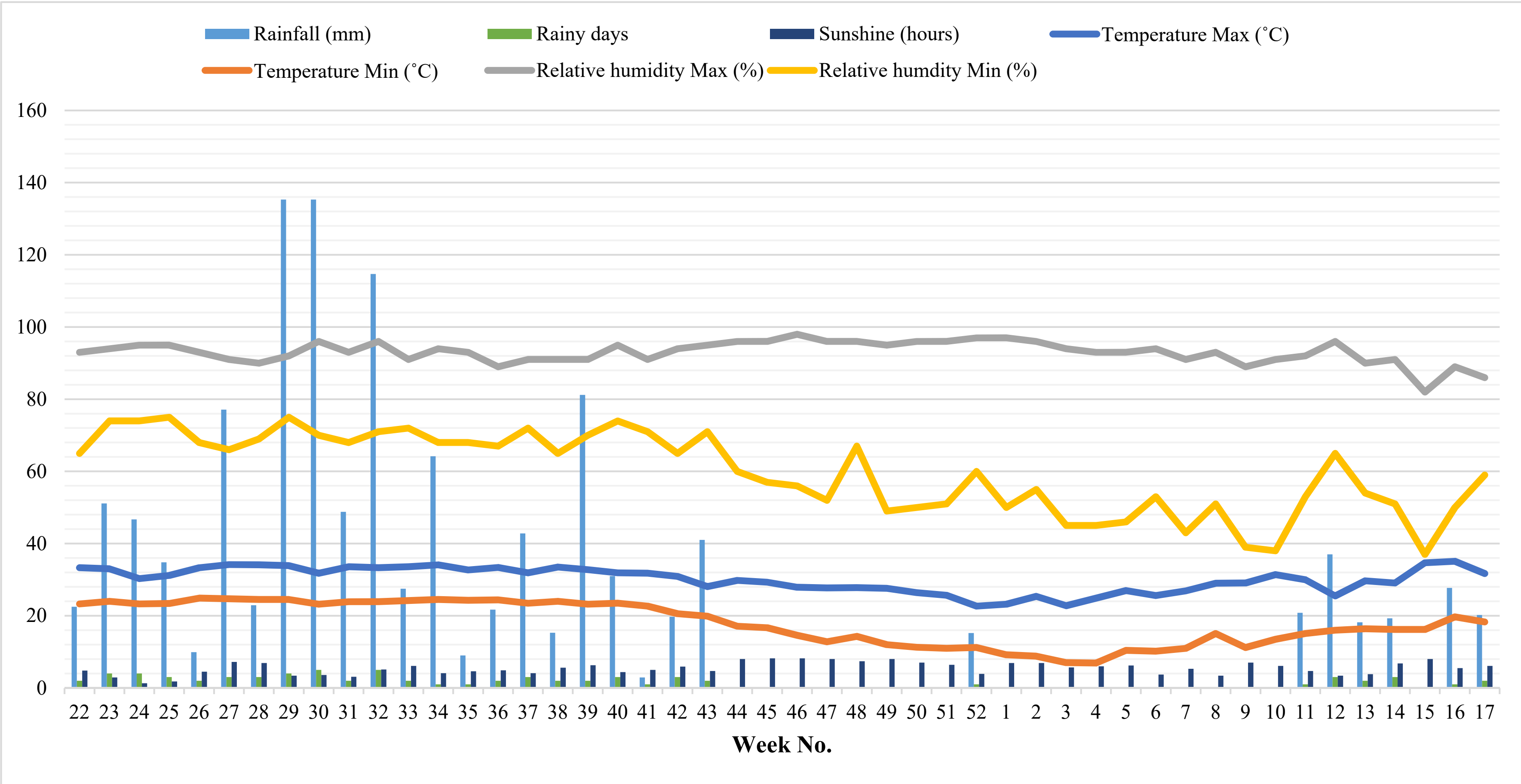


Fig 3.1(b) Meteorological data during the cropping season (2022-2023)

Table 3.2: Initial soil fertility status of the experimental field

Characteristics	Method followed	2021		2022	
		Content	Remark	Content	Remark
Soil texture	International pipette method (Piper, 1966)	Sand: 52.87% Silt: 27.1% Clay: 20.66%	Sandy loam	Sand: 53.47% Silt: 27.3% Clay: 20.10%	Sandy loam
Soil pH	Glass electrode pH meter (Jackson, 1973)	4.59	Strongly acidic	4.61	Strongly acidic
Organic carbon (%)	Titrimetric determination (Walkley and Black method, 1934)	1.44	High	1.49	High
Available soil nitrogen (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	264.52	Low	257.28	Low
Available soil phosphorus (kg ha^{-1})	Bray's No. 1 method (Bray and Kurtz, 1945)	39.15	High	39.52	High
Available soil potassium (kg ha^{-1})	Neutral normal ammonium acetate method (Hanway and Heidal, 1952)	147.92	Medium	147.30	Medium
Bulk density (g cc^{-1})	(Chopra and Kanwar, 1976)	(0-5 cm): 1.015		(0-5 cm): 0.998	
		(5-15 cm): 1.212		(5-15 cm): 1.206	
		(15-30 cm): 1.278		(15-30 cm): 1.269	

3.1.4 Cropping history of the experimental site

The details of the crops grown and cropping system adopted on the experimental site for the last few years are shown in the Table 3.3.

Table 3.3: Cropping history of the experimental site

Sl. No.	Year	Season	
		Kharif	***Rabi***
1.	2019	Rice + soybean + groundnut	Fallow
2.	2020	Rice + soybean + groundnut	Fallow

3.2 DETAILS OF THE EXPERIMENTAL TECHNIQUES

3.2.1 Experimental design and layout

The experiment was laid out in Split-Plot Design (SPD) consisting of three tillage system in the main plot and six weed management system in the sub-plot and were replicated thrice. The detailed plan of layout of the experiment for both the years are presented in Fig 3.3.

3.2.2 Detail layout of the experiment

The details of the experiment are given below:

1. Crop-I : Rice (*Oryza sativa* L.)
   - i. Variety : CAU-R 2
   - ii. Spacing : 20 cm × 10 cm
   - iii. Recommended fertilizer dose : 60:40:40 kg ha^{-1} (NPK)
2. Sequential Crop : Sunflower (*Helianthus annuus* L.)
   - i. Variety : KBSH-41
   - ii. Spacing : 60 cm × 20 cm
   - iii. Recommended fertilizer dose : 60:60:40 kg ha^{-1} (NPK)
3. Experimental design : Split-Plot Design (SPD)

4. Main plot treatments : 3

5. Sub- plot treatments : 6

6. Number of treatment combinations : 18

7. Number of replications : 3

8. Total number of plots : 54

9. Gross experimental area : 5 m × 4 m

10. Net experimental area : 4.4 × 3.8 m

11. Block border : 1 m

12. Plot border : 0.5 m

13. Length of the experimental field : 82.5 m

14. Width of the experimental field : 17 m

15. Total area of the experimental field: 1402.5 m^2

3.2.3 Treatment details

The details of the treatments in the main and sub-plots along with symbols used to represent are given below:

3.2.3.1 Main plot

Tillage

T_1: Zero tillage

T_2: Minimum tillage

T_3: Conventional tillage

3.2.3.2 Sub-plot

Weed management practices

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence)

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop- butyl @ 90 g ha^{-1} at 25 DAS

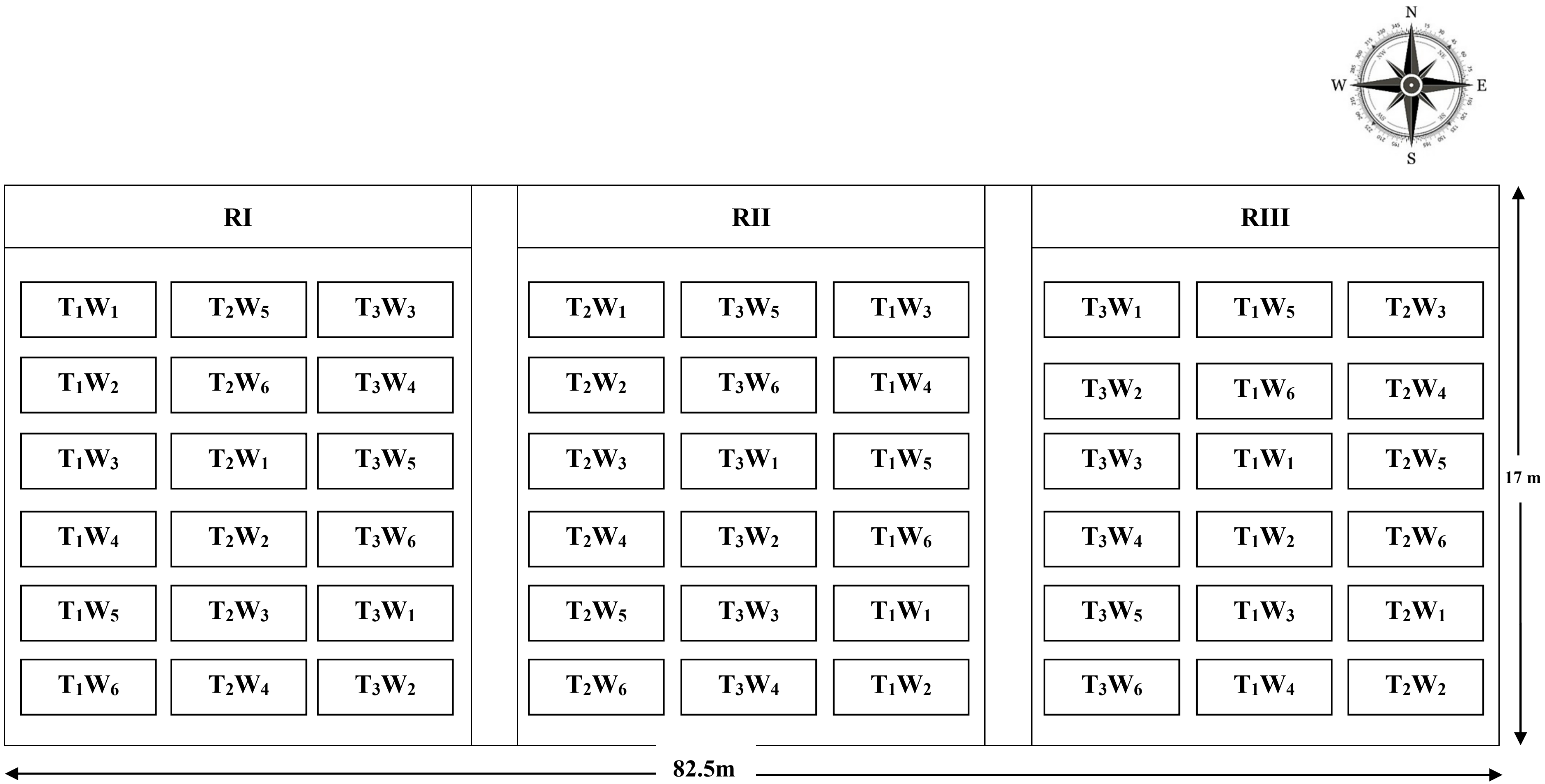
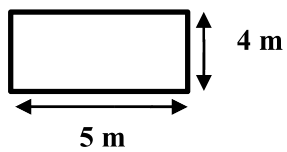


Fig 3.2 Layout of the experimental field in Split-Plot Design



W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS

W_5: Weed free

W_6: Weedy check

3.2.3.3 Treatment combinations

There were total of eighteen (18) treatment combinations that were obtained from three main plots and six sub-plots as given below:

T_1 W_1	**T_2 W_1**	**T_3 W_1**
T_1 W_2	**T_2 W_2**	**T_3 W_2**
T_1 W_3	**T_2 W_3**	**T_3 W_3**
T_1 W_4	**T_2 W_4**	**T_3 W_4**
T_1 W_5	**T_2 W_5**	**T_3 W_5**
T_1 W_6	**T_2 W_6**	**T_3 W_6**

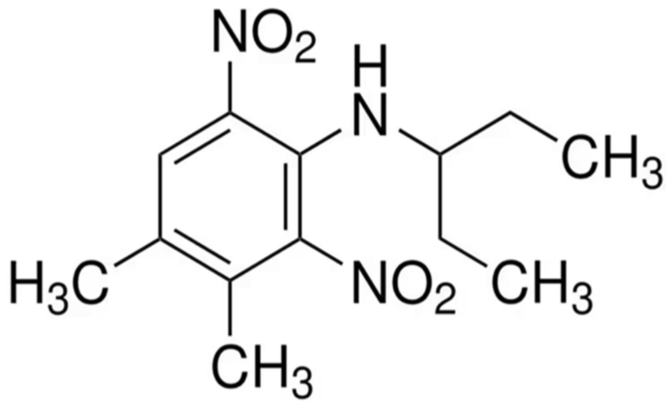
3.2.4 Details of the herbicides used during the experiment

a. Pendimethalin

Common name : Pendimethalin

Chemical formula : N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine

Structural formula :



Trade name : Stomp/ Dhanutop

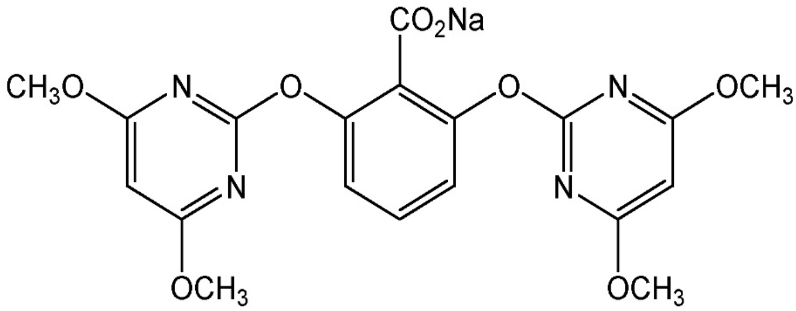
Molecular formula	: $C_{13}H_{19}N_3O_4$
Chemical group	: Dinitroaniline
Molecular weight	: 281.31
Melting point	: 56-57˚C
Boiling point	: 330˚C
Density	: 1.17
Vapour pressure	: 4×10^{-5} m bar at 25˚C
Physical state	: Orange-yellow crystals
Colour	: Yellow-orange brown
Formulation	: 30% EC
Mode of action	: Its primary mode of action is to prevent plant cell division responsible for chromosome separation and inhibit cell wall formation and elongation in susceptible species. Pendimethalin inhibits root and shoot growth in seedlings. It controls the weed population and prevents weeds from emerging, particularly during the crucial development phase of the crop.
Application	: Used both as pre-emergence, that is spraying before weed seeds have sprouted, and early post-emergence. It can also be incorporated into the soil by either during cultivation or irrigation within 7 days following application.
Uses	: It is used for controlling broadleaf and grassy weeds on many crops, including: cotton, corn, sorghum, peanuts, rice, beans, peas, wheat, potatoes, soybeans, sunflowers, tobacco, ornamentals, non-bearing fruit and nut crops and vineyards.

b. Bispyribac-sodium

Common name : Bispyribac-sodium

Chemical formula : Sodium 2,6-bis[(4,6-dimethoxypyrimidin-2-yl)oxy]benzoate

Structural formula :



Trade name : Nomineegold

Molecular formula : $C_{19}H_{17}N_4NaO_8$

Chemical group : Pyrimidinyloxybenzoic acid

Molecular weight : 452.4

Melting point : 223 to 224 ˚C

Boiling point : 686.4˚C at 760 mm Hg

Density : 0.0737 g mL^{-1}

Vapour pressure : < 1 x 10-7 mm Hg at 25˚C

Physical state : Powder

Colour : White

Formulation : 10 % SC

Mode of action : It is a broad spectrum, selective and systemic herbicide absorbed by foliage and roots. Its main mechanism of action is by inhibiting plant acetolactate synthase (ALS), an enzyme necessary for growth.

Application : Used as post-emergence herbicide that is spraying after the weed seeds have sprouted. It is usually applied at 25 days after sowing of the crop.

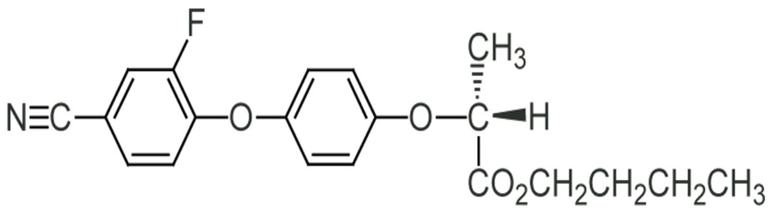
Uses : It is used as a broad spectrum post-emergent herbicide for the control of grasses, sedges and broadleaf weeds in rice crops.

c. Cyhalofop-butyl

Common name : Cyhalofop-butyl

Chemical formula : Butyl (2R)-2-[4-(4-cyano-2-fluorophenoxy) phenoxy] propanoate

Structural formula :



Trade name : Clincher

Molecular formula : $C_{20}H_{20}FNO_4$

Chemical group : Aryloxyphenoxy propionic acid herbicide

Molecular weight : 357.4 g mol^{-1}

Melting point : 49.5˚C

Boiling point : >270 ˚C (decomposes)

Density : 1.172 at 20 ˚C

Vapour pressure : 5.3 x 10^{-8} kPa (4.0 x 10 @10^{-7}mm Hg or Torr)

Physical state : Off-white to beige waxy solid

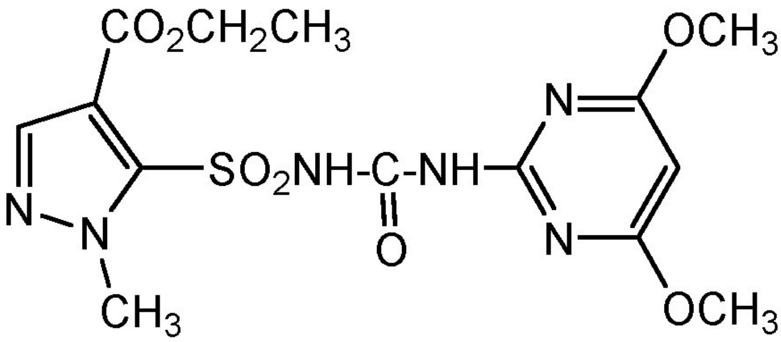
Colour : Off white

Formulation : 10% EC

Mode of action	:Cyhalofop-butyl is an inhibitor of acetyl coenzyme -A carboxylase, a pivotal enzyme in plant fatty acid.
Application	: It is a systemic post-emergence herbicide used for postemergence grass weed control in rice
Uses	: It is used for controlling CLINCHER is systemic post-emergence herbicide for the control of grassy weeds in direct seeded rice.

d. Pyrazosulfuron-ethyl

Common name	: Pyrazosulfuron-ethyl
Chemical formula	: Ethyl 5-(4,6-dimethoxypyrimidin-2-ylcarbamoylsulfamoyl)-1-methylpyrazole-4-carboxylate pyrazosulfuron-ethyl
Structural formula	:



Trade name	: Saathi
Molecular formula	: $C_{14}H_{18}N_6O_7S$
Chemical group	: Sulfonylurea
Molecular weight	: 414.40 g mol^{-1}
Melting point	: 181.5˚C
Density	: 1.55 g ml^{-1}
Vapour pressure	: 0.0147 mPa at 20 °C
Physical state	: Colourless crystal

Colour	: Off white
Formulation	: 10% WP
Mode of action	: Broad-spectrum, systemic herbicide, absorbed by roots and translocated throughout the plant meristems, inhibiting plant amino acid synthesis - acetohydroxyacid synthase AHAS, an enzyme required for biosynthesis of three essential amino acids viz. leucine, isoleucine and valine.
Application	: It is a systemic herbicide used for controlling annual and perennial broad-leaved weeds and sedges weed control in rice.
Uses	: It is used for controlling annual and perennial broad-leaved weeds and sedges as pre- or post-emergence in wet sown or transplanted rice.

3.2.5 Details of the experimental crop

3.2.5.1 Rice variety- CAU-R2

Rice (*Oryza sativa* L.) belongs to the family Poaceae. CAU-R2 is also called as Tomthinphou. It is an upland paddy variety evolved from the cross between Cauvery × V20-B developed by Modified Pedigree with single panicle descent breeding method. It has a semi dwarf (80cm) plant stature and matures within 95-100 days showing a yield improvement of 40-50 % over the local check. The average yield of this variety is 2.0 t ha^{-1}. The variety is an early maturing type suitable for rainfed upland and jhum ecosystem condition with high organic matter content.

3.2.5.2 Sunflower variety-KBSH-41

Sunflower belongs to the family Asteraceae. KBSH-41. This variety is developed from cross between CMS-234 A x RHA-95C-1. The variety matures within 90-92 days (*Kharif*) and 90-95 days (*Rabi*). It has an average yield of

1400-1600 kg ha^{-1} and a potential yield of 2000-2500 kg ha^{-1}. The percentage of oil content is 40-42 % with plant height of 170-200 cm.

3.2.6 Calendar of agronomic operations

The dates and operations from the initial field preparation to final crop harvest have been presented below in the Table 3.4.

Table 3.4: Calendar of agronomic practices

Sl. No.	Operations	Year- 2021	Year- 2022
		Date	
1.	**Land preparation**		
	Ploughing for conventional tillage	04.07.2021	03.07.2022
	Harrowing and planking	06.07.2021	05.07.2022
2.	Layout	07.07.2021	06.07.2022
3.	Manure application	07.07.2021	06.07.2022
4.	Glyphosate application for stale seed bed	13.07.2021	12.07.2022
5.	Fertilizer application	15.07.2021	14.07.2022
6.	Sowing of main crop	15.07.2021	14.07.2022
7.	**Herbicide application**		
	Pyrazosulfuron-ethyl and pendimethalin	18.07.2021	17.07.2022
	Bispyribac sodium and Cyhalofop-butyl	09.08.2021	08.08.2022
8.	**Hand weeding**		
	15 DAS	02.08.2021	01.08.2022
	30 DAS	18.08.2021	17.08.2022

	45 DAS	01.09.2021	31.08.2022
	60 DAS	16.09.2021	15.09.2022
9.	Harvesting	18.10.2021	20.10.2022
10.	Threshing	22.10.2021	24.10.2022
11.	Fertilizer application for sunflower	03.11.2021	05.11.2022
12.	Sowing of sunflower	03.11.2021	05.11.2022
13.	Earthing up	20.12.2021	24.12.2022
14.	Harvesting	29.03.2022	30.03.2023

3.2.7 Agronomic management

The details of various agronomic field operations as well as the inter-cultural operations carried out during the period of investigation are presented below.

3.2.7.1 Field preparation for rice

The experimental field was divided into three blocks to represent three replications and each replication was divided into three main plots where treatments in the main plots were randomized. Different tillage system *viz*., zero, minimum and conventional tillage system were imposed. Each main plots were then divided into six equal sub-plots where different weed management practices were allocated randomly. For zero tillage, no soil disturbance was done except opening of furrows for placement of seeds by tractor drawn zero till drill. Minimum tillage includes on ploughing only with disc plough followed by furrow preparation for sowing seeds. The field was first ploughed for conventionally tilled plots with disc plough (primary tillage) and followed by 2-3 times harrowing and planking as secondary tillage for seedbed preparation.

3.2.7.2 Manure and Fertilizer application

Uniformly well decomposed FYM @ 7 t ha^{-1} was broadcasted over the field and incorporated thoroughly during the time of field preparation. Recommended dose of fertilizers (RDF) at the rate of 60, 40 and 40 kg NPK ha^{-1} were applied to all the plots in the form of urea, single super phosphate and muriate of potash in both the years. Split application of nitrogen was done with half dose of the recommended dose of nitrogen along with full dose of phosphatic and potassic fertilizers were applied as basal dose. The remaining half dose of nitrogen was split into two equal halves and applied as top dressed *i.e.* one third of nitrogen was top dressed at the onset of active tillering stage and rest one third of nitrogen was top dressed at panicle initiation stage.

3.2.7.3 Seed rate, seed treatment and method of sowing

The seeds were soaked overnight, drained and kept inside muslin cloth wrapped with gunny bag for 24 hours for initial sprouting. The sprouted seeds were then treated with Bavistin @ 2 g kg^{-1}. The seeds were line sown @ 80 kg ha^{-1} maintaining a row distance of 20 cm and plant to plant distance of 10 cm respectively. It is then covered with a thin layer of soil and light irrigation was given better plant stand.

3.2.7.4 Weeding and herbicide application

Herbicide application was carried out as per the treatment. Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} were applied three days after sowing of the crop. Bispyribac sodium @ 25 g ha^{-1} and cyhalofop-butyl @ 90 g ha^{-1} were applied twenty-five days after sowing of the crop in the respective treatments using knapsack sprayer fitted with flat fan nozzle. For weed free plots, hand weeding was done manually keeping fifteen days interval. As for stale seedbed, a false seedbed was prepared two weeks before sowing of the crop. Light irrigation was given for the weed seeds to germinate where they were killed by spraying glyphosate @1 kg ha^{-1}.

3.2.7.8 Plant protection measures

Regular inspection of the field was done to monitor pest and diseases for the experimental crop.

3.2.7.9 Harvesting and threshing

The crop was harvested plot wise manually with the help of sickle when more than 80 percent of the grains ripen. Then it was sun dried for 3-4 days and it was manually threshed and winnowed. The grains were again dried properly and weight was recorded plot wise. The straw was also dried properly and weight was recorded separately.

3.2.7.10 Land preparation of succeeding crop

After harvesting of the main crop, the land was utilised for sowing of sunflower without destroying the layout. Line furrows was made manually with spade maintaining row spacing of 60 cm.

3.2.7.11 Fertilizer application

A recommended dose of 60, 60 and 40 kg ha^{-1} N, P and K was applied before sowing. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal dose in each plot. The remaining dose of nitrogen was top dressed at the time flowering stage.

3.2.7.12 Sowing

Line sowing of sprouted seeds was done maintaining a spacing of 20 cm between the plants and row spacing of 60 cm by placing the seeds at a depth of 2-3 cm.

3.2.7.13 Intercultural operations

Intercultural operations like earthing up was done when the plant attained at knee high- stage along the rows. This will prevent lodging against high intensity of wind which will likely occur at the heading stage.

3.2.7.14 Irrigation

Irrigation was given as per requirement of the crop. *Rabi* crop may be irrigated thrice after 40, 75, and 110 days of sowing which will roughly coincide with four to five-leaf stage, flowering, and grain filling stages of the crop. Sunflower crop is highly sensitive to water stress between flowering and grain filling stages (75-110 DAS) and at least one of the irrigations must be applied during this period preferably in the evening hours.

3.2.7.15 Harvesting and threshing

Sunflower heads ripe when the back of the head turns yellowish-brown. Harvesting of head is not done at a time. It is ready for harvesting when moisture content of seeds is 20%. The harvested heads were sun dried well and then threshed by beating the centre of the head with a small stick.

3.3 Formulae adopted for calculation of different

Chemicals required in the experiment

3.3.1 Herbicide application

The amount of herbicides required by the experiment was calculated by using the following formula:

$$Q = \frac{(R \times A)}{C} \times 100$$

Where, Q = quantity of herbicides required in kg or litre ha^{-1}

R = Recommended rate in kg *a.i.* ha^{-1}

C = % *a.i.* in herbicide formulation

3.3.2 Fertilizer application

The amount of fertilizers required was calculated by using the following formula:

$$\mathit{A}\text{mount of fertilizer required (kg)} = \frac{\text{Recommended rate } (kg\ ha^{-1}) \times \text{Area to be fertilized } \times 100}{\text{\% element in fertlizer}}$$

3.3.3 Insecticide application

The amount of insecticides required was calculated by using the following formula:

$$\text{Amount of insecticide} = \frac{\text{Rate desired (kg ha}^{-1}) \times 100}{\text{Concentration of insecticide (\%)}}$$

3.3.4 Energy analysis

The energy equivalents of input and output indices and the energy use efficiency were calculated by the equations given below (Chaudhary *et al.*, 2017).

a. Energy input (MJ ha^{-1})

$$\text{Energy input} = \sum_{\mathrm{i=1}}^{\mathrm{n}} (\mathrm{C1} + \mathrm{C2} + \cdots \mathrm{Ci})$$

Where, C_1+C_2+…C_i is energy of each component

b. Energy output (MJ ha^{-1})

Energy output = SP×EC

Where, SP = System productivity (kg ha^{-1})

EC = Energy coefficient

c. Energy use efficiency (%)

$$\text{Energy use efficiency} = \frac{\text{Energy Output}}{\text{Energy Input}}$$

3.4 Methods of recording different observations

3.4.1 Rice

3.4.1.1 Growth attributes

To collect data on plant growth parameters, five random plants were selected and tagged from each plot leaving the boarder. For destructive plant parameters, sampling was done from the boarder rows. To evaluate the effect of treatments on various growth attributing characters, periodic plant sampling was done in both the years of observation. The average value of each parameter was calculated from the five tagged plant samples.

3.4.1.1.1 Plant height (cm)

Five plants were selected randomly from each plot and tagged. Plant height was recorded in centimetre from the ground level to the tip portion of the longest leaf of each tagged plant at 30, 60, 90 DAS and at harvest.

3.4.1.1.2 Number of tillers (m^{-2})

In every plot, two locations with a row length of one meter each were chosen and marked. The total number of tillers from each selected spot within the plot were counted and expressed in number of tillers m^{-2} at each stage of observations (at 30, 60 and 90 DAS).

3.4.1.1.3 Dry matter accumulation (g $plant^{-1}$)

Plant dry matter accumulation was recorded at 30, 60 and 90 DAS by using plant destructive method. Five plants were randomly selected and cut from the base avoiding the broader rows. Then the collected plant samples were kept in hot air oven and dried at 55 °C till it attained a constant dry weight and their weight were recorded. The weight was then expressed in g $plant^{-1}$ and the average weight was taken from these five plant dry weight.

3.4.1.1.4 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate (CGR) (g m^{-2} day^{-1}) at 25-50 DAS and 50-75 DAS was calculated by using the dry matter accumulation (g) of plant from each plot at 25, 50 and 75 DAS with the following formula (Watson, 1956):

$$\mathrm{CGR} = \frac{W_1 - W_2}{(t_1 - t_2)\mathrm{S}}$$

Where, W_1 and W_2 are the dry weights of plants at t_1 and t_2, respectively. S is the land area (m^2) over which dry matter was recorded.

3.4.1.1.5 Relative growth rate (g g^{-1} day^{-1})

The Relative growth rate (RGR) (g g^{-1} day^{-1}) at 25-50 DAS and 50-75 DAS was also calculated using the data of dry matter accumulation (g) of plant from each plot at 30 DAS and 60 DAS with the following formula (Blackman, 1919):

$$\mathrm{RGR} = \frac{\ln \mathrm{W}_1 - \ln \mathrm{W}_2}{\mathrm{t}_1 - \mathrm{t}_2}$$

Where, W_1 and W_2 are the dry matter produced by a gram (g) of existing dry matter in the day at a time t_1 and t_2, respectively.

3.4.1.1.6 Leaf area index (LAI)

Leaf area measured through portable hand-held leaf area metre, was divided by ground area to calculate leaf area index at 25 and 50 DAS by using the given formula below:

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2)}{\text{Unit land area (cm}^2)}$$

Where, land area plant^{-1} = Row distance × Plant distance

3.4.1.1.7 Chlorophyll content (micro mol m^{-2})

Non-destructive and rapid estimation of extractable chlorophyll in leaves was done by using chlorophyll meter SPAD-502 (Minolta Corporation, Ramsey, NJ) (Zhang *et al*., 2022). It is a simple hand held portable diagnostic tool to measure the greenness/relative chlorophyll content of leaves. It gives indirect measurement of leaf-chlorophyll contents in a rapid, non-destructive, and convenient manner. A silicon photo diode detects transmittance of light emitted by two diodes through a leaf sample. Of these, peak emittance of one is 650 nm with high absorbance by chlorophyll which is relatively unaffected by carotene. The other one having peak emittance at 940 nm with negligible absorbance by chlorophyll. The reading (SPAD) correlated with leaf chlorophyll concentration and calculated by the transmittance through leaf tissue at given wavelength. For each treatment, five plants were chosen randomly and SPAD values were recorded at 25 and 50 DAS. The values were averaged and shown as the leaf's mean SPAD reading.

3.4.1.2 Yield and yield attributes

3.4.1.2.1 Length of panicle (cm)

Five panicles were randomly sampled from the five tagged plants in each plot. The panicle length was then measured from the neck node to the tip of the top most spikelet. Average panicle length was computed and expressed in centimetres.

3.4.1.2.2 Number of panicle (m^{-2})

Leaving the boundary row, the number of panicles m^{-2} in each plot was counted.

3.4.1.2.3 Weight of panicle (g)

Weight of panicle was taken by randomly selecting five panicles from the tagged plants from each plot. The average value was recorded and expressed ingrams.

3.4.1.2.4 Number of grains panicle^{-1}

The number of grains panicle^{-1} was counted from five randomly selected panicles taken from the tagged plants of each plot and the average value was recorded.

3.4.1.2.5 Number of filled grains panicle^{-1}

From every plot, five panicles were selected randomly, and the average number of filled grains in each panicle was determined by counting the number of filled grains in each panicle.

3.4.1.2.6 Number of unfilled grains panicle^{-1}

The number of unfilled grains in each panicle was determined by counting the number of unfilled grains from randomly selected five panicle and the average was recorded.

3.4.1.2.7 Test weight (g)

1000 grains were counted from each plot separately from the sample plants after proper sundry to a constant weight and the weight was recorded and expressed in grams.

3.4.1.2.8 Grain yield (kg ha^{-1})

The harvested plants were sun dried first and the grains were manually separated by threshing. The separated grains were sundried properly to bring down moisture content to 14 %. The grains were winnowed, cleaned and weighted plot wise and expressed in kg ha^{-1} using the formula.

$$\text{Grain Yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of grain per plot (kg)}}{\text{Size of the plot (m}^2\text{)}}$$

3.4.1.2.9 Straw yield (kg ha^{-1})

After the grains were properly threshed, the straws were gathered from each plot and sun-dried. The weight of the straws was then recorded and represented in kg ha-^{1} using the formula.

$$\text{Straw Yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the straw per plot (kg)}}{\text{Size of the plot (m}^2\text{)}}$$

3.4.1.2.10 Harvest index (%)

Harvest Index is the ratio of economic yield to biological yield. Harvest index was calculated by using the formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (grain yield)(kg ha}^{-1}\text{)}}{\text{Biological yield (grain + straw yield)(kg ha}^{-1}\text{)}} \times 100$$

3.4.2 Biometric weed observations

3.4.2.1 Weed samplings

Sampling of weeds was done by placing a quadrate of size 0.5 m × 0.5 m (0.25 m^2) at two random spots at each plot. The weeds within the quadrate frame were counted, recorded, identified and the mean values were expressed in m^{-2}. Species wise weed densities were recorded at 30, 60 and 90 DAS. The collected weed samples were then washed off thoroughly to remove the dirt, sun dried first and then finally oven dried at a temperature of 55˚C for 48 hours and dry weight of weeds were recorded separately at 30, 60 and 90 DAS.

3.4.2.2 Weed flora (Species wise)

The different weed flora found in the experimental field was surveyed, identified and classified morphologically into three categories as grasses, sedges and broad-leaved weeds. The reading was done at 30, 60 and 90 DAS for both the years.

3.4.2.3 Importance value index (%)

Importance value index (IVI) was recorded at 30, 60 and 90 DAS. The importance value of a species indicates the degree of dominance of a species over the other species in given area. It is calculated by using the formula given below (Kastanja *et al*., 2021):

$$\begin{aligned}\text{Importance value index (\%)} \\ &= \text{Relative density} + \text{Relative frequency} \\ &+ \text{Relative abundance}\end{aligned}$$

Relative density is the population of a particular species expressed as percentage of all the species in a community.

$$\text{Density} = \frac{\text{Total no. of individual of a species}}{\text{Quadrates studied}}$$

$$\text{Relative density} = \frac{\text{Density of a particular species}}{\text{Total density of all the species}} \times 100$$

Relative frequency refers to the degree of dispersion of individual species in an area.

$$\text{Frequency} = \frac{\text{Quadrated of occurrence}}{\text{Quadrates studied}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Relative abundance is an expression of area covered or occupied by different species and usually expressed as percentage.

$$\text{Abundance} = \frac{\text{Total no. of individuals of a species}}{\text{Quadrates of occurrence}}$$

$$\text{Relative abundance} = \frac{\text{Species abundance}}{\text{Total abundance of all species}} \times 100$$

3.4.2.4 Weed population (no. m^{-2})

The population of different weed species observed in the experimental plots were recorded at 30, 60 and 90 DAS. A quadrate with a dimension of 0.5 m × 0.5 m (0.25 m^2) was placed randomly at two places in each plot and the weeds from that area were removed. Weed population was counted species wise as grasses, broad leaved and sedge weeds separately from the same quadrate and their sum was used to obtain total weed population. The weed data was subjected to square root transformation with the help of the formula $\sqrt{(x + 0.5)}$, where x is the actual weed count.

3.4.2.5 Weed dry weight (g m^{-2})

The collected weed samples from each plot were washed properly to remove soil or any other unwanted particles adhering to them, sun dried and oven dried at a temperature of 55°C for 48 hours. The dry weight of the weeds was recorded at 30, 60 and 90 DAS after it attained a constant weight and expressed in g m^{-2}.

3.4.2.6 Weed control efficiency (%)

Weed control efficiency (WCE) was calculated at 60 DAS by using the formula given below Kumari *et al*. (2023):

$$\text{WCE (\%)} = \frac{\text{DWC} - \text{DWT}}{\text{DWC}} \times 100$$

Where, DWC = Dry weight of weeds (g m^{-2}) per unit area of control plots

DWT = Dry weight of weeds (g m^{-2}) per unit area of treated plots

3.4.2.7 Weed index (%)

Weed index (WI) was calculated at harvest by using the following formula (Gill and Kumar, 1969):

$$\mathrm{WI}\ (\%) = \frac{Y_{WF} - Y_{T}}{Y_{WF}} \times 100$$

Where, Y_{WF} = Yield from weed free plot

Y_{T} = Yield from treated plot

Transformation of data

For weeds, the original values were transformed using square root transformations and analyzed statistically. Data on weed count and weed dry weight have shown high degree of variation. A relationship between the means and variance was observed. Therefore, the data on weed density or count and weed biomass (dry weight) were subjected to transformation to make analysis of variance more valid. Wherever the treatment difference was found, significant (F test), critical difference was worked out at 5% probability level and the values were furnished. If there are non-significant difference between treatments, it was denoted by symbol NS.

3.4.3 Soil analysis

The soil samples were collected treatment wise from the experimental field before sowing and after harvesting of the main crop. The collected soil samples were then mixed properly, shade dried, crushed and sieved through 2 mm sieve for further use for analysis of soil texture, pH, bulk density, soil organic carbon and available soil nitrogen, phosphorus and potassium.

3.4.3.1 Soil texture

Soil texture was determined by international pipette method as outlined by Piper (1966).

3.4.3.2 Soil pH (soil reaction)

Soil pH was determined in soil: water (1:2) ratio by digital pH meter (Jackson, 1967).

3.4.3.3 Bulk density (g cm^{-3})

The bulk density of soil was determined by using method as described by Chopra and Kanwar (1976).

3.4.3.4 Soil organic carbon (%)

Organic carbon of soil was determined by rapid titration method as described by Walkley and Black method (1934) and the results were expressed in terms of percentage.

3.4.3.5 Available nitrogen (kg ha^{-1})

The available soil nitrogen was determined by alkaline potassium permanganate method proposed by Subbiah and Asija (1956). The procedure involves determination of ammonia liberated on distillation of alkaline potassium permanganate solution using 'Kel Plus' nitrogen distillation machine. This serves as an index of the available soil nitrogen and the data is calculated in terms of kg ha^{-1}.

3.4.3.6 Available phosphorus (kg ha^{-1})

Available phosphorus was determined by using Bray's No. 1 method as outlined by Bray and Kurtz (1945). In this method, soil was extracted using 0.03 N NH4F + 0.025 N HCL (pH 3.5) and available phosphorus was estimated colorimetrically using ascorbic acid method where ammonium molybdate and stannous chloride was added to the filtered extract. The intensity (% transmittance) of characteristics blue colour 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 % transmittance of the P in the test solution, concentration of P was read from the standard curve. The results were expressed in kg ha^{-1}. The procedure is primarily meant for soils which is moderate to strongly acidic with pH around 5.5 or less.

3.4.3.7 Available potassium (kg ha^{-1})

The available potassium was extracted from 5 g of soil by shaking with 25 ml of neutral ammonium acetate (pH 7) solution for 5 minutes and the extract was filtered immediately using dry Whatman No. 1 filter paper and then potassium concentration in the extract was determined by using Flame Photometer (Hanway and Heidal, 1952). The data is expressed in terms of kg ha^{-1}.

3.4.4 Chemical analysis of plant

3.4.4.1 N, P and K contents in weeds (%)

Weed samples were randomly collected from each plot at 60 DAS of crop for estimation of N, P and K content in weed plants. Collected weed samples were first shade dried and then oven dried at a temperature of 55˚C and grinded thoroughly. The samples were analyzed using standard procedure as for nitrogen by modified Kjeldahl method, phosphorus by di-acid digestion and yellow colour development method (Jackson, 1973) and potassium by flame photometer method (Jackson, 1973).

3.4.4.2 N, P and K depletion by weeds (kg ha^{-1})

Nutrient depletion by weeds is the amount of nutrients taken up by weeds. The percentage of nutrient depletion by weeds is calculated by multiplying the nutrient contents in weeds with weed dry matter production of each plot. The nutrient depletion by weeds was computed by using the formula given below:

$$\text{Nutrient depletion by weeds (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)in weeds} \times \text{weed dry matter production (kg ha}^{-1}\text{)}}{100}$$

3.4.4.3 N, P and K content in grain and straw (%)

After harvesting, sample plants were randomly selected, dried and threshed properly for each plot. The grains and straw were separated, air dried and then finally oven dried at a temperature 65˚C. The samples were grounded to powder and subjected to chemical estimation for N, P and K content using the following methods.

Nutrient	Method
Nitrogen	Modified Kjeldhal method as described by (Black, 1965)
Phosphorous	Vanado-molybdate-phosphoric acid method (Jackson, 1973)
Potassium	Flame photometer (Chapman and Pratt, 1961)

3.4.4.4 N, P and K uptake by grain and straw (kg ha^{-1})

Nutrient uptake by crop is the amount of nutrient taken up by the crop. Nutrient uptake in grain and straw was estimated by multiplying percentage nutrient content in their respective grain or straw with grain or straw yield. The crop nutrient uptake was computed using the formula below:

$$\text{Nutrient uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{Percent nutrient content in grain (\%)} \times \text{Grain yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Percent nutrient content in straw (\%)} \times \text{Straw yield (kg ha}^{-1}\text{)}}{100}$$

3.4.5 Observation for sequential crop sunflower

3.4.5.1 Growth attributes

3.4.5.1.1 Initial plant population (no. m^{-2})

Plant population per square meter area in each plot was counted using 0.25 m^2 quadrate placed at random spots. The data from these two spots were doubled for conversion into per m^2 and expressed in number metre^{-2}.

3.4.5.1.2 Plant height (cm) at harvest

Five plants were randomly chosen from each plot to record the plant height at harvest stage of sunflower. The average height of these five plants were used for determining the average plant height in each treatment and expressed in centimeter.

3.4.5.1.3 Chlorophyll content at 25 and 50 DAS (micro mol m^{-2})

Chlorophyll content of sunflower was estimated by using SPAD meter at 25 and 50 DAS. It is a simple hand held portable diagnostic tool to measure the greenness/relative chlorophyll content of leaves.

3.4.5.2 Yield attributes

3.4.5.2.1 Head diameter (cm)

Five random heads were chosen from each plot to record the head diameter at the time of harvesting of sunflower. It was measured using measuring tape. The average head diameter of these five head represents the head diameter of the respective plot and is expressed in centimeter.

3.4.5.2.2 No. of seeds per head

Five sunflower heads were selected randomly to count the number of seeds per head.

3.4.5.2.3 Test weight (g)

Thousand bold seeds were counted from randomly selected head/ capitulum of sunflower. The weight of thousand seeds was recorded and expressed in gram.

3.4.5.2.4 Seed yield (kg ha^{-1})

The seed yield from each plot after threshing and cleaning was sun dried properly and weighted to determine in terms of ha^{-1}.

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

3.4.5.2.5 Stover yield (kg ha^{-1})

The stover yield from each plot was sun dried thoroughly after harvesting and threshing for some days. The weight was then recorded plot wise to determine the stover yield in terms of ha^{-1} using the formula given below:

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

3.4.5.2.6 Harvest index (%)

Harvest index was calculated by using the formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (grain yield)(kg ha}^{-1}\text{)}}{\text{Biological yield (grain + straw yield)(kg ha}^{-1}\text{)}} \times 100$$

3.4.5.3 Weed observations

3.4.5.3.1 Weed population (no. m^{-2}) at 20 DAS

Weed density was recorded using 0.25 m^2 quadrant from two randomly selected places in each plot and expressed as number m^{-2}. The weeds were then counted, categorized into grasses, sedges and broad-leaved weeds and subjected to square root transformation using the formula $\sqrt{(x + 0.5)}$, where x is the actual weed count.

3.4.5.3.2 Weed dry weight (g m^{-2}) at 20 DAS

The weed collected from within the quadrate from two random spots within each plot were washed properly to remove soil completely and other adhering particles, sundried and then oven dried at 55˚C for 48 hours till it reaches a constant weight. The weed dry weight was then recorded and expressed in terms of g m^{-2}.

3.5 Economic analysis

Economics of different treatments was worked out as per existing market prices.

3.5.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation was calculated as per item wise cost incurred in each treatment.

3.5.2 Gross return (₹ ha^{-1})

Gross return for each treatment was calculated by multiplying the values of economic produce with the prevailing support prices of output.

3.5.3 Net return (₹ ha^{-1})

Net return of each treatment was calculated by subtracting the total cost of cultivation from the gross return.

$$\text{Net return} = \text{Gross return} - \text{Total cost of cultivation}$$

3.5.4 Benefit: Cost ratio

Benefit: cost ratio was estimated by using the formula:

$$\text{B: C Ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}} \times 100$$

3.6 Statistical analysis

Data obtained from various studies were statistically analyzed in split plot design using the technique of Analysis of Variance as described by Gomez and Gomez (1984). The significance differences were tested by 'F' test. Critical difference of different groups of treatments and their interactions at 5 per cent probability level were calculated whenever 'F' test was significance.

Plate 1: Field preparation

Plate 2: Sowing of rice

Plate 3: Seedling stage of rice

Plate 4: Tillering stage of rice

Plate 5: Flowering stage of rice

Plate 6: Maturity stage of rice

Plate 7: Harvested rice

Plate 8: Drying before threshing

Plate 9: General view of the experimental site of upland rice

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The experimental results recorded during the current experiment entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)"** are presented in this chapter. The data collected at different stages of observation for the two experimental years (2021 and 2022), along with their pooled data have been statistically evaluated, presented in respective tables and figures, and graphically depicted wherever necessary with available piece of literature and evidence supporting the result. The findings have been presented in a way that provides a clear and understandable view of how tillage system and weed management practices affect weed dynamics, growth, yield, soil fertility, economics of rice and residual effect on succeeding crop.

4.1 Effect of weather on crop and weeds

Weather condition plays a very vital role that influence the growth and yield of the crops as well as the weed diversity. The actual weather parameters that prevailed during the cropping period are maximum and minimum temperature, maximum and minimum relative humidity, rainfall, number of rainy days and sunshine hours. The variations in weather conditions during the period of investigation influence the growth and expected yield of the crop to a large extend. Each crop requires its own cardinal temperature, relative humidity, amount of rainfall, number of rainy days and number of sunshine hours for optimum growth and development. Huge fluctuation from their cardinal temperature resulted in poor growth, development and hence poor crop productivity.

A perusal of the weather data, it can be clearly known that the weather conditions during the second year of investigation was more favourable for optimum growth and development of crop. The weekly total amount of rainfall received during the first and second year of the study was 1083.5 mm and 1214.0 mm respectively. The experimental site received rainfall much lesser than the normal and uneven distribution resulted in poor growth, more incidence of weed growth and ultimately less yield of rice during the first year of the study. While higher amount of rainfall with uniform distribution resulted in better growth and development of crop and less weed emergence during the second year. The maximum and minimum temperature during both the years was found almost same. The weekly sunshine hours and number of rainy days was almost constant during both the years of the study. However, the weekly mean relative humidity was higher in the first year than the second year. The weather data presented in the previous chapter in Table no. 3(a) and 3(b) clearly indicates that meteorological weather data significantly influence the crop parameters like growth parameters, yield attributes, yield of rice and nutrient uptake by crop as well as on the weed parameters like weed density, dry weight etc.

4.2 Observation on weeds

To evaluate the effect tillage system and weed management practices on different weed dynamics, importance value index (%), weed population (m^{-2}) and weed dry matter (g m^{-2}) were recorded at 30, 60 and 90 DAS. Weed control efficiency (%) and nutrient (nitrogen, phosphorus and potassium) depletion (kg ha^{-1}) by weeds were recorded at 60 DAS.

4.2.1 Importance value index (IVI)

Details on importance value index of different weed flora at 30, 60 and 90 DAS are presented in Table 4.1 and depicted in Fig 4.1(a), 4.1(b) and 4.1(c). *Borreria latifolia* (Aubl.) K. Schum. recorded the maximum importance value index at all stages of observations (82.40% at 30 DAS, 47.60% at 60 DAS and 51.56% at 90 DAS) while *Cynodon dactylon* L. recorded the lowest value (3.46% and 12.92%) at 30 and 90 DAS during both the years of investigation. While at 60 DAS, *Lindernia crustacea* L. (11.08%) recorded the lowest IVI.

Hence, *Borreria latifolia* (Aubl.) K. Schum. registered the highest IVI showing its highest degree of dominance over the other weed species found in the experimental area in both years of experiment. The dominance of this weed species might be due to the suitable weather and environmental condition that favour its growth. These findings were also reported by Kastanja *et al*. (2021).

4.2.2 Weed flora

Throughout the course of the two experimental years (2021 and 2022), a total of eleven (11) major weed flora were found, identified and classified to three categories as grasses, sedges and broad leaved weeds. Table 4.2 showed the detail information on these types of weed flora. The grasses include *Cynadon dactylon* L., *Digitaria sanguinalis* L. and *Eleusine indica* L.; sedge include *Cyperus iria* L. and broad leaved weeds include *Ageratum conyzoides* L., *Alternanthera sessiles* L., *Borreria latifolia* (Aubl.) K. Schum., *Borreria ocymoides* L., *Mollugo pentaphylla* L., *Lindernia crustacea* L. and *Sida cordifolia* L. respectively. This might be due to the fact that the experimental field was rich in weed seedbank of various weed species that was uniformly distributed across the field and most of the weed species were broad leaved weeds. Similar weed species in upland direct seeded rice were reported by Longkumer and Singh (2013).

Table 4.1: Importance value index (%) at different crop growth stages

Sl. No.	Weed species	30 DAS			60 DAS			90 DAS		
		2021	2022	Average	2021	2022	Average	2021	2022	Average
1.	***Cynadon dactylon* L.**	3.52	3.40	3.46	23.32	23.55	23.43	12.90	12.94	12.92
2.	***Digitaria sanguinalis* L.**	30.24	30.58	30.41	47.34	47.93	47.63	31.46	31.68	31.57
3.	***Eleusine indica* L.**	12.97	12.94	12.95	13.41	13.31	13.36	14.28	14.27	14.27
4.	***Cyperus iria* L.**	14.16	14.23	14.20	12.99	12.90	12.94	17.12	17.09	17.10
5.	***Ageratum conyzoides* L.**	52.96	49.24	51.10	43.17	43.50	43.34	45.93	46.11	46.02
6.	***Alternanthera sessiles* L.**	15.79	15.56	15.67	18.44	18.52	18.48	23.94	24.07	24.00
7.	***Borreria latifolia* (Aubl.) K. Schum.**	80.97	83.83	82.40	47.50	47.70	47.60	51.07	52.06	51.56
8.	***Borreria ocymoides* L.**	14.59	14.61	14.60	32.03	29.87	30.95	25.67	25.48	25.58
9.	***Mollugo pentaphylla* L.**	48.42	49.64	49.03	37.37	38.23	37.80	42.13	42.27	42.20
10.	***Lindernia crustacea.* L.**	11.86	11.69	11.78	11.08	11.07	11.08	19.06	18.21	18.63
11.	***Sida cordifolia* L.**	14.52	14.27	14.40	13.37	13.41	13.39	16.45	15.83	16.14

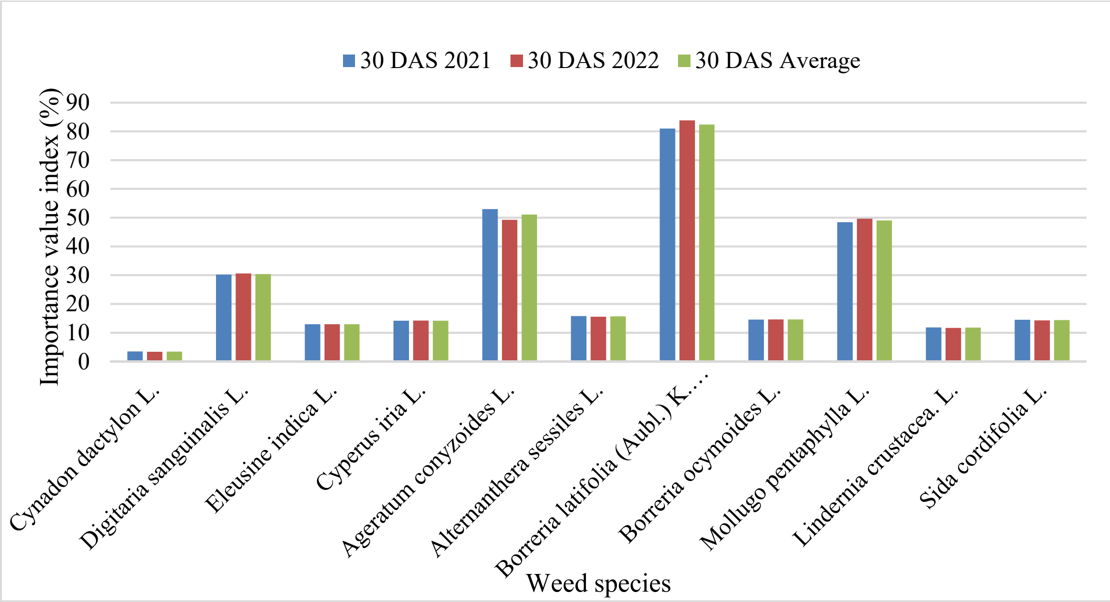


Fig 4.1(a): Effect of tillage system and weed management practices on Importance value index at 30 DAS

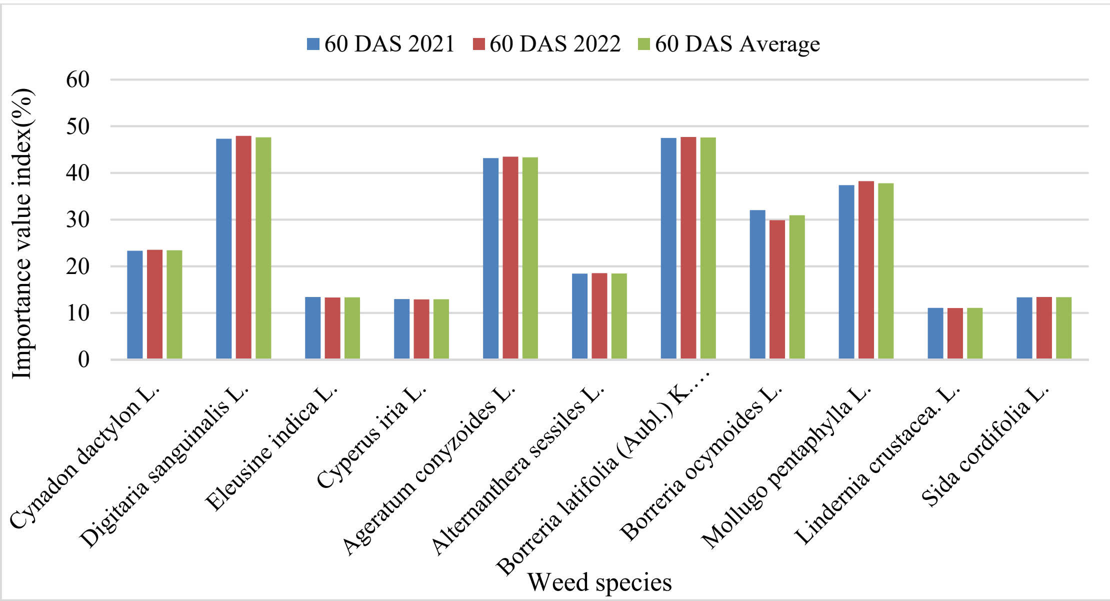


Fig 4.1(b): Effect of tillage system and weed management practices on Importance value index at 60 DAS

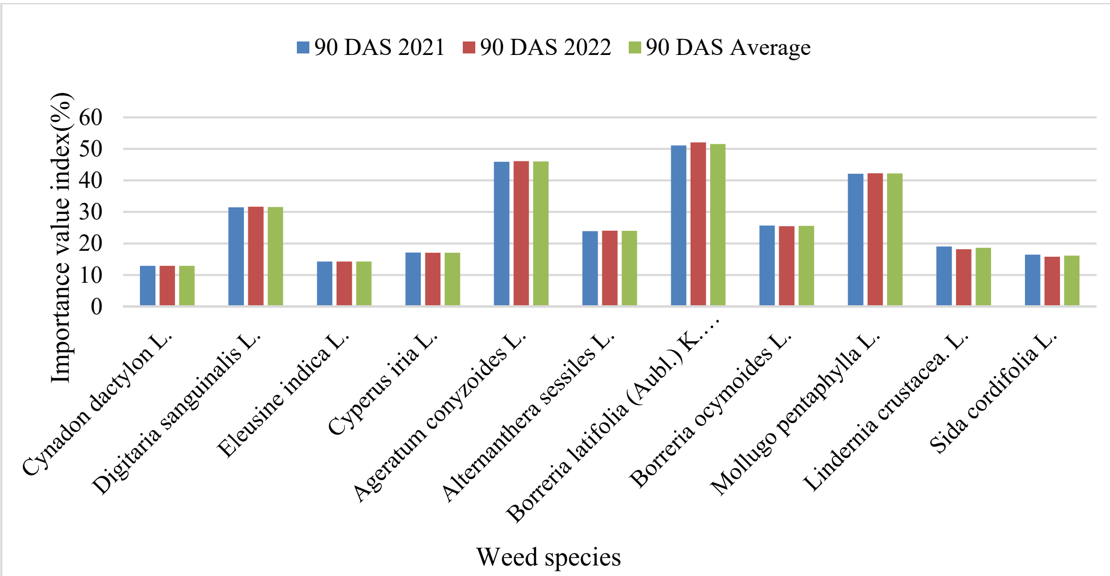


Fig 4.1(c): Effect of tillage system and weed management practices on Importance value index at 90 DAS

Table 4.2: Weed flora of the experimental field

Sl. No.	Scientific name	English name	Family	Habitat
GRASSY WEEDS				
1.	*Cynodon dactylon* L.	Bermuda grass	Poaceae	Perennial grass
2	*Digitaria sanguinalis* L.	Finger grass, Purple or Large Crab-grass	Poaceae	Prostrate annual grass
3.	*Eleusine indica* L.	Indian goose grass, Crow-foot gras	Poaceae	Annual grass
SEDGES				
4.	*Cyperus iria* L.	Rice field flat sedge	Cyperaceae	Annual sedge
BROAD LEAVED WEEDS				
5.	*Ageratum conyzoides* L.	Goat weed	Asteraceae	Erect-decumbent annual herb
6.	*Alternanthera sessiles* L.	Sessile joyweed	Amaranthaceae	Perennial
7.	*Borreria latifolia* (Aubl.) K. Schum.	Broadleaf buttonweed	Rubiaceae	Annual
8.	*Borreria ocymoides* L.	Purple-leaved buttonweed	Rubiaceae	Annual herb
9.	*Mollugo pentaphylla* L.	Five leaved carpet weed	Molluginaceae	Decumbent-erect annual herb
10.	*Lindernia crustacea.* L.	Malaysian false pimpernel	Scrophulariaceae	Erect-posture annual herb
11.	*Sida cordifolia* L.	Heart-leaf sida	Malvaceae	Perennial erect undershurb

Eleusine indica

Digiteria sanguinalis

Cynodon dactylon

Plate 10: Dominant grasses in the experimental field

Cyperus iria

Ageratum conyzoides

Alternanthera sessiles

Plate 11: Dominant sedges and broad-leaved weeds in the experimental field

Borreria latifolia

Borreria ocymoides

Lindernia crustaceae

Mollugo pentaphylla

Sida cordifolia

Plate 12: Dominant broad-leaved weeds in the experimental field

4.2.2.1 Total weed population (no. m^{-2})

The data pertaining to total weed population due to the different tillage system and weed management practices at all different days of intervals are presented in Table 4.3(a) and illustrated in Fig 4.2(a), 4.2(b) and 4.2(c). The data showed that different tillage system and weed management practices significantly influence the total weed population. Overall, the total weed population decreased subsequently thereafter till 90 DAS throughout the cropping season.

At 30 DAS, among all the tillage system, conventional tillage system recorded significantly minimum total population of weeds (348.00 and 319.89) while zero tillage recorded significantly maximum total weed population (442.33 and 426.83), which was followed by minimum tillage during the period of study. Similar trends on total population of weeds were seen in both the years at 60 and 90 DAS. The minimum weed population in conventional tillage system might be due to maximum inversion of surface soil and burial of weed seeds deeply in the soil. This tillage system buried 25% of the weed seeds at a depth of 5-10 cm in soil. Similar findings were reported by Chauhan (2012). Dolma (2017) reported that periodic appraisal of weeds showed significant reduction in weed population m^{-2} in conventional tillage among the different tillage system. Zero tillage system have low soil disturbance that would likely to leave a significant amount of the weed seed bank on or near the soil surface. Since light may only reach the soil's top layer, it may encourage the germination of weed seeds, which would increase the number of weeds in a zero-tillage system by increasing seedling emergence. This was in close proximity with Chauhan (2012) and Bhargaw *et al.* (2023).

The data displayed in Table 4.2 (a) demonstrated that, during all growth phases, the total weed density differed significantly as a result of weed management treatments in comparison to weedy check. All the herbicidal treatments were found to be significantly superior over weedy check in reducing the weed population of total weeds in both the years. At 30 DAS, the lowest total weed population was recorded in weed free treatment (0.00 and 0.00) while the maximum was recorded in weedy check (1130.44 and 1054.78) in both the years. The data further revealed that among the herbicidal treatments, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS, recorded significantly lowest total weed density (133.56 and 124.67) during both the years which was followed by stale seedbed *fb* pyrazosulfuron ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS. This might be due to effective controlling of grasses and broad leaved weeds with pre emergence application of pendimethalin in early stages of crop. It restricts the cell mitosis that inhibit growth and development of roots and shoots in susceptible weed species. The later emerging weeds were effectively suppressed by post- emergence application of bispyribac-sodium. It is a systemic, broad spectrum herbicide effective in controlling grasses, sedges and broad leaved weeds in the later stages of crop growth by obstructing the growth-promoting enzyme acetolactate synthase (ALS). There was subsequent decreased in total weed density till 90 DAS, which might be due to effective control of weeds resulting from application of post emergence herbicides at 25 DAS. Jat *et al.* (2019) reported that sequential application of pendimethalin EC @ 750-1000 g ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} effectively reduced the density of overall weeds. These findings were in close proximity as observed by Mahajan and Chauhan (2013), and Singh *et al.* (2016b). Similar patterns were followed at 60 and 90 DAS as found at 30 DAS.

The interaction effect of tillage system and weed management practices on total weed population was found to be significant on total weed population at 30, 60 and 90 DAS in both the years. This indicated that herbicidal treatment varied under different tillage system. Herbicide performance, particularly for soil-active herbicides changes due different tillage practices. The amount of soil disturbance, the degree of herbicide incorporation, the location of weed seeds in the soil and the quantity of plant residue all have an impact on herbicide performance (Chauhan *et al*. 2006 b, c). The performance of pre- emergence herbicides is influenced by the amount of soil moisture.

The data pertaining to the interaction effect of tillage system and weed management practices are presented in the Table 4.2(b), 4.2(c) and 4.2(d). The lowest weed total density was associated with weed free treatment under all the tillage system (T_1W_5, T_2W_5 and T_3W_5). While the highest total weed density was recorded with weedy check under zero tillage system (T_1W_5) (1176.67 and 1145.67) at 30 DAS as shown in Table 4.2(b). Similar trends were followed at 60 and 90 DAS as shown in Table 4.2(c) and Table 4.2(d).

4.2.2.2 Total weed dry weight (g m^{-2})

The data pertaining to the total weed dry weight due to the different tillage system and weed management practices at all different intervals of observation are presented in Table 4.4(a) and illustrated in Fig 4.3(a), 4.3(b) and 4.3(c). The perusal of the data showed that total weed dry weight was significantly influenced by different tillage system and weed management practices. Overall, the total weed dry weight increased till 60 DAS and slightly decreased subsequently thereafter till 90 DAS throughout the cropping season. At the later stages of crop, majority of the weed ceased weed growth that might have attributed from senescence and life cycle completion of weeds that further resulted in declining trend of weed dry matter accumulation.

It was observed that total weed dry weight was found to be lower in the second year of the investigation as compared to the first year. The probable reason might be due to the favourable weather and environmental condition during the second year that favored vigorous growth of crop that helped up in suppressing the weed growth.

Table 4.3(a): Effect of tillage system and weed management practices on total weed population (no. m^{-2}) at different crop growth stages

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	18.33 (442.33)	17.99 (426.83)	18.16 (434.58)	16.38 (382.61)	15.89 (361.50)	16.13 (372.06)	9.95 (139.50)	9.56 (130.78)	9.76 (135.14)
T_2	17.21 (399.56)	16.74 (376.67)	16.98 (388.11)	14.73 (328.11)	14.35 (313.89)	14.54 (321.00)	8.65 (116.39)	8.28 (109.67)	8.46 (113.03)
T_3	15.77 (348.00)	15.17 (319.89)	15.47 (333.94)	13.20 (285.00)	12.81 (271.67)	13.01 (278.33)	7.77 (100.61)	7.44 (95.22)	7.60 (97.92)
SEm±	0.04	0.03	0.03	0.03	0.06	0.03	0.04	0.02	0.02
CD (p=0.05)	0.19	0.13	0.10	0.13	0.23	0.11	0.18	0.08	0.08
Weed management practices (W)									
W_1	18.63 (348.56)	18.31 (336.89)	18.47 (342.72)	14.63 (217.67)	14.24 (206.00)	14.44 (211.83)	8.49 (73.56)	8.10 (66.89)	8.29 (70.22)
W_2	23.25 (542.56)	22.69 (517.00)	22.97 (529.78)	18.98 (362.33)	18.39 (339.78)	18.68 (351.06)	11.36 (130.22)	10.92 (120.44)	11.14 (125.33)
W_3	14.95 (224.67)	14.57 (213.44)	14.76 (219.06)	10.86 (120.67)	10.41 (111.44)	10.63 (116.06)	6.04 (38.11)	5.54 (32.33)	5.79 (35.22)
W_4	11.47 (133.56)	11.06 (124.67)	11.27 (129.11)	8.57 (76.00)	8.19 (69.33)	8.38 (72.67)	5.03 (26.00)	4.54 (21.11)	4.79 (23.56)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	33.63 (1130.44)	32.47 (1054.78)	33.05 (1092.61)	34.85 (1214.78)	34.17 (1167.56)	34.51 (1191.17)	21.11 (445.11)	20.76 (430.56)	20.93 (437.83)
SEm±	0.06	0.06	0.04	0.08	0.05	0.05	0.07	0.05	0.04
CD (p=0.05)	0.18	0.17	0.12	0.24	0.15	0.14	0.19	0.14	0.11

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.3(b): Interaction effect of tillage system and weed management practices on total weed population (no. m^{-2}) at 30 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	20.15 (405.67)	18.97 (359.33)	16.77 (280.67)	19.90 (395.00)	18.65 (347.33)	16.40 (268.33)	20.03 (400.33)	18.81 (353.33)	16.58 (274.50)
W_2	25.00 (624.33)	23.60 (556.33)	21.15 (447.00)	24.35 (592.33)	23.17 (535.67)	20.58 (423.00)	24.67 (608.33)	23.38 (546.00)	20.87 (435.00)
W_3	16.25 (263.67)	15.38 (236.00)	13.22 (174.33)	15.93 (253.33)	14.92 (222.00)	12.86 (165.00)	16.09 (258.50)	15.15 (229.00)	13.04 (169.67)
W_4	13.57 (183.67)	11.10 (122.67)	9.74 (94.33)	13.23 (174.67)	10.76 (115.33)	9.19 (84.00)	13.40 (179.17)	10.93 (119.00)	9.46 (89.17)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	34.31 (1176.67)	33.52 (1123.00)	33.05 (1091.67)	33.85 (1145.67)	32.25 (1039.67)	31.30 (979.00)	34.08 (1161.17)	32.88 (1081.33)	32.17 (1035.33)
SEm± (T×W)	0.11			0.10			0.07		
CD (P=0.05) (W at same level of T)	0.31			0.30			0.21		
SEm± (W×T)	0.10			0.09			0.09		
CD (P=0.05) (T at same or different level of W)	0.29			0.26			0.26		

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage, **W_1:** Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.3(c): Interaction effect of tillage system and weed management practices on total weed population (no. m^{-2}) at 60 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	16.87 (284.67)	14.95 (223.00)	12.07 (145.33)	16.44 (269.67)	14.54 (211.00)	11.74 (137.33)	16.65 (277.17)	14.75 (217.00)	11.91 (141.33)
W_2	20.84 (433.67)	19.22 (369.00)	16.88 (284.33)	19.97 (398.33)	18.79 (352.67)	16.42 (268.33)	20.40 (416.00)	19.01 (360.83)	16.65 (276.33)
W_3	13.28 (176.00)	10.21 (103.67)	9.10 (82.33)	13.02 (169.00)	9.70 (93.33)	8.51 (72.00)	13.15 (172.50)	9.95 (98.50)	8.81 (77.17)
W_4	10.65 (113.00)	8.65 (74.33)	6.41 (40.67)	10.14 (102.00)	8.35 (69.33)	6.09 (36.67)	10.40 (107.50)	8.50 (71.83)	6.25 (38.67)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	35.90 (1288.33)	34.63 (1198.67)	34.03 (1157.33)	35.08 (1230.00)	34.02 (1157.00)	33.41 (1115.67)	35.49 (1259.17)	34.33 (1177.83)	33.72 (1136.50)
SEm± (T×W)	0.15			0.09			0.09		
CD (P=0.05) (W at same level of T)	0.42			0.27			0.25		
SEm± (W×T)	0.12			0.10			0.11		
CD (P=0.05) (T at same or different level of W)	0.36			0.28			0.30		

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage, **W_1:** Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.3(d): Interaction effect of tillage system and weed management practices on total weed population (no. m^{-2}) at 90 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	10.09 (101.33)	8.71 (75.33)	6.67 (44.00)	9.65 (92.67)	8.27 (68.00)	6.39 (40.00)	9.87 (97.00)	8.49 (71.67)	6.53 (42.00)
W_2	12.77 (162.67)	11.61 (134.33)	9.70 (93.67)	12.39 (152.33)	11.22 (125.33)	9.17 (83.67)	12.58 (157.50)	11.41 (129.83)	9.44 (88.67)
W_3	8.05 (64.33)	5.21 (26.67)	4.88 (23.33)	7.58 (57.00)	4.64 (21.00)	4.41 (19.00)	7.81 (60.67)	4.92 (23.83)	4.65 (21.17)
W_4	6.49 (41.67)	4.64 (21.00)	3.98 (15.33)	5.90 (34.33)	4.18 (17.00)	3.53 (12.00)	6.20 (38.00)	4.41 (19.00)	3.75 (13.67)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	21.62 (467.00)	21.01 (441.00)	20.68 (427.33)	21.19 (448.33)	20.67 (426.67)	20.43 (416.67)	21.40 (457.67)	20.84 (433.83)	20.56 (422.00)
SEm± (T×W)	0.12			0.09			0.07		
CD (P=0.05) (W at same level of T)	0.33			0.25			0.21		
SEm± (W×T)	0.11			0.07			0.09		
CD (P=0.05) (T at same or different level of W)	0.30			0.22			0.25		

Note: Data in parenthesis indicates original values which were subjected to √(x+0.5) transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

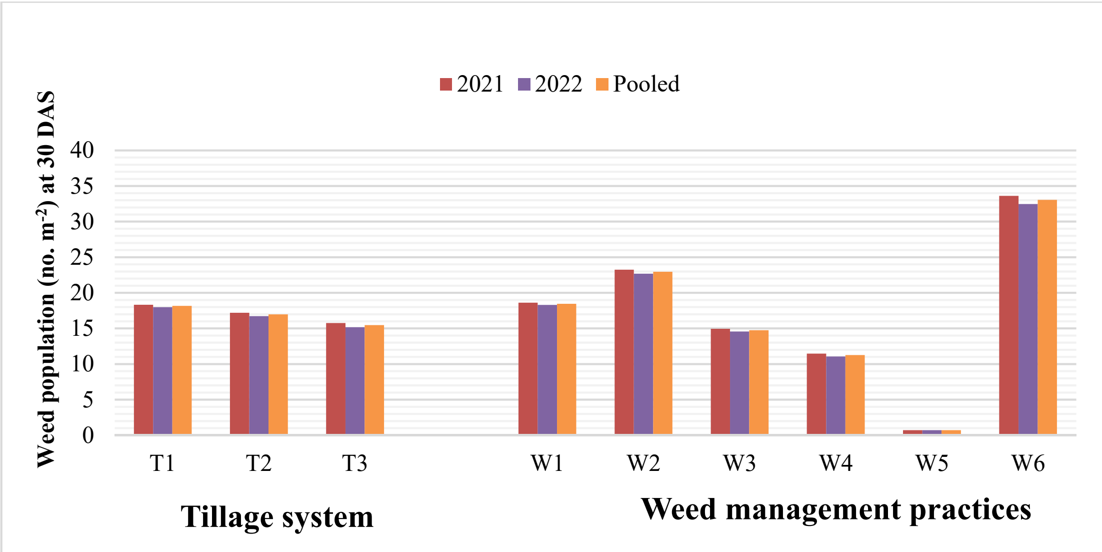


Fig 4.2(a): Effect of tillage system and weed management practices on total weed population at 30 DAS (no. m^{-2})

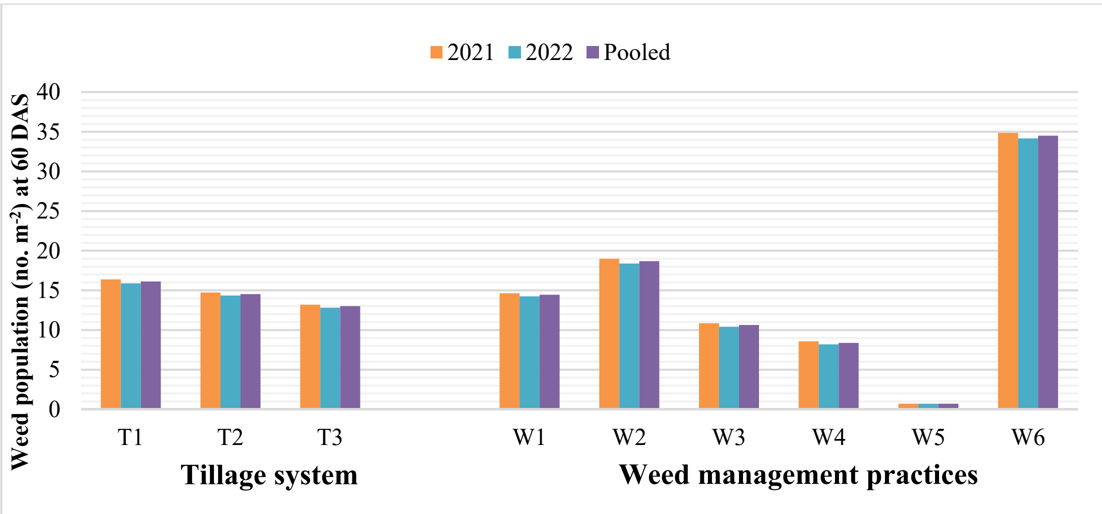


Fig 4.2(b): Effect of tillage system and weed management practices on total weed population at 60 DAS (no. m^{-2})

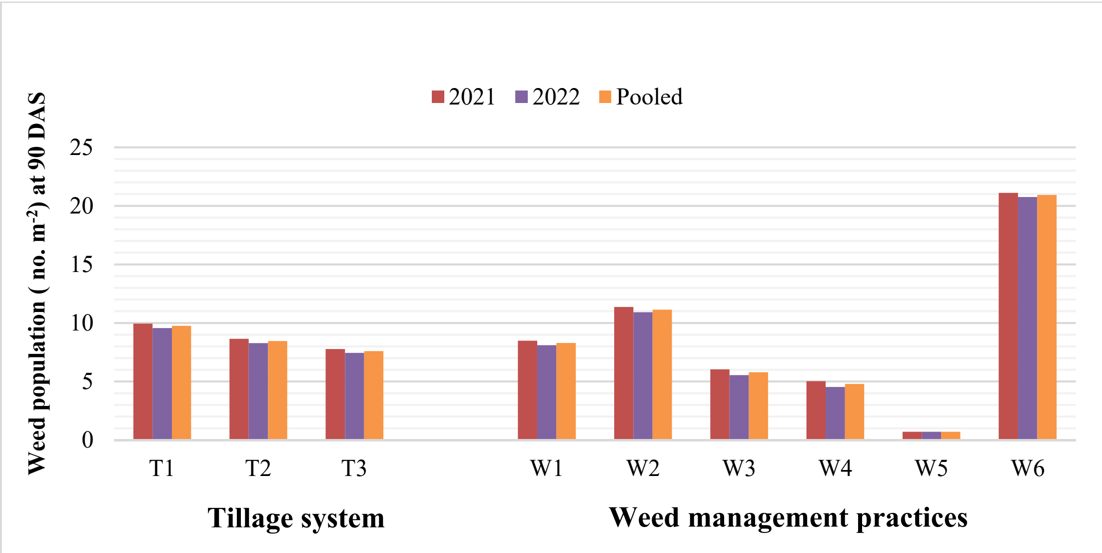


Fig 4.2(c): Effect of tillage system and weed management practices on total weed population at 90 DAS (no. m^{-2}

Total weed dry weight was significantly influenced by different tillage system at each stage of observations. Among the tillage system, the appraisal of the data showed that significantly lower total dry of weeds (104.28 and 99.21 g m^{-2}) was recorded under conventional tillage system at 30 DAS in both the years. Whereas, the highest total weed biomass was recorded under zero tillage system at all stages of observations. Similar trend of total dry of weeds was followed at 60 and 90 DAS in both the years of observation. The minimum total weed biomass under conventional tillage system might be due to less weed seedling emergence due to deep burial of weed seeds and less light transmittance that add up unfavourable condition for the weed seed germination (Chauhan, 2012). Hence, less total weed densities with lesser weed dry matter accumulation. Higher total weed biomass under zero tillage system might be ascribed to more weed seed deposition in the surface soil layer which emerged immediately in huge number once they received the optimum moisture and light that favours their germination thereby resulting in more weed density and ultimately more weed biomass. Chauhan (2013) also reported that weed biomass was higher in zero tillage plots than in the conventional tillage plots. The findings are in close agreement with Sapre *et al*. (2022).

Among the herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS was found to be significantly superior recording the lowest total weed dry weight (46.40 and 42.24 g m^{-2}). Similar trend was observed at 60 and 90 DAS. Weedy check recorded significantly higher total weed dry matter at all stages of observations during both the years. It was that due to effective controlling of weeds with dual combined herbicidal effect of pre and post emergence herbicides. Application of pendimethalin during the early stages of the rice crop allows for the efficient control of grasses and broad-leaved weeds by hampering the growth and development of roots and shoots. According to Verma *et al.* (2023), the herbicidal treatment with bispyribac sodium 25 g ha^{-1}, a systemic herbicide that prevents the synthesis of branch-chain amino acid, successfully reduced the total weed biomass. By blocking the production of the growth-promoting enzyme acetolactate synthase (ALS), it effectively controlled a variety of weeds without endangering the rice plant. Similar findings were reported by Singh *et al*. (2014) and Menon (2019). Goswami *et al*. (2017) also reported that pendimethalin *fb* bispyribac- sodium @ 25 g ha^{-1} was the most effective treatment for reducing the overall dry weight of weeds, much superior to the other treatments. Additionally, Walia *et al*. (2008) also reported that the herbicidal performance of applying pendimethalin at a rate of 0.75 kg ha^{-1} prior to weed emergence and then bispyribac-sodium at a rate of 25 g ha^{-1} as post-emergence was found to be effective, leading to a significant reduction in weed dry biomass relative to other treatments. This might be attributed to application of pendimethalin inhibits cell division and elongation thereby preventing growth and development of roots and shoots of susceptible weed species (grasses and broad-leaved weeds) and thus prevents emerging of weeds prior to crop emergence. While those weeds that emerged after crop emergence has been effectively controlled by post-emergence application of bispyribac-sodium, which is a systemic herbicide that interfered the growth of those susceptible weeds (grasses, sedges and broad-leaved weeds) by restricting the production of growth enzymes (acetolactate synthase-ALS).

The interaction effect of tillage system and weed management practices on total weed dry weight was found to be significant in both the years of experimentation at all stages of observations. The details of the data on interaction effect were presented in Table 4.4(b), 4.4(c) and 4.4(d). The lowest total weed dry was associated with weed free treatment under all the tillage system (T_1W_5, T_2W_5 and T_3W_5). While the appraisal of the data of the two years showed that the highest total weed dry biomass was recorded with weedy check under zero tillage system (T_1W_5) (331.92, 1014.04 and 654.49 g m^{-2}) at 30, 60 and 90 DAS.

Table 4.4(a): Effect of tillage system and weed management practices on total weed dry weight (g m^{-2}) at different crop growth stages

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	10.25 (133.76)	9.97 (126.78)	10.11 (130.27)	16.40 (360.31)	16.06 (344.39)	16.23 (352.35)	13.88 (251.47)	13.60 (241.24)	13.74 (246.35)
T_2	9.37 (117.10)	9.11 (111.11)	9.24 (114.10)	14.56 (301.14)	14.38 (295.44)	14.47 (298.29)	12.20 (208.47)	11.81 (196.16)	12.00 (202.31)
T_3	8.75 (104.28)	8.49 (99.21)	8.62 (101.75)	13.30 (268.89)	13.12 (263.69)	13.21 (266.29)	11.14 (181.25)	10.87 (174.28)	11.00 (177.77)
SEm±	0.06	0.06	0.04	0.06	0.03	0.03	0.05	0.04	0.03
CD (p=0.05)	0.24	0.24	0.14	0.24	0.12	0.11	0.20	0.16	0.11
Weed management practices (W)									
W_1	10.01 (100.24)	9.66 (93.67)	9.84 (96.96)	15.53 (244.42)	15.26 (236.21)	15.40 (240.31)	13.45 (182.30)	13.13 (173.78)	13.29 (178.04)
W_2	12.91 (166.51)	12.59 (158.27)	12.75 (162.39)	19.69 (389.10)	19.40 (377.78)	19.55 (383.44)	16.92 (288.18)	16.35 (269.47)	16.64 (278.82)
W_3	8.19 (68.12)	7.91 (63.55)	8.05 (65.84)	11.95 (144.64)	11.73 (139.48)	11.84 (142.06)	9.80 (98.69)	9.54 (93.55)	9.67 (96.12)
W_4	6.77 (46.40)	6.46 (42.24)	6.62 (44.32)	9.12 (88.25)	8.88 (84.03)	9.00 (86.14)	8.17 (69.62)	7.91 (65.43)	8.04 (67.53)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	18.15 (329.01)	17.80 (316.47)	17.98 (322.74)	31.53 (994.25)	31.14 (969.56)	31.34 (981.91)	25.37 (643.58)	24.93 (621.12)	25.15 (632.35)
SEm±	0.09	0.07	0.06	0.09	0.05	0.05	0.07	0.05	0.04
CD (p=0.05)	0.26	0.21	0.16	0.27	0.13	0.15	0.19	0.15	0.12

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.4(b): Interaction effect of tillage system and weed management practices on total weed dry matter (g m^{-2}) at 30 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	10.82 (116.63)	10.23 (104.17)	8.97 (79.92)	10.56 (111.00)	9.96 (98.64)	8.48 (71.37)	10.69 (113.81)	10.09 (101.41)	8.72 (75.65)
W_2	13.69 (186.91)	12.95 (167.12)	12.08 (145.49)	13.23 (174.46)	12.53 (156.53)	12.01 (143.81)	13.46 (180.68)	12.74 (161.82)	12.05 (144.65)
W_3	9.71 (94.33)	7.88 (61.56)	7.00 (48.47)	9.43 (88.77)	7.62 (57.56)	6.70 (44.33)	9.57 (91.55)	7.75 (59.56)	6.85 (46.40)
W_4	8.18 (66.42)	6.23 (38.32)	5.91 (34.46)	7.84 (60.93)	5.95 (34.89)	5.60 (30.91)	8.01 (63.68)	6.09 (36.61)	5.76 (32.69)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	18.41 (338.29)	18.22 (331.40)	17.83 (317.34)	18.06 (325.55)	17.87 (319.03)	17.47 (304.84)	18.23 (331.92)	18.05 (325.22)	17.65 (311.09)
SEm± (T×W)	0.16			0.12			0.10		
CD (P=0.05) (W at same level of T)	0.45			0.36			0.28		
SEm± (W×T)	0.14			0.12			0.12		
CD (P=0.05) (T at same or different level of W)	0.41			0.34			0.35		

Note: Data in parenthesis indicates original values which were subjected to √(x+0.5) transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage
W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.4(c): Interaction effect of tillage system and weed management practices on total weed dry weight (g m^{-2}) at 60 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	17.61 (309.94)	16.01 (255.99)	12.95 (167.32)	17.29 (298.48)	15.83 (250.18)	12.67 (159.95)	17.45 (304.21)	15.92 (253.09)	12.81 (163.64)
W_2	21.59 (465.83)	19.13 (365.44)	18.35 (336.04)	21.25 (451.07)	18.86 (355.22)	18.10 (327.06)	21.42 (458.45)	18.99 (360.33)	18.22 (331.55)
W_3	13.93 (193.68)	11.72 (136.83)	10.19 (103.42)	13.69 (186.79)	11.56 (133.21)	9.95 (98.44)	13.81 (190.24)	11.64 (135.02)	10.07 (100.93)
W_4	12.23 (149.22)	8.55 (72.68)	6.58 (42.87)	12.06 (145.08)	8.22 (67.04)	6.36 (39.96)	12.15 (147.15)	8.38 (69.86)	6.47 (41.42)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	32.30 (1043.17)	31.24 (975.90)	31.05 (963.70)	31.39 (984.92)	31.10 (967.02)	30.94 (956.73)	31.85 (1014.04)	31.17 (971.46)	30.99 (960.21)
SEm± (T×W)	0.16			0.08			0.09		
CD (P=0.05) (W at same level of T)	0.47			0.23			0.26		
SEm± (W×T)	0.15			0.07			0.11		
CD (P=0.05) (T at same or different level of W)	0.42			0.21			0.31		

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.4(d): Interaction effect of tillage system and weed management practices on total weed dry weight (g m^{-2}) at 90 DAS

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	15.05 (225.88)	13.62 (185.00)	11.68 (136.02)	14.72 (216.25)	13.33 (177.17)	11.33 (127.92)	14.88 (221.07)	13.47 (181.08)	11.51 (131.97)
W_2	18.75 (350.91)	16.94 (286.62)	15.08 (227.00)	18.47 (340.77)	15.87 (251.35)	14.72 (216.30)	18.61 (345.84)	16.41 (268.99)	14.90 (221.65)
W_3	12.23 (149.02)	9.04 (81.26)	8.14 (65.80)	11.98 (143.03)	8.76 (76.25)	7.87 (61.37)	12.10 (146.03)	8.90 (78.75)	8.00 (63.59)
W_4	10.67 (113.45)	7.53 (56.18)	6.30 (39.23)	10.41 (107.95)	7.29 (52.69)	6.01 (35.66)	10.54 (110.70)	7.41 (54.44)	6.16 (37.45)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	25.88 (669.55)	25.34 (641.77)	24.90 (619.42)	25.30 (639.42)	24.90 (619.49)	24.60 (604.45)	25.59 (654.49)	25.12 (630.63)	24.75 (611.94)
SEm± (T×W)	0.12			0.09			0.07		
CD (P=0.05) (W at same level of T)	0.33			0.27			0.21		
SEm± (W×T)	0.11			0.09			0.09		
CD (P=0.05) (T at same or different level of W)	0.31			0.25			0.26		

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

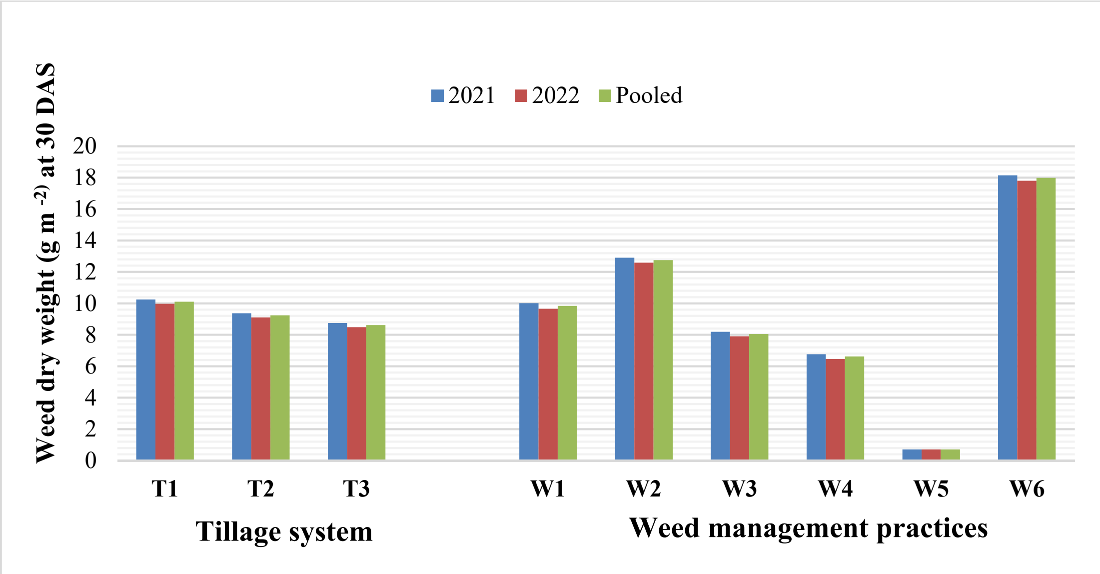


Fig 4.3(a): Effect of tillage system and weed management practices on total weed dry weight at 30 DAS (g m^{-2})

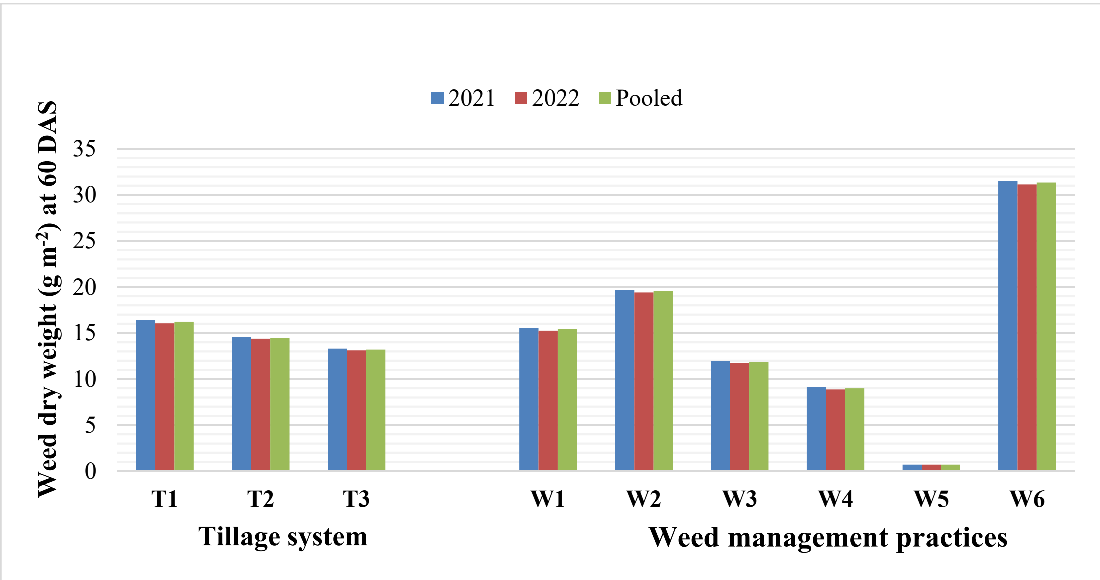


Fig 4.3(b): Effect of tillage system and weed management practices on total weed dry weight at 60 DAS (g m^{-2})

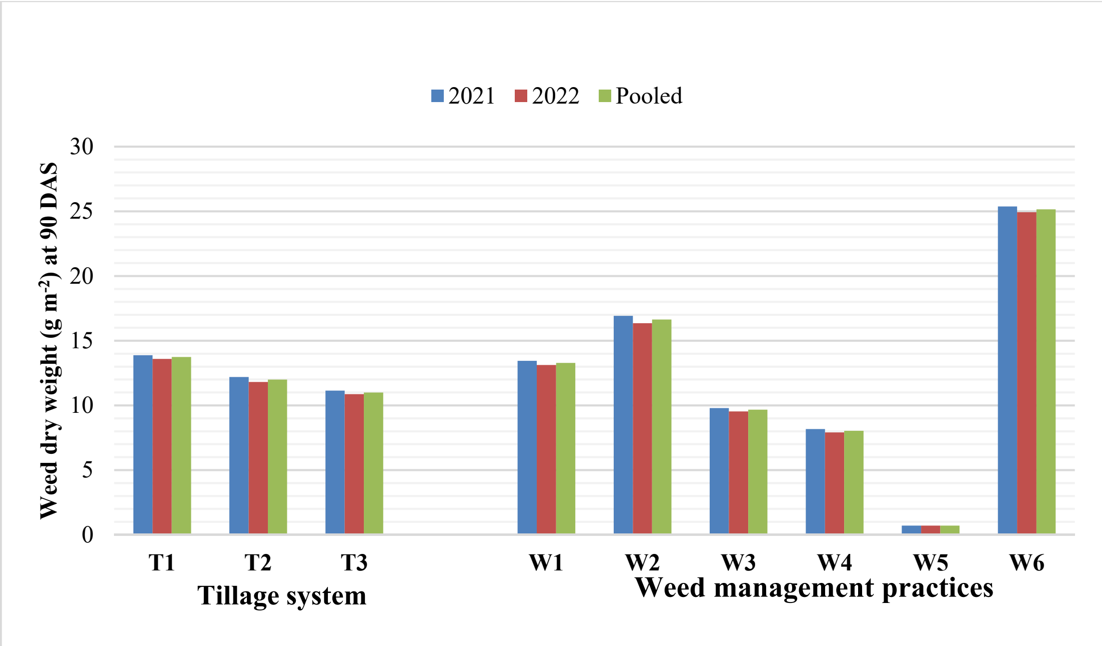


Fig 4.3(c): Effect of tillage system and weed management practices on total weed dry weight at 90 DAS (g m^{-2})

4.2.3 Weed control efficiency (%)

The data pertaining to weed control efficiency (WCE) as influenced by effect of tillage system and weed management practices is presented in Table 4.5(a) and depicted in Fig 4.4(a). The relative effectiveness of weed control treatments in comparison to weedy check is indicated by the term weed control efficiency.

Tillage system showed a significant effect on WCE at 60 DAS. The maximum WCE was recorded under conventional tillage system (72.09 and 72.44%) followed by minimum tillage system during both the years of experimentation. While the minimum was recorded under zero tillage system (65.45 and 65.03%). The maximum WCE recorded under conventional tillage system may be attributed by fewer weed seedling emergence brought on by deep seed burial and reduced light transmittance, which together create unfavourable conditions for weed seed germination and hence decreased the overall weed biomass resulting in higher WCE. The results are in close corroborated with Govindan and Chinnusamy (2014) and Chaudhary (2022).

Weed management practices showed significant influenced on WCE in both years of experimentation. Among the herbicidal treatments, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum WCE (91.27 and 91.39%) and pre emergence application of pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} recorded the lowest (60.99 and 61.09%). The higher WCE might be due to effective controlling of weeds that resulted from cumulative effect of both pre and post emergence application of herbicides thereby reducing the weed density and simultaneously weed dry weight and hence increased weed control efficiency. Pre-emergence application of pendimethalin can considerably reduce dry weight and weed density in DDSR fields (Goswami *et al.*, 2017). Bispyribac-sodium has a wider spectrum of activity and more phytotoxic effects on both grass and broad-leaved weeds, which may explain its higher WCE. Goswami *et al*. (2017) also reported that higher WCE was found with treatment pendimethalin *fb* bispyribac-sodium @ 25 g ha^{-1}. These findings are in close agreement with results as found by Mahajan and Chauhan (2015), Baghel *et al*. (2018) and Singh *et al*. (2019).

The interaction effect of tillage system and weed management practices on weed control efficiency was found to be significant and is showed in Table 4.4(b) and depicted in Fig 4.4(b). The maximum WCE was recorded in treatment combination T_3W_4 (application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage) (95.56 and 95.82%) which was preceded by T_3W_5 (conventional tillage with weed free) (100 and 100%). While the minimum was recorded in T_1W_2 (pre emergence application of pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} under zero tillage) (55.32 and 54.20%). Weedy check recorded the lowest WCE irrespective of the tillage system during both the years of study. The higher WCE in T_3W_4 might be attributed to effective control of weeds.

4.2.4 Weed Index (%)

The data pertaining to weed index as influenced by tillage system and weed management practices is presented in Table 4.5(a) and depicted in Fig 4.5(a) and 4.5(b). The percentage of yield lost as a result of weed interference is provided by the weed index (WI). Grain yield and the weed index are negatively correlated. It implies that the grain yield decreases as the WI increases.

The perusal of data showed that different tillage system had significant effect on weed index of rice. Conventional tillage system recorded significantly minimum WI (11.22 and 11.10%) in both years of experimentation. While zero tillage system recorded significantly maximum weed index (17.67 and 17.75%). This might be attributed from better controlled of weeds and subsequently minimum weed competition under conventional tillage as compared to other tillage system. The results are in close conformity as reported by Chaudhary (2022).

The perusal of data showed that different weed management practices had significant effect on weed index of rice. Among the weed management practices, the lowest WI was recorded in weed free treatment (0.00 and 0.00%) and the highest in weedy check (34.64 and 34.77%) during both the years of observation. The less crop-weed competition in weed free plot might attributed to minimum WI. Among the herbicidal treatments, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the minimum WI (2.20 and 2.20%) in both years of experimentation. The result further indicated that all weed management practices exhibited significantly minimum weed index when compared with weedy check. The minimum WI under this treatment might be due to effective controlled of weeds with dual efficiency of pre and post emergence herbicides thus reducing weed density and crop-weed competition for nutrients, moisture, space and other essential nutrients. The conclusions drawn are in close consistent with the study findings of Verma *et al*. (2016b), Baghel *et al*. (2018) and Singh *et al*. (2019).

Tillage system and weed management practices showed significant interaction effect on weed index as shown in Table 4.5(b). The minimum WI (1.69 and 1.52%) was recorded with T_3W_4 (conventional tillage system with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS) during both the years of observation. Significantly maximum WI (35.39 and 35.59%) was recorded with T_1W_6 (weedy check under zero tillage system).

Table 4.5(a): Effect of tillage system and weed management practices on weed control efficiency (%) and weed index (%)

Treatments	Weed control efficiency (%)			Weed Index (%)		
	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)						
T_1	65.45	65.03	65.24	17.67	17.75	17.71
T_2	69.13	69.45	69.29	13.83	13.86	13.85
T_3	72.09	72.44	72.27	11.22	11.10	11.16
SEm±	0.30	0.11	0.16	0.16	0.18	0.12
CD (P=0.05)	1.16	0.42	0.51	0.63	0.69	0.39
Weed management practices (W)						
W_1	75.54	75.70	75.62	15.23	15.25	15.24
W_2	60.99	61.09	61.04	25.04	24.82	24.93
W_3	85.55	85.66	85.60	8.34	8.39	8.36
W_4	91.27	91.39	91.33	2.20	2.20	2.20
W_5	100.00	100.00	100.00	0.00	0.00	0.00
W_6	0.00	0.00	0.00	34.64	34.77	34.71
SEm±	0.27	0.11	0.15	0.34	0.24	0.21
CD (P=0.05)	0.78	0.32	0.41	0.98	0.69	0.59

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS,
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.5(b): Interaction effect of tillage system and weed management practices on weed control efficiency (%)

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	70.25	73.76	82.62	69.69	74.13	83.28	69.97	73.95	82.95
W_2	55.32	62.53	65.11	54.20	63.27	65.81	54.76	62.90	65.46
W_3	81.42	85.97	89.27	81.03	86.22	89.71	81.23	86.10	89.49
W_4	85.69	92.55	95.56	85.27	93.07	95.82	85.48	92.81	95.69
W_5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
W_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm± (T×W)	0.47			0.19			0.25		
CD (P=0.05) (W at same level of T)	1.35			0.55			0.71		
SEm± (W×T)	0.48			0.19			0.33		
CD (P=0.05) (T at same or different level of W)	1.39			0.55			0.94		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS,
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.5(c): Interaction effect of tillage system and weed management practices on weed index (%)

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	21.07	19.93	4.69	21.17	19.88	4.70	21.12	19.91	4.70
W_2	27.73	23.58	23.82	27.69	23.65	23.13	27.71	23.62	23.47
W_3	18.99	3.04	2.97	19.07	3.03	3.05	19.03	3.04	3.01
W_4	2.83	2.07	1.69	2.98	2.11	1.52	2.91	2.09	1.61
W_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W_6	35.39	34.38	34.16	35.59	34.51	34.21	35.49	34.44	34.18
SEm± (T×W)	0.58			0.42			0.36		
CD (P=0.05) (W at same level of T)	1.69			1.20			1.02		
SEm± (W×T)	0.50			0.38			0.43		
CD (P=0.05) (T at same or different level of W)	1.46			1.11			1.22		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

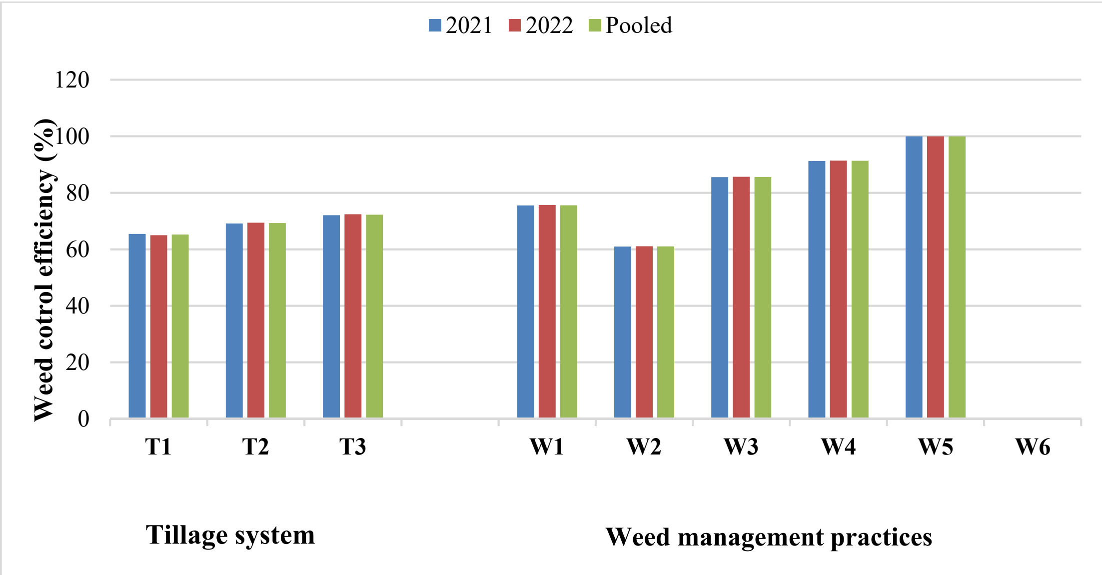


Fig 4.4(a): Effect of tillage system and weed management practices on weed control efficiency (%)

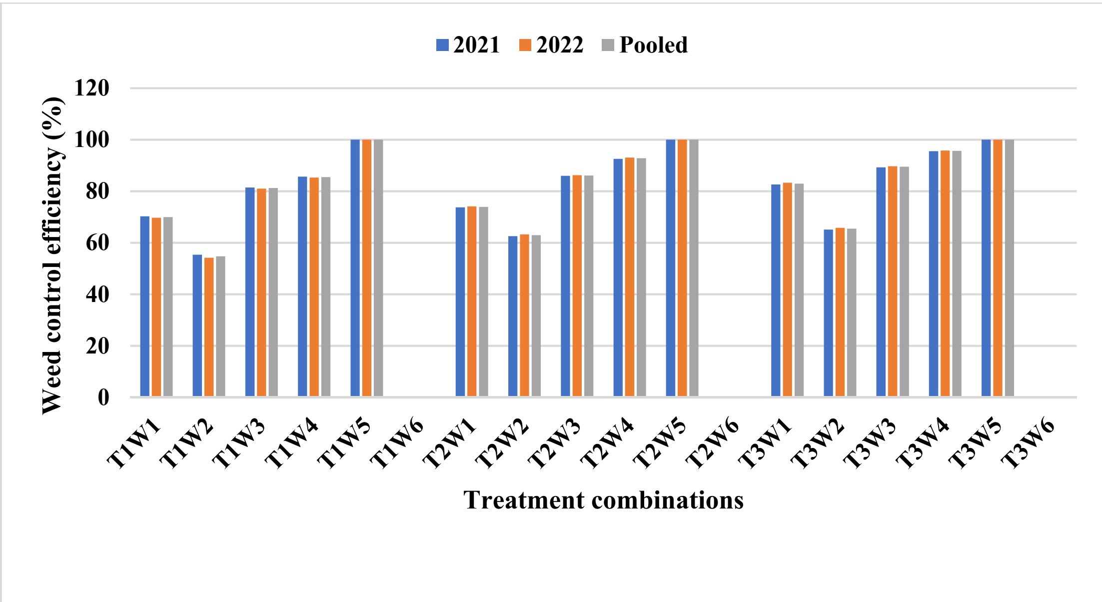


Fig 4.4(b): Interaction effect of tillage system and weed management practices on weed control efficiency (%)

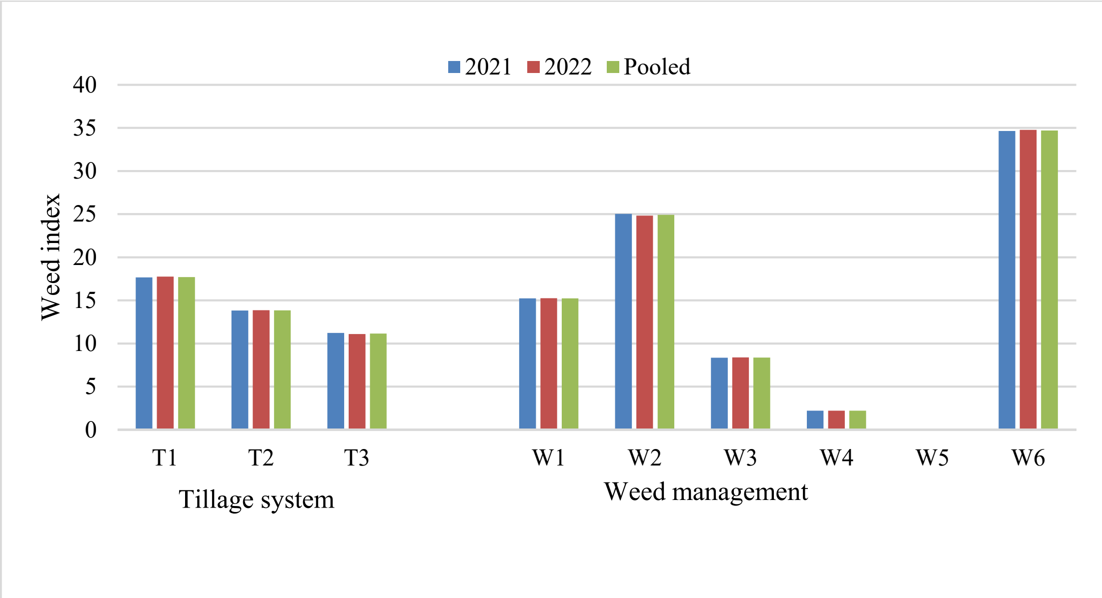


Fig 4.5(a): Effect of tillage system and weed management practices on weed index

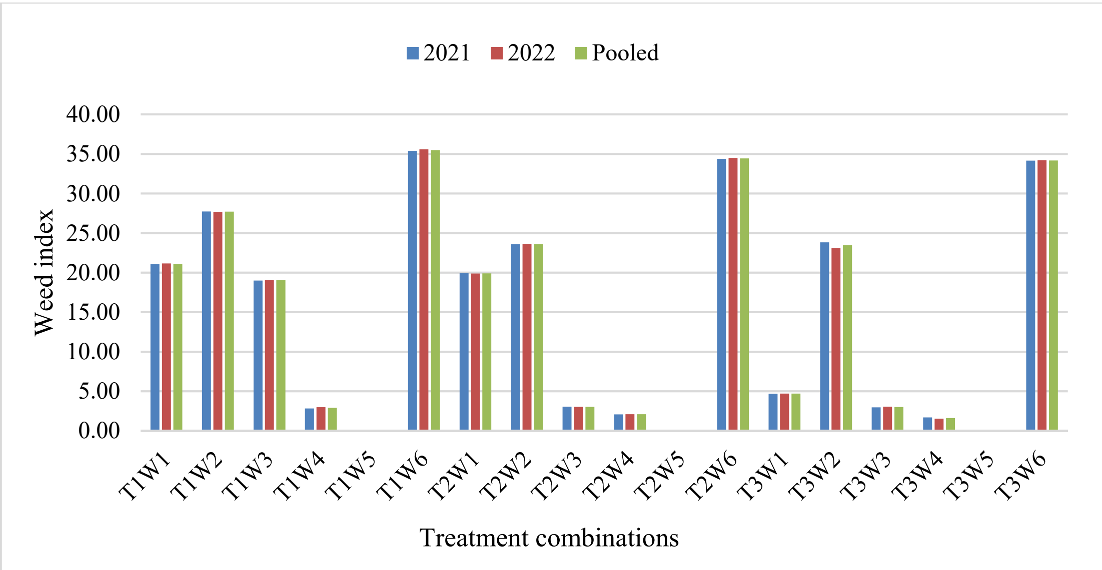


Fig 4.5(b): Interaction effect of tillage system and weed management practices on weed index

4.2.5 Nutrient (NPK) content (%) and their depletion by weeds (kg ha^{-1})

4.2.5.1 Nutrient (NPK) content (%) in weeds

The effect of tillage system and weed management practices on N, P and K contents (%) in weeds were found to be non-significant in both the years of experimentation as shown in Table 4.6(a).

4.2.5.2 Nutrient (NPK) depletion by weeds (kg ha^{-1})

The data pertaining to the nutrient (NPK) depletion by weeds (60 DAS) as influenced by tillage system and weed management practices is presented in Table 4.6(a) and 4.7(a). The amount of nutrients in weed plants and their dry weight influence how much soil nutrients are depleted by weeds. There is a negative relationship between the effectiveness of the weed-control treatments and the depletion of nutrients by weeds.

4.2.5.2.1 Nitrogen depletion by weeds

The perusal of the data showed that tillage system had significant effect on nitrogen depletion by weeds. Conventional tillage system recorded significantly minimum nitrogen depletion by weeds (33.35 and 32.70 kg ha^{-1}) and proved significantly superior to minimum (37.36 and 36.66 kg ha^{-1}) and zero tillage system (44.68 and 42.72 kg ha^{-1}). The lowest nitrogen depletion by weeds was reflected by minimum weed density and their dry matter accumulation under conventional tillage system over the other tillage system. While the maximum nitrogen depletion under zero tillage system might be attributed primarily due to higher dry matter accumulation. The results are in close agreement with Dolma (2017), Dhaliwal *et al*. (2021) and Chaudhary (2022). Among the herbicidal treatments, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the minimum nitrogen depletion by weeds (10.95 and 10.42 kg ha^{-1}) and found to be most effective in reducing nitrogen depletion as compared to other herbicidal treatments during both the years of experimentation. This might be due to control of different weed species due to the consecutive application of pendimethalin as pre emergence followed by post emergence application of bispyribac-sodium herbicides that led to decrease weed density and weed biomass production, which contribute to the less nitrogen removal by weeds. However, maximum nitrogen depletion was observed under weedy check (123.37 and 120.28 kg ha^{-1}) during both the years of observation. The reason for the maximum amount of nitrogen depletion by weeds in the weedy check treatment is because of unchecked weed growth, which led to an increase in weeds dry matter production. The results are in close conformity as reported by Chongtham *et al*. (2015) and Kumari and Kaur (2016).

The interaction effect of tillage system and weed management practices on nitrogen depletion by weeds was found to be significant with the treatment combination T_3W_4 (conventional tillage system with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS) recording the lowest nitrogen depletion by weeds (5.32 and 4.96 kg ha^{-1}) in both the years. The data further revealed that the maximum (129.45 and 122.23 kg ha^{-1}) with T_1W_6 (weedy check under zero tillage system).

4.2.5.2.2 Phosphorus depletion by weeds

The perusal of the data showed that tillage system had significant effect on phosphorus depletion by weeds. Conventional tillage system proved to be significantly superior in reducing phosphorus depletion by weeds recording the lowest (8.59 and 8.42 kg ha^{-1}) as compared to other tillage system during both the years of observation. This might be due to less dry matter accumulation by weeds which might be attributed by effective controlled of weeds under conventional tillage system. However, the maximum phosphorus depletion (11.42 and 10.96 kg ha^{-1}) was recorded under zero tillage system. This result might be due to vigorous growth of weeds and higher weed biomass resulted in more phosphorus depletion. These findings are in close agreement with research findings of Dolma (2017) and Dhaliwal *et al*. (2021).

Analysis of the data showed that pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the significantly lower phosphorus depletion by weeds (2.82 and 2.68 kg ha^{-1}) as compared to other herbicidal treatments during both the years of experimentation. Data further revealed that significantly maximum phosphorus depletion (31.68 and 30.96 kg ha^{-1}) was found under weedy check in both the years of experimentation. However, all the herbicidal treatments recorded significantly lower phosphorus depletion as compared to weedy check in both the years of study. The lowest phosphorus depletion was attributed to effective controlling of weeds with the combined effect of both pre and post emergence herbicides, thereby less weed biomass. Furthermore, the maximum depletion in weedy check was due to poor weed control resulted in lush weed growth and increased weed dry matter accumulation. The results are in close corroborated with findings of Chongtham *et al*. (2015).

Interaction effect of tillage system and weed management practices on phosphorus depletion by weeds was found to be significant in both the years of experimentation. The minimum phosphorus depletion (1.37 and 1.28 kg ha^{-1}) was obtained with treatment T_3W_4 (conventional tillage system with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS) while the maximum (33.03 and 31.39 kg ha^{-1}) with T_1W_6 (weedy check under zero tillage system).

4.2.5.2.3 Potassium depletion by weeds

A critical analysis of the data revealed that different tillage system had significant effect on potassium depletion by weeds. The significantly lower potassium depletion (35.03 and 34.33 kg ha^{-1}) by weeds was recorded under conventional tillage system as compared to other tillage system. This might be due to less weed seed germination due to deep burial of weed seed in the soil and thus less weed density and ultimately resulted in less weed dry matter accumulation. Hence, less potassium removal by weeds under conventional tillage system. However, the maximum potassium removal by weeds (46.88 and 44.67 kg ha^{-1}) was recorded under zero tillage system. The probable reason might be due to rapid germination of seeds and emergence of weed seedlings under this tillage system due to presence of abundant weed seeds on the upper layer of the soil. Similar findings were reported by Kumar *et al*. (2007) and Chaudhary (2022).

Among the weed management practices, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the significantly minimum potassium depletion by weeds (11.44 and 10.89 kg ha^{-1}) as compared to other herbicidal treatments during both the years of experimentation. This finding could be attributed to the excellent performance of pre-emergence herbicide in inhibiting or postponing the germination of weed seeds for at least 15 to 20 days, that provides rice plants with favourable conditions for germination and growth without crop-weed competition during this time. Additionally, this provided a relative advantage for post-emergence herbicide in killing germinated weeds based on age selectivity without posing a risk to rice crops. It is evident from the data that significantly maximum potassium depletion (129.36 and 126.04 kg ha^{-1}) by weeds was recorded in weedy check in both the years of study. The findings are in close agreement with Kumari and Kaur (2016).

Tillage system and weed management practices was found to have significant interaction effect on potassium depletion by weeds in both the years of experimentation. Significantly minimum potassium depletion (5.56 and 5.17 kg ha^{-1}) was recorded in T_3W_4 (conventional tillage system with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS) while the maximum (33.03 and 31.39 kg ha^{-1}) with T_1W_6 (weedy check under zero tillage system).

4.3 Crop observation

4.3.1 Growth attributes

4.3.1.1 Plant height (cm)

The data pertaining to the plant height due to the influence of tillage system and weed management practices is presented in Table 4.8. The data showed that plant height was comparatively higher in second year as compared to first year.

A critical analysis of the data showed that different tillage system had significant effect on plant height of rice at all stages of observation. At 30 DAS, the maximum plant height (41.90 and 41.52 cm) was recorded with conventional tillage system which was found to be statistically at par with minimum tillage system and significantly superior to zero tillage system, which recorded the minimum plant height (39.25 and 39.40 cm) during both the years of experimentation. Similar trend of plant height was followed at 60, 90 DAS and at harvest. The probable reason for maximum plant height could be due to less weed population at the initial stage of crop growth that resulted to less crop weed competition for growth elements like nutrients, water, light, space etc. This is again attributed from deep burial of weed seeds due to high-soil-disturbance systems in conventional tillage systems leading to lower weed seedling emergence. While under zero tillage system where there is low-soil-disturbance that more likely to leave a sizable amount of the weed seed bank on or near the

Table 4.6(a): Effect of tillage system and weed management practices on nitrogen content, phosphorus content in weeds and their depletion at 60 DAS

Treatments	Weed nitrogen content (%)			Nitrogen depletion by weeds (kg ha^{-1})			Weed phosphorus content (%)			Phosphorus depletion by weeds (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	1.240	1.240	1.240	5.880 (44.68)	5.764 (42.72)	5.822 (43.70)	0.318	0.319	0.318	3.081 (11.42)	3.028 (10.96)	3.054 (11.19)
T_2	1.241	1.241	1.241	5.241 (37.36)	5.179 (36.66)	5.210 (37.01)	0.318	0.479	0.398	2.769 (9.58)	2.745 (9.44)	2.757 (9.51)
T_3	1.240	1.240	1.240	4.804 (33.35)	4.740 (32.70)	4.772 (33.03)	0.320	0.320	0.320	2.565 (8.59)	2.533 (8.42)	2.549 (8.50)
SEm±	0.0006	0.0003	0.0003	0.02	0.01	0.01	0.0006	0.0924	0.0462	0.0088	0.0045	0.0049
CD (P=0.05)	NS	NS	NS	0.08	0.04	0.04	NS	NS	NS	0.0344	0.0175	0.0160
Weed management practices (W)												
W_1	1.239	1.240	1.240	5.506 (30.29)	5.416 (29.29)	5.461 (29.79)	0.317	0.318	0.318	2.853 (7.75)	2.810 (7.50)	2.832 (7.63)
W_2	1.240	1.240	1.240	6.965 (48.25)	6.866 (46.86)	6.915 (47.55)	0.317	0.319	0.318	3.574 (12.33)	3.534 (12.04)	3.554 (12.19)
W_3	1.239	1.241	1.240	4.259 (17.93)	4.186 (17.30)	4.223 (17.62)	0.318	0.319	0.319	2.244 (4.61)	2.210 (4.45)	2.227 (4.53)
W_4	1.241	1.240	1.241	3.285 (10.95)	3.201 (10.42)	3.243 (10.69)	0.319	0.319	0.319	1.779 (2.82)	1.741 (2.68)	1.760 (2.75)
W_5	1.241	1.240	1.241	0.707 (0.00)	0.707 (0.00)	0.707 (0.00)	0.319	0.639	0.479	0.707 (0.00)	0.707 (0.00)	0.707 (0.00)
W_6	1.241	1.241	1.241	11.127 (123.37)	10.990 (120.28)	11.059 (121.83)	0.319	0.319	0.319	5.672 (31.68)	5.609 (30.96)	5.640 (31.32)
SEm±	0.0007	0.0007	0.0005	0.03	0.02	0.02	1.05	0.70	0.63	0.0159	0.0077	0.0088
CD (P=0.05)	NS	NS	NS	0.09	0.05	0.05	NS	NS	NS	0.0459	0.0223	0.0250

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage **W_1:** Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kgha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.6(b): Interaction effect of tillage system and weed management practices on nitrogen depletion by weeds (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	6.23 (38.38)	5.68 (31.76)	4.61 (20.72)	6.12 (36.99)	5.62 (31.05)	4.51 (19.83)	6.18 (37.69)	5.65 (31.40)	4.56 (20.27)
W_2	7.63 (57.72)	6.77 (45.33)	6.50 (41.69)	7.51 (55.90)	6.68 (44.09)	6.41 (40.58)	7.57 (56.81)	6.72 (44.71)	6.45 (41.13)
W_3	4.95 (24.04)	4.18 (16.95)	3.65 (12.81)	4.87 (23.19)	4.12 (16.51)	3.57 (12.21)	4.91 (23.61)	4.15 (16.73)	3.61 (12.51)
W_4	4.36 (18.51)	3.09 (9.03)	2.41 (5.32)	4.30 (17.99)	2.97 (8.32)	2.33 (4.96)	4.33 (18.25)	3.03 (8.67)	2.37 (5.14)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	11.40 (129.45)	11.03 (121.11)	10.96 (119.56)	11.08 (122.23)	10.98 (119.97)	10.91 (118.63)	11.24 (125.84)	11.00 (120.54)	10.94 (119.10)
SEm± (T×W)	0.96			0.37			0.51		
CD (P=0.05) (W at same level of T)	2.76			1.07			1.45		
SEm± (W×T)	0.85			0.34			0.62		
CD (P=0.05) (T at same or different level of W)	2.47			0.98			1.76		

Note: Data in parenthesis indicates original values which were subjected to √(x+0.5) transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage ,**W_1:** Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.6(c): Interaction effect of tillage system and weed management practices on phosphorus depletion by weeds (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	3.20 (9.74)	2.94 (8.16)	2.42 (5.34)	3.15 (9.41)	2.91 (7.99)	2.37 (5.11)	3.17 (9.57)	2.93 (8.07)	2.39 (5.23)
W_2	3.91 (14.78)	3.46 (11.46)	3.35 (10.75)	3.86 (14.37)	3.43 (11.30)	3.31 (10.46)	3.88 (14.58)	3.45 (11.38)	3.33 (10.60)
W_3	2.59 (6.18)	2.20 (4.33)	1.95 (3.31)	2.55 (5.98)	2.18 (4.24)	1.91 (3.15)	2.57 (6.08)	2.19 (4.28)	1.93 (3.23)
W_4	2.29 (4.76)	1.68 (2.32)	1.37 (1.37)	2.26 (4.63)	1.63 (2.14)	1.33 (1.28)	2.28 (4.69)	1.65 (2.23)	1.35 (1.32)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	5.79 (33.03)	5.63 (31.23)	5.59 (30.77)	5.65 (31.39)	5.61 (30.98)	5.57 (30.52)	5.72 (32.21)	5.62 (31.10)	5.58 (30.65)
SEm± (T×W)	0.24			0.08			0.13		
CD (P=0.05) (W at same level of T)	0.69			0.24			0.36		
SEm± (W×T)	0.21			0.07			0.15		
CD (P=0.05) (T at same or different level of W)	0.61			0.22			0.43		

Note: Data in parenthesis indicates original values which were subjected to √(x+0.5) transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage, **W_1:** Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.7(a): Effect of tillage system and weed management practices on potassium content in weeds and their depletion at 60 DAS

Treatments	Weed potassium content (%)			Potassium depletion by weeds (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)						
T_1	1.304	1.297	1.300	6.023 (46.88)	5.892 (44.67)	5.957 (45.77)
T_2	1.294	1.300	1.297	5.354 (39.08)	5.294 (38.33)	5.324 (38.71)
T_3	1.297	1.299	1.298	4.914 (35.03)	4.847 (34.33)	4.880 (34.68)
SEm±	0.0006	0.0003	0.0003	0.0207	0.0078	0.0111
CD (P=0.05)	NS	NS	NS	0.0814	0.0305	0.0361
Weed management practices (W)						
W_1	1.300	1.301	1.301	5.638 (31.79)	5.546 (30.75)	5.592 (31.27)
W_2	1.299	1.291	1.295	7.126 (50.53)	7.002 (48.74)	7.064 (49.63)
W_3	1.300	1.307	1.303	4.363 (18.87)	4.294 (18.25)	4.328 (18.56)
W_4	1.297	1.296	1.296	3.354 (11.44)	3.268 (10.89)	3.311 (11.17)
W_5	1.294	1.298	1.296	0.707 (0.00)	0.707 (0.00)	0.707 (0.00)
W_6	1.301	1.300	1.301	11.393 (129.36)	11.249 (126.04)	11.321 (127.70)
SEm±	0.0007	0.0007	0.0005	0.0371	0.0227	0.0217
CD (P=0.05)	NS	NS	NS	0.1071	0.0656	0.0615

Note: Data in parenthesis indicates original values which were subjected to $\sqrt{(x+0.5)}$ transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.7(b): Interaction effect of tillage system and weed management practices on potassium depletion by weeds (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	6.41 (40.61)	5.79 (33.02)	4.72 (21.75)	6.28 (38.91)	5.75 (32.61)	4.61 (20.74)	6.34 (39.76)	5.77 (32.81)	4.66 (21.24)
W_2	7.80 (60.39)	6.93 (47.50)	6.65 (43.69)	7.63 (57.74)	6.83 (46.18)	6.54 (42.30)	7.72 (59.06)	6.88 (46.84)	6.59 (42.99)
W_3	5.11 (25.63)	4.27 (17.70)	3.71 (13.27)	5.00 (24.53)	4.24 (17.45)	3.64 (12.77)	5.06 (25.08)	4.25 (17.57)	3.68 (13.02)
W_4	4.45 (19.35)	3.15 (9.42)	2.46 (5.56)	4.39 (18.81)	3.03 (8.69)	2.38 (5.17)	4.42 (19.08)	3.09 (9.06)	2.42 (5.36)
W_5	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
W_6	11.65 (135.30)	11.28 (126.83)	11.24 (125.94)	11.34 (128.03)	11.21 (125.07)	11.20 (125.01)	11.49 (131.67)	11.24 (125.95)	11.22 (125.47)
SEm± (T×W)	0.06			0.03			0.03		
CD (P=0.05) (W at same level of T)	0.19			0.11			0.11		
SEm± (W×T)	0.05			0.03			0.04		
CD (P=0.05) (T at same or different level of W)	0.16			0.09			0.12		

Note: Data in parenthesis indicates original values which were subjected to √(x+0.5) transformation

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

soil surface following crop sowing where light may encourage the germination of seeds (Chauhan and Johnson, 2008). Thus, more weed emergence resulting in higher competition for nutrients, water, light, space etc. with crop and thus attributed to lower plant height. Das *et al*. (2014) also reported that plant height of rice was significantly higher under conventional tillage system. Dolma (2017) and Pandey and Kandel (2020) also revealed similar results with respect to plant height of rice.

A perusal of the data revealed that different weed management practices showed significant effect on plant height of rice at all stages of observation. In the both years of the study, the maximum plant height (47.71 and 47.09 cm) was recorded in weed free while the minimum (35.84 and 35.73 cm) in weedy check. This might be attributed due to better availability of nutrients, water, light etc. to crop due to weed free condition. Among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded higher plant height (43.15 and 42.33 cm) and was significantly superior as compared to other herbicidal treatments during both the years at all stages of observations. These results may be due higher efficiency of sequential application pre and post emergence herbicides that create comparatively less weed population during critical period of rice-weed competition that increased rice's capacity to absorb macro- and micronutrients, water, sunlight, and thus increases photosynthesis process that resulted in higher plant height. Kumari and Kaur (2016) also reported significantly higher plant height with application of pendimethalin *fb* bispyribac-sodium. Significantly highest rice plant height (59.2 cm) was obtained with the pre- emergence application of pendimethalin @ 0.75 kg ha^{-1} followed by post-emergence application of bispyribac-sodium @ 25 g ha^{-1} as compared to all other herbicidal treatments as this treatment effectively controls the associated diverse weed flora as reported by Walia *et al*. (2008). This result is closely aligned with results reported by Joshi *et al*. (2016) and Singh *et al*. (2016b).

4.3.1.2 Number of tillers (no. m^{-2})

The data pertaining to number of tillers m^{-2} as influenced by tillage system and weed management practices is presented in Table 4.9. It is evident from the data that tillage system and weed management practices showed significant effect on number of tillers m^{-2} at all stages of observation.

At 30 DAS, conventional tillage system recorded significantly maximum number of tillers (180.00 and 183.33 m^{-2}) in both the years of observations but was found to be statistically at par with minimum tillage system in the first year (165.56 m^{-2}). At 60 DAS, conventional tillage system was found to be significantly superior and recording the maximum number of tillers (242.67 and 248.89 m^{-2}) and found be statistically at par with minimum tillage system in the second year (231.06 m^{-2}). At 90 DAS, data revealed that the maximum number of tillers (232.11 and 235.72 m^{-2}) was recorded under conventional tillage system which was statistically at par with minimum tillage system in both the years of observation (218.83 and 219.17 m^{-2}). At all stages of observation, zero tillage recorded significantly lower number of tillers in both the years of observation.

The probable reason for the higher number of tillers m^{-2} under conventional tillage may be that this treatment creates an environment that is favourable for better photosynthesis, with sufficient water, light, nutrients and space through better uptake of nutrients and translocation by crop. This resulted in healthy plants and a higher number of tillers per unit area. Further, these are resulted from less crop-weed competition due to less weed emergence under this treatment. The result of this investigation is in close agreement with the findings of Mukhrejee (2019).

A critical analysis of the data showed that different weed management had significant effect on number of tillers. Weed free recording the maximum

Table 4.8: Effect of tillage system and weed management practices on plant height (cm) of rice at different growth stages

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			Harvest		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	39.25	39.40	39.32	60.26	60.00	60.13	73.14	73.36	73.25	75.02	75.30	75.16
T_2	41.34	40.08	40.71	61.37	61.68	61.53	74.60	75.21	74.90	76.19	76.99	76.59
T_3	41.90	41.52	41.71	61.89	63.06	62.47	76.00	76.09	76.04	77.66	77.95	77.80
SEm±	0.53	0.25	0.29	0.26	0.47	0.27	0.50	0.39	0.32	0.38	0.49	0.31
CD (P=0.05)	2.07	1.00	0.95	1.02	1.84	0.88	1.98	1.54	1.04	1.51	1.92	1.01
Weed management practices (W)												
W_1	39.97	39.19	39.58	61.42	61.47	61.45	73.74	74.35	74.05	75.90	75.84	75.87
W_2	37.11	37.51	37.31	59.49	59.52	59.50	72.25	72.42	72.34	73.40	73.84	73.62
W_3	41.18	40.14	40.66	61.95	62.08	62.01	75.33	75.75	75.54	77.22	77.67	77.44
W_4	43.15	42.33	42.74	62.49	62.51	62.50	76.99	76.67	76.83	78.68	79.09	78.88
W_5	47.71	47.09	47.40	65.87	67.71	66.79	79.91	80.32	80.11	81.77	82.75	82.26
W_6	35.84	35.73	35.78	55.81	56.20	56.01	69.25	69.80	69.53	70.75	71.30	71.02
SEm±	0.59	0.62	0.43	0.51	0.63	0.41	0.67	0.69	0.48	0.64	0.67	0.46
CD (P=0.05)	1.71	1.78	1.21	1.49	1.83	1.16	1.93	2.00	1.36	1.85	1.92	1.31

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_5: Weed free

W_6: Weedy check

number of tillers while minimum in weedy check at all stages of observation in both the years of experimentation.

Among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded highest number of tillers (184.44 and 197.78 m^{-2}) which was at par with stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS (175.56 and 186.67 m^{-2}) at 30 DAS in both the years of study. At 60 DAS, highest number of tillers (259.22 and 261.78 m^{-2}) was recorded with application pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS and found to be statistically at par with stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS in the second year of the study (241.11 m^{-2}). Similar pattern of number of tillers was observed at 90 DAS as that of 30 DAS. Maximum number of tillers in weed free might be due to less competition between crop and weeds for light, water, and nutrients which is again attributed from better control of weeds with sequential application of both pre and post emergence herbicides. The simultaneous effect of pendimethalin in inhibiting weed seeds from germinating at the beginning stage and suppressing weed growth with bispyribac-sodium afterwards may be the plausible reason for this occurrence. Kumari and Kaur (2016) also reported that application of pendimethalin @ 750 g ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} recorded significantly higher number of tillers m^{-2} as compared to other herbicidal treatments. The findings are closely corroborated as reported by Walia *et al*. (2008), Joshi *et al*. (2016), Singh *et al*. (2016a) and Kumar *et al*. (2018).

4.2.1.3 Dry matter accumulation (g plant^{-1})

The data related to plant dry matter accumulation as influenced by tillage system and weed management practices is presented in Table 4.10. The size of a plant's photosynthetic system, its effectiveness, how long it stays

Table 4.9: Effect of tillage system and weed management practices on number of tillers m^{-2} of rice at different growth stages

Treatments	Number of tillers (no. m^{-2})								
	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	157.22	158.33	157.78	212.50	214.94	213.72	193.00	201.67	197.33
T_2	165.56	170.00	167.78	226.67	231.06	228.86	218.83	219.17	219.00
T_3	180.00	183.33	181.67	242.67	248.89	245.78	232.11	235.72	233.92
SEm±	3.86	3.24	2.52	3.57	4.74	2.96	4.71	4.81	3.37
CD (P=0.05)	15.17	12.72	8.22	14.02	18.59	9.67	18.48	18.91	10.98
Weed management practices (W)									
W_1	161.11	156.67	158.89	214.44	214.89	214.67	201.33	203.33	202.33
W_2	140.00	134.44	137.22	185.56	194.89	190.22	170.33	170.00	170.17
W_3	175.56	186.67	181.11	237.78	241.11	239.44	231.78	234.22	233.00
W_4	184.44	197.78	191.11	259.22	261.78	260.50	246.11	248.89	247.50
W_5	231.11	227.78	229.44	298.89	307.78	303.33	287.22	297.78	292.50
W_6	113.33	120.00	116.67	167.78	169.33	168.56	151.11	158.89	155.00
SEm±	6.91	7.21	4.99	5.61	13.28	7.21	6.98	9.42	5.86
CD (P =0.05)	19.95	20.82	14.12	16.21	38.36	20.40	20.17	27.20	16.58

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage
W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

Table 4.10: Effect of tillage system and weed management practices on dry matter accumulation plant^{-1} of rice at different growth stages

Treatments	Dry matter accumulation (g plant^{-1})								
	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	2.09	2.11	2.10	4.49	4.73	4.61	11.82	11.88	11.85
T_2	2.22	2.27	2.25	5.10	5.23	5.16	12.31	12.60	12.46
T_3	2.34	2.39	2.37	5.25	5.36	5.30	12.93	13.50	13.22
SEm±	0.02	0.05	0.03	0.13	0.08	0.08	0.19	0.20	0.14
CD (P =0.05)	0.07	0.21	0.09	0.53	0.31	0.25	0.76	0.78	0.45
Weed management practices (W)									
W_1	2.04	2.08	2.06	4.93	5.28	5.10	12.03	12.22	12.13
W_2	1.73	1.76	1.75	4.29	4.23	4.26	10.81	10.93	10.87
W_3	2.36	2.45	2.41	4.92	5.43	5.17	12.95	13.11	13.03
W_4	2.65	2.72	2.69	5.63	5.79	5.71	13.93	14.09	14.01
W_5	2.88	2.88	2.88	6.42	6.49	6.46	16.19	16.47	16.33
W_6	1.62	1.66	1.64	3.48	3.42	3.45	8.22	9.15	8.68
SEm±	0.06	0.07	0.04	0.13	0.11	0.09	0.33	0.37	0.25
CD (P =0.05)	0.17	0.19	0.12	0.38	0.33	0.25	0.95	1.07	0.70

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

active, and the degree to which crop weeds compete with the plant for resources like light, moisture, and nutrients all affect how much dry matter a crop can produce (Kumar *et al*., 2014).

Critical analysis of the data revealed that plant dry matter accumulation was significantly influenced by different tillage system. At 30 DAS, significantly higher plant dry matter accumulation (2.34 and 2.39 g plant^{-1}) was observed under conventional tillage system which was statistically at par with minimum tillage system in the second year but not in the first year. At 60 DAS, conventional tillage system recorded the maximum plant dry matter accumulation (5.25 and 5.36 g plant^{-1}) and found to be at par with minimum tillage system in both the years of study. Significantly maximum plant dry matter accumulation (12.93 and 13.50 g plant^{-1}) was observed under conventional tillage system and was at par with minimum tillage system in the first year of the study. Significantly minimum plant dry matter accumulation was recorded under zero tillage system at all stages of observation in the both years of observation.

The increased plant dry matter accumulation under conventional tillage system could be attributed to significantly less weed density and their dry weight that resulted from burial of weed seeds. Additionally, improved soil physical properties under this tillage system might have led to better soil aeration, soil moisture and nutrients availability and better rhizosphere environment that might have aided to better uptake of growth elements resulting in production of greater source, efficient translocation and assimilation of photosynthates into the larger sink. Hence, better root growth and penetration into deeper layer of soil that allowed the crop to utilize available nutrients, moisture etc. more efficiently. Similarly, Saini *et al*. (2022) also reported higher dry matter accumulation under conventional tillage at 30, 60 and 90 DAS.

Among the herbicidal treatments, significantly superior plant dry matter accumulation (2.65 and 2.72 g plant^{-1}) was recorded with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS which was at par with weed free in both the year of study at 30 DAS. While at 60 and 90 DAS, similar trend of plant dry matter accumulation in both the years. While pre emergence of application pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} recorded the lowest plant dry matter accumulation at all stages of observation among different herbicidal treatments. This might be due to better control of weeds with application of pendimethalin that effectively control seedling of grass and broad-leaved weeds at the earlier stages of crop by inhibiting cell mitosis that represses development of roots and shoots. While the later emerged weeds are efficiently controlled by bispyribac-sodium by inhibiting a growth enzyme called acetolactate synthase (ALS). Hence, the rice plant grows without any competition with weeds for essential nutrients, water, space and solar radiation thereby contributing to growth and dry matter accumulation.

4.2.1.4 Crop growth rate (CGR) (g m^{-2} day^{-1})

The data pertaining to crop growth rate as influenced by tillage system and weed management practices is presented in Table 4.11. The daily rate of increase in dry matter accumulation of a crop at a particular area is known as the CGR.

It is evident from the data that different tillage system showed non-significant effect on CGR at all stages of observation during both the years. A perusal of the data revealed that different weed management practices had significant effect on CGR. Between 25-50 DAS, weed free treatment recorded significantly maximum CGR (2.98 and 3.15 g m^{-2} day^{-1}) in both the years. Among the herbicidal treatments, stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS recorded the highest CGR (2.03 g m^{-2} day^{-1}) which was at par with pre emergence application of pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} and application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS in the first year. While in the second year, at 25-50 DAS, maximum CGR (2.28 g m^{-2} day^{-1}) was recorded with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS and was statistically at par with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS. Between 50-75 DAS, significantly maximum CGR (9.46 and 9.52 g m^{-2} day^{-1}) was observed in weed free treatment and was found to be statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS in both the years. The probable reason for this might be due to higher degree of weed suppression, less nutrient uptake by weeds, more light interception, more photosynthetic rates and increased leaf area index thus resulted in better dry matter accumulation. Hence, resulted in more CGR. The result is closely aligned with the finding observed by Kumari *et al*. (2023).

4.2.1.5 Relative growth rate (RGR) (g g^{-1}day^{-1})

The data pertaining to crop growth rate as influenced by tillage system and weed management practices is presented in Table 4.11.

An inquisition of the data from the experiment revealed that tillage system had no significant effect on RGR at all stages of observation in both the years of experimentation.

A critical analysis of the data revealed that weed management practices showed no significant variation on RGR except in first year of the study between 50-75 DAS. In first year, the highest RGR (0.033 g g^{-1}day^{-1}) was recorded with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS.

Table 4.11: Effect of tillage system and weed management practices on crop growth rate (CGR) and relative growth rate (RGR) of rice at different growth stages

Treatments	Crop growth rate (CGR) (g m^{-2} day^{-1})						Relative growth rate (RGR) (g $g^{-1}day^{-1}$)					
	25-50 DAS			50-75 DAS			25-50 DAS			50-75 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	1.92	1.85	1.89	6.46	7.27	6.87	0.015	0.014	0.015	0.028	0.032	0.030
T_2	2.16	2.31	2.24	6.88	7.44	7.16	0.016	0.016	0.016	0.028	0.030	0.029
T_3	2.20	2.43	2.32	7.69	7.75	7.72	0.016	0.017	0.016	0.030	0.029	0.029
SEm±	0.11	0.14	0.09	0.33	0.29	0.22	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices (W)												
W_1	2.03	2.06	2.04	6.86	7.08	6.97	0.016	0.016	0.016	0.030	0.030	0.030
W_2	2.00	1.86	1.93	5.12	6.25	5.68	0.018	0.017	0.017	0.027	0.031	0.029
W_3	1.82	2.28	2.05	8.29	7.83	8.06	0.013	0.015	0.014	0.033	0.030	0.031
W_4	1.93	2.26	2.09	8.41	8.28	8.34	0.012	0.014	0.013	0.031	0.029	0.030
W_5	2.98	3.15	3.07	9.46	9.52	9.49	0.017	0.018	0.017	0.029	0.029	0.029
W_6	1.81	1.58	1.69	3.94	5.97	4.95	0.017	0.015	0.016	0.023	0.032	0.027
SEm±	0.23	0.24	0.17	0.47	0.44	0.32	0.002	0.002	0.001	0.002	0.002	0.001
CD (P=0.05)	0.69	0.70	0.48	1.34	1.27	0.90	NS	NS	NS	0.006	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage
W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

4.2.1.6 Leaf Area Index (LAI)

The data pertaining to leaf area index as influenced by tillage system and weed management practices is presented in Table 4.12.

Data on LAI due to different tillage system showed significant variation at all stages of observation during the both years of study. Conventional tillage system recorded maximum LAI (0.31 and 0.31at 25 DAS and 1.81 and 1.92 at 50 DAS) while zero tillage recorded the minimum value (0.26 and 0.27 at 25 DAS and 1.54 and 1.56 at 50 DAS) in both years of experimentation. Higher LAI under conventional tillage system might be due to less weed intensity and pressure that allowed crop to attain lush growth that can resulted in a higher chlorophyll content and photosynthetic output due to more light interception by crop. A higher photon flux density (PFD) captured by the canopy, which results in a higher chlorophyll content and photosynthetic output, is indicated by a larger leaf area index (leaf area per unit ground area) according to Ashrafi and Pandit (2014). This result is corroborated with the finding of Mukherjee (2019) where conventional tillage system recorded the highest LAI at 90 DAS in both direct seeded rice as well as transplanted rice.

Different weed management revealed significant effect on LAI at all stages of observation. Th maximum LAI was recorded in weed free treatment (W_5) followed by pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS at all stages of observation during the both years of study. While the minimum LAI was observed under weedy check. This might be due to higher WCE due to the cumulative effect of both pre and post emergence herbicides that control most of the weed flora at the critical stages of crop growth. This further resulted in higher uptake of nutrients, better light transmission, enhanced translocation of photosynthates from source towards sink that resulted in an increased leaf area. Pavithra *et al*. (2021) also reported that maximum LAI was obtained with application of pendimethalin 1.0

kg ha^{-1} at 3 DAS *fb* bispyribac-sodium 30 g ha^{-1} at 30 DAS in comparison to other treatments. The finding is in close conformity as observed by Joshi *et al*. (2016) and Jaiswal and Duary (2023). There was no significant interaction effect of tillage system and weed management practices on LAI during both the years.

4.2.1.7 Chlorophyll content (micro mol m^{-2})

The data related to chlorophyll content of rice due to the influence of tillage system and weed management practices is presented in Table 4.12.

A perusal of the data showed that different tillage system had significant effect on chlorophyll content of rice. Among the tillage system, increased chlorophyll content (31.67 and 31.22 micro mol m^{-2}) of rice was observed under conventional tillage system and was statistically at par with minimum tillage system and significantly superior to zero tillage system at 25 DAS. Similar trend of chlorophyll content of rice was followed at 50 DAS. Higher chlorophyll content of rice under conventional tillage might be due to lower weed pressure that avoids competition with crop for all the essential elements and improved mineralization of nutrients and better root growth that led to better uptake of nutrient especially nitrogen that is required for the synthesis of chlorophyll. Further, conventional tillage improves the soil physical, chemical and biological condition that helps in better nutrients movement and thus uptake. Munyao *et al*. (2019) concluded that higher chlorophyll content per unit area depends on increased nitrogen content in plant. Mukherjee (2019) also reported that the maximum chlorophyll content was found under conventional tillage as compared to other tillage system. Vaishnav *et al*. (2023) also reported similar result where conventional tillage recorded higher SPAD reading than zero tillage in rice.

Table 4.12: Effect of tillage system and weed management practices on leaf area index (LAI) and chlorophyll content of rice at different growth stages

Treatments	Leaf area index (LAI)						Chlorophyll content (micro mol m^{-2})					
	25-50 DAS			50-75 DAS			25 DAS			50 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	0.26	0.27	0.27	1.54	1.56	1.55	29.36	29.71	29.53	34.81	34.82	34.82
T_2	0.28	0.29	0.29	1.72	1.77	1.74	30.90	30.80	30.85	35.88	35.46	35.67
T_3	0.31	0.31	0.31	1.81	1.92	1.87	31.67	31.22	31.44	36.81	36.39	36.60
SEm±	0.005	0.004	0.003	0.025	0.029	0.019	0.37	0.29	0.23	0.29	0.24	0.19
CD (P=0.05)	0.021	0.015	0.011	0.099	0.114	0.063	1.44	1.13	0.76	1.16	0.95	0.62
Weed management practices (W)												
W_1	0.28	0.29	0.29	1.52	1.46	1.49	30.17	30.29	30.23	35.31	34.93	35.12
W_2	0.21	0.22	0.22	1.24	1.27	1.25	28.75	29.46	29.10	33.84	33.78	33.81
W_3	0.33	0.33	0.33	1.77	1.86	1.81	31.30	30.81	31.06	37.07	36.82	36.95
W_4	0.35	0.35	0.35	1.95	2.06	2.00	32.36	31.61	31.99	37.88	37.29	37.59
W_5	0.40	0.41	0.41	2.64	2.76	2.70	34.85	33.81	34.33	39.14	38.85	38.99
W_6	0.13	0.14	0.14	1.04	1.09	1.06	26.42	27.46	26.94	31.75	31.67	31.71
SEm±	0.008	0.006	0.005	0.030	0.048	0.028	1.05	0.70	0.63	0.63	0.54	0.41
CD (P=0.05)	0.022	0.017	0.014	0.086	0.138	0.079	3.04	2.01	1.79	1.81	1.55	1.17

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

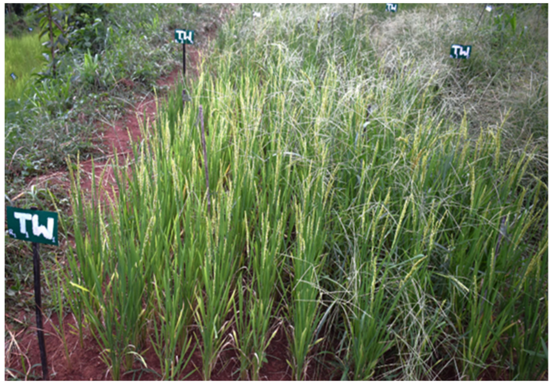
W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

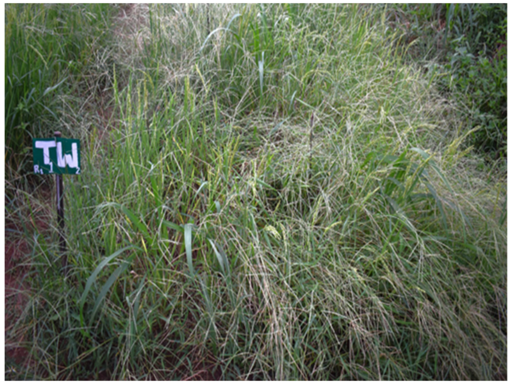
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free

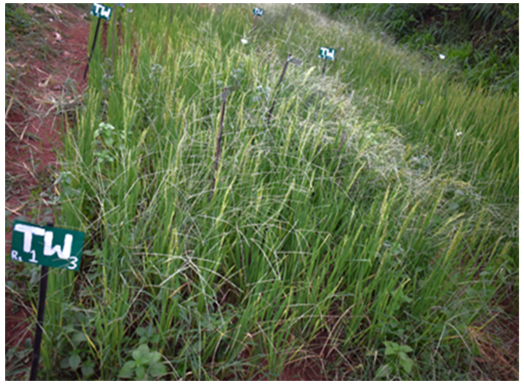
W_6: Weedy check



T_1W_1



T_1W_2



T_1W_3

T_1W_4

T_1W_5 (Weed free plot)

T_1W_6 (Weedy check)

Plate 13: Different experimental plots (Zero tillage system)

T_2W_1

T_2W_2

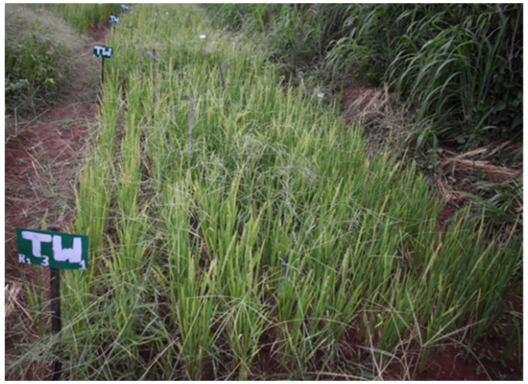
T_2W_3

T_2W_4

T_2W_5 (Weed free plot)

T_2W_6 (Weedy check)

Plate 14: Different experimental plots (Minimum tillage system)



T_3W_1

T_3W_2

T_3W_3

T_3W_4

T_3W_5 (Weed free plot)

T_3W_6 (Weedy check)

Plate 15: Different experimental plots (Conventional tillage system)

Among the weed management practices, weed free treatment recorded maximum chlorophyll content of rice and was statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS at 25 DAS in both the years. Similarly at 50 DAS, weed free treatment recorded maximum chlorophyll content of rice and was statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} only in the first year. The reason might be due to broad spectrum effective control of weeds at the early critical stages of the crop that resulted in better uptake of nitrogen along with the other essential elements. Thus, due to better uptake and translocation of nitrogen along with the other nutrients towards the sink resulted in more nitrogen content in the crop. Higher photosynthetic efficiency is indicated by higher leaf chlorophyll content of plants resulting in higher yield (Channappagoudar *et al*., 2008). This result is closely corroborated with the findings of Jaiswal and Duary (2023).

4.2.2 Yield attributes and yield

4.2.2.1 Panicle length (cm)

The data pertaining to panicle length as influenced by tillage system and weed management practices is presented in Table 4.13.

A perusal of the data showed that different tillage system significantly influenced the panicle length during the both years of study. Conventional tillage system recorded the highest panicle length (17.71 and 18.02 cm) which was statistically at par with minimum tillage system (17.38 and 17.73 cm) and was significantly superior to zero tillage system. The reason for the higher values of panicle length in conventional tillage system might be the consequence of improved photosynthate partitioning from source to sink as a result of improved growth, which was attained because of favourable growing conditions brought on by lowered crop-weed competition during the crucial stages of crop growth. Bhargaw *et al*. (2023) also reported that conventional tillage system recorded

15% longer panicle as compared to zero tillage system. This result is in close agreement with that finding obtained by El-Din *et al*. (2008) and Saini *et al*. (2022).

A critical analysis of the data showed that different weed management practices showed significant effect on panicle length with weed free treatment recording the maximum panicle length (18.75 and 19.28 cm) and was statistically superior over weedy check (17.07 and 17.02 cm). Among the herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum panicle length (17.74 and 18.61 cm) and was statistically at par with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS only in the first year of experimentation. This can be explained by effective controlling of all kinds of weeds and higher weed control efficiency by applying pre-emergence herbicide to control weeds at early stage, and subsequent weed growth was again suppressed further by early post-emergence herbicide. Thus, less crop-weed competition that ultimately created an ideal microenvironment for the rice plant to efficiently uptake the essential nutrients, moisture, solar energy etc. for better rate of photosynthesis and translocation of photosynthates to sink. The lowest panicle length under weedy check was due to severe weed competition with crop for various growth elements. The result is closely corroborated with the results of Walia *et al*. (2008) who reported that highest panicle length was obtained with the application of pendimethalin @ 750 g ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 30 DAS. These results are also in close agreement with the findings of Singh *et al*. (2016b) and Singh *et al*. (2019).

4.2.2.2 Panicle weight (g)

The data related to panicle weight as influenced by tillage system and weed management practices is presented in Table 4.13.

Panicle weight significantly differed with different tillage system in both the years. Significantly maximum panicle weight (2.11 and 2.19 g) was recorded with conventional tillage system and was statistically at par with minimum tillage system in both the years. While the minimum (1.83 and 1.90 g) was found under zero tillage system in both the years of experimentation. The reason for maximum panicle weight under conventional tillage may be ascribed due to better crop growth and weed suppressing ability of crop due to less weed density and dry matter at the crucial stage of crop. According to Gathala *et al*. (2011), tillage operation enhances soil physical, chemical and biological characteristics and hinders weed growth, allowing the crop to flourish and perform efficiently. The result is closely substantiated with that obtained by El-Din *et al*. (2008) who reported that conventional tillage (CT) gave higher panicle weight than reduced tillage (RT).

Weed management practices differed significantly on panicle weight in both the years of study. The maximum panicle weight (2.49 and 2.73 g) was recorded in weed free treatment and was statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS only in the first year of experimentation, which recorded the highest panicle weight (2.31 and 2.38 g) among all the other herbicidal treatments in both the years. While statistically minimum panicle weight was recorded with weedy check during both the years of investigation. The possible reason for maximum panicle weight under weed free treatment might be due to no weeds compete with crop for either essential growth element, water, space and solar radiation and hence ultimately resulted in high photosynthesis rate, better partitioning of metabolites and translocation of photosynthates from source to sink that led to better healthy crop growth. While among the herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest panicle weight which might be due to the combine effect of pre and post emergence herbicides that significantly suppressed the complex weed flora in terms of weed density and dry weight and thereby resulted in better crop uptake of growth factors. Hence, better translocation of photosynthates from source to sink which translated through increased panicle weight.

4.2.2.3 Number of panicle (no.m^{-2})

The data related to number of panicle m^{-2} as influenced by tillage system and weed management practices is presented in Table 4.13.

Significant effect of different tillage system was found on number of panicle m^{-2} in both the years of experimentation. The maximum number of panicle (213.72 and 219.73 m^{-2}) was recorded in conventional tillage system and was statistically at par with minimum tillage system (206.28 and 210.39 m^{-2}) in both the years. Increased in number of panicle might be attributed to increase soil porosity and aeration that encouraged greater root and shoot growth as well as better nutrient availability and uptake by crop. In addition to this, conventional tillage suppresses weed emergence due to deep burial of weed seeds that resulted in less weed competition. Chauhan (2013) also reported that there was slightly lower number of panicles per unit area in zero tillage plot than in conventional tillage system. The result also agrees with El-Din *et al*. (2008).

Among the weed management practices, the maximum number of panicle (276.33 and 284.02 m^{-2}) was recorded in weed free treatment and the minimum (140.00 and 145.56 m^{-2}) in weedy check. While among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest number of panicle (232.78 and 236.56 m^{-2}) which was statistically at par with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS in both the years. The higher number of panicles with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS might be due to the fact that application of pendimethalin *fb* bispyribac-sodium resulted in lesser weed intensity and pressure that resulted in better translocation of metabolites and photosynthates, consequently increase maximum number of panicle. Similar result was reported by Mahajan and Chauhan (2013) where the highest number of panicles was recorded with the plots treated with sequential application of pendimethalin *fb* bispyribac-sodium which might be due to less weed competition as a result of dual efficiency of the herbicides.

4.2.2.4 Number of grains (no. panicle^{-1})

The data related to number of grains panicle^{-1} of rice due to the influence of tillage system and weed management practices is presented in Table 4.14.

Number of grains panicle^{-1} significantly differed with different tillage system in both the years. Conventional tillage system recorded the highest number of grains panicle^{-1} (84.73 and 87.24) which was statistically at par with minimum tillage system only in the first year of the study and was significantly superior to zero tillage system. Because of the ideal tillage condition created by conventional tillage system resulted in the optimum soil physical, biological and chemical condition that resulted in better nutrients absorption and translocation of nutrient and water uptake by crop, which ascribed to the effective partitioning of metabolites and movement of photosynthates towards sink. The result is in close agreement with findings of Seth *et al*. (2019), Saini *et al*. (2022) and Bhargaw *et al*. (2023).

Different weed management practices significantly influenced number of grains panicle^{-1} in both years of the study. The maximum number of grains panicle^{-1} (91.33 and 95.42) was recorded in weed free treatment and the minimum (66.31 and 66.61) in weedy check.

Table 4.13: Effect of tillage system and weed management practices on yield attributing characters of rice (panicle length, panicle weight and number of panicles m^{-2})

Treatments	Panicle length (cm)			Panicle weight (g)			Number of panicles m^{-2}		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T$_1$	17.10	17.35	17.23	1.83	1.90	1.86	180.11	189.72	184.92
T$_2$	17.38	17.73	17.55	2.01	2.08	2.05	206.28	210.39	208.33
T$_3$	17.71	18.02	17.87	2.11	2.19	2.15	213.72	219.73	216.73
SEm±	0.09	0.11	0.07	0.03	0.04	0.03	4.15	4.89	3.21
CD (P=0.05)	0.36	0.43	0.24	0.12	0.17	0.09	16.29	19.21	10.46
Weed management practices (W)									
W$_1$	17.39	17.58	17.48	2.04	2.07	2.06	182.22	192.33	187.28
W$_2$	17.07	17.02	17.05	1.54	1.58	1.56	154.89	160.67	157.78
W$_3$	17.61	18.01	17.81	2.28	2.32	2.30	214.00	220.56	217.28
W$_4$	17.74	18.61	18.17	2.31	2.38	2.35	232.78	236.56	234.67
W$_5$	18.75	19.28	19.02	2.49	2.73	2.61	276.33	284.02	280.18
W$_6$	15.83	15.70	15.77	1.24	1.25	1.24	140.00	145.56	142.78
SEm±	0.23	0.20	0.15	0.07	0.05	0.04	7.41	8.87	5.78
CD (P=0.05)	0.66	0.59	0.43	0.21	0.15	0.12	21.40	25.63	16.35

T$_1$: Zero tillage, **T$_2$:** Minimum tillage, **T$_3$:** Conventional tillage

W$_1$: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W$_2$: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W$_3$: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W$_4$: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W$_5$:** Weed free
W$_6$: Weedy check

Among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest number of grains panicle^{-1} (89.05 and 90.49) which was statistically at par with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS only in both the year. The probable explanation for this may be attributed to higher weed control efficiency that lessened crop-weed competition for nutrients, allowing crop plants to utilize the available nutrients more effectively throughout the crop growth period, which in turn increased the number of grains panicle^{-1}. According to Gogoi *et al*. (2000) due to reduce crop-weed competition and less depletion of nutrients by weeds will enhance crop capacity for N, P, K uptake and increase the source and sink size and ultimately increased number of grains panicle^{-1}. The result is in close proximity with that of Joshi *et al*. (2016), Kumar *et al*. (2018), Singh *et al*. (2019) and Marasini *et. al* (2020).

4.2.2.5 Number of filled grains (no. panicle^{-1})

The data related to number of filled grains panicle^{-1} due to the influence of tillage system and weed management practices is presented in Table 4.14.

Tillage system significantly influenced number of filled grains panicle^{-1} in both the years. The significantly maximum number of filled grains panicle^{-1} (69.55 and 72.14) was recorded in conventional tillage system and was statistically at par with minimum tillage system only in the first year. While, zero tillage recorded the lowest number of filled grains panicle^{-1} (64.52 and 65.84) in both the years of experimentation.

The higher number of filled grains panicle^{-1} in conventional tillage might be due to effective weed control along with favourable micro-climatic condition, soil moisture and availability of nutrients, higher degree of soil loosening that helps in good air exchange and root growth at the critical period of crop growth like maximum tillering, panicle initiation, flowering and grain filling stages that allowed the plants to utilize the essential growth factors (nutrient, water, solar energy) resulting better crop establishment and growth thus reflecting more number of filled grain with higher photosynthetic activity, assimilates transportation, starch biosynthesis and cell proliferation. El-Din *et al*. (2008) and Bhargaw *et al*. (2023) also reported almost similar results with conventional tillage system recording the highest number of filled grains panicle^{-1}.

Number of filled grains panicle^{-1} significantly differed with different weed management practices in both the years. The maximum number of filled grains panicle^{-1} (78.87 and 83.48) was recorded in weed free treatment and the minimum (45.31 and 47.53) in weedy check. In weed free treatment, there is no competition of weeds with crops for the available nutrients, water, light etc. leading better growth and development. Among the herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS was found to be significantly superior recording the highest number of filled grains panicle^{-1} (75.14 and 76.22) in both the years. With highest weed control efficiency, pendimethalin *fb* bispyribac-sodium offered efficient weed control throughout the crop growing season promoting greater tillering, more panicles and higher photosynthate accumulation, which enhanced crop development and increased number of filled grains significantly.

4.2.2.6 Number of unfilled grains (no. panicle^{-1})

The data related to number of unfilled grains panicle m^{-2} as influenced by tillage system and weed management practices is presented in Table 4.14.

The significantly minimum number of unfilled grains panicle^{-1} (15.19 and 15.05) was recorded in conventional tillage system and maximum (17.22 and 16.62) in zero tillage system in both the years. Better translocation of photosynthates from source to sink that resulted in a greater number of filled grains and less number of unfilled grains due to less competition for nutrients,

Table 4.14: Effect of tillage system and weed management practices on yield attributing characters of rice (number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of filled grains panicle^{-1})

Treatments	Number of grains panicle^{-1}			Number of filled grains panicle^{-1}			Number of unfilled grains panicle^{-1}		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	81.74	82.16	81.95	64.52	65.84	65.18	17.22	16.62	16.92
T_2	82.89	84.08	83.49	67.11	68.63	67.87	15.78	15.40	15.59
T_3	84.73	87.24	85.99	69.55	72.14	70.84	15.19	15.05	15.12
SEm±	0.57	0.62	0.42	0.56	0.54	0.39	0.29	0.20	0.18
CD (P=0.05)	2.22	2.44	1.37	2.21	2.11	1.27	1.14	0.80	0.58
Weed management practices (W)									
W_1	84.28	85.45	84.87	68.23	69.45	68.84	16.04	15.82	15.93
W_2	80.14	81.15	80.64	62.69	63.50	63.10	17.44	16.92	17.18
W_3	87.61	87.84	87.73	72.10	73.04	72.57	15.51	15.20	15.35
W_4	89.05	90.49	89.77	75.14	76.22	75.68	13.91	13.73	13.82
W_5	91.33	95.42	93.38	78.87	83.48	81.17	12.47	12.58	12.52
W_6	66.31	66.61	66.46	45.31	47.53	46.42	21.00	19.90	20.45
SEm±	1.51	1.59	1.10	1.07	0.74	0.65	0.88	0.69	0.56
CD (P=0.05)	4.35	4.60	3.10	3.10	2.13	1.84	2.53	1.99	1.58

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free

W_6: Weedy check

water, sunlight and space for better crop growth and development. Different weed management practices showed significant variation in number of unfilled grains panicle^{-1} in both the years of experimentation. The minimum number of unfilled grains panicle^{-1} (12.47 and 12.58) was recorded in weed free treatment and the maximum (21.00 and 19.90) in weedy check.

Among the herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the minimum number of unfilled grains panicle^{-1} (13.91 and 13.73) in both the years of study. This resulted from the fact that the subsequent herbicidal treatment with pre and post emergence herbicides improved crop development, which in turn enhanced photosynthate accumulation in reproductive organs and, in turn, significantly boosted grain filling rate. Hence, ultimately resulted in more number of filled grains and less number of unfilled grains attributed to efficient controlling of weeds.

4.2.2.7 Test weight (g)

The data related to test weight of rice due to the influence of tillage system and weed management practices is presented in Table 4.15(a). Tillage system and weed management practices had no significant effect on test weight of rice in both the years.

4.2.2.8 Grain yield (kg ha^{-1})

Tillage system and weed management practices significantly influenced the grain yield of rice in both years and pooled data of the two years as shown in Table 4.15(a) and illustrated in Fig 4.6(a) and 4.6(b). The grain yields of all the treatments in second year were higher than the first year due to more rainfall and its uniform distribution throughout the cropping season, resulting in more favourable environmental conditions for crop growth. Furthermore, due to the dual absorption by the foliage and roots, the weed-controlling efficacy of bispyribac-sodium may have been affected by soil moisture. So, the efficiency of bispyribac-sodium may have been enhanced in 2022 due to higher soil moisture levels compared to 2021 (Jat *et al*., 2019).

After critical analysis of the data, different tillage system was found to have significant effect on grain yield of rice in both the years. The maximum grain yield was recorded under conventional tillage system in both years (2021 and 2022) with values 4078.83 and 4094.31 kg ha^{-1} respectively in the first and second year. This might be due to the lesser weed density and their dry weight, which allowed the crop to attain lush growth with better availability of nutrients, moisture, space and light which in turn resulted in better source and sink relationship which improved growth and yield attributes and finally maximum grain yield during both the year of experimentation. The lesser weed density under conventional tillage system, is again attributed due higher intensity of soil disturbance and burial of weed seeds in deeper soil layer. The minimum grain yield was found with zero tillage system in both the years (3760.60 and 3772.89 kg ha^{-1}). In addition, increased water retention and penetration in the conventional system might have given the rice crop favourable water conditions. Meanwhile, in zero tillage the soil tends to dry out rapidly as water retains for shorter period, which causes less water penetration into the soil and stresses to rice plants. These results are in close proximity with Chauhan (2013), Singh *et al*. (2015) and Seth *et al*. (2019).

The weed free treatment yielded the highest grain production (4581.67 and 4596.16 kg ha^{-1}) in comparison to the weedy check, which recorded the lowest grain yield (2994.52 and 2998.07 kg ha^{-1}) in both the years of study. Among the herbicidal treatment, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the significantly maximum grain yield (4480.93 and 4494.92 kg ha^{-1}). This might be due effective controlling of complex weed flora during the active growing stage of crop thereby resulting decreased weed dry weight and higher weed control efficiency. Additionally, this had a favourable impact on increased grain yield in this treatment resulting from higher number of panicles m^{-2}, panicle weight, length, number of filled grains $panicles^{-1}$ and test weight. The findings are in accordance with Singh *et al*. (2015), Jat *et al*. (2019) and Marasini *et. al* (2020).

The analysis of data clearly showed significant interaction between tillage system and weed management practices on grain yield in both seasons and the pooled data of two years as shown in Table 4.15(b). All the herbicidal treatments under different tillage system showed significant variation in grain yield relative to weedy check under all tillage system. The treatment combination T_3W_5 (conventional tillage system with weed free) recorded significantly maximum grain yield in both the years as well as the pooled data (4594.44, 4605.70 and 4526.13 kg ha^{-1}) which was followed by T_2W_5 (minimum tillage system with weed free) (4582.78, 4595.67 and 4589.22 kg ha^{-1}). This might be attributed to better control of weeds and crop growth due to deep burial of weed seeds in the soil profile and maintenance of weed free condition throughout the cropping period that allows the crop for better utilization of nutrients, water, solar energy which then resulted in efficient partitioning of metabolites and photosynthates toward sinks hence increased yield attributes and grain yield. The significantly lower grain yield (2951.11, 2954.44 and 2952.78 kg ha^{-1} during 2021, 2022 and pooled) was recorded with T_1W_6 (weedy check under zero tillage system). The minimum grain yield in this treatment might be due to more weed pressure under zero tillage. This was reported by Singh *et al*. (2015).

4.2.2.9 Straw yield (kg ha^{-1})

The data pertaining to straw yield as influenced by tillage system and weed management practices is presented in Table 4.15(a) and illustrated in Fig 4.7(a) and 4.7(b).

A critical analysis of the data showed that different tillage system was found to have significant effect on straw yield of rice in both the years of study. The significantly maximum straw yield (5846.09 and 5842.20 kg ha^{-1}) was recorded under conventional tillage system in both the years of experimentation. This might be due to the fact that conventional tillage is known increased the soil's porosity and aeration, which promoted greater root and shoot growth as well as improved nutrient availability and uptake, all of which led to increased photosynthesis rate, assimilation and translocation of photosynthates to sink that ultimately resulted in increased plant dry matter accumulation, and various growth and yield attributes. In addition to this, less weed pressure contributed to higher straw yield under this tillage system. Ranjit and Suwanketnikom (2005) and Saini *et al*. (2022) also reported higher straw yield under conventional tillage The minimum straw yield was found under zero tillage system in both the years (5612.16 and 5607.88 kg ha^{-1}).

The statistical data clearly showed that weed management practices had significant influence on straw yield in both the years. The weed free treatment yielded the highest straw yield (6082.20 and 6099.12 kg ha^{-1}) in comparison to the weedy check, which recorded the lowest straw yield (4940.52 and 4949.00 kg ha^{-1}). Among the herbicidal treatment, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the significantly maximum straw yield (6180.92 and 6183.52 kg ha^{-1} This may be ascribed to the higher WCE, lower weed density, dry matter and weed index that resulted from higher efficiency of cumulative effect of pendimethalin and bispyribac-sodium that led to enhance crop uptake of nutrients, decrease weed removal of nutrients and improve solar radiation transmission for photosynthesis promoting higher straw yield. The finding is in close conformity as reported by Awan *et al*. (2015), Chakraborti *et al*. (2017) and Baghel *et al*. (2018).

Significant interaction effect of tillage system and weed management practices was observed in straw yield of rice in both the years of study. In 2021, the treatment combination T_3W_4 (application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) recorded significantly maximum straw yield (6181.11 kg ha^{-1}) which was followed by T_3W_3 (conventional tillage system with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS) (6175.22 kg ha^{-1}). While in 2022, significantly maximum straw yield was observed with the treatment combination T_3W_4 (application of pendimethalin @ 1kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) followed by T_3W_1 (conventional tillage system with state seedbed followed by bispyribac-sodium @ 25 g ha^{-1} at 25 DAS) (6184.44 kg ha^{-1}).

4.2.2.10 Harvest index (%)

The data related to harvest index of rice as influenced by tillage system and weed management practices is presented in Table 4.15(a).

Different tillage system was found to have significant effect on harvest index of rice in both the years of study. Conventional tillage system recorded the maximum harvest index (40.90 and 41.02%) which was followed by minimum tillage in both the years. During both the years of investigation, zero tillage recorded the lowest harvest index (39.92 and 40.02%). This may be ascribed to the greater ability of soil physical, chemical, biological properties and suppresses the weed growth at the active growth period of crop which enables the crop to grow by efficiently utilizing the available nutrients, enhancing the metabolic activities and translocation of more photosynthates towards sink and positively influenced the grain yield by improving yield attributes. The result is in close conformity with that finding of Kumar *et al*. (2019).

Among the weed management practices, weed free treatment recorded significantly maximum harvest index (42.96 and 42.97%) while weedy check recorded the minimum (37.66 and 37.77%) during both the years of investigation. Pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest harvest index (42.03 and 42.09%) in comparison to other herbicidal treatments. Higher harvest index in this treatment might be due to higher weed control efficiency resulting in competition free environment for the crop that resulted in better availability and uptake of growth factors, increased source (LAI) and sink size. This ultimately increased the economic yield which is reflected from higher harvest index. According to Bahadur *et al*. (2013) and Shukla *et al*. (2016), higher harvest index indicates that plants maintained a higher supply of photosynthates to the reproductive part as compared to vegetative biomass. The result is in close agreement with findings of Vivek *et al*. (2018) and Sen *et al*. (2020).

There was significant effect on harvest index due to the interaction of tillage system and weed management practices in both the years. The interaction treatment combination T_3W_5 (weed free under conventional tillage system) recorded significantly maximum harvest index (42.97 and 42.98%) which was followed by T_3W_4 (application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) (42.22 and 42.28%) in both the years of study.

4.2.3 Nutrient (NPK) concentration and uptake by rice (kg ha^{-1})

4.2.3.1 N, P and K content in grain (%)

The data pertaining to N, P and K content in grain as influenced by tillage system and weed management practices is presented in Table 4.16(a), 4.17(a) and 4.18(a).

Different tillage system did not show significant variation on nitrogen content in grain in both the years of observations. However, numerically higher nitrogen

Table 4.15(a): Effect of tillage system and weed management practices on test weight, yield and harvest index of rice

Treatments	Test weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	26.64	26.69	26.67	3760.60	3772.89	3766.74	5612.16	5607.88	5610.02	39.92	40.02	39.97
T_2	26.81	26.68	26.74	3948.80	3958.57	3953.68	5743.64	5738.31	5740.97	40.54	40.62	40.58
T_3	26.78	26.94	26.86	4078.83	4094.31	4086.57	5846.09	5842.20	5844.14	40.90	41.02	40.96
SEm±	0.19	0.14	0.12	8.82	8.39	6.09	12.66	7.17	7.27	0.03	0.07	0.04
CD (p=0.05)	NS	NS	NS	34.63	32.96	19.85	49.70	28.14	23.72	0.12	0.28	0.13
Weed management practices (W)												
W_1	26.59	26.60	26.60	3884.57	3895.69	3890.13	5772.74	5770.85	5771.80	40.16	40.24	40.20
W_2	26.61	26.68	26.65	3434.41	3455.49	3444.95	5420.14	5417.19	5418.66	38.78	38.94	38.86
W_3	26.80	26.73	26.76	4200.37	4211.19	4205.78	5990.29	5965.56	5977.93	41.15	41.32	41.24
W_4	26.91	26.83	26.87	4480.93	4494.92	4487.92	6180.92	6183.52	6182.22	42.03	42.09	42.06
W_5	27.21	27.40	27.31	4581.67	4596.16	4588.91	6082.20	6099.12	6090.66	42.96	42.97	42.97
W_6	26.34	26.38	26.36	2994.52	2998.07	2996.30	4957.48	4940.52	4949.00	37.66	37.77	37.71
SEm±	0.21	0.23	0.16	15.42	11.07	9.49	11.93	14.27	9.30	0.12	0.08	0.07
CD (p=0.05)	NS	NS	NS	44.53	31.98	26.85	34.46	41.21	26.31	0.35	0.24	0.21

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

Table 4.15(b): Interaction effect of tillage system and weed management practices on grain yield (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	3605.27	3669.56	4378.89	3616.11	3681.89	4389.07	3610.69	3675.72	4383.98
W_2	3301.11	3502.11	3500.00	3317.22	3508.71	3540.56	3309.17	3505.41	3520.28
W_3	3700.00	4443.33	4457.78	3712.22	4456.32	4465.02	3706.11	4449.83	4461.40
W_4	4438.33	4487.78	4516.67	4450.22	4498.94	4535.59	4444.28	4493.36	4526.13
W_5	4567.78	4582.78	4594.44	4587.11	4595.67	4605.70	4577.44	4589.22	4600.07
W_6	2951.11	3007.22	3025.22	2954.44	3009.89	3029.89	2952.78	3008.56	3027.56
SEm± (T×W)	26.71			19.18			16.44		
CD (P=0.05) (W at same level of T)	77.31			55.39			46.65		
SEm± (W×T)	23.52			17.77			19.93		
CD (P=0.05) (T at same or different level of W)	67.94			51.31			56.39		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1}*fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.15(c): Interaction effect of tillage system and weed management practices on straw yield (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	5548.00	5597.44	6172.78	5561.33	5566.78	6184.44	5554.67	5582.11	6178.61
W_2	5311.67	5482.09	5466.67	5322.22	5485.44	5443.89	5316.94	5483.77	5455.28
W_3	5626.26	6169.39	6175.22	5603.89	6153.14	6139.67	5615.07	6161.26	6157.44
W_4	6186.20	6175.44	6181.11	6185.44	6172.22	6192.89	6185.82	6173.83	6187.00
W_5	6068.93	6080.26	6097.41	6093.73	6094.12	6109.50	6081.33	6087.19	6103.46
W_6	4931.89	4957.22	4983.33	4880.64	4958.13	4982.80	4906.26	4957.68	4983.07
SEm± (T×W)	20.67			24.71			16.11		
CD (P=0.05) (W at same level of T)	59.69			71.38			45.57		
SEm± (W×T)	21.09			21.41			19.97		
CD (P=0.05) (T at same or different level of W)	60.93			61.85			56.50		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.15(d): Interaction effect of tillage system and weed management practices on harvest index (%)

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	39.39	39.60	41.50	39.40	39.81	41.51	39.39	39.70	41.50
W_2	38.33	38.98	39.03	38.40	39.01	39.41	38.36	39.00	39.22
W_3	39.67	41.87	41.92	39.85	42.00	42.10	39.76	41.93	42.01
W_4	41.77	42.08	42.22	41.84	42.16	42.28	41.81	42.12	42.25
W_5	42.94	42.98	42.97	42.95	42.99	42.98	42.95	42.98	42.98
W_6	37.44	37.76	37.78	37.71	37.78	37.82	37.57	37.77	37.80
SEm± (T×W)	0.21			0.15			0.13		
CD (P=0.05) (W at same level of T)	0.60			0.42			0.36		
SEm± (W×T)	0.17			0.14			0.15		
CD (P=0.05) (T at same or different level of W)	0.50			0.40			0.43		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

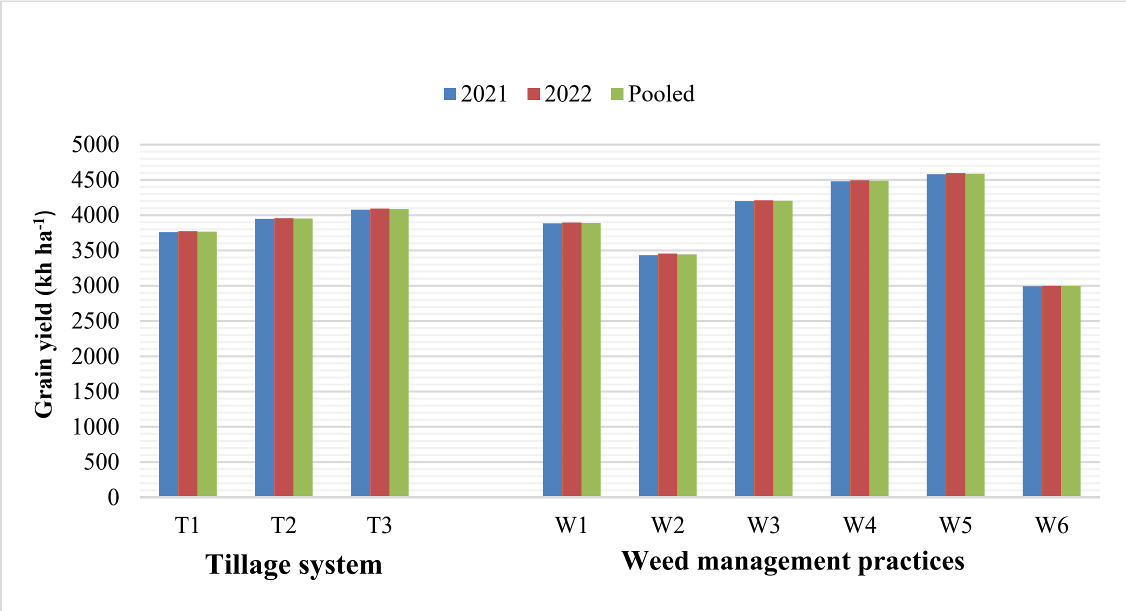


Fig 4.6(a): Effect of tillage system and weed management practices on grain yield (kg ha^{-1})

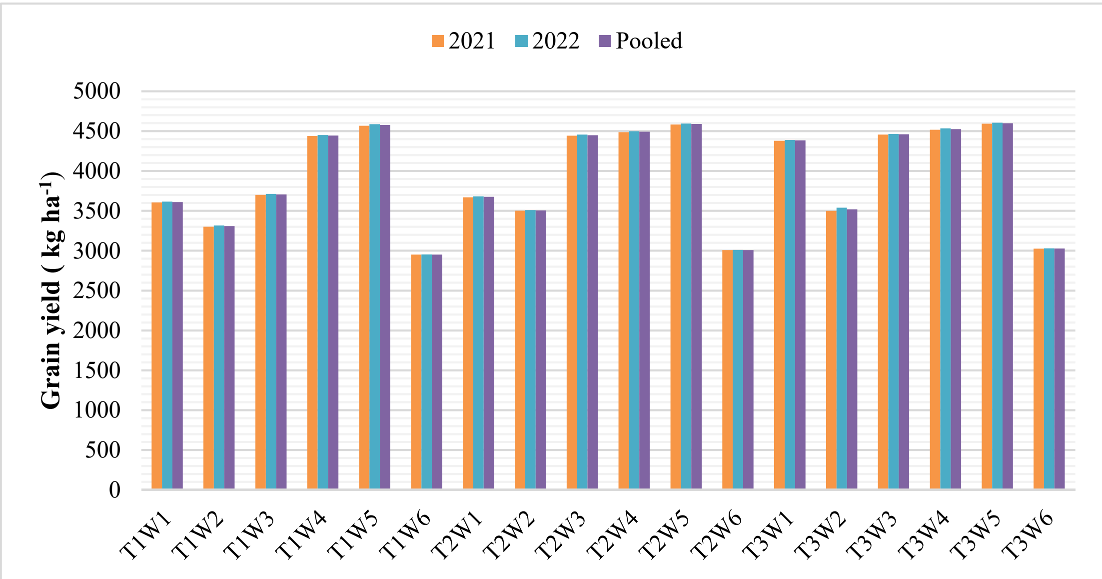


Fig 4.6(b): Interaction effect of tillage system and weed management practices on grain yield (kg ha^{-1})

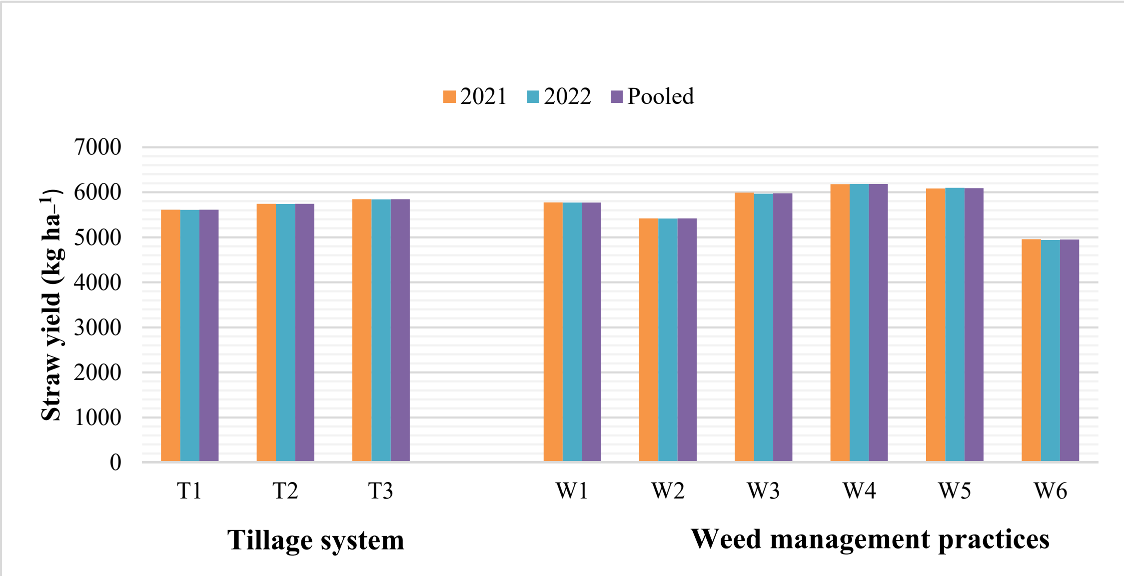


Fig 4.7(a): Effect of tillage system and weed management practices on straw yield (kg ha^{-1})

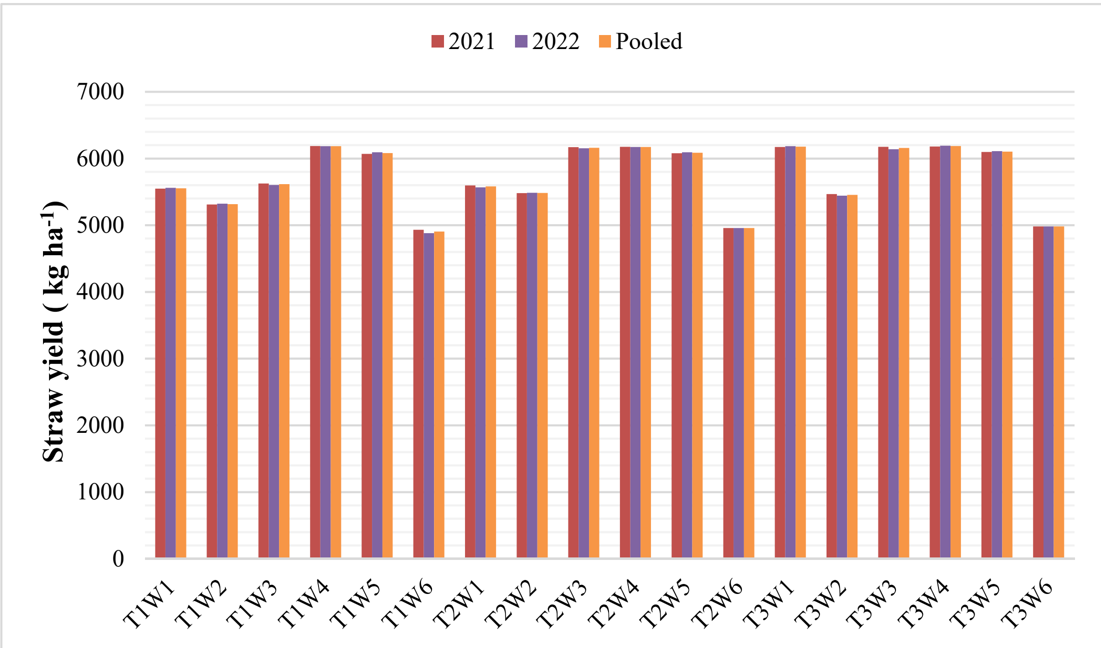


Fig 4.7(b): Interaction effect of tillage system and weed management practices on straw yield (kg ha^{-1})

content in rice grain was observed under conventional tillage system (1.632 and 1.637%) and followed by minimum tillage system (1.616 and 1.622%). Similar trend for grain phosphorus and potassium content were observed in both the years of investigation.

Weed management practices showed no significant effect on nitrogen content in grain in both the years of observations. Although, weed free treatment recorded numerically maximum nitrogen content in grain (1.630 and 1.630%). Likewise, phosphorus and potassium content in grain followed the similar pattern as that of nitrogen.

4.2.3.2 N, P and K content in straw (%)

The data related to N, P and K content in straw as influenced by tillage system and weed management practices is presented in Table 4.17(a).

Different tillage system did not show significant variation on nitrogen content in straw in both the years of observations. However, numerically higher nitrogen content in rice straw was observed under conventional tillage system (1.632 and 1.637%) and followed by minimum tillage system (1.616 and 1.622%).

Weed management practices showed no significant effect on nitrogen content in straw in both the years of observations. Although, weed free treatment recorded numerically maximum nitrogen content in grain (1.630 and 1.630%).

4.2.3.3 Nitrogen uptake by grain (kg ha^{-1})

The perusal of data on nitrogen uptake by grain as influenced by tillage system and weed management practices is presented in Table 4.16(a).

Tillage system resulted in significant variation on nitrogen uptake by rice grain in both the years of investigation. N uptake by grain was significantly higher under conventional tillage system (66.595 and 67.067 kg ha^{-1}) in comparison to other tillage system. Higher grain N uptake under conventional tillage system might be attributed to higher nitrogen content and higher grain yield which was due to favourable soil physical condition that promotes better air, water and nutrient movement thereby allowing plants to absorb nutrients and water from wider soil profile resulting in better plant stand, increased root volume and ultimately early growth and yield. While the minimum grain N uptake was recorded with zero tillage system during both the years due less availability of nutrients due to soil compaction and more depletion of nutrients by weeds. Dolma (2017) also reported the similar result where conventional tillage recorded significantly higher N uptake by grain. The results agree with the findings of Chongtham *et. al* (2015).

Different weed management practices showed significant variation on grain N uptake in both the years of study. Significantly highest grain N uptake (74.681 and 74.918 kg ha^{-1}) was recorded in weed free in both the years. However, among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS (W_4) recorded significantly maximum N uptake by grain (72.590 and 73.019 kg ha^{-1}) followed by stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS (67.766 and 68.629 kg ha^{-1}) during both the years of study. The probable reason of higher grain N uptake might be due to sequential application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} resulted in effective controlling of overall weeds and thus lesser weed dry weight that might have attributed to better utilization of N, P, K, moisture and other elements by crop. This further resulted to higher grain yield and higher nutrient content in grain that attributed to higher grain nitrogen uptake. Weedy check registered significantly lower nitrogen uptake by grain in both the years of investigation. It is probable that the overgrowth of weeds increased crop-weed competition for growth factors, which hindered rice plants from taking up enough nutrients in the weedy check. Verma *et al*. (2016a) reported similar results where pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 18 DAS as early post emergence recorded highest N uptake by crop.

Significant interaction effect of tillage system and weed management practices showed on nitrogen uptake by grain during both the years of investigation and is presented in Table 4.16(b). The treatment T_3W_5 (conventional tillage system with weed free) recorded significantly higher grain nitrogen uptake (75.35 kg ha^{-1}) in the first year (2021) which was at par with T_2W_5 (weed free under minimum tillage system) (74.85 kg ha^{-1}) and T_3W_4 (pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) (74.22 kg ha^{-1}).

In 2022, significantly higher grain nitrogen uptake (75.53 kg ha^{-1}) was registered with T_3W_5 (conventional tillage system with weed free) and was statistically at par with T_2W_5 (weed free under minimum tillage system) (74.76 kg ha^{-1}) and T_3W_4 (stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS under conventional tillage system) (73.82 kg ha^{-1}).While significantly lower grain nitrogen uptake (47.71 and 47.86 kg ha^{-1}) was recorded with T_1W_6 (weedy check under zero tillage system) during both the years of observation.

4.2.3.4 Nitrogen uptake by straw (kg ha^{-1})

The perusal of data on nitrogen uptake by straw as influenced by tillage system and weed management practices is presented in Table 4.16(a).

A critical analysis of the data revealed that tillage system showed significant variation in straw nitrogen uptake during both the years of the study. Conventional tillage system recorded maximum N uptake by straw (44.185 and 44.462 kg ha^{-1}) and was significantly superior to other tillage system in both the years of investigation. This might be ascribed to more straw yield and more straw nitrogen content. Conventional tillage system provides favourable soil condition that allows better availability of nutrients and water to crop thereby enhancing better vegetative growth leading to stronger plant anchorage, increase number of tillers, decreases weed growth and less weed nutrient depletion. The results are in agreement with the findings reported by Seth *et. al* (2020) where conventional tillage recorded higher straw N uptake.

Marked variation in N uptake by straw was observed due to different weed management practices. Among the weed management practices, the maximum N uptake by straw (46.769 and 46.926 kg ha^{-1}) was observed with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS which was followed by weed free in both the years of observation. This might be due to more dry matter accumulation, more N content in vegetative parts of the crop and higher straw yield resulted from more N uptake by straw. Furthermore, lesser weed density and diversity resulted from better controlled of weeds by this treatment attributed the crop to flourish the available nutrients and other essential elements. The result confirms with the findings of Verma *et al*. (2016a).

The data in respect to interaction of tillage system and weed management practices on N uptake by straw is presented in Table 4.16(c). Tillage system and weed management practices showed significant interaction effect on N uptake by straw in both the years. In the first year, significantly higher N uptake by straw was recorded with treatment combination T_3W_4 (pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) (46.77 kg ha^{-1}) which was at par with T_3W_3 (stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS under conventional tillage system) and T_3W_4 (pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) (46.73 and 46.73 kg ha^{-1}).

Table 4.16(a): Effect of tillage system and weed management practices on nitrogen content in grain and straw and their uptake

Treatments	N content in grain (%)			N uptake by grain (kg ha^{-1})			N content in straw (%)			N uptake by straw (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage syatem (T)												
T_1	1.604	1.619	1.612	60.349	61.108	60.729	0.758	0.758	0.758	42.565	42.511	42.538
T_2	1.616	1.622	1.619	63.829	64.204	64.016	0.755	0.759	0.757	43.371	43.556	43.464
T_3	1.632	1.637	1.634	66.595	67.067	66.831	0.756	0.761	0.758	44.185	44.462	44.324
SEm±	0.007	0.007	0.005	0.232	0.432	0.245	0.001	0.002	0.001	0.100	0.164	0.096
CD (P=0.05)	NS	NS	NS	0.912	1.698	0.801	NS	NS	NS	0.393	0.645	0.314
Weed management practices (W)												
W_1	1.616	1.627	1.621	62.807	63.411	63.109	0.756	0.759	0.757	43.619	43.818	43.718
W_2	1.607	1.624	1.616	55.189	56.145	55.667	0.754	0.757	0.756	40.889	40.992	40.940
W_3	1.612	1.629	1.621	67.766	68.629	68.198	0.757	0.759	0.758	45.327	45.277	45.302
W_4	1.620	1.624	1.622	72.590	73.019	72.805	0.757	0.759	0.758	46.769	46.926	46.848
W_5	1.630	1.630	1.630	74.681	74.918	74.799	0.761	0.768	0.764	46.292	46.828	46.560
W_6	1.620	1.622	1.621	48.513	48.636	48.574	0.753	0.753	0.753	37.347	37.219	37.283
SEm±	0.011	0.009	0.007	0.515	0.427	0.334	0.002	0.003	0.002	0.159	0.239	0.144
CD (P=0.05)	NS	NS	NS	1.486	1.234	0.946	NS	NS	NS	0.460	0.690	0.406

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.16(b): Interaction effect of tillage system and weed management practices on grain nitrogen uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	57.57	59.33	71.52	58.46	59.64	72.13	58.01	59.49	71.82
W_2	52.72	56.15	56.69	53.29	57.08	58.07	53.01	56.61	57.38
W_3	59.09	71.54	72.66	60.02	72.04	73.82	59.56	71.79	73.24
W_4	71.16	72.39	74.22	72.54	72.75	73.77	71.85	72.57	74.00
W_5	73.84	74.85	75.35	74.46	74.76	75.53	74.15	74.80	75.44
W_6	47.71	48.71	49.12	47.86	48.96	49.08	47.79	48.83	49.10
SEm± (T×W)	0.90			0.74			0.58		
CD (P=0.05) (W at same level of T)	2.6			2.14			1.64		
SEm± (W×T)	0.76			0.74			0.71		
CD (P=0.05) (T at same or different level of W)	2.20			2.15			2.01		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.16(c): Interaction effect of tillage system and weed management practices on straw nitrogen uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	41.79	42.35	46.71	41.52	42.31	47.62	41.66	42.33	47.16
W_2	40.37	41.48	40.82	40.28	41.69	41.01	40.32	41.59	40.91
W_3	42.57	46.68	46.73	42.40	46.56	46.87	42.49	46.62	46.80
W_4	46.81	46.73	46.77	47.01	46.70	47.07	46.91	46.72	46.92
W_5	46.53	45.80	46.54	46.92	46.72	46.84	46.73	46.26	46.69
W_6	37.32	37.18	37.55	36.93	37.36	37.37	37.12	37.27	37.46
SEm± (T×W)	0.28			0.41			0.25		
CD (P=0.05) (W at same level of T)	0.80			1.20			0.70		
SEm± (W×T)	0.25			0.38			0.30		
CD (P=0.05) (T at same or different level of W)	0.71			1.09			0.86		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

In the second year, T_3W_1 (stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) recorded the maximum straw N uptake (47.62 kg ha^{-1}) and was at par with T_3W_4 (pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system) (47.07 kg ha^{-1}).

4.2.3.5 Phosphorus uptake by grain (kg ha^{-1})

Significant variation regarding to phosphorus uptake by grain as influenced by tillage system and weed management practices is presented in Table 4.17(a).

Among the tillage system, conventional tillage system was found to be significantly superior during both the years recording the highest grain P uptake (12.104 and 12.112 kg ha^{-1}) and was statistically at par with minimum tillage system (11.538 kg ha^{-1}) only in the first year of the study. Significantly lower grain P uptake was registered with zero tillage system (10.711 and 10.947 kg ha^{-1}) during both the years of study. Higher P uptake by grain under conventional tillage system was the resultant of higher grain yield along with higher P content in grain that might have resulted from higher nutrient availability and better root growth for more nutrient absorption. This could be owing to that conventional tillage system provides desirable physical changes in soil environment like loosening of soil for better aeration and moisture movement, lower bulk density, less weed pressure thus ultimately resulted in better nutrient uptake by crop. Seth *et al.* (2020) also reported similar findings where conventional tillage system recorded higher grain P uptake.

Among weed management practices, weed free recorded significantly higher grain P uptake (13.848 and 13.942 kg ha^{-1}) and the lowest with weedy check (8.615 and 8.694 kg ha^{-1}) in both the years of experimentation. Further data analysis revealed that pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly maximum grain P uptake (13.287 and 13.267 kg ha^{-1}) as compared to other herbicidal treatments during both the years of investigation. This might be due to effective controlling of weeds resulted from the cumulative effect of both pre and post emergence herbicides creating less crop- weed competition that substantially led to higher phosphorus availability and more uptake by crop. Hence, resulted in higher grain yield. Similar findings of as reported by Kumari *et al*. (2016).

Interaction effect between tillage system and weed management practices was found to be significant in influencing the P uptake by grain and presented in Table 4.17(b). The treatment combination of conventional tillage with weed free (T_3W_5) recorded the highest P uptake by grain (14.09 and 14.43 kg ha^{-1}) during both the years of observation. While the weedy check under zero tillage system (T_1W_6) recorded significantly lower grain P uptake (8.46 and 8.67 kg ha^{-1}) in both the years.

4.2.3.6 Phosphorus uptake by straw (kg ha^{-1})

Phosphorus uptake by straw varied significantly due to the influence of tillage system and weed management practices and presented in Table 4.17(a).

Tillage system showed significant effect on straw P uptake only in the first year of the study. The significantly higher straw P uptake was recorded with conventional tillage system (9.431 kg ha^{-1}) and was statistically at par with minimum tillage system (9.038 kg ha^{-1}) in 2021. Zero tillage system recorded significantly lower straw P uptake during the first year of observation. The probable reason behind higher P uptake by straw might be due to higher crop biomass accumulation, more straw yield as well as more P content in straw. Seth *et. al* (2020) also reported similar findings where higher P uptake by straw was recorded under conventional tillage.

Weed free recorded significantly higher P uptake by straw (10.070 and 10.165 kg ha^{-1}) as compared to other weed management practices and was statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly maximum straw P uptake (9.821 and 10.031 kg ha^{-1}) during both the years of experimentation. Furthermore, among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS was found to be significantly superior in terms of P uptake by straw in both the years. This might be due to better nutrient availability to the crop due to effective weed suppression under this treatment indicating higher efficacy of the herbicide application. Verma *et al*. (2016a) also reported similar results.

4.2.3.7 Potassium uptake by grain (kg ha^{-1})

The data pertaining to potassium uptake by grain as influenced by tillage system and weed management practices is presented in Table 4.18(a).

It is evident from the data that different tillage system resulted in significant variation in grain K uptake during both the years of experimentation. Conventional tillage system recorded significantly maximum grain K uptake (14.546 and 14.569 kg ha^{-1}) and found to be significantly superior to zero tillage system during both the years of observation. Potassium uptake by grain is the function of grain yield and grain K content. Better crop growth and less weed pressure under conventional tillage system resulted in better nutrient uptake leading higher grain yield. Seth *et al*. (2020) reported similar findings.

Among weed management practices, weed free recorded significantly higher grain K uptake (16.190 and 16.547 kg ha^{-1}) in both the years of observation. Furthermore, it was observed that pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly maximum grain K uptake (15.831 and15.932 kg ha^{-1}) in comparison to other herbicidal treatment. The probable reason might be due to

Table 4.17(a): Effect of tillage system and weed management practices on phosphorus content in grain and straw and their uptake

Treatments	P content in grain (%)			P uptake by grain (kg ha^{-1})			P content in straw (%)			P uptake by straw (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	0.284	0.291	0.288	10.711	10.947	10.829	0.157	0.156	0.156	8.798	8.725	8.761
T_2	0.291	0.294	0.293	11.538	11.689	11.613	0.157	0.160	0.159	9.038	9.195	9.116
T_3	0.296	0.295	0.295	12.104	12.112	12.108	0.161	0.163	0.162	9.431	9.558	9.495
SEm±	0.003	0.002	0.002	0.152	0.078	0.085	0.002	0.004	0.002	0.113	0.205	0.117
CD (P=0.05)	NS	NS	NS	0.596	0.307	0.278	NS	NS	NS	0.445	NS	0.382
Weed management practices (W)												
W_1	0.286	0.291	0.288	11.112	11.321	11.217	0.157	0.158	0.157	9.050	9.110	9.080
W_2	0.281	0.289	0.285	9.653	9.981	9.817	0.156	0.157	0.156	8.431	8.488	8.459
W_3	0.290	0.291	0.291	12.231	12.270	12.251	0.158	0.158	0.158	9.453	9.421	9.437
W_4	0.296	0.296	0.296	13.247	13.287	13.267	0.159	0.162	0.161	9.821	10.031	9.926
W_5	0.302	0.303	0.303	13.848	13.942	13.895	0.166	0.167	0.166	10.070	10.165	10.118
W_6	0.288	0.290	0.289	8.615	8.694	8.655	0.156	0.157	0.156	7.710	7.739	7.725
SEm±	0.005	0.003	0.003	0.197	0.136	0.120	0.003	0.003	0.002	0.150	0.177	0.116
CD (P=0.05)	NS	NS	NS	0.568	0.393	0.338	NS	NS	NS	0.432	0.513	0.328

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.17(b): Interaction effect of tillage system and weed management practices on grain phosphorus uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	10.34	10.16	12.85	10.73	10.80	12.44	10.53	10.48	12.64
W_2	9.35	9.81	9.80	9.73	9.94	10.27	9.54	9.87	10.04
W_3	9.99	13.18	13.52	10.64	12.92	13.25	10.32	13.05	13.38
W_4	12.58	13.47	13.70	12.61	13.65	13.61	12.59	13.56	13.65
W_5	13.55	13.90	14.09	13.30	14.09	14.43	13.43	14.00	14.26
W_6	8.46	8.72	8.67	8.67	8.73	8.69	8.56	8.72	8.68
SEm± (T×W)	0.34			0.24			0.21		
CD (P=0.05) (W at same level of T)	0.98			0.68			0.59		
SEm± (W×T)	0.32			0.21			0.25		
CD (P=0.05) (T at same or different level of W)	0.91			0.60			0.72		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.17(c): Interaction effect of tillage system and weed management practices on straw phosphorus uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	8.69	8.58	9.88	8.53	8.91	9.90	8.61	8.74	9.89
W_2	8.32	8.41	8.56	7.98	8.78	8.71	8.15	8.59	8.64
W_3	8.81	9.67	9.88	8.60	9.84	9.82	8.70	9.76	9.85
W_4	9.49	9.68	10.30	9.69	9.88	10.53	9.59	9.78	10.41
W_5	9.91	10.13	10.16	9.75	10.16	10.59	9.83	10.15	10.38
W_6	7.56	7.77	7.80	7.81	7.61	7.80	7.69	7.69	7.80
SEm± (T×W)	0.26			0.31			0.20		
CD (P=0.05) (W at same level of T)	NS			NS			NS		
SEm± (W×T)	0.24			0.32			0.26		
CD (P=0.05) (T at same or different level of W)	NS			NS			NS		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre-emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre-emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

lower potassium depletion by weeds owing to better weed control that might have resulted in more potassium available to crop and thus higher grain yield along with higher K uptake. The results are in close conformity with findings of Mandira (2016). The minimum K uptake by grain was recorded in weedy check (W_6) during both the years of observation which might be attributed to higher weed competition resulting in more K depletion by weeds.

The interaction effect of tillage system and weed management practices on K uptake by grain was found to be significant during both the years of study and presented in Table 4.18(b). Conventional tillage with weed free (T_3W_5) recorded the highest K uptake by grain (16.69 and 16.73 kg ha^{-1}) and was statistically at par with minimum tillage in weed free treatment combination (T_2W_5) (16.50 and 16.70 kg ha^{-1}) during both the years of observation. While the lowest grain K uptake was recorded with zero tillage in weedy check treatment (T_1W_6) during both the years.

4.2.3.8 Potassium uptake by straw (kg ha^{-1})

The data regarding the K uptake by straw as influenced by tillage system and weed management practices is presented in Table 4.18(a).

Among the tillage system, conventional tillage system recorded significantly maximum K uptake (86.324 and 86.883 kg ha^{-1}) by straw while zero tillage system recorded significantly lowest K uptake by straw (81.942 and 81.674 kg ha^{-1}) during both years of the study. The probable reason might be primarily due to good crop stand that suppressed weed growth thereby resulting in lower weed density and weed dry matter accumulation and ultimately more potassium available to crop. The results are in conformity/ agreement with findings of Seth *et al*. (2020).

Table 4.18(a): Effect of tillage system and weed management practices on potassium content in grain and straw and their uptake

Treatments	K content in grain (%)			K uptake by grain (kg ha^{-1})			K content in straw (%)			K uptake by straw (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	0.346	0.348	0.347	12.990	13.156	13.073	1.460	1.457	1.458	81.942	81.674	81.808
T_2	0.350	0.349	0.349	13.841	13.847	13.844	1.465	1.461	1.463	84.133	83.846	83.990
T_3	0.356	0.356	0.356	14.546	14.569	14.557	1.476	1.487	1.482	86.324	86.883	86.604
SEm±	0.002	0.003	0.002	0.093	0.142	0.085	0.003	0.009	0.005	0.141	0.536	0.277
CD (P=0.05)	NS	NS	NS	0.365	0.558	0.277	NS	NS	NS	0.552	2.106	0.904
Weed management practices (W)												
W_1	0.350	0.348	0.349	13.613	13.553	13.583	1.466	1.459	1.462	84.598	84.197	84.397
W_2	0.348	0.344	0.346	11.945	11.903	11.924	1.464	1.466	1.465	79.379	79.436	79.407
W_3	0.351	0.351	0.351	14.760	14.781	14.771	1.468	1.466	1.467	87.938	87.471	87.704
W_4	0.353	0.354	0.354	15.831	15.932	15.881	1.472	1.481	1.477	90.997	91.572	91.284
W_5	0.353	0.360	0.357	16.190	16.547	16.368	1.469	1.463	1.466	89.342	89.252	89.297
W_6	0.348	0.348	0.348	10.414	10.429	10.421	1.463	1.475	1.469	72.544	72.881	72.713
SEm±	0.003	0.004	0.002	0.111	0.170	0.101	0.004	0.010	0.005	0.311	0.576	0.327
CD (P=0.05)	NS	NS	NS	0.321	0.490	0.287	NS	NS	NS	0.899	1.662	0.926

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

Table 4.18(b): Interaction effect of tillage system and weed management practices on grain potassium uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	12.38	12.84	15.62	12.66	12.64	15.36	12.52	12.74	15.49
W_2	11.44	12.02	12.37	11.39	11.81	12.51	11.42	11.92	12.44
W_3	12.83	15.55	15.90	13.11	15.30	15.93	12.97	15.43	15.91
W_4	15.68	15.70	16.11	15.43	16.19	16.18	15.55	15.95	16.14
W_5	15.38	16.50	16.69	16.21	16.70	16.73	15.79	16.60	16.71
W_6	10.23	10.42	10.59	10.14	10.43	10.71	10.19	10.43	10.65
SEm± (T×W)	0.19			0.29			0.18		
CD (P=0.05) (W at same level of T)	0.56			0.849			0.50		
SEm± (W×T)	0.18			0.28			0.22		
CD (P=0.05) (T at same or different level of W)	0.53			0.81			0.62		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre-emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre-emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.18(c): Interaction effect of tillage system and weed management practices on straw potassium uptake (kg ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	81.00	82.47	90.32	81.24	81.06	90.29	81.12	81.76	90.31
W_2	77.37	80.04	80.72	77.11	80.09	81.12	77.24	80.06	80.92
W_3	82.14	89.87	91.80	81.13	89.83	91.45	81.64	89.85	91.63
W_4	90.52	90.37	92.10	90.92	90.73	93.06	90.72	90.55	92.58
W_5	88.61	89.18	90.24	87.75	88.98	91.03	88.18	89.08	90.64
W_6	72.01	72.87	72.75	71.89	72.39	74.35	71.95	72.63	73.55
SEm± (T×W)	0.54			1.00			0.57		
CD (P=0.05) (W at same level of T)	1.56			2.88			1.60		
SEm± (W×T)	0.46			0.97			0.71		
CD (P=0.05) (T at same or different level of W)	1.33			2.82			2.01		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre-emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre-emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Weed management practices significantly influenced K uptake by straw in both the years of study. Pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly higher value (90.997 and 91.572 kg ha^{-1}) followed by weed free treatment. Weedy check recorded significantly lower K uptake by straw in both the years of observation. This might be due to higher weed control efficiency of the herbicides leading to less crop- weed competition thus efficient nutrients uptake by crop resulting in more straw yield. The results are in close agreement with Brar and Bhullar (2013), Mandira (2016) and Verma *et al*. (2017). Significant interaction effect of tillage system and weed management practices on K uptake by straw was observed during both the years of study. The highest K uptake by straw was recorded with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system (92.10 and 93.06 kg ha^{-1}) and was statistically at par with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS under conventional tillage system (91.80 and 91.45 kg ha^{-1}) during both the years. Whereas, the lowest straw K uptake (72.01and 71.89 kg ha^{-1}) was recorded with zero tillage in weedy check treatment (T_1W_6) during both the years.

4.3 Soil status after harvest of rice

4.3.1 Soil pH

The data related to soil pH as influenced by tillage system and weed management practices presented in Table 4.19 was found to be non-significant in both the years of experimentation.

4.3.2 Soil organic carbon (%)

The data presented in Table 4.19 regarding to soil organic carbon clearly showed that it was significantly influenced by tillage system as well as weed management practices in both the years.

With respect to tillage system, significantly higher soil organic carbon was recorded under zero tillage system (1.497 and 1.500%) while the lowest was recorded under conventional tillage system (1.431 and 1.437%) during both the years of experimentation. The plausible reason might be due to less soil disturbance and restricted decomposition or oxidation of crop residues, decreased mineralization and degradation of soil nutrients which then adds up to increase carbon input. Since intensity of tillage system plays a significant role in determining SOM by affecting soil disturbance, mechanical compaction and surface residue retention thus have negative effect on soil organic matter. Mishra *et al*. (2010) and Liu *et al.* (2021) also reported the similar findings where soil organic matter was found be high under no-tillage system as compared to conventional tillage system. The result is also in close proximity with the findings of Pratap *et al.* (2021) where zero till DSR recorded the maximum soil organic carbon.

In case of weed management practices, weed free recorded significantly highest organic carbon content in soil (1.505 and 1.523%). While among the herbicidal treatments, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly maximum soil organic carbon (1.493 and 1.499%) during both the years of study. This might be due to reduced crop-weed competition during the critical stage of crop creating a favourable condition for better growth and development, better root growth and biomass.

Table 4.19: Effect of tillage system and weed management practices on soil pH, organic carbon

Treatments	pH			Soil organic carbon (%)		
	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)						
T_1	4.77	4.88	4.83	1.497	1.500	1.498
T_2	4.76	4.76	4.76	1.446	1.457	1.452
T_3	4.76	4.80	4.78	1.431	1.437	1.434
SEm±	0.038	0.050	0.031	0.003	0.003	0.002
CD (P=0.05)	NS	NS	NS	0.012	0.013	0.007
Weed management practices (W)						
W_1	4.82	4.78	4.80	1.452	1.451	1.452
W_2	4.71	4.87	4.79	1.416	1.431	1.424
W_3	4.73	4.76	4.75	1.470	1.471	1.471
W_4	4.80	4.81	4.81	1.493	1.499	1.496
W_5	4.75	4.80	4.77	1.505	1.523	1.514
W_6	4.78	4.85	4.81	1.410	1.414	1.412
SEm±	0.043	0.046	0.031	0.008	0.009	0.006
CD (P=0.05)	NS	NS	NS	0.024	0.025	0.017

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre-emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre-emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.20: Effect of tillage system and weed management practices on soil bulk density (g cc^{-1}) at different soil depths

Treatments	0-5 cm			5-15 cm			15-30 cm		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	1.024	1.018	1.021	1.2719	1.2688	1.2703	1.337	1.336	1.336
T_2	1.017	1.015	1.016	1.2228	1.2116	1.2172	1.287	1.285	1.286
T_3	0.999	0.969	0.984	1.1503	1.1454	1.1479	1.243	1.239	1.241
SEm±	0.009	0.005	0.005	0.0031	0.0043	0.0026	0.004	0.001	0.002
CD (P=0.05)	NS	0.021	0.017	0.0122	0.0168	0.0086	0.015	0.005	0.007
Weed management practices (W)									
W_1	1.009	1.001	1.005	1.2132	1.2039	1.2086	1.289	1.287	1.288
W_2	1.010	1.002	1.006	1.2110	1.1981	1.2045	1.291	1.284	1.287
W_3	1.015	1.003	1.009	1.2138	1.2139	1.2138	1.287	1.282	1.285
W_4	1.032	1.001	1.017	1.2137	1.2132	1.2135	1.294	1.290	1.292
W_5	1.018	1.011	1.014	1.2253	1.2142	1.2197	1.293	1.295	1.294
W_6	0.997	0.986	0.991	1.2129	1.2084	1.2106	1.281	1.282	1.281
SEm±	0.011	0.007	0.007	0.0036	0.0053	0.0032	0.004	0.004	0.003
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free
W_6: Weedy check

4.3.3 Soil bulk density (g cc^{-1})

The data pertaining to soil bulk density at different depth of soil as influenced by tillage system and weed management practices is presented in Table 4.20 for both the years. Generally, soil bulk density increases with increase in soil depth.

Significant variation in soil bulk density was observed due to different tillage system in both the years of study at different soil depth. At 0-5 cm soil depth, tillage system had significant effect only in the second year of the study. Zero tillage system recording the higher soil bulk density (1.018 g cc^{-1}). At 5-15 cm soil depth, the significantly maximum soil bulk density was recorded under zero tillage system (1.2719 and 1.2688 g cc^{-1}) while conventional tillage system recorded significantly lower soil bulk density during both the years of study. Further, at 15-30 cm soil depth, similar trend was observed with zero tillage recorded significantly maximum bulk density (1.337 and 1.336 g cc^{-1}). The high bulk density under zero tillage might be due to reduce or no soil disturbance of tillage operation, less soil pulverization, more soil compaction, reduce pore space and less soil aggregation. Similar findings were reported by Kahlon (2014) in rice-wheat cropping system. A critical analysis of the data showed that weed management practices had no significant effect on soil bulk density during both the years of the study.

4.3.4 Soil available nitrogen (kg ha^{-1})

The data related to soil available nitrogen as influenced by tillage system and weed management practices is presented in Table 4.21.

Different tillage system showed significant variation on soil available nitrogen in both the years of study with conventional tillage system recording the maximum available soil N (243.85 and 245.13 kg ha^{-1}) in both the

Table 4.21: Effect of tillage system and weed management practices on available soil nutrients

Treatments	Available soil nitrogen (kg ha^{-1})			Available soil phosphorus (kg ha^{-1})			Available soil potassium (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	234.39	235.45	234.92	35.27	35.55	35.41	142.71	145.63	144.17
T_2	236.40	238.71	237.56	35.95	36.52	36.23	146.26	146.83	146.55
T_3	243.85	245.13	244.49	36.61	36.93	36.77	149.74	149.88	149.81
SEm±	0.96	0.73	0.60	0.23	0.20	0.15	0.86	0.62	0.53
CD (P=0.05)	3.77	2.85	1.96	0.91	0.77	0.49	3.39	2.44	1.74
Weed management practices (W)									
W_1	238.36	240.53	239.44	34.85	35.40	35.12	146.25	148.19	147.22
W_2	231.19	231.58	231.38	34.39	34.79	34.59	143.49	145.99	144.74
W_3	235.46	236.54	236.00	35.61	35.59	35.60	147.56	148.86	148.21
W_4	242.11	246.30	244.21	37.00	37.54	37.27	146.86	147.45	147.16
W_5	253.96	255.00	254.48	38.73	39.33	39.03	149.23	149.35	149.29
W_6	228.21	228.63	228.42	35.06	35.36	35.21	144.01	144.84	144.43
SEm±	2.45	1.55	1.45	0.26	0.34	0.21	1.47	1.64	1.10
CD (P=0.05)	7.08	4.48	4.10	0.76	0.97	0.61	NS	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed+Pyrazosulfuron-ethyl @ 0.02 kgha^{-1} (pre emergence) *fb* Cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1}*fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free (4 hand weeding at 15 days interval)

W_6: Weedy check

years of experimentation. This might be attributed to that conventional tillage promotes better soil aeration and microbial activities that increases the rate of decomposition and mineralization of organic matter resulting in release of more available soil nitrogen for more uptake by crop. Whereas, zero tillage recorded the lowest available soil N (234.39 and 235.45 kg ha^{-1}). The highest available nitrogen under conventional tillage system was also reported by Chaudhary (2022).

Significant variation in soil available nitrogen was observed due to different weed management practices during both the years of observation. Weed free recorded significantly higher available soil N (253.96 and 255.00 kg ha^{-1}) in both the years of study. While, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded significantly maximum soil available nitrogen (242.11 and 246.30 kg ha^{-1}) among the herbicidal treatment and was statistically at par with stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS only during the first year.

The maximum available soil N in W_4 might be due to broad spectrum controlling of weeds thereby reducing nutrient depletion by weeds and more available for plant uptake produced in this treatment.

4.3.5 Soil available phosphorus (kg ha^{-1})

The data regarding the soil available phosphorus as influenced by tillage system and weed management practices is presented in Table 4.21.

Available soil phosphorus showed significant variation due to different tillage system in both the years. Maximum soil available phosphorus was recorded under conventional tillage system (36.61 and 36.93 kg ha^{-1}) which was statistically at par with minimum tillage (36.52 kg ha^{-1}) only during the second year of experimentation. Whereas, zero tillage recorded the lowest available soil

P (35.27 and 35.55 kg ha^{-1}). The possible reason behind this might be due to accelerated mineralization of organic phosphorus compound where conventional tillage system disrupts the soil structure, exposed the organic matter to microbial activities and increase soil aeration that adds up more rapid decomposition of organic matter and thus release more available form of phosphorus.

A critical analysis of the data revealed that there was significant variation in available soil phosphorus in both the years due to different weed management practices. It was observed that weed free recorded significantly maximum available soil phosphorus (38.73 and 39.33 kg ha^{-1}) among the weed management practices in both the years. In case of herbicidal treatment, the significantly maximum soil available P (37.00 and 37.54 kg ha^{-1}) was recorded with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS. Weedy check recorded the lowest available soil phosphorus in both the years.

4.3.6 Soil available potassium (kg ha^{-1})

The perusal of data on soil available potassium as influenced by tillage system and weed management practices is presented in Table 4.21.

It is evident from the data that different tillage system resulted in significant variation in soil available potassium during both the years of experimentation. Conventional tillage system recorded significantly maximum soil available potassium (149.74 and 149.88 kg ha^{-1}) and found to be significantly superior to zero tillage system during both the years of observation. This might be ascribed to conventional tillage system creates a favourable soil condition for root growth and exploration, better soil aeration and accelerated rate of mineralization of organic matter, improves soil CEC resulting in more retention and available for plant uptake.

However, none of the weed management practices showed any significant variation on available soil potassium during both the years of experimentation.

4.4 Energy analysis

The data on total input energy, total output energy and energy use efficiency were worked out for different tillage system and weed management practices and presented in Table 4.22(a), 4.22(b) and 4.22(c).

4.4.1 Total input energy (MJ ha^{-1})

Among the tillage system, conventional tillage system recorded maximum total input energy (18410.13 and 18410.13 MJ ha^{-1}) in both the years as compared to other tillage system. This might be due to high energy consumption incurred during land preparation and sowing under conventional tillage system as it involves both primary and secondary tillage operation that require double fuel energy for operating the machinery. Mishra and Singh (2011) reported similar results where total operational energy input was obtained higher under conventional tillage due to consumption of higher energy during field preparation. While the minimum input energy (18339.90 and 18339.90 MJ ha^{-1}) was recorded under zero tillage in both the years which might be due to absence of multiple tillage operations like tilling, harrowing and planking. The findings is in close agreement with Kumar *et al*. (2017) in wheat.

With respect to weed management practices, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded highest total input energy (18560.54 and 18560.54 MJ ha^{-1}) followed by stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS (18487.88 and 18487.88 MJ ha^{-1}) in both the years. The probable reason behind this might be attributed to higher application dose required according to their mode of action, effectiveness and persistence for broad spectrum control of weeds. Pooja *et al*. (2021) also outlined that sequential application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 0.02 kg ha^{-1} recorded the highest input energy. The lowest energy input was recorded under weedy check (18255.20 and 18255.20 MJ ha^{-1}) in both the years of the study as no application of herbicide neither hand weeding was done under this treatment.

4.4.2 Total output energy (MJ ha^{-1})

Conventional tillage system recorded maximum total output energy (139493.22 and 139709.57 MJ ha^{-1}) while the lowest (131276.09 and 131433.63 MJ ha^{-1}) was recorded under zero tillage system in both the years. High output energy under this system might be due to high grain and straw yield. While the probable reason for lowest output energy under zero tillage might be due to lower grain and straw yield resulting from the negative effect of heavy weed infestation.

Among the weed management practices, weed free recorded the highest total output energy (150874.74 and 151324.15 MJ ha^{-1}) followed by pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS (150615.80 and 150481.28 MJ ha^{-1}) during both the years of study. This might be due to better control of weeds with pre and post emergence herbicide application resulted in proper growth of crop leading to higher yield with efficient nutrient uptake by crop. Output energy is directly dependent on crop biomass production (grain and straw yield) under the respective treatment. Sreedevi *et al*. (2015) reported similar results where herbicide pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 35 g ha^{-1} recorded the highest energy output and highest grain yield.

Table 4.22(a): Effect of tillage system and weed management practices on energy studies (input, output energy and energy use efficiency)

Treatments	Total input energy (MJ ha^{-1})			Total output energy (MJ ha^{-1})			Energy use efficiency (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	18339.90	18339.90	18339.90	131276.09	131433.63	131354.86	7.15	7.16	7.16
T_2	18369.30	18369.30	18369.30	136053.23	136155.32	136104.28	7.40	7.41	7.41
T_3	18410.13	18410.13	18410.13	139493.22	139709.57	139601.39	7.57	7.59	7.58
SEm±				293.23	134.79	161.36	0.016	0.007	0.009
CD (p=0.05)				1151.35	529.24	526.23	0.063	0.029	0.029
Weed management practices (W)									
W_1	18321.23	18321.23	18321.23	135310.59	135476.97	135393.78	7.38	7.39	7.39
W_2	18260.61	18260.61	18260.61	123426.60	123749.63	123588.11	6.76	6.78	6.77
W_3	18487.88	18487.88	18487.88	143289.78	143176.98	143233.38	7.75	7.74	7.75
W_4	18560.54	18560.54	18560.54	150346.76	150615.80	150481.28	8.10	8.11	8.11
W_5	18353.20	18353.20	18353.20	150874.74	151324.15	151099.45	8.22	8.25	8.23
W_6	18255.20	18255.20	18255.20	110396.59	110253.53	110325.06	6.05	6.04	6.04
SEm±				290.95	283.78	203.21	0.016	0.015	0.011
CD (p=0.05)				840.31	819.62	574.86	0.046	0.045	0.031

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free

W_6: Weedy check

Table 4.22(b): Interaction effect of tillage system and weed management practices on total energy output (MJ ha^{-1})

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	127865.53	128209.89	128037.71	129551.78	129393.44	129472.61	148514.44	148827.58	148671.01
W_2	119858.89	120259.44	120059.17	125320.92	125473.33	125397.12	125100.00	125516.11	125308.06
W_3	130415.12	130354.44	130384.78	149569.33	149595.11	149582.22	149884.89	149581.40	149733.14
W_4	149686.07	149879.11	149782.59	150397.56	150548.59	150473.07	150956.67	151419.70	151188.18
W_5	150479.37	151105.67	150792.52	150870.34	151255.82	151063.08	151274.52	151610.96	151442.74
W_6	109351.56	108793.25	109072.40	110609.44	110665.66	110637.55	111228.78	111301.69	111265.23
SEm± (T×W)	503.93			491.53			351.98		
CD (P=0.05) (W at same level of T)	1455.46			1419.63			995.68		
SEm± (W×T)	505.25			423.36			437.29		
CD (P=0.05) (T at same or different level of W)	1459.28			1222.75			1237.02		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.22(c): Interaction effect of tillage system and weed management practices on energy use efficiency (%)

Treatments	Tillage system								
	2021			2022			Pooled		
Weed management practices	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
W_1	6.99	7.01	7.00	7.07	7.07	7.07	8.09	8.11	8.10
W_2	6.58	6.60	6.59	6.86	6.87	6.87	6.84	6.86	6.85
W_3	7.07	7.06	7.06	8.09	8.09	8.09	8.09	8.08	8.08
W_4	8.08	8.09	8.08	8.10	8.11	8.11	8.12	8.14	8.13
W_5	8.21	8.25	8.23	8.22	8.24	8.23	8.23	8.24	8.24
W_6	6.00	5.97	5.99	6.06	6.06	6.06	6.08	6.09	6.08
SEm± (T×W)	0.027			0.027			0.019		
CD (P=0.05) (W at same level of T)	0.079			0.077			0.054		
SEm± (W×T)	0.028			0.023			0.024		
CD (P=0.05) (T at same or different level of W)	0.080			0.067			0.067		

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_2:** Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence), **W_3:** Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS, **W_4:** Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

4.4.3 Energy use efficiency (%)

In respect to tillage system, the maximum energy use efficiency (EUE) (7.57 and 7.59%) was recorded under conventional tillage system followed by minimum tillage (7.40 and 7.41%) in both the years. The lowest energy use efficiency was observed under zero tillage in both the years of observation. The high EUE might be due to high energy output incurred under conventional tillage which again might be due to higher yield.

Weed free recorded the highest energy use efficiency (8.22 and 8.25%) and weedy check recorded the lowest (6.05 and 6.04%) in both the years. The probable reason for high EUE under weed free treatment might be due to high yield resulting in high output energy. Among the herbicidal treatment the maximum energy use efficiency (8.10 and 8.11%) was recorded with pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS followed by stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS during both the years of study. This might be due to higher output energy with higher yield with the sequential application of herbicide through minimizing weed competitiveness for nutrients, water, solar energy and space and hence increasing crop productivity. The result is in agreement with findings reported by Pooja *et al*. (2021)

4.5 Economics

Data regarding the cost of cultivation, gross return, net return, and benefit-cost ratio for various tillage system and weed management practices are presented in Table 4.23(a) and 4.23(b).

4.5.1 Cost of cultivation (₹ ha^{-1})

A critical of the data revealed that conventional tillage system recorded the highest cost of cultivation (₹ 51914.85 ha^{-1} and ₹ 51914.85 ha^{-1}) among the tillage system in both the years. The highest cost of cultivation under conventional tillage system might be due to more labour cost during field preparation as compared to other tillage system where conventional tillage involves both primary and secondary tillage operations. Zero tillage recorded the lowest cost of cultivation (₹ 37914.85 ha^{-1} and ₹ 37914.85 ha^{-1}). This might be due to considerably reduced establishment cost under zero tillage system. Similar findings were reported by Mukhrejee *et al*. (2019) and Sapre *et al*. (2022) where conventional tillage recorded higher cost of cultivation as compared to zero tillage system.

Among the weed management practices, weed free recorded the highest cost of cultivation (₹ 59506.85 ha^{-1} and ₹ 59506.85 ha^{-1}) while the lowest (₹ 39506.85 ha^{-1} and ₹ 39506.85 ha^{-1}) in weedy check during both the years of investigation. However, in comparison to herbicidal treatments, stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS recorded the highest cost of cultivation (₹ 43367.85 ha^{-1} and ₹ 43367.85 ha^{-1}) followed by stale seedbed *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS and pre emergence application of pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} during both the years of study.

The higher cost of cultivation in weed free plot was due to more labour incurred and higher labour cost for manual weeding. While in case of herbicidal treatment, stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS recorded higher cost of cultivation due to more labour requirement for establishment of state seedbed and application of herbicides.

4.5.2 Gross returns (₹ ha^{-1})

Among the tillage system, conventional tillage system recorded maximum gross returns (₹ 87422.75 ha^{-1} and ₹ 87728.31 ha^{-1}) in both the years as compared to other tillage system. This might be due to higher grain and straw yield under this tillage. While the lowest gross returns (₹ 80824.16 ha^{-1} and ₹ 81065.65 ha^{-1}) was recorded under zero tillage system in both the years. The higher value of gross returns associated under conventional tillage system might be attributed with higher grain and straw yield resulting from less crop-weed competition thereby allowing crops for better nutrient uptake. The result is in close conformity with findings of Abbas *et al*. (2019).

With respect to weed management practices, weed free recorded the highest gross returns (₹ 97715.53 ha^{-1} and ₹ 98022.33 ha^{-1}) followed by pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS (₹ 95799.44 ha^{-1} and ₹ 96081.84 ha^{-1}) during both the years of study. The reason behind this might be ascribed to effective control of weeds for efficient utilization of nutrients, sunlight, water and space resulting in higher yield and thus gross return. While the lowest gross returns (₹ 64847.85 ha^{-1} and ₹ 64902.00 ha^{-1}) was recorded with weedy check. This agrees with findings of Saravanane *et al*. (2021).

4.5.3 Net returns (₹ ha^{-1})

Among the tillage system, zero tillage system recorded maximum net returns (₹ 42909.31 ha^{-1} and ₹ 43150.81 ha^{-1}) in both the years as compared to other tillage system. This might be attributed to lower cost of cultivation where zero tillage require less labour, machinery and fuel that lead ultimately to significantly higher net return. While conventional tillage system recorded the lowest net returns (₹ 35507.91 ha^{-1} and ₹ 35813.47 ha^{-1}) in both the years of experimentation which might be due to higher input cost which require various tillage operation. The result is in close agreement with the findings of and Abbas *et al*. (2019) and Sapre *et al*. (2022).

As per different weed management practices, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest net returns (₹ 53896.59 ha^{-1} and ₹ 54179.00 ha^{-1}) followed by stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS (₹ 46629.85 ha^{-1} and ₹ 46821.49 ha^{-1}). This might be ascribed to efficient control of weeds during the critical stage of crop that ultimately create a favourable condition for the crop to flourish the available growth resources thus resulting in more grain and straw yield. The lowest net returns (₹ 25341.01 ha^{-1} and ₹ 25395.16 ha^{-1}) was recorded under weedy check during both the years of investigation which might be due to high crop-weed competition for nutrient, water, space and solar energy thus leading to poor crop growth, low grain and straw yield. The result is in lined with the findings reported by Mandira (2016).

4.5.4 B:C ratio

A perusal of the data in Table 4.23 showed that among the different tillage system, zero tillage system resulted in highest B:C ratio (1.13 and 1.14) during both the years of observation. While the lowest B:C ratio (0.68 and 0.69) was registered under conventional tillage system. This might be due to low cost of cultivation under zero tillage system as compared to other tillage system. Mishra and Singh (2008), Abbas *et al*. (2019) and Chaudhary (2022) also reported that the maximum benefit: cost ratio was recorded with zero tillage system.

Among the different weed management practices, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest B:C ratio (1.29 and 1.29) which was followed by stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS (1.08 and 1.08) in both the years of experimentation. The higher benefit: cost ratio under this treatment might be due to high net return resulting from the high weed control efficiency, lower weed density with broad spectrum control of weed with the sequential application of pre and post emergence herbicide thereby resulting in higher grain and straw yield. Weedy check recorded the lowest B:C ratio (0.64 and 0.64) in both the years. Similar results were also reported by Dhakal *et al*. (2019) and Bhargaw and Roy (2020).

4.6 Residual effect of tillage system and weed management practices sequential crop sunflower

4.6.1 Weed observations

The data pertaining to total weed density and dry weight at 20 DAS as influenced by tillage system and weed management practices is presented in Table 4.24 for both the years.

4.6.1.1 Total weed density at 20 DAS (no. m^{-2})

Different tillage system showed significant variation on total weed density of succeeding crop during both the years of experimentation. Among the tillage system, the lowest total weed density (24.50 and 23.50) was recorded under conventional tillage system while the maximum (29.28 and 28.72) was under zero tillage system in the both the years. Variation on total weed density due to different tillage system might be due to initial weed suppression by soil disturbance leading to weed seed burial into deeper. soil layer and inhibiting their germination and emergence and subsequently lowering weed density during the initial stage of succeeding crop Weed management practices had significant effect on total weed density only during the second year. Weed free recorded the lowest total weed density (13.33 and 12.56) and weedy check recorded the highest weed density (34.78 and 33.67 6.04). Variation on total weed density due to different management practices might be due to maintenance of weed free condition during the main crop period might have resulted in lesser weed density in succeeding crop.

Table 4.23(a): Effect of tillage system and weed management practices on cost of cultivation, gross returns, net returns and B:C ratio

Treatments	Cost of cultivation (₹ kg^{-1})			Gross returns (₹ kg^{-1})			Net returns (₹ kg^{-1})			B:C		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	37914.85	37914.85	37782.35	80824.16	81065.65	80944.91	42909.31	43150.81	43030.06	1.13	1.14	1.13
T_2	43914.85	43914.85	43964.85	84719.57	84909.66	84814.61	40804.72	40994.81	40899.77	0.93	0.93	0.93
T_3	51914.85	51914.85	51782.35	87422.75	87728.31	87575.53	35507.91	35813.47	35660.69	0.68	0.69	0.69
Weed management practices (W)												
W_1	42821.85	42821.85	42424.35	83464.15	83684.67	83574.41	40642.30	40862.83	40752.56	0.95	0.95	0.95
W_2	40382.85	40382.85	40747.85	74108.29	74527.07	74317.68	32730.44	34144.23	33934.83	0.84	0.85	0.84
W_3	43367.85	43367.85	42970.35	89997.70	90189.34	90093.52	46629.85	46821.49	46725.67	1.08	1.08	1.08
W_4	41902.85	41902.85	41902.85	95799.44	96081.84	95940.64	53896.59	54179.00	54037.79	1.29	1.29	1.29
W_5	59506.85	59506.85	59506.85	97715.53	98022.33	97868.93	38208.69	38515.48	38362.08	0.64	0.65	0.64
W_6	39506.85	39506.85	39506.85	64847.85	64902.00	64874.93	25341.01	25395.16	25368.08	0.64	0.64	0.64

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Table 4.23(b): Interaction effect of tillage system and weed management practices on cost of cultivation, gross returns, net returns and B:C ratio

Treatments	Cost of cultivation (₹ kg^{-1})			Gross returns (₹ kg^{-1})			Net returns (₹ kg^{-1})			B:C		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1W_1	36155.18	36155.18	36155.18	77653.33	77883.56	77768.44	41498.15	41728.38	41613.26	1.15	1.15	1.15
T_1W_2	33716.18	33716.18	33716.18	71333.89	71666.67	71500.28	37617.71	37950.49	37784.10	1.12	1.13	1.12
T_1W_3	36701.18	36701.18	36701.18	79626.26	79848.33	79737.30	42925.08	43147.15	43036.12	1.17	1.18	1.17
T_1W_4	35236.18	35236.18	35236.18	94952.87	95189.89	95071.38	59716.69	59953.71	59835.20	1.69	1.70	1.70
T_1W_5	52840.18	52840.18	52840.18	97424.48	97835.95	97630.22	44584.30	44995.77	44790.04	0.84	0.85	0.85
T_1W_6	32840.18	32840.18	32840.18	63954.11	63969.53	63961.82	31113.93	31129.35	31121.64	0.95	0.95	0.95
T_2W_1	42155.18	42155.18	42155.18	78988.56	79204.56	79096.56	36833.38	37049.38	36941.38	0.87	0.88	0.88
T_2W_2	39716.18	39716.18	42701.18	75524.31	75659.56	75591.93	35808.13	35943.38	35875.75	0.90	0.91	0.90
T_2W_3	42701.18	42701.18	42701.18	95036.06	95279.54	95157.80	52334.88	52578.36	52456.62	1.23	1.23	1.23
T_2W_4	41236.18	41236.18	41236.18	95931.00	96150.96	96040.98	54694.82	54914.78	54804.80	1.33	1.33	1.33
T_2W_5	58840.18	58840.18	58840.18	97735.82	98007.46	97871.64	38895.64	39167.28	39031.46	0.66	0.67	0.66
T_2W_6	38840.18	38840.18	38840.18	65101.67	65155.91	65128.79	26261.49	26315.73	26288.61	0.68	0.68	0.68
T_3W_1	50155.18	50155.18	50155.18	93750.56	93965.91	93858.23	43595.38	43810.73	43703.05	0.87	0.87	0.87
T_3W_2	47716.18	47716.18	47716.18	75466.67	76255.00	75860.83	27750.49	28538.82	28144.65	0.58	0.60	0.59
T_3W_3	50701.18	50701.18	50701.18	95330.78	95440.13	95385.46	44629.60	44738.95	44684.28	0.88	0.88	0.88
T_3W_4	49236.18	49236.18	49236.18	96514.44	96904.69	96709.57	47278.26	47668.51	47473.39	0.96	0.97	0.96
T_3W_5	66840.18	66840.18	66840.18	97986.30	98223.57	98104.93	31146.12	31383.39	31264.75	0.47	0.47	0.47
T_3W_6	46840.18	46840.18	46840.18	65487.78	65580.58	65534.18	18647.60	18740.40	18694.00	0.40	0.40	0.40

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

4.6.1.2 Total weed dry weight at 20 DAS (g m^{-2})

A perusal of the data revealed that different tillage system showed no significant variation on total weed dry weight of succeeding crop during both the years of experimentation.

Among the weed management practices, weed free recorded the lowest total weed dry weight (5.64 and 4.87) and weedy check recorded the highest value (29.96 and 25.74) during both the years of investigation. Lowest total weed dry weight under weed free plot might be due to maintenance of weed free condition throughout cropping period of main crop might have resulted in lesser weed density thereby resulting lower weed dry weight in succeeding crop.

4.6.2 Crop observations

4.6.2.1 Growth attributes

The data on initial plant population, chlorophyll content and plant height at harvest as influenced by different tillage system and weed management practices and presented in Table 4.25.

4.6.2.1.1 Initial plant population (no. m^{-2})

A perusal of the data revealed that neither tillage system nor weed management practices showed any significant variation on initial plant population of sunflower during both the years of experimentation.

4.6.2.1.2 Chlorophyll content at 25 and 50 DAS (micro mol m^{-2})

Among the tillage system, chlorophyll content of sunflower at 25 and 50 DAS showed significant variation only during the second year of the investigation with conventional tillage system recorded the maximum (38.63 and 43.23 micro mol m^{-2}). Higher chlorophyll content under conventional tillage might be due to better soil structure where compacted soils are loosened for

Table 4.24: Effect of tillage system and weed management practices on sunflower total density (no. m^{-2}) and total dry weight (g m^{-2}) of weeds at 20 DAS

Treatments	Total weed density			Total weed dry weight		
	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)						
T_1	5.41 (29.28)	5.37 (28.72)	5.39 (29.00)	4.07 (17.67)	3.91 (16.00)	3.99 (16.83)
T_2	5.22 (27.50)	5.14 (26.67)	5.18 (27.08)	3.99 (16.49)	3.93 (15.84)	3.96 (16.17)
T_3	4.89 (24.50)	4.82 (23.50)	4.85 (24.00)	3.95 (16.36)	3.63 (14.42)	3.79 (15.39)
SEm±	0.13	0.03	0.07	0.14	0.13	0.10
CD (P=0.05)	0.53	0.10	0.22	NS	NS	NS
Weed management practices (W)						
W_1	5.16 (27.44)	5.18 (26.89)	5.17 (27.17)	4.22 (17.32)	4.18 (16.99)	4.20 (17.16)
W_2	5.59 (31.22)	5.52 (30.00)	5.56 (30.61)	4.05 (16.93)	4.01 (16.48)	4.03 (16.71)
W_3	5.32 (27.89)	5.38 (28.67)	5.35 (28.28)	3.97 (15.83)	3.76 (14.39)	3.86 (15.11)
W_4	5.32 (27.89)	5.14 (26.00)	5.23 (26.94)	3.96 (15.34)	3.70 (14.05)	3.83 (14.70)
W_5	3.70 (13.33)	3.59 (12.56)	3.65 (12.94)	2.46 (5.64)	2.30 (4.87)	2.38 (5.26)
W_6	5.94 (34.78)	5.84 (33.67)	5.89 (34.22)	5.37 (29.96)	5.00 (25.74)	5.18 (27.85)
SEm±	0.20	0.12	0.12	0.31	0.30	0.22
CD (P=0.05)	NS	0.33	0.33	0.90	0.87	0.61

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,

W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),

W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS

W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

better root growth allowing the crop to efficient nutrient uptake and better control of weeds through wed seed burial. While the lowest chlorophyll content (37.91 and 40.12 micro mol m^{-2}) was recorded under zero tillage system.

No significant variation was observed in chlorophyll content of sunflower at 25 DAS and 50 DAS due to weed management practices during both the years of study.

4.6.2.1.3 Plant height at harvest (cm)

Different tillage system showed significant variation on plant height of sunflower at harvest only the second year of the investigation and is presented in Table 4.25. Conventional tillage system recorded the maximum plant height (99.36 cm) and the minimum under zero tillage system (97.52). This might have attributed from better growth of plants that might have resulted from initial weed seed burial inhibiting weed seed germination, suitable soil structure, aeration, more nutrient availability of nutrients to subsequent crop thus consequently higher plant height.

Weed management practices showed no significant variation on plant height of sunflower at harvest during both the years of observation.

4.6.2.2 Yield attributes and yield

The data regarding the yield attributes and yield as influenced by tillage system and weed management practices is presented in Table 4.26.

4.6.2.2.1 Head diameter (cm)

A critical analysis of the data showed that neither tillage system nor weed management practices showed any significant variation on head diameter of sunflower during both the years of experimentation.

Table 4.25: Residual effect of tillage system and weed management practices on sunflower initial plant population, chlorophyll content and plant height

Treatments	Initial plant population (no. m^{-2})			Chlorophyll content (micro mol m^{-2})						Plant height (cm) at Harvest		
				25 DAS			50 DAS					
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)												
T_1	26.11	27.06	26.58	38.03	37.91	37.97	40.27	40.12	40.20	96.75	97.52	97.13
T_2	27.28	27.72	27.50	38.16	38.39	38.28	41.09	41.18	41.14	97.91	97.85	97.88
T_3	30.22	30.28	30.25	38.21	38.63	38.42	41.64	43.23	42.44	98.99	99.36	99.18
SEm±	0.86	0.77	0.58	0.19	0.13	0.11	0.75	0.50	0.45	1.22	0.37	0.64
CD (P=0.05)	NS	NS	NS	NS	0.51	NS	NS	1.98	NS	NS	1.45	NS
Weed management practices (W)												
W_1	26.89	27.44	27.17	37.97	38.00	37.99	40.84	41.44	41.14	96.89	97.37	97.13
W_2	26.56	27.78	27.17	37.84	38.21	38.03	41.59	40.52	41.06	97.54	97.68	97.61
W_3	27.11	27.56	27.33	37.86	38.26	38.06	38.40	41.86	40.13	96.67	97.80	97.24
W_4	30.00	29.89	29.94	38.18	38.19	38.19	43.95	42.49	43.22	97.95	98.98	98.47
W_5	29.33	29.89	29.61	39.42	39.18	39.30	40.70	41.95	41.32	100.68	100.10	100.39
W_6	27.33	27.56	27.44	37.53	38.01	37.77	40.53	40.81	40.67	97.56	97.53	97.55
SEm±	0.97	0.76	0.61	0.49	0.29	0.28	1.52	0.65	0.83	1.17	0.69	0.68
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

Plate16: Sowing of succeeding crop

Plate 17: Seedling stage of sunflower

Plate 18: Irrigation at head formation

Plate 19: Crop at seed filling stage

Plate 20: General view of the experimental site of sunflower (Flowering stage)

4.6.2.2.2 Number of seeds (no. head^{-1})

Marked variation was observed on number of seeds head^{-1} due to different tillage system during both the years of experimentation. The maximum number of seeds head^{-1} was recorded under conventional tillage system (376.34 and 383.97) while the minimum was under zero tillage system (348.43 and. 356.24). This might be due to less weed pressure that competes with crop for essential growth resources which might have resulted from initial weed seed burial under conventional tillage system and hence leads to more nutrient uptake by crop thus reflecting on more number of seeds per sunflower head No significant variation was observed on number of seeds head^{-1} of sunflower weed management practices during both the years of study.

4.6.2.2.3 Test weight (g)

Test weight of sunflower showed no significant variation due to tillage system and weed management practices during both the years of experimentation.

4.6.2.2.4 Seed yield (kg ha^{-1})

The data pertaining to seed yield as influenced by tillage system and weed management practices is presented in Table 4.27 for both the years.

A perusal of the data showed that among the different tillage system, conventional tillage system resulted in highest seed yield (1197.05 and 1205.54 kg ha^{-1}) during both the years of observation. This might be due to initial weed suppression reducing the competition for essential resources, better physical soil structure and aeration and accelerated residue decomposition thus making the nutrients more available to the subsequent crop through nutrient cycling under conventional tillage system which might have attributed to better sunflower growth and hence higher yield. While the lowest seed yield (1188.36 and 1188.69 kg ha^{-1}) was registered under zero tillage system. The results are in close agreement with findings of Rabiee *et al*. (2011) in rapeseed as sequential crop

Table 4.26: Residual effect of tillage system and weed management practices on yield attributes of sunflower

Treatments	Head diameter (cm)			Number of seeds head^{-1}			Test weight (g)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	16.72	16.75	16.74	348.43	356.24	352.34	39.68	39.48	39.58
T_2	16.79	17.08	16.94	351.90	362.57	357.24	39.78	39.49	39.63
T_3	16.96	17.06	17.01	376.34	383.97	380.16	39.75	39.64	39.70
SEm±	0.11	0.10	0.08	2.91	5.41	3.07	0.10	0.18	0.11
CD (P=0.05)	NS	NS	NS	11.44	21.24	10.02	NS	NS	NS
Weed management practices (W)									
W_1	16.69	16.75	16.72	355.12	363.58	359.35	39.50	39.29	39.39
W_2	16.53	16.78	16.66	346.61	363.43	355.02	39.90	39.39	39.64
W_3	16.81	17.07	16.94	356.63	363.62	360.12	39.61	39.41	39.51
W_4	17.11	17.25	17.18	376.25	376.24	376.24	39.70	39.74	39.72
W_5	17.13	17.26	17.20	374.67	380.66	377.67	40.01	40.12	40.06
W_6	16.67	16.67	16.67	344.09	358.04	351.07	39.71	39.27	39.49
SEm±	0.20	0.17	0.13	9.66	7.47	6.10	0.12	0.21	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + prazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

after rice where conventional tillage recorded the maximum grain yield.

Weed management practices showed no significant variation on number of seed yield of sunflower during both the years of study.

4.6.2.2.5 Stover yield (kg ha^{-1})

Both tillage system and weed management practices showed no significant variation on stover yield of sunflower during both the years of investigation.

4.6.2.2.2 Harvest index (%)

No significant marked variation was observed on harvest index of sunflower due to different tillage system and weed management practices in both the years of experimentation.

Table 4.27: Residual effect of tillage system and weed management practices on yield and harvest index of sunflower

Treatments	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Tillage system (T)									
T_1	1188.36	1188.69	1188.53	2230.93	2237.02	2233.97	34.81	34.75	34.78
T_2	1191.52	1192.00	1191.76	2273.33	2284.22	2278.77	34.49	34.39	34.44
T_3	1197.05	1205.54	1201.30	2286.48	2294.64	2290.56	34.39	34.47	34.43
SEm±	0.91	2.26	1.22	36.49	46.18	29.43	0.33	0.42	0.27
CD (P=0.05)	3.59	8.87	3.97	NS	NS	NS	NS	NS	NS
Weed management practices (W)									
W_1	1190.65	1191.77	1191.21	2192.59	2199.88	2196.24	35.22	35.16	35.19
W_2	1190.23	1190.74	1190.49	2205.19	2219.92	2212.55	35.08	34.93	35.00
W_3	1192.13	1192.26	1192.20	2278.70	2282.85	2280.78	34.37	34.34	34.35
W_4	1194.29	1201.22	1197.75	2307.04	2311.60	2309.32	34.28	34.37	34.32
W_5	1197.25	1206.54	1201.90	2379.63	2388.67	2384.15	33.50	33.58	33.54
W_6	1189.31	1189.92	1189.61	2218.33	2228.82	2223.58	34.94	34.84	34.89
SEm±	1.91	5.21	2.77	52.70	49.78	36.24	0.50	0.46	0.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: Zero tillage, **T_2:** Minimum tillage, **T_3:** Conventional tillage

W_1: Stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS,
W_2: Pyrazosulfuron-ethyl @ 0.02 kg ha^{-1}(pre emergence),
W_3: Stale seedbed + pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (pre emergence) *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS
W_4: Pendimethalin @ 1 kg ha^{-1} *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS, **W_5:** Weed free, **W_6:** Weedy check

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

The present investigation entitled **"Studies on tillage system and weed management practices in upland rice (*Oryza sativa* L.) and their residual effect on sunflower (*Helianthus annuus* L.)"** was conducted at the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema campus during the *Kharif* and *Rabi* seasons of 2021-2022 and 2022-2023 with the following objectives:

1. To study the effect of tillage system and weed management practices on the growth and yield of upland rice.
2. To study the effect of tillage system and weed management practices on weed dynamics.
3. To evaluate the residual effect of different treatments in sunflower.
4. To work out the economics of the treatment.

The experiment was laid out in split-plot design (SPD) with eighteen treatments combinations, replicated thrice. The main plot consisted of three tillage systems *viz*., T_1: zero tillage, T_2: minimum tillage and T_3: conventional tillage and sub plot with six weed management practices *viz*., W_1: stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS, W_2: pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (PE), W_3: stale seedbed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} (PE) *fb* cyhalofop-butyl @ 90 g ha^{-1} (PoE) at 25 DAS, W_4: pendimethalin @ 1 kg ha^{-1} (PE) *fb* bispyribac sodium @ 25 g ha^{-1} (PoE) at 25 DAS, W_5: weed free and W_6: weedy check. Rice variety CAU-R1 was sown using seed rate of 80 kg ha^{-1} with spacing of 20 cm × 10 cm as per the treatments. Herbicides were applied at the recommended rates as per the treatments using knap-sack sprayer with flat-fan nozzle. Recommended doses of nitrogen, phosphorus and potassium fertilizers (60:40:40 kg ha^{-1}) were applied through urea, SSP and muriate of potash. Nitrogen was applied in split doses. Half dose of N and full doses of P and K applied just before sowing of crop as basal application. While the remaining half of nitrogen was divided into two split and applied as top dressed at active tillering stage and panicle initiation stage. The succeeding crop was sown using a seed rate of 80 kg ha^{-1} with spacing of 60 cm × 20 cm as per the treatments. A uniform recommended fertilizer dose @ 60-80:60:40-50 kg NPK ha^{-1} weres applied as basal dose. The relevant experimental data on crops and weeds along with soil available nutrients, nutrient uptake and depletion by crop and weeds, economics and the residual effect of the treatments on the succeeding crop were recorded following the standard field techniques and analyzed using appropriate statistical methods during the period of investigation.

The salient features of the present investigation have been summarized below:

5.1 Effect of tillage system and weed management practices on weeds

1. The dominant species of grasses include *Cynodon dactylon* L., *Digitaria sanguinalis* L. and *Eleusine indica* L. while *Cyperus iria* L. sedge include and *Ageratum conyzoides* L., *Alternanthera sessiles* L., *Borreria latifolia* (Aubl.) K. Schum., *Borreria ocymoides* L., *Mollugo pentaphylla* L., *Lindernia crustacea* L. and *Sida cordifolia* L. were broad leaved weeds found in the experimental field.
2. Based on the data analysis, tillage system significantly influenced the overall weeds density and dry weight at all the stages of observation during both the years of study. The lowest population and dry weight of weeds were recorded with conventional tillage system among the different tillage system. While the highest population and dry weight of weeds was found with zero tillage system.

   All the weed management practices were found to show significant influenced on weeds with weedy check recording the maximum density and dry weight of weeds. Among the herbicidal treatments, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS, recorded significantly lower density and dry weight of weeds.

Different tillage system and weed management practices showed significant interaction effect on density and dry weight of weeds. Significantly lower density and dry weight of weeds were recorded with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system and the highest was recorded with weedy check under zero tillage system.

3. The highest weed control efficiency was recorded under conventional tillage system while lowest was recorded under zero tillage system. Among the weed management practices, the maximum weed control efficiency was recorded with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS and weedy check recorded the lowest.

   Interaction of tillage system and weed management practices showed significant effect on weed control efficiency. Application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system recorded significantly maximum weed control efficiency while weedy check under all the tillage system recorded the lowest weed control efficiency.

4. Conventional tillage system was found to be significantly superior recording the lowest weed index, while zero tillage recording the highest value during both the years. Weedy check recorded the maximum weed index value while the lowest was recorded with application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS among the herbicidal treatment.

   Tillage system and weed management practices showed interaction effect on weed index with herbicide application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system recorded significantly lower while weedy check under all the tillage system recorded the highest weed index.

5. Conventional tillage system recorded the minimum N, P and K depletion by weeds while zero tillage recorded the maximum during both the years of experimentation. Among the weed management practices, maximum and minimum N, P and K depletion by weeds was observed with weedy check and pre- emergence herbicide application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS.

   Interaction of tillage system and weed management practices were found to be significant on N, P and K depletion by weeds. Pre- emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system recorded the lowest N, P and K depletion by weeds while the highest was observed with weedy check under all the tillage system.

5.2 Effect of tillage system and weed management practices on crops

1. Result revealed that among the tillage system, conventional tillage system recorded the highest plant height, number of tillers m^{-2}, plant dry matter accumulation, leaf area index and chlorophyll content as compared to minimum and zero tillage system. However, tillage system did not show any significant effect on crop growth rate and relative growth rate during both the years of experimentation. Among the weed management practices, significantly higher plant height, number of tillers m^{-2}, plant dry matter accumulation, leaf area index, chlorophyll content and crop growth rate were observed under weed free treatment while in case of herbicidal treatment, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum. While relative growth rate was found to be significant only in the first year with

stale seed bed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS recording the highest value.

Tillage system and weed management practices showed no significant interaction effect on plant height, number of tillers m^{-2}, plant dry matter accumulation, leaf area index, chlorophyll content, crop growth rate and relative growth rate during both the years.

2. Conventional tillage system recorded significantly highest panicle length, panicle weight, number of panicles m^{-2}, number of filled grains panicle^{-1}, grain yield, straw yield and harvest index as compared to other tillage system. Among the weed management practices, weed free recorded the highest panicle length, panicle weight, number of panicles m^{-2}, number of filled grains panicle^{-1}, grain yield, straw yield and harvest index while in case of herbicidal treatment, pre emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum.

   Interaction effect of tillage system and weed management practices was found to be significant in case of grain yield, straw yield and harvest index. Conventional tillage system with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum values of grain yield, straw yield and harvest index during both the years.

3. Tillage system and weed management practices did not show any significant effect on NPK content of grain and straw during both the years of investigation.

4. Conventional tillage system recorded the highest N, P and K uptake by grain and straw as compared to other tillage system. Among the herbicidal treatment, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest NPK uptake by crop.

The interaction effect of tillage system and weed management practices was found to be significant on N uptake by grain and straw. Conventional tillage system with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the maximum N uptake by grain and straw during first year. While in the second year, conventional tillage system with stale seed bed *fb* pyrazosulfuron-ethyl @ 0.02 kg ha^{-1} *fb* cyhalofop-butyl @ 90 g ha^{-1} at 25 DAS recording the maximum grain N uptake and stale seedbed *fb* bispyribac sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system recorded the highest N uptake by straw.

Highest grain P uptake was recorded with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage while no significant interaction effect was found in straw P uptake during both the years.

Tillage system and weed management practices showed significant interaction effect on K uptake by grain and straw with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage recording the highest values.

5.3 Effect of tillage system and weed management practices on succeeding crop

1. Conventional tillage system recorded the lowest total weed density and total dry weight of weeds during both the years while zero tillage system observed the highest values.

   Among the herbicidal treatment, application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the lowest total weed density only during the second year and lowest total weed dry weight in both the years.

2. Tillage system showed significant effect on plant height at harvest of sunflower in the second year while chlorophyll content at 25 and 50 DAS,

number of seed per head and seed yield during both the years. Conventional tillage showed highest plant height in second year, while chlorophyll content, number of seed per head and seed yield in both the years as compared to other tillage system. Tillage system showed no significant effect on initial plant population, head diameter, straw yield and harvest index of sunflower during both the years.

Weed management practices showed no significant effect on initial plant population, plant height at harvest, chlorophyll content, head diameter, number of seed per head, seed yield, straw yield and harvest index during both the years.

5.4 Economic analysis

1. From the data, it can be observed that conventional tillage system recorded the highest cost of cultivation and gross returns as compared to other tillage system in both the years. While highest net returns and benefit: cost ratio were observed under zero tillage system. Among the herbicidal treatment, the maximum gross returns, net returns and benefit: cost ratio was recorded with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS during both years of the study.

From the findings of the present investigation, the following conclusions can be drawn:

1. Conventional tillage system was found to be the best tillage system in terms of higher growth parameters, yield attributes and yield of rice. While among the weed management practices, pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded highest growth parameters, yield attributes and yield of rice.
2. Lowest weed density, weed dry weight, weed index and highest weed control efficiency were observed under conventional tillage system. Pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS was found to be most effective in controlling of weeds thereby reducing weed density and weed dry weight.
3. Lowest NPK depletion by weeds and highest NPK uptake by crop was observed with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS under conventional tillage system.
4. Tillage system showed residual effect on chlorophyll content, number of seed $head^{-1}$ and seed yield of sunflower with conventional tillage system recorded the highest values while different weed management practices showed no significant residual effect on sunflower.
5. Conventional tillage system with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest gross returns while zero tillage system with pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS recorded the highest net returns and benefit: cost ratio.

Recommendation

Based on the results of two year of field experiment, it can be recommended that upland rice cultivation with zero tillage system along with sequential application of pendimethalin @ 1 kg ha^{-1} *fb* bispyribac-sodium @ 25 g ha^{-1} at 25 DAS performed best in terms of efficient weed control, yield along with higher economic returns and benefit: cost ratio.

Future line of research

More field experiments should be carried out in direct seeded upland rice with residual study of the treatments on succeeding crop sunflower with more observations on different growth, yield and quality parameters.

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APPENDICES

APPENDIX -I

Common Cost of Cultivation

Sl.no	Particulars	Input/ Quantity	Rate (₹ $unit^{-1}$)	Cost (₹ ha^{-1})
1.	Manures and Fertilizer			
	a) FYM	2.5 t	₹ 2	5000
	b) Nitrogen (Urea)	130.2 kg	₹ 320/50 kg bag	833.28
	c) Phophorus (SSP)	250 kg	₹ 420/50 kg bag	2100
	d) Potasium (MOP)	66.68 kg	₹ 980/50 kg bag	1306.9
	e) Application of manures and fertilizer	2 man days	400/man/day	800
2.	Seed	80 kg	₹ 20	1600
3.	Plant protection			
	a. Labour charges	12 man days	400/man/day	4800
	b. Insecticide			
	Chloropyriphos	4 litre	550/500ml	4400
	c. Fungicide			
	Carbendazim 50% WP	2 kg	200/100g	4000
4.	Harvesting, threshing drying and winnowing	15 man days	400/man/day	6000
			Total	**30840.18**

APPENDIX-II

Cost of cultivation for different tillage system and weed management practices

	Inputs	Inputs/ Quantity	Rate (₹ $unit^{-1}$)	Cost (₹ ha^{-1})
Factor 1	**Tillage system**			
T_1	Zero tillage	5 labours	₹ 400	2000
T_2	Minimum tillage	20 labours	₹ 400	8000
T_3	Conventional tillage	40 labours	₹ 400	16000
Factor 2	**Weed management system**			
W_1	a. Staleseedbed (Glyphosate)	1kg	₹795/kg	795
	b. Bispyrabic sodium	25 g	₹ 4800/lit	120
	c. Labours required	6	₹ 400	2400
			TOTAL	**3315**
W_2	a. Pyrazosulfuron-ethyl	0.02kg	₹ 3800/kg	76
	b. Application of herbicides	2	₹ 400	800
			TOTAL	**876**
W_3	a. Staleseedbed (Glyphosate)	1kg	₹795/kg	795
	b. Pyrazosulfuron-ethyl	0.02kg	₹ 3800/kg	76
	c. Cyhalofop-butyl	90g	₹ 2200/lit	190
	c. Labours required	7	₹ 400	2800
			TOTAL	**3861**
W_4	a. Pendimethalin	1kg	₹ 676/ kg	676
	b. Bispyrabic sodium	25 g	₹4800/lit	120
	c. Labours required	4	₹ 400	1600
			TOTAL	**2396**
W_5	Weed free (HW@15, 30, 45 and 60DAS)	50	₹ 400	20000
W_6	Weedy check			0

APPENDIX-III

Schedule of field operations carried out

Sl. No.	Operations	Year- 2021	Year- 2022
		Date	
1.	**Land preparation**		
	Ploughing for conventional tillage	04.07.2021	03.07.2022
	Harrowing and planking	06.07.2021	05.07.2022
2.	Layout	07.07.2021	06.07.2022
3.	Manure application	07.07.2021	06.07.2022
4.	Paraquat application for stale seed bed	13.07.2021	12.07.2022
5.	Fertilizer application	15.07.2021	14.07.2022
6.	Sowing of main crop	15.07.2021	14.07.2022
7.	**Herbicide application**		
	Pyrazosulfuron-ethyl and pendimethalin	18.07.2021	17.07.2022
	Bispyribac sodium and Cyhalofop-butyl	09.08.2021	08.08.2022
8.	**Hand weeding**		
	15 DAS	02.08.2021	01.08.2022
	30 DAS	18.08.2021	17.08.2022
	45 DAS	01.09.2021	31.08.2022
	60 DAS	16.09.2021	15.09.2022
9.	Harvesting	18.10.2021	20.10.2022
10.	Threshing	22.10.2021	24.10.2022
11.	Fertilizer application for sunflower	03.11.2021	05.11.2022
12.	Sowing of sunflower	03.11.2021	05.11.2022
13.	Earthing up	20.12.2021	24.12.2022
14.	Harvesting	29.03.2022	30.03.2023

APPENDIX-IV

ANOVA for crop growth, yield parameters and yield

1(a) Analysis of variance on plant height (cm) at 30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	15.98	7.99	1.60	6.94	NS
Tillage system (T)	2	70.25	35.13	7.02	6.94	*
Error I	4	20.01	5.00			
Weed management practices (W)	5	830.64	166.13	52.81	2.53	*
T x W interaction	10	22.82	2.28	0.73	2.16	NS
Error II	30	94.37	3.15			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	3.47	1.73	1.50	6.94	NS
Tillage system (T)	2	42.29	21.15	18.26	6.94	*
Error I	4	4.63	1.16			
Weed management practices (W)	5	721.25	144.25	42.30	2.53	*
T x W interaction	10	32.36	3.24	0.95	2.16	NS
Error II	30	102.29	3.41			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	6.57	6.57	2.13	5.32	NS
Replication within years	4	19.45	4.86	1.58	3.48	NS
Tillage system (T)	4	112.54	28.14	9.13	3.84	*
Error I	8	24.65	3.08			
Weed management practices (W)	10	1551.89	155.19	47.35	1.99	*
T x W interaction	20	55.18	2.76	0.84	1.75	NS
Pooled Error II	60	196.66	3.28			

*Significant NS-Non significant

1(b) Analysis of variance on plant height (cm) at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.16	1.08	0.89	6.94	NS
Tillage system (T)	2	24.71	12.36	10.20	6.94	*
Error I	4	4.85	1.21			
Weed management practices (W)	5	504.29	100.86	42.26	2.53	*
T x W interaction	10	10.27	1.03	0.43	2.16	NS
Error II	30	71.60	2.39			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	6.42	3.21	0.81	6.94	NS
Tillage system (T)	2	84.27	42.13	10.61	6.94	*
Error I	4	15.89	3.97			
Weed management practices (W)	5	647.47	129.49	35.74	2.53	*
T x W interaction	10	59.77	5.98	1.65	2.16	NS
Error II	30	108.69	3.62			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	4.49	4.49	1.73	5.32	NS
Replication within years	4	8.58	2.14	0.83	3.48	NS
Tillage system (T)	4	108.98	27.24	10.51	3.84	*
Error I	8	20.74	2.59			
Weed management practices (W)	10	1151.76	115.18	38.33	1.99	*
T x W interaction	20	70.04	3.50	1.17	1.75	NS
Pooled Error II	60	180.29	3.00			

*Significant NS-Non significant

1(c) Analysis of variance on plant height (cm) at 90 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	4.26	2.13	0.47	6.94	NS
Tillage system (T)	2	73.46	36.73	8.02	6.94	*
Error I	4	18.31	4.58			
Weed management practices (W)	5	623.04	124.61	31.04	2.53	*
T x W interaction	10	12.38	1.24	0.31	2.16	NS
Error II	30	120.45	4.02			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	14.00	7.00	2.54	6.94	NS
Tillage system (T)	2	69.42	34.71	12.58	6.94	*
Error I	4	11.03	2.76			
Weed management practices (W)	5	591.03	118.21	27.46	2.53	*
T x W interaction	10	43.58	4.36	1.01	2.16	NS
Error II	30	129.14	4.30			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2.54	2.54	0.69	5.32	NS
Replication within years	4	18.26	4.57	1.24	3.48	NS
Tillage system (T)	4	142.88	35.72	9.74	3.84	*
Error I	8	29.34	3.67			
Weed management practices (W)	10	1214.07	121.41	29.18	1.99	*
T x W interaction	20	55.96	2.80	0.67	1.75	NS
Pooled Error II	60	249.59	4.16			

*Significant NS-Non significant

1(d) Analysis of variance on plant height (cm) at harvest as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	8.97	4.49	1.69	6.94	NS
Tillage system (T)	2	63.11	31.55	11.90	6.94	*
Error I	4	10.60	2.65			
Weed management practices (W)	5	682.53	136.51	37.09	2.53	*
T x W interaction	10	20.00	2.00	0.54	2.16	NS
Error II	30	110.42	3.68			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	26.02	13.01	3.04	6.94	NS
Tillage system (T)	2	64.59	32.29	7.53	6.94	*
Error I	4	17.15	4.29			
Weed management practices (W)	5	732.02	146.40	36.68	2.53	*
T x W interaction	10	31.98	3.20	0.80	2.16	NS
Error II	30	119.73	3.99			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	5.75	5.75	1.66	5.32	NS
Replication within years	4	34.99	8.75	2.52	3.48	NS
Tillage system (T)	4	127.70	31.92	9.20	3.84	*
Error I	8	27.75	3.47			
Weed management practices (W)	10	1414.55	141.46	36.88	1.99	*
T x W interaction	20	51.98	2.60	0.68	1.75	NS
Pooled Error II	60	230.15	3.84			

*Significant NS-Non significant

2(a) Analysis of variance on number of tillers m^{-2} (no. m^{-2}) at 30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	381.48	190.74	0.71	6.94	NS
Tillage system (T)	2	4781.48	2390.74	8.90	6.94	*
Error I	4	1074.07	268.52			
Weed management practices (W)	5	73164.81	14632.96	34.09	2.53	*
T x W interaction	10	1107.41	110.74	0.26	2.16	NS
Error II	30	12877.78	429.26			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	211.11	105.56	0.56	6.94	NS
Tillage system (T)	2	5633.33	2816.67	14.91	6.94	*
Error I	4	755.56	188.89			
Weed management practices (W)	5	74950.00	14990.00	32.05	2.53	*
T x W interaction	10	2300.00	230.00	0.49	2.16	NS
Error II	30	14033.33	467.78			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	237.04	237.04	1.04	5.32	NS
Replication within years	4	592.59	148.15	0.65	3.48	NS
Tillage system (T)	4	10414.81	2603.70	11.38	3.84	*
Error I	8	1829.63	228.70			
Weed management practices (W)	10	148114.81	14811.48	33.02	1.99	*
T x W interaction	20	3407.41	170.37	0.38	1.75	NS
Pooled Error II	60	26911.11	448.52			

*Significant NS-Non significant

2(b) Analysis of variance on number of tillers m^{-2} (no. m^{-2}) at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	20.33	10.17	0.04	6.94	NS
Tillage system (T)	2	8200.33	4100.17	17.88	6.94	*
Error I	4	917.33	229.33			
Weed management practices (W)	5	105340.83	21068.17	74.34	2.53	*
T x W interaction	10	4348.33	434.83	1.53	2.16	NS
Error II	30	8501.67	283.39			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	206.81	103.41	0.26	6.94	NS
Tillage system (T)	2	10378.93	5189.46	12.86	6.94	*
Error I	4	1614.52	403.63			
Weed management practices (W)	5	110774.81	22154.96	13.95	2.53	*
T x W interaction	10	5162.19	516.22	0.33	2.16	NS
Error II	30	47637.33	1587.91			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	511.34	511.34	1.62	5.32	NS
Replication within years	4	227.15	56.79	0.18	3.48	NS
Tillage system (T)	4	18579.26	4644.81	14.68	3.84	*
Error I	8	2531.85	316.48			
Weed management practices (W)	10	216115.65	21611.56	23.10	1.99	*
T x W interaction	20	9510.52	475.53	0.51	1.75	NS
Pooled Error II	60	56139.00	935.65			

*Significant NS-Non significant

2(c) Analysis of variance on number of tillers m^{-2} (no. m^{-2}) at 90 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	53.93	26.96	0.07	6.94	NS
Tillage system (T)	2	14240.04	7120.02	17.85	6.94	*
Error I	4	1595.19	398.80			
Weed management practices (W)	5	114555.43	22911.09	52.22	2.53	*
T x W interaction	10	4504.19	450.42	1.03	2.16	NS
Error II	30	13161.56	438.72			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	911.26	455.63	1.09	6.94	NS
Tillage system (T)	2	10440.70	5220.35	12.51	6.94	*
Error I	4	1669.19	417.30			
Weed management practices (W)	5	122315.93	24463.19	30.64	2.53	*
T x W interaction	10	4796.85	479.69	0.60	2.16	NS
Error II	30	23948.89	798.30			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	477.12	477.12	1.17	5.32	NS
Replication within years	4	965.19	241.30	0.59	3.48	NS
Tillage system (T)	4	24680.74	6170.19	15.12	3.84	*
Error I	8	3264.37	408.05			
Weed management practices (W)	10	236871.35	23687.14	38.30	1.99	*
T x W interaction	20	9301.04	465.05	0.75	1.75	NS
Pooled Error II	60	37110.44	618.51			

*Significant NS-Non significant

3(a) Analysis of variance on dry matter accumulation (g plant^{-1}) at 30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.03	0.01	2.85	6.94	NS
Tillage system (T)	2	0.56	0.28	53.96	6.94	*
Error I	4	0.02	0.01			
Weed management practices (W)	5	11.47	2.29	73.99	2.53	*
T x W interaction	10	0.53	0.05	1.71	2.16	NS
Error II	30	0.93	0.03			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.01	0.00	0.09	6.94	NS
Tillage system (T)	2	0.75	0.37	7.14	6.94	*
Error I	4	0.21	0.05			
Weed management practices (W)	5	11.59	2.32	60.77	2.53	*
T x W interaction	10	0.65	0.06	1.70	2.16	NS
Error II	30	1.14	0.04			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.05	0.05	1.72	5.32	NS
Replication within years	4	0.04	0.01	0.34	3.48	NS
Tillage system (T)	4	1.31	0.33	11.38	3.84	*
Error I	8	0.23	0.03			
Weed management practices (W)	10	23.06	2.31	66.70	1.99	*
T x W interaction	20	1.18	0.06	1.70	1.75	NS
Pooled Error II	60	2.07	0.03			

*Significant NS-Non significant

3(b) Analysis of variance on dry matter accumulation (g $plant^{-1}$) at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Replication	2	0.20	0.10	0.30	6.94	NS
Tillage system (T)	2	5.75	2.88	8.85	6.94	*
Error I	4	1.30	0.33			
Weed management practices (W)	5	47.03	9.41	59.37	2.53	*
T x W interaction	10	0.80	0.08	0.50	2.16	NS
Error II	30	4.75	0.16			

ANOVA table for second year 2022

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Replication	2	0.18	0.09	0.79	6.94	NS
Tillage system (T)	2	4.06	2.03	18.22	6.94	*
Error I	4	0.45	0.11			
Weed management practices (W)	5	55.29	11.06	96.53	2.53	*
T x W interaction	10	1.62	0.16	1.41	2.16	NS
Error II	30	3.44	0.11			

ANOVA TABLE OF POOLED ANALYSIS

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Years	1	0.70	0.70	3.23	5.32	NS
Replication within years	4	0.37	0.09	0.43	3.48	NS
Tillage system (T)	4	9.82	2.45	11.24	3.84	*
Error I	8	1.75	0.22			
Weed management practices (W)	10	102.32	10.23	74.97	1.99	*
T x W interaction	20	2.41	0.12	0.88	1.75	NS
Pooled Error II	60	8.19	0.14			

*Significant NS-Non significant

3(c) Analysis of variance on dry matter accumulation (g $plant^{-1}$) at 90 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.27	0.64	0.95	6.94	NS
Tillage system (T)	2	11.04	5.52	8.26	6.94	*
Error I	4	2.67	0.67			
Weed management practices (W)	5	333.99	66.80	68.93	2.53	*
T x W interaction	10	2.75	0.27	0.28	2.16	NS
Error II	30	29.07	0.97			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.66	0.33	0.46	6.94	NS
Tillage system (T)	2	23.90	11.95	16.66	6.94	*
Error I	4	2.87	0.72			
Weed management practices (W)	5	291.07	58.21	47.44	2.53	*
T x W interaction	10	2.50	0.25	0.20	2.16	NS
Error II	30	36.81	1.23			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2.53	2.53	3.65	5.32	NS
Replication within years	4	1.93	0.48	0.70	3.48	NS
Tillage system (T)	4	34.94	8.74	12.61	3.84	*
Error I	8	5.54	0.69			
Weed management practices (W)	10	625.06	62.51	56.92	1.99	*
T x W interaction	20	5.25	0.26	0.24	1.75	NS
Pooled Error II	60	65.88	1.10			

*Significant NS-Non significant

4(a) Analysis of variance on chlorophyll content (micro mol m^{-2}) at 25 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.91	0.96	0.39	6.94	NS
Tillage system (T)	2	49.63	24.82	10.19	6.94	*
Error I	4	9.74	2.44			
Weed management practices (W)	5	384.35	76.87	7.71	2.53	*
T x W interaction	10	13.87	1.39	0.14	2.16	NS
Error II	30	299.15	9.97			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.70	0.85	0.57	6.94	NS
Tillage system (T)	2	21.75	10.87	7.26	6.94	*
Error I	4	5.99	1.50			
Weed management practices (W)	5	203.96	40.79	9.34	2.53	*
T x W interaction	10	6.39	0.64	0.15	2.16	NS
Error II	30	131.02	4.37			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.12	0.12	0.06	5.32	NS
Replication within years	4	3.61	0.90	0.46	3.48	NS
Tillage system (T)	4	71.38	17.85	9.08	3.84	*
Error I	8	15.73	1.97			
Weed management practices (W)	10	588.31	58.83	8.21	1.99	*
T x W interaction	20	20.25	1.01	0.14	1.75	NS
Pooled Error II	60	430.17	7.17			

*Significant NS-Non significant

4(b) Analysis of variance on chlorophyll content (micro mol m^{-2}) at 50 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	7.67	3.84	2.45	6.94	NS
Tillage system (T)	2	36.05	18.03	11.53	6.94	*
Error I	4	6.26	1.56			
Weed management practices (W)	5	338.18	67.64	19.12	2.53	*
T x W interaction	10	5.94	0.59	0.17	2.16	NS
Error II	30	106.14	3.54			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	3.49	1.75	1.67	6.94	NS
Tillage system (T)	2	22.21	11.10	10.62	6.94	*
Error I	4	4.18	1.05			
Weed management practices (W)	5	307.43	61.49	23.63	2.53	*
T x W interaction	10	12.58	1.26	0.48	2.16	NS
Error II	30	78.06	2.60			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2.04	2.04	1.56	5.32	NS
Replication within years	4	11.16	2.79	2.14	3.48	NS
Tillage system (T)	4	58.26	14.57	11.16	3.84	*
Error I	8	10.44	1.30			
Weed management practices (W)	10	645.61	64.56	21.03	1.99	*
T x W interaction	20	18.52	0.93	0.30	1.75	NS
Pooled Error II	60	184.20	3.07			

*Significant NS-Non significant

5(a) Analysis of variance on leaf area index (LAI) at 25 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0031	0.0015	2.8644	6.9443	NS
Tillage system (T)	2	0.0187	0.0093	17.3438	6.9443	*
Error I	4	0.0022	0.0005			
Weed management practices (W)	5	0.4280	0.0856	160.1973	2.5336	*
T x W interaction	10	0.0031	0.0003	0.5712	2.1646	NS
Error II	30	0.0160	0.0005			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0022	0.0011	4.2302	6.9443	NS
Tillage system (T)	2	0.0163	0.0081	31.1457	6.9443	*
Error I	4	0.0010	0.0003			
Weed management practices (W)	5	0.4366	0.0873	276.3500	2.5336	*
T x W interaction	10	0.0023	0.0002	0.7200	2.1646	NS
Error II	30	0.0095	0.0003			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.0008	0.0008	1.8863	5.3177	NS
Replication within years	4	0.0053	0.0013	3.3108	3.4780	NS
Tillage system (T)	4	0.0349	0.0087	21.8548	3.8379	*
Error I	8	0.0032	0.0004			
Weed management practices (W)	10	0.8646	0.0865	203.3618	1.9926	*
T x W interaction	20	0.0053	0.0003	0.6265	1.7480	NS
Pooled Error II	60	0.0255	0.0004			

*Significant NS-Non significant

5(b) Analysis of variance on leaf area index (LAI) at 50 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0119	0.0059	0.5136	6.9443	NS
Tillage system (T)	2	0.6796	0.3398	29.4279	6.9443	*
Error I	4	0.0462	0.0115			
Weed management practices (W)	5	14.6994	2.9399	370.3689	2.5336	*
T x W interaction	10	0.2927	0.0293	3.6879	2.1646	*
Error II	30	0.2381	0.0079			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0941	0.0471	3.1229	6.9443	NS
Tillage system (T)	2	1.2075	0.6038	40.0612	6.9443	*
Error I	4	0.0603	0.0151			
Weed management practices (W)	5	16.9110	3.3822	165.1038	2.5336	*
T x W interaction	10	0.1864	0.0186	0.9100	2.1646	NS
Error II	30	0.6146	0.0205			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.0937	0.0937	7.0406	5.3177	*
Replication within years	4	0.1060	0.0265	1.9910	3.4780	NS
Tillage system (T)	4	1.8871	0.4718	35.4485	3.8379	*
Error I	8	0.1065	0.0133			
Weed management practices (W)	10	31.6103	3.1610	222.4282	1.9926	*
T x W interaction	20	0.4791	0.0240	1.6858	1.7480	NS
Pooled Error II	60	0.8527	0.0142			

*Significant NS-Non significant

6(a) Analysis of variance on crop growth rate (g m^{-2} day^{-1}) at 25-30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.34	0.17	0.75	6.94	NS
Tillage system (T)	2	0.81	0.40	1.80	6.94	NS
Error I	4	0.90	0.22			
Weed management practices (W)	5	8.76	1.75	3.45	2.53	*
T x W interaction	10	2.50	0.25	0.49	2.16	NS
Error II	30	15.24	0.51			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.07	0.04	0.09	6.94	NS
Tillage system (T)	2	3.43	1.71	4.31	6.94	NS
Error I	4	1.59	0.40			
Weed management practices (W)	5	13.00	2.60	4.95	2.53	*
T x W interaction	10	2.14	0.21	0.41	2.16	NS
Error II	30	15.75	0.53			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.28	0.28	0.89	5.32	NS
Replication within years	4	0.41	0.10	0.33	3.48	NS
Tillage system (T)	4	4.24	1.06	3.40	3.84	NS
Error I	8	2.49	0.31			
Weed management practices (W)	10	21.76	2.18	4.21	1.99	*
T x W interaction	20	4.64	0.23	0.45	1.75	NS
Pooled Error II	60	30.99	0.52			

*Significant NS-Non significant

6(b) Analysis of variance on crop growth rate (g m^{-2} day^{-1}) at 50-75 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.29	0.15	0.07	6.94	NS
Tillage system (T)	2	14.04	7.02	3.44	6.94	NS
Error I	4	8.16	2.04			
Weed management practices (W)	5	203.39	40.68	20.71	2.53	*
T x W interaction	10	7.70	0.77	0.39	2.16	NS
Error II	30	58.92	1.96			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	6.04	3.02	1.98	6.94	**NS**
Tillage system (T)	2	2.14	1.07	0.70	6.94	**NS**
Error I	4	6.11	**1.53**			
Weed management practices (W)	5	80.16	16.03	9.22	2.53	**Significant**
T x W interaction	10	9.92	0.99	0.57	2.16	**NS**
Error II	30	52.16	**1.74**			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	6.12	6.12	3.43	5.32	NS
Replication within years	4	6.33	1.58	0.89	3.48	NS
Tillage system (T)	4	16.18	4.05	2.27	3.84	NS
Error I	8	14.27	1.78			
Weed management practices (W)	10	283.55	28.36	15.32	1.99	*
T x W interaction	20	17.62	0.88	0.48	1.75	NS
Pooled Error II	60	111.08	1.85			

*Significant NS-Non significant

7(a) Analysis of variance relative growth rate (g g^{-1} m^{-2}) at 25-50 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00005	0.00002	2.28754	6.94427	NS
Tillage system (T)	2	0.00001	0.00000	0.29017	6.94427	NS
Error I	4	0.00004	0.00001			
Weed management practices (W)	5	0.00024	0.00005	2.06537	2.53355	NS
T x W interaction	10	0.00018	0.00002	0.75589	2.16458	NS
Error II	30	0.00070	0.00002			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00000	0.00000	0.10100	6.94427	NS
Tillage system (T)	2	0.00006	0.00003	2.14806	6.94427	NS
Error I	4	0.00006	0.00001			
Weed management practices (W)	5	0.00009	0.00002	0.83540	2.53355	NS
T x W interaction	10	0.00020	0.00002	0.90444	2.16458	NS
Error II	30	0.00065	0.00002			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00000	0.00000	0.04284	5.31766	NS
Replication within years	4	0.00005	0.00001	1.02413	3.47805	NS
Tillage system (T)	4	0.00007	0.00002	1.36368	3.83785	NS
Error I	8	0.00010	0.00001			
Weed management practices (W)	10	0.00033	0.00003	1.47261	1.99259	NS
T x W interaction	20	0.00037	0.00002	0.82748	1.74798	NS
Pooled Error II	60	0.00135	0.00002			

*Significant NS-Non significant

7(b) Analysis of variance on relative growth rate (g g^{-1} m^{-2}) at 50-75 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00000	0.00000	0.08772	6.94427	NS
Tillage system (T)	2	0.00003	0.00001	0.52596	6.94427	NS
Error I	4	0.00011	0.00003			
Weed management practices (W)	5	0.00054	0.00011	2.87041	2.53355	*
T x W interaction	10	0.00006	0.00001	0.16953	2.16458	NS
Error II	30	0.00112	0.00004			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00005	0.00003	1.24363	6.94427	NS
Tillage system (T)	2	0.00008	0.00004	1.86105	6.94427	NS
Error I	4	0.00008	0.00002			
Weed management practices (W)	5	0.00005	0.00001	0.29476	2.53355	NS
T x W interaction	10	0.00013	0.00001	0.35337	2.16458	NS
Error II	30	0.00106	0.00004			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00006	0.00006	2.48372	5.31766	NS
Replication within years	4	0.00006	0.00001	0.58611	3.47805	NS
Tillage system (T)	4	0.00011	0.00003	1.10161	3.83785	NS
Error I	8	0.00020	0.00002			
Weed management practices (W)	10	0.00059	0.00006	1.61598	1.99259	NS
T x W interaction	20	0.00019	0.00001	0.25906	1.74798	NS
Pooled Error II	60	0.00218	0.00004			

*Significant NS-Non significant

8. Analysis of variance on number of panicles m^{-2} as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	427.26	213.63	0.69	6.94	NS
Tillage system (T)	2	11218.93	5609.46	18.10	6.94	Significant
Error I	4	1239.74	309.94			
Weed management practices (W)	5	117433.93	23486.79	47.54	2.53	Significant
T x W interaction	10	10793.74	1079.37	2.18	2.16	Significant
Error II	30	14822.33	494.08			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	818.97	409.49	0.95	6.94	NS
Tillage system (T)	2	8490.18	4245.09	9.85	6.94	*
Error I	4	1724.24	431.06			
Weed management practices (W)	5	118132.80	23626.56	33.34	2.53	*
T x W interaction	10	4540.87	454.09	0.64	2.16	NS
Error II	30	21260.64	708.69			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	1168.11	1168.11	3.15	5.32	NS
Replication within years	4	1246.23	311.56	0.84	3.48	NS
Tillage system (T)	4	19709.11	4927.28	13.30	3.84	*
Error I	8	2963.98	370.50			
Weed management practices (W)	10	235566.72	23556.67	39.17	1.99	*
T x W interaction	20	15334.61	766.73	1.27	1.75	NS
Pooled Error II	60	36082.97	601.38			

*Significant NS-Non significant

9. Analysis of variance on panicle length (cm) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.03	0.02	0.10	6.94	NS
Tillage system (T)	2	3.45	1.73	11.13	6.94	*
Error I	4	0.62	0.16			
Weed management practices (W)	5	40.99	8.20	17.52	2.53	*
T x W interaction	10	0.29	0.03	0.06	2.16	NS
Error II	30	14.03	0.47			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.61	0.31	1.39	6.94	NS
Tillage system (T)	2	4.00	2.00	9.13	6.94	*
Error I	4	0.88	0.22			
Weed management practices (W)	5	71.12	14.22	38.41	2.53	*
T x W interaction	10	0.57	0.06	0.15	2.16	NS
Error II	30	11.11	0.37			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2.49	2.49	13.31	5.32	*
Replication within years	4	0.64	0.16	0.86	3.48	NS
Tillage system (T)	4	7.45	1.86	9.95	3.84	*
Error I	8	1.50	0.19			
Weed management practices (W)	10	112.11	11.21	26.75	1.99	*
T x W interaction	20	0.86	0.04	0.10	1.75	NS
Pooled Error II	60	25.15	0.42			

*Significant NS-Non significant

10. Analysis of variance on weight of panicle (g) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.02	0.01	0.72	6.94	NS
Tillage system (T)	2	0.76	0.38	23.61	6.94	*
Error I	4	0.06	0.02			
Weed management practices (W)	5	10.87	2.17	47.72	2.53	*
T x W interaction	10	0.25	0.02	0.54	2.16	NS
Error II	30	1.37	0.05			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.12	0.06	1.78	6.94	NS
Tillage system (T)	2	0.78	0.39	11.76	6.94	*
Error I	4	0.13	0.03			
Weed management practices (W)	5	13.49	2.70	118.81	2.53	*
T x W interaction	10	0.15	0.02	0.67	2.16	NS
Error II	30	0.68	0.02			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.14	0.14	5.74	5.32	*
Replication within years	4	0.14	0.04	1.43	3.48	NS
Tillage system (T)	4	1.54	0.38	15.63	3.84	*
Error I	8	0.20	0.02			
Weed management practices (W)	10	24.36	2.44	71.37	1.99	*
T x W interaction	20	0.40	0.02	0.59	1.75	NS
Pooled Error II	60	2.05	0.03			

*Significant NS-Non significant

11. Analysis of variance on number of grains panicle^{-1} as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	9.60	4.80	0.83	6.94	NS
Tillage system (T)	2	82.07	41.03	7.12	6.94	*
Error I	4	23.06	5.77			
Weed management practices (W)	5	3740.71	748.14	36.67	2.53	*
T x W interaction	10	90.13	9.01	0.44	2.16	NS
Error II	30	612.10	20.40			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.90	0.95	0.30	6.94	NS
Tillage system (T)	2	209.46	104.73	33.24	6.94	*
Error I	4	12.60	3.15			
Weed management practices (W)	5	4371.55	874.31	112.21	2.53	*
T x W interaction	10	122.20	12.22	1.57	2.16	NS
Error II	30	233.75	7.79			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	55.89	55.89	12.54	5.32	*
Replication within years	4	11.50	2.87	0.64	3.48	NS
Tillage system (T)	4	291.53	72.88	16.35	3.84	*
Error I	8	35.67	4.46			
Weed management practices (W)	10	8112.26	811.23	57.54	1.99	*
T x W interaction	20	212.33	10.62	0.75	1.75	NS
Pooled Error II	60	845.85	14.10			

*Significant NS-Non significant

12. Analysis of variance on number of filled grains panicle^{-1} as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	8.54	4.27	0.75	6.94	NS
Tillage system (T)	2	227.40	113.70	19.89	6.94	Significant
Error I	4	22.87	5.72			
Weed management practices (W)	5	6512.49	1302.50	125.53	2.53	Significant
T x W interaction	10	87.08	8.71	0.84	2.16	NS
Error II	30	311.28	10.38			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.41	0.20	0.04	6.94	NS
Tillage system (T)	2	359.14	179.57	34.40	6.94	*
Error I	4	20.88	5.22			
Weed management practices (W)	5	6922.30	1384.46	282.01	2.53	*
T x W interaction	10	87.68	8.77	1.79	2.16	NS
Error II	30	147.28	4.91			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	88.53	88.53	16.19	5.32	*
Replication within years	4	8.95	2.24	0.41	3.48	NS
Tillage system (T)	4	586.54	146.64	26.82	3.84	*
Error I	8	43.75	5.47			
Weed management practices (W)	10	13434.78	1343.48	175.79	1.99	*
T x W interaction	20	174.75	8.74	1.14	1.75	NS
Pooled Error II	60	458.55	7.64			

*Significant   NS-Non significant

13. Analysis of variance on number of unfilled grains panicle^{-1} as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.04	0.02	0.01	6.94	NS
Tillage system (T)	2	39.41	19.70	12.91	6.94	*
Error I	4	6.11	1.53			
Weed management practices (W)	5	397.36	79.47	11.46	2.53	*
T x W interaction	10	49.88	4.99	0.72	2.16	NS
Error II	30	207.99	6.93			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.32	0.66	0.88	6.94	NS
Tillage system (T)	2	24.34	12.17	16.34	6.94	*
Error I	4	2.98	0.74			
Weed management practices (W)	5	296.97	59.39	13.96	2.53	*
T x W interaction	10	32.10	3.21	0.75	2.16	NS
Error II	30	127.64	4.25			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	3.74	3.74	3.29	5.32	NS
Replication within years	4	1.36	0.34	0.30	3.48	NS
Tillage system (T)	4	63.75	15.94	14.03	3.84	*
Error I	8	9.08	**1.14**			
Weed management practices (W)	10	694.34	69.43	12.41	1.99	*
T x W interaction	20	81.98	4.10	0.73	1.75	NS
Pooled Error II	60	335.63	**5.59**			

*Significant NS-Non significant

14. Analysis of variance on test weight (g) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.55	1.27	2.01	6.94	NS
Tillage system (T)	2	0.27	0.14	0.22	6.94	NS
Error I	4	2.54	0.64			
Weed management practices (W)	5	4.06	0.81	2.09	2.53	NS
T x W interaction	10	0.28	0.03	0.07	2.16	NS
Error II	30	11.66	0.39			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.12	0.06	0.17	6.94	NS
Tillage system (T)	2	0.77	0.39	1.06	6.94	NS
Error I	4	1.46	0.36			
Weed management practices (W)	5	5.29	1.06	2.21	2.53	NS
T x W interaction	10	1.69	0.17	0.35	2.16	NS
Error II	30	14.38	0.48			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.02	0.02	0.04	5.32	NS
Replication within years	4	2.67	0.67	1.34	3.48	NS
Tillage system (T)	4	1.05	0.26	0.53	3.84	NS
Error I	8	4.00	0.50			
Weed management practices (W)	10	9.35	0.93	2.15	1.99	*
T x W interaction	20	1.97	0.10	0.23	1.75	NS
Pooled Error II	60	26.04	0.43			

*Significant NS-Non significant

15. Analysis of variance on grain yield (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	51.57	25.79	0.02	6.94	NS
Tillage system (T)	2	921599.59	460799.79	329.07	6.94	*
Error I	4	5601.23	1400.31			
Weed management practices (W)	5	17316795.05	3463359.01	1618.57	2.53	*
T x W interaction	10	1410573.66	141057.37	65.92	2.16	*
Error II	30	64192.91	2139.76			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	3663.12	1831.56	1.44	6.94	NS
Tillage system (T)	2	937261.42	468630.71	369.44	6.94	*
Error I	4	5073.93	1268.48			
Weed management practices (W)	5	17423396.68	3484679.34	3158.64	2.53	*
T x W interaction	10	1393360.34	139336.03	126.30	2.16	*
Error II	30	33096.61	1103.22			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	4226.13	4226.13	3.17	5.32	NS
Replication within years	4	3714.69	928.67	0.70	3.48	NS
Tillage system (T)	4	1858861.01	464715.25	348.26	3.84	*
Error I	8	10675.16	1334.39			
Weed management practices (W)	10	34740191.73	3474019.17	2142.48	1.99	*
T x W interaction	20	2803933.99	140196.70	86.46	1.75	*
Pooled Error II	60	97289.52	1621.49			

*Significant NS-Non significant

16. Analysis of variance on straw yield (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	204.18	102.09	0.04	6.94	NS
Tillage system (T)	2	495038.65	247519.33	85.84	6.94	*
Error I	4	11534.59	2883.65			
Weed management practices (W)	5	9806893.65	1961378.73	1530.54	2.53	*
T x W interaction	10	883827.48	88382.75	68.97	2.16	*
Error II	30	38444.93	1281.50			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	949.17	474.58	0.51	6.94	NS
Tillage system (T)	2	496269.32	248134.66	268.46	6.94	*
Error I	4	3697.20	924.30			
Weed management practices (W)	5	10081915.24	2016383.05	1100.37	2.53	*
T x W interaction	10	923817.52	92381.75	50.41	2.16	*
Error II	30	54973.63	1832.45			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	547.15	547.15	0.29	5.32	NS
Replication within years	4	1153.34	288.34	0.15	3.48	NS
Tillage system (T)	4	991307.97	247826.99	130.16	3.84	*
Error I	8	15231.79	1903.97			
Weed management practices (W)	10	19888808.89	1988880.89	1277.40	1.99	*
T x W interaction	20	1807645.00	90382.25	58.05	1.75	*
Pooled Error II	60	93418.56	1556.98			

*Significant NS-Non significant

17. Analysis of variance on harvest index as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.02	0.01	0.48	6.94	NS
Tillage system (T)	2	8.86	4.43	255.72	6.94	*
Error I	4	0.07	0.02			
Weed management practices (W)	5	179.80	35.96	277.62	2.53	*
T x W interaction	10	10.62	1.06	8.20	2.16	*
Error II	30	3.89	0.13			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.07	0.04	0.38	6.94	NS
Tillage system (T)	2	8.99	4.50	49.08	6.94	*
Error I	4	0.37	0.09			
Weed management practices (W)	5	173.52	34.70	545.20	2.53	*
T x W interaction	10	10.14	1.01	15.93	2.16	*
Error II	30	1.91	0.06			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.26	0.26	4.74	5.32	NS
Replication within years	4	0.09	0.02	0.40	3.48	NS
Tillage system (T)	4	17.85	4.46	81.94	3.84	*
Error I	8	0.44	**0.05**			
Weed management practices (W)	10	353.32	35.33	365.79	1.99	*
T x W interaction	20	20.77	1.04	10.75	1.75	*
Pooled Error II	60	5.80	**0.10**			

*Significant NS-Non significant

18. Analysis of variance on weed index as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.13	0.07	0.14	6.94	NS
Tillage system (T)	2	378.75	189.37	403.12	6.94	*
Error I	4	1.88	0.47			
Weed management practices (W)	5	8249.26	1649.85	1607.84	2.53	*
T x W interaction	10	671.36	67.14	65.43	2.16	*
Error II	30	30.78	1.03			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.68	0.34	0.61	6.94	NS
Tillage system (T)	2	401.42	200.71	360.00	6.94	*
Error I	4	2.23	0.56			
Weed management practices (W)	5	8247.63	1649.53	3168.88	2.53	*
T x W interaction	10	659.34	65.93	126.67	2.16	*
Error II	30	15.62	0.52			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00	0.00	0.00	5.32	NS
Replication within years	4	0.81	0.20	0.39	3.48	NS
Tillage system (T)	4	780.17	195.04	379.72	3.84	*
Error I	8	4.11	0.51			
Weed management practices (W)	10	16496.89	1649.69	2133.22	1.99	*
T x W interaction	20	1330.70	66.54	86.04	1.75	*
Pooled Error II	60	46.40	0.77			

*Significant NS-Non significant

APPENDIX-V

ANOVA for weed parameters in rice field

1(a) Analysis of variance on weed population m^{-2} at 30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.07	0.03	0.78	6.94	NS
Tillage system (T)	2	59.24	29.62	702.81	6.94	*
Error I	4	0.17	0.04			
Weed management practices (W)	5	5564.65	1112.93	31830.16	2.53	*
T x W interaction	10	20.86	2.09	59.65	2.16	*
Error II	30	1.05	0.03			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.15	0.07	3.40	6.94	NS
Tillage system (T)	2	71.93	35.96	1661.34	6.94	*
Error I	4	0.09	0.02			
Weed management practices (W)	5	5212.71	1042.54	32709.99	2.53	*
T x W interaction	10	18.72	1.87	58.75	2.16	*
Error II	30	0.96	0.03			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	5.95	5.95	186.64	5.32	*
Replication within years	4	0.21	0.05	1.67	3.48	NS
Tillage system (T)	4	131.17	32.79	1028.06	3.84	*
Error I	8	0.26	0.03			
Weed management practices (W)	10	10777.36	1077.74	32249.72	1.99	*
T x W interaction	20	39.58	1.98	59.22	1.75	*
Pooled Error II	60	2.01	0.03			

*Significant NS-Non significant

1(b) Analysis of variance on weed population m^{-2} at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.14	0.07	3.58	6.94	NS
Tillage system (T)	2	90.81	45.41	2269.56	6.94	*
Error I	4	0.08	0.02			
Weed management practices (W)	5	6052.02	1210.40	18878.81	2.53	*
T x W interaction	10	28.64	2.86	44.68	2.16	*
Error II	30	1.92	0.06			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.28	0.14	2.12	6.94	NS
Tillage system (T)	2	85.29	42.64	651.66	6.94	*
Error I	4	0.26	0.07			
Weed management practices (W)	5	5839.01	1167.80	45019.86	2.53	*
T x W interaction	10	29.59	2.96	114.08	2.16	*
Error II	30	0.78	0.03			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	4.72	4.72	110.54	5.32	*
Replication within years	4	0.42	0.10	2.46	3.48	NS
Tillage system (T)	4	176.10	44.02	1030.48	3.84	*
Error I	8	0.34	0.04			
Weed management practices (W)	10	11891.03	1189.10	26408.63	1.99	*
T x W interaction	20	58.23	2.91	64.67	1.75	*
Pooled Error II	60	2.70	0.05			

*Significant NS-Non significant

1(c) Analysis of variance on weed population m^{-2} at 90 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.01	0.00	0.08	6.94	NS
Tillage system (T)	2	43.54	21.77	561.05	6.94	*
Error I	4	0.16	0.04			
Weed management practices (W)	5	2208.19	441.64	11030.75	2.53	*
T x W interaction	10	18.41	1.84	45.99	2.16	*
Error II	30	1.20	0.04			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.11	0.06	6.62	6.94	NS
Tillage system (T)	2	41.35	20.67	2485.98	6.94	*
Error I	4	0.03	0.01			
Weed management practices (W)	5	2172.86	434.57	18764.14	2.53	*
T x W interaction	10	19.28	1.93	83.25	2.16	*
Error II	30	0.69	0.02			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	3.56	3.56	151.29	5.32	*
Replication within years	4	0.12	0.03	1.23	3.48	NS
Tillage system (T)	4	84.89	21.22	900.78	3.84	*
Error I	8	0.19	0.02			
Weed management practices (W)	10	4381.05	438.10	13864.80	1.99	*
T x W interaction	20	37.69	1.88	59.64	1.75	*
Pooled Error II	60	1.90	0.03			

*Significant NS-Non significant

2(a) Analysis of variance on weed dry weight (g m^{-2}) at 30 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.08	0.04	0.57	6.94	NS
Tillage system (T)	2	20.53	10.27	151.43	6.94	*
Error I	4	0.27	0.07			
Weed management practices (W)	5	1558.20	311.64	4307.84	2.53	*
T x W interaction	10	9.75	0.98	13.48	2.16	*
Error II	30	2.17	0.07			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.10	0.05	0.77	6.94	NS
Tillage system (T)	2	19.75	9.88	144.85	6.94	*
Error I	4	0.27	0.07			
Weed management practices (W)	5	1502.75	300.55	6618.09	2.53	*
T x W interaction	10	10.17	1.02	22.39	2.16	*
Error II	30	1.36	0.05			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	1.91	1.91	28.14	5.32	*
Replication within years	4	0.18	0.05	0.67	3.48	NS
Tillage system (T)	4	40.28	10.07	148.13	3.84	*
Error I	8	0.54	0.07			
Weed management practices (W)	10	3060.96	306.10	5198.80	1.99	*
T x W interaction	20	19.92	1.00	16.91	1.75	*
Pooled Error II	60	3.53	0.06			

*Significant NS-Non significant

2(b) Analysis of variance on weed dry weight (g m^{-2}) at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.16	0.08	1.24	6.94	NS
Tillage system (T)	2	87.13	43.56	674.60	6.94	*
Error I	4	0.26	0.06			
Weed management practices (W)	5	4890.49	978.10	12279.29	2.53	*
T x W interaction	10	37.16	3.72	46.66	2.16	*
Error II	30	2.39	0.08			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.10	0.05	3.14	6.94	NS
Tillage system (T)	2	78.62	39.31	2494.97	6.94	*
Error I	4	0.06	0.02			
Weed management practices (W)	5	4780.48	956.10	49553.29	2.53	*
T x W interaction	10	43.37	4.34	224.76	2.16	*
Error II	30	0.58	0.02			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	1.46	1.46	36.46	5.32	*
Replication within years	4	0.26	0.06	1.62	3.48	NS
Tillage system (T)	4	165.75	41.44	1031.62	3.84	*
Error I	8	0.32	0.04			
Weed management practices (W)	10	9670.97	967.10	19547.48	1.99	*
T x W interaction	20	80.53	4.03	81.39	1.75	*
Pooled Error II	60	2.97	0.05			

*Significant NS-Non significant

2(c) Analysis of variance on weed dry weight (g m^{-2}) at 90 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.20	0.10	2.17	6.94	NS
Tillage system (T)	2	68.99	34.49	767.01	6.94	*
Error I	4	0.18	0.04			
Weed management practices (W)	5	3161.69	632.34	15696.05	2.53	*
T x W interaction	10	27.86	2.79	69.16	2.16	*
Error II	30	1.21	0.04			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.08	0.04	1.36	6.94	NS
Tillage system (T)	2	69.05	34.53	1115.79	6.94	*
Error I	4	0.12	0.03			
Weed management practices (W)	5	3039.66	607.93	23469.14	2.53	*
T x W interaction	10	30.11	3.01	116.22	2.16	*
Error II	30	0.78	0.03			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2.60	2.60	68.59	5.32	*
Replication within years	4	0.28	0.07	1.84	3.48	NS
Tillage system (T)	4	138.04	34.51	909.18	3.84	*
Error I	8	0.30	0.04			
Weed management practices (W)	10	6201.35	620.14	18738.06	1.99	*
T x W interaction	20	57.97	2.90	87.58	1.75	*
Pooled Error II	60	1.99	0.03			

*Significant NS-Non significant

3. Analysis of variance on weed control efficiency (%) at 60 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	3.42	1.71	1.08	6.94	NS
Tillage system (T)	2	399.10	199.55	126.31	6.94	*
Error I	4	6.32	1.58			
Weed management practices (W)	5	59388.95	11877.79	18141.83	2.53	*
T x W interaction	10	245.82	24.58	37.55	2.16	*
Error II	30	19.64	0.65			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.54	0.27	1.31	6.94	NS
Tillage system (T)	2	499.68	249.84	1198.95	6.94	*
Error I	4	0.83	0.21			
Weed management practices (W)	5	59471.17	11894.23	109659.97	2.53	*
T x W interaction	10	306.19	30.62	282.30	2.16	*
Error II	30	3.25	0.11			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.18	0.18	0.20	5.32	NS
Replication within years	4	3.97	0.99	1.11	3.48	NS
Tillage system (T)	4	898.78	224.69	251.31	3.84	*
Error I	8	7.15	0.89			
Weed management practices (W)	10	118860.12	11886.01	31148.52	1.99	*
T x W interaction	20	552.01	27.60	72.33	1.75	*
Pooled Error II	60	22.90	0.38			

*Significant NS-Non significant

APPENDIX-VI

ANOVA for soil parameters

1. Analysis of variance on soil pH as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.05	0.02	0.86	6.94	NS
Tillage system (T)	2	0.00	0.00	0.04	6.94	NS
Error I	4	0.10	0.03			
Weed management practices (W)	5	0.07	0.01	0.88	2.53	NS
T x W interaction	10	0.30	0.03	1.80	2.16	NS
Error II	30	0.50	0.02			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.02	0.01	0.17	6.94	NS
Tillage system (T)	2	0.14	0.07	1.50	6.94	NS
Error I	4	0.18	0.04			
Weed management practices (W)	5	0.08	0.02	0.82	2.53	NS
T x W interaction	10	0.27	0.03	1.46	2.16	NS
Error II	30	0.56	0.02			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.06	0.06	1.81	5.32	NS
Replication within years	4	0.06	0.02	0.43	3.48	NS
Tillage system (T)	4	0.14	0.03	0.96	3.84	NS
Error I	8	0.28	0.04			
Weed management practices (W)	10	0.15	0.02	0.85	1.99	NS
T x W interaction	20	0.58	0.03	1.62	1.75	NS
Pooled Error II	60	1.07	0.02			

*Significant NS-Non significant

2. Analysis of variance on organic carbon (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00	0.00	2.44	6.94	NS
Tillage system (T)	2	0.04	0.02	126.12	6.94	*
Error I	4	0.00	0.00			
Weed management practices (W)	5	0.07	0.01	22.59	2.53	*
T x W interaction	10	0.00	0.00	0.79	2.16	NS
Error II	30	0.02	0.00			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00	0.00	1.32	6.94	NS
Tillage system (T)	2	0.04	0.02	101.05	6.94	*
Error I	4	0.00	0.00			
Weed management practices (W)	5	0.08	0.02	21.99	2.53	*
T x W interaction	10	0.01	0.00	1.45	2.16	NS
Error II	30	0.02	0.00			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00	0.00	7.22	5.32	*
Replication within years	4	0.00	0.00	1.86	3.48	NS
Tillage system (T)	4	0.08	0.02	113.13	3.84	*
Error I	8	0.00	0.00			
Weed management practices (W)	10	0.14	0.01	22.27	1.99	*
T x W interaction	20	0.01	0.00	1.14	1.75	NS
Pooled Error II	60	0.04	0.00			

*Significant NS-Non significant

3(a)Analysis of variance on bulk density (g cc^{-1}) at 0-5 cm depth as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0001	0.0000	0.03	6.94	NS
Tillage system (T)	2	0.0060	0.0030	2.19	6.94	NS
Error I	4	0.0055	0.0014			
Weed management practices (W)	5	0.0062	0.0012	1.15	2.53	NS
T x W interaction	10	0.0039	0.0004	0.36	2.16	NS
Error II	30	0.0325	0.0011			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00004	0.00002	0.04	6.94	NS
Tillage system (T)	2	0.02717	0.01359	26.72	6.94	*
Error I	4	0.00203	0.00051			
Weed management practices (W)	5	0.00293	0.00059	1.19	2.53	NS
T x W interaction	10	0.00447	0.00045	0.91	2.16	NS
Error II	30	0.01472	0.00049			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.0044	0.0044	4.70	5.32	NS
Replication within years	4	0.0001	0.0000	0.03	3.48	NS
Tillage system (T)	4	0.0332	0.0083	8.81	3.84	*
Error I	8	0.0075	0.0009			
Weed management practices (W)	10	0.0091	0.0009	1.16	1.99	NS
T x W interaction	20	0.0084	0.0004	0.53	1.75	NS
Pooled Error II	60	0.0472	0.0008			

*Significant NS-Non significant

3(b) Analysis of variance on bulk density (g cc^{-1}) at 5-15 cm depth as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0001	0.0001	0.38	6.94	NS
Tillage system (T)	2	0.1346	0.0673	385.14	6.94	*
Error I	4	0.0007	0.0002			
Weed management practices (W)	5	0.0012	0.0002	2.00	2.53	NS
T x W interaction	10	0.0020	0.0002	1.66	2.16	NS
Error II	30	0.0036	0.0001			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0009	0.0004	1.36	6.94	NS
Tillage system (T)	2	0.1372	0.0686	208.36	6.94	*
Error I	4	0.0013	0.0003			
Weed management practices (W)	5	0.0019	0.0004	1.54	2.53	NS
T x W interaction	10	0.0031	0.0003	1.25	2.16	NS
Error II	30	0.0075	0.0002			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.0011	0.0011	4.37	5.32	NS
Replication within years	4	0.0010	0.0003	1.02	3.48	NS
Tillage system (T)	4	0.2718	0.0679	269.63	3.84	*
Error I	8	0.0020	0.0003			
Weed management practices (W)	10	0.0031	0.0003	1.69	1.99	NS
T x W interaction	20	0.0051	0.0003	1.38	1.75	NS
Pooled Error II	60	0.0110	0.0002			

*Significant NS-Non significant

3(c) Analysis of variance on bulk density (g cc^{-1}) at 15-30 cm depth as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0003	0.0002	0.59	6.94	NS
Tillage system (T)	2	0.0780	0.0390	141.99	6.94	*
Error I	4	0.0011	0.0003			
Weed management practices (W)	5	0.0010	0.0002	1.54	2.53	NS
T x W interaction	10	0.0009	0.0001	0.71	2.16	NS
Error II	30	0.0038	0.0001			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.0001	0.0000	1.22	6.94	NS
Tillage system (T)	2	0.0842	0.0421	1526.55	6.94	*
Error I	4	0.0001	0.0000			
Weed management practices (W)	5	0.0011	0.0002	1.67	2.53	NS
T x W interaction	10	0.0024	0.0002	1.80	2.16	NS
Error II	30	0.0039	0.0001			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.0002	0.0002	1.07	5.32	NS
Replication within years	4	0.0004	0.0001	0.65	3.48	NS
Tillage system (T)	4	0.1623	0.0406	268.30	3.84	*
Error I	8	0.0012	0.0002			
Weed management practices (W)	10	0.0021	0.0002	1.61	1.99	NS
T x W interaction	20	0.0033	0.0002	1.27	1.75	NS
Pooled Error II	60	0.0077	0.0001			

*Significant NS-Non significant

4. Analysis of variance on soil available nitrogen (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	45.35	22.67	1.37	6.94	NS
Tillage system (T)	2	893.42	446.71	26.98	6.94	*
Error I	4	66.24	16.56			
Weed management practices (W)	5	3781.94	756.39	14.00	2.53	*
T x W interaction	10	486.57	48.66	0.90	2.16	NS
Error II	30	1620.97	54.03			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	14.73	7.36	0.77	6.94	NS
Tillage system (T)	2	872.25	436.12	45.87	6.94	*
Error I	4	38.03	9.51			
Weed management practices (W)	5	4289.93	857.99	39.57	2.53	*
T x W interaction	10	376.77	37.68	1.74	2.16	NS
Error II	30	650.41	21.68			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	64.79	64.79	4.97	5.32	NS
Replication within years	4	60.07	15.02	1.15	3.48	NS
Tillage system (T)	4	1765.67	441.42	33.87	3.84	*
Error I	8	104.27	13.03			
Weed management practices (W)	10	8071.87	807.19	21.32	1.99	*
T x W interaction	20	863.34	43.17	1.14	1.75	NS
Pooled Error II	60	2271.38	37.86			

*Significant NS-Non significant

5. Analysis of variance on soil available phosphorus (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.04	0.02	0.02	6.94	NS
Tillage system (T)	2	16.16	8.08	8.44	6.94	*
Error I	4	3.83	0.96			
Weed management practices (W)	5	120.54	24.11	38.35	2.53	*
T x W interaction	10	5.05	0.51	0.80	2.16	NS
Error II	30	18.86	0.63			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.29	0.64	0.94	6.94	NS
Tillage system (T)	2	18.04	9.02	13.15	6.94	*
Error I	4	2.74	0.69			
Weed management practices (W)	5	136.36	27.27	26.70	2.53	*
T x W interaction	10	10.62	1.06	1.04	2.16	NS
Error II	30	30.65	1.02			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	4.19	4.19	5.10	5.32	NS
Replication within years	4	1.33	0.33	0.40	3.48	NS
Tillage system (T)	4	34.21	8.55	10.41	3.84	*
Error I	8	6.57	0.82			
Weed management practices (W)	10	256.90	25.69	31.14	1.99	*
T x W interaction	20	15.67	0.78	0.95	1.75	NS
Pooled Error II	60	49.51	0.83			

*Significant NS-Non significant

6. Analysis of variance on soil available potassium (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.65	1.33	0.10	6.94	NS
Tillage system (T)	2	444.75	222.37	16.55	6.94	*
Error I	4	53.73	13.43			
Weed management practices (W)	5	212.40	42.48	2.19	2.53	NS
T x W interaction	10	106.31	10.63	0.55	2.16	NS
Error II	30	583.09	19.44			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	16.55	8.28	1.19	6.94	NS
Tillage system (T)	2	172.36	86.18	12.35	6.94	*
Error I	4	27.91	6.98			
Weed management practices (W)	5	135.44	27.09	1.12	2.53	NS
T x W interaction	10	443.65	44.36	1.84	2.16	NS
Error II	30	723.31	24.11			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	39.78	39.78	3.90	5.32	NS
Replication within years	4	19.21	4.80	0.47	3.48	NS
Tillage system (T)	4	617.11	154.28	15.12	3.84	Significant
Error I	8	81.64	10.20			
Weed management practices (W)	10	347.84	34.78	1.60	1.99	NS
T x W interaction	20	549.95	27.50	1.26	1.75	NS
Pooled Error II	60	1306.40	21.77			

*Significant NS-Non significant

APPENDIX-VII

ANOVA for plant analysis

1. Analysis of variance on nitrogen depletion by weeds (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.02	0.01	1.07	6.94	NS
Tillage system (T)	2	10.55	5.28	629.62	6.94	*
Error I	4	0.03	0.01			
Weed management practices (W)	5	567.10	113.42	11892.61	2.53	*
T x W interaction	10	4.46	0.45	46.79	2.16	*
Error II	30	0.29	0.01			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.01	0.01	3.00	6.94	NS
Tillage system (T)	2	9.50	4.75	2420.39	6.94	*
Error I	4	0.01	0.00			
Weed management practices (W)	5	553.93	110.79	44808.22	2.53	*
T x W interaction	10	5.19	0.52	209.96	2.16	*
Error II	30	0.07	0.00			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.18	0.18	34.12	5.32	*
Replication within years	4	0.03	0.01	1.43	3.48	NS
Tillage system (T)	4	20.06	5.01	969.49	3.84	*
Error I	8	0.04	0.01			
Weed management practices (W)	10	1121.03	112.10	18669.08	1.99	*
T x W interaction	20	9.65	0.48	80.38	1.75	*
Pooled Error II	60	0.36	0.01			

*Significant NS-Non significant

2. Analysis of variance on phosphorus depletion by weeds (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.01	0.00	2.42	6.94	NS
Tillage system (T)	2	2.43	1.21	876.60	6.94	*
Error I	4	0.01	0.00			
Weed management practices (W)	5	131.20	26.24	11567.58	2.53	*
T x W interaction	10	1.06	0.11	46.53	2.16	*
Error II	30	0.07	0.00			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00	0.00	6.14	6.94	NS
Tillage system (T)	2	2.22	1.11	3112.91	6.94	*
Error I	4	0.00	0.00			
Weed management practices (W)	5	128.45	25.69	47828.23	2.53	*
T x W interaction	10	1.21	0.12	225.68	2.16	*
Error II	30	0.02	0.00			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.04	0.04	41.11	5.32	*
Replication within years	4	0.01	0.00	3.18	3.48	NS
Tillage system (T)	4	4.65	1.16	1334.70	3.84	*
Error I	8	0.01	0.00			
Weed management practices (W)	10	259.65	25.96	18509.52	1.99	*
T x W interaction	20	2.27	0.11	80.82	1.75	*
Pooled Error II	60	0.08	0.00			

*Significant NS-Non significant

3. Analysis of variance on potassium depletion by weeds (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.04	0.02	2.69	6.94	NS
Tillage system (T)	2	11.22	5.61	726.08	6.94	*
Error I	4	0.03	0.01			
Weed management practices (W)	5	596.05	119.21	9624.50	2.53	*
T x W interaction	10	4.81	0.48	38.82	2.16	*
Error II	30	0.37	0.01			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.01	0.01	6.00	6.94	NS
Tillage system (T)	2	9.89	4.94	4546.69	6.94	*
Error I	4	0.00	0.00			
Weed management practices (W)	5	581.08	116.22	25034.59	2.53	*
T x W interaction	10	5.56	0.56	119.73	2.16	*
Error II	30	0.14	0.00			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.20	0.20	45.26	5.32	*
Replication within years	4	0.05	0.01	3.10	3.48	NS
Tillage system (T)	4	21.11	5.28	1197.27	3.84	*
Error I	8	0.04	0.00			
Weed management practices (W)	10	1177.14	117.71	13825.56	1.99	*
T x W interaction	20	10.37	0.52	60.88	1.75	*
Pooled Error II	60	0.51	0.01			

*Significant NS-Non significant

4. Analysis of variance on nitrogen content in grain (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00135	0.00067	0.68	6.94	NS
Tillage system (T)	2	0.00671	0.00336	3.38	6.94	NS
Error I	4	0.00397	0.00099			
Weed management practices (W)	5	0.00286	0.00057	0.55	2.53	NS
T x W interaction	10	0.00140	0.00014	0.13	2.16	NS
Error II	30	0.03114	0.00104			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00034	0.00017	0.19	6.94	NS
Tillage system (T)	2	0.00343	0.00172	1.88	6.94	NS
Error I	4	0.00366	0.00091			
Weed management practices (W)	5	0.00039	0.00008	0.10	2.53	NS
T x W interaction	10	0.00306	0.00031	0.38	2.16	NS
Error II	30	0.02420	0.00081			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00205	0.00205	2.14	5.32	NS
Replication within years	4	0.00169	0.00042	0.44	3.48	NS
Tillage system (T)	4	0.01015	0.00254	2.66	3.84	NS
Error I	8	0.00763	0.00095			
Weed management practices (W)	10	0.00325	0.00033	0.35	1.99	NS
T x W interaction	20	0.00445	0.00022	0.24	1.75	NS
Pooled Error II	60	0.05534	0.00092			

*Significant NS-Non significant

5. Analysis of variance on nitrogen content in straw (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00003	0.00001	1.00	6.94	NS
Tillage system (T)	2	0.00011	0.00006	4.43	6.94	NS
Error I	4	0.00005	0.00001			
Weed management practices (W)	5	0.00033	0.00007	1.98	2.53	NS
T x W interaction	10	0.00055	0.00006	1.67	2.16	NS
Error II	30	0.00099	0.00003			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00006	0.00003	0.32	6.94	NS
Tillage system (T)	2	0.00007	0.00004	0.38	6.94	NS
Error I	4	0.00037	0.00009			
Weed management practices (W)	5	0.00103	0.00021	2.00	2.53	NS
T x W interaction	10	0.00102	0.00010	0.99	2.16	NS
Error II	30	0.00310	0.00010			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00021	0.00021	3.91	5.32	NS
Replication within years	4	0.00009	0.00002	0.40	3.48	NS
Tillage system (T)	4	0.00019	0.00005	0.87	3.84	NS
Error I	8	0.00043	0.00005			
Weed management practices (W)	10	0.00136	0.00014	1.99	1.99	NS
T x W interaction	20	0.00157	0.00008	1.15	1.75	NS
Pooled Error II	60	0.00409	0.00007			

*Significant NS-Non significant

6. Analysis of variance on phosphorus content in grain (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00010	0.00005	0.24	6.94	NS
Tillage system (T)	2	0.00113	0.00056	2.61	6.94	NS
Error I	4	0.00086	0.00022			
Weed management practices (W)	5	0.00255	0.00051	2.09	2.53	NS
T x W interaction	10	0.00205	0.00021	0.84	2.16	NS
Error II	30	0.00730	0.00024			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00010	0.00005	1.06	6.94	NS
Tillage system (T)	2	0.00021	0.00011	2.24	6.94	NS
Error I	4	0.00019	0.00005			
Weed management practices (W)	5	0.00131	0.00026	2.48	2.53	NS
T x W interaction	10	0.00201	0.00020	1.90	2.16	NS
Error II	30	0.00318	0.00011			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00024	0.00024	1.80	5.32	NS
Replication within years	4	0.00020	0.00005	0.39	3.48	NS
Tillage system (T)	4	0.00134	0.00033	2.54	3.84	NS
Error I	8	0.00105	0.00013			
Weed management practices (W)	10	0.00386	0.00039	2.21	1.99	*
T x W interaction	20	0.00406	0.00020	1.16	1.75	NS
Pooled Error II	60	0.01048	0.00017			

*Significant NS-Non significant

7. Analysis of variance on phosphorus content in straw (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00014	0.00007	1.18	6.94	NS
Tillage system (T)	2	0.00021	0.00011	1.73	6.94	NS
Error I	4	0.00024	0.00006			
Weed management practices (W)	5	0.00064	0.00013	2.04	2.53	NS
T x W interaction	10	0.00023	0.00002	0.37	2.16	NS
Error II	30	0.00188	0.00006			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00016	0.00008	0.32	6.94	NS
Tillage system (T)	2	0.00055	0.00027	1.11	6.94	NS
Error I	4	0.00099	0.00025			
Weed management practices (W)	5	0.00073	0.00015	1.60	2.53	NS
T x W interaction	10	0.00045	0.00005	0.50	2.16	NS
Error II	30	0.00272	0.00009			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00005	0.00005	0.30	5.32	NS
Replication within years	4	0.00030	0.00008	0.49	3.48	NS
Tillage system (T)	4	0.00076	0.00019	1.23	3.84	NS
Error I	8	0.00123	0.00015			
Weed management practices (W)	10	0.00136	0.00014	1.78	1.99	NS
T x W interaction	20	0.00069	0.00003	0.45	1.75	NS
Pooled Error II	60	0.00460	0.00008			

*Significant NS-Non significant

8. Analysis of variance on potassium content in grain (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00014	0.00007	0.70	6.94	NS
Tillage system (T)	2	0.00101	0.00051	4.92	6.94	NS
Error I	4	0.00041	0.00010			
Weed management practices (W)	5	0.00028	0.00006	0.99	2.53	NS
T x W interaction	10	0.00092	0.00009	1.62	2.16	NS
Error II	30	0.00171	0.00006			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00019	0.00010	0.61	6.94	NS
Tillage system (T)	2	0.00058	0.00029	1.85	6.94	NS
Error I	4	0.00063	0.00016			
Weed management practices (W)	5	0.00141	0.00028	2.13	2.53	NS
T x W interaction	10	0.00086	0.00009	0.65	2.16	NS
Error II	30	0.00398	0.00013			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00000	0.00000	0.03	5.32	NS
Replication within years	4	0.00034	0.00008	0.65	3.48	NS
Tillage system (T)	4	0.00159	0.00040	3.06	3.84	NS
Error I	8	0.00104	0.00013			
Weed management practices (W)	10	0.00169	0.00017	1.79	1.99	NS
T x W interaction	20	0.00179	0.00009	0.94	1.75	NS
Pooled Error II	60	0.00569	0.00009			

*Significant NS-Non significant

9. Analysis of variance on potassium content in straw (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00003	0.00001	0.07	6.94	NS
Tillage system (T)	2	0.00245	0.00122	6.51	6.94	NS
Error I	4	0.00075	0.00019			
Weed management practices (W)	5	0.00048	0.00010	0.53	2.53	NS
T x W interaction	10	0.00240	0.00024	1.33	2.16	NS
Error II	30	0.00542	0.00018			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00342	0.00171	1.14	6.94	NS
Tillage system (T)	2	0.00996	0.00498	3.32	6.94	NS
Error I	4	0.00599	0.00150			
Weed management practices (W)	5	0.00295	0.00059	0.72	2.53	NS
T x W interaction	10	0.00311	0.00031	0.38	2.16	NS
Error II	30	0.02455	0.00082			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00005	0.00005	0.06	5.32	NS
Replication within years	4	0.00345	0.00086	1.02	3.48	NS
Tillage system (T)	4	0.01240	0.00310	3.68	3.84	NS
Error I	8	0.00674	0.00084			
Weed management practices (W)	10	0.00344	0.00034	0.69	1.99	NS
T x W interaction	20	0.00550	0.00028	0.55	1.75	NS
Pooled Error II	60	0.02997	0.00050			

*Significant NS-Non significant

10. Analysis of variance on grain nitrogen uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.03	1.02	1.05	6.94	NS
Tillage system (T)	2	352.54	176.27	181.36	6.94	*
Error I	4	3.89	0.97			
Weed management practices (W)	5	4679.76	935.95	392.68	2.53	*
T x W interaction	10	383.04	38.30	16.07	2.16	*
Error II	30	71.51	2.38			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.37	0.18	0.05	6.94	NS
Tillage system (T)	2	319.82	159.91	47.50	6.94	*
Error I	4	13.47	3.37			
Weed management practices (W)	5	4679.75	935.95	570.02	2.53	*
T x W interaction	10	407.42	40.74	24.81	2.16	*
Error II	30	49.26	1.64			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	7.74	7.74	3.57	5.32	NS
Replication within years	4	2.40	0.60	0.28	3.48	NS
Tillage system (T)	4	672.36	168.09	77.49	3.84	*
Error I	8	17.35	2.17			
Weed management practices (W)	10	9359.51	935.95	465.02	1.99	*
T x W interaction	20	790.46	39.52	19.64	1.75	*
Pooled Error II	60	120.76	2.01			

*Significant NS-Non significant

11. Analysis of variance on straw nitrogen uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.16	0.08	0.44	6.94	NS
Tillage system (T)	2	23.61	11.81	65.58	6.94	*
Error I	4	0.72	0.18			
Weed management practices (W)	5	597.70	119.54	523.70	2.53	*
T x W interaction	10	57.08	5.71	25.01	2.16	*
Error II	30	6.85	0.23			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.53	0.27	0.55	6.94	NS
Tillage system (T)	2	34.31	17.16	35.27	6.94	*
Error I	4	1.95	0.49			
Weed management practices (W)	5	646.29	129.26	251.34	2.53	*
T x W interaction	10	72.62	7.26	14.12	2.16	*
Error II	30	15.43	0.51			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.50	0.50	1.50	5.32	NS
Replication within years	4	0.69	0.17	0.52	3.48	NS
Tillage system (T)	4	57.93	14.48	43.46	3.84	*
Error I	8	2.67	0.33			
Weed management practices (W)	10	1243.99	124.40	335.06	1.99	*
T x W interaction	20	129.70	6.49	17.47	1.75	*
Pooled Error II	60	22.28	0.37			

*Significant NS-Non significant

12. Analysis of variance on grain phosphorus uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.15	0.07	0.18	6.94	NS
Tillage system (T)	2	17.67	8.84	21.30	6.94	*
Error I	4	1.66	0.41			
Weed management practices (W)	5	188.75	37.75	108.53	2.53	*
T x W interaction	10	21.67	2.17	6.23	2.16	*
Error II	30	10.44	0.35			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.07	0.03	0.32	6.94	NS
Tillage system (T)	2	12.52	6.26	57.01	6.94	Significant
Error I	4	0.44	0.11			
Weed management practices (W)	5	179.30	35.86	214.78	2.53	Significant
T x W interaction	10	9.70	0.97	5.81	2.16	Significant
Error II	30	5.01	0.17			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.47	0.47	1.78	5.32	NS
Replication within years	4	0.22	0.05	0.21	3.48	NS
Tillage system (T)	4	30.20	7.55	28.77	3.84	*
Error I	8	2.10	0.26			
Weed management practices (W)	10	368.05	36.80	142.99	1.99	*
T x W interaction	20	31.37	1.57	6.09	1.75	*
Pooled Error II	60	15.44	0.26			

*Significant NS-Non significant

13. Analysis of variance on straw phosphorus uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Replication	2	0.58	0.29	1.26	6.94	NS
Tillage system (T)	2	3.68	1.84	7.97	6.94	*
Error I	4	0.92	0.23			
Weed management practices (W)	5	35.69	7.14	35.41	2.53	*
T x W interaction	10	2.72	0.27	1.35	2.16	NS
Error II	30	6.05	0.20			

ANOVA table for second year 2022

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Replication	2	0.51	0.25	0.34	6.94	NS
Tillage system (T)	2	6.28	3.14	4.16	6.94	NS
Error I	4	3.02	0.76			
Weed management practices (W)	5	38.80	7.76	27.38	2.53	*
T x W interaction	10	3.26	0.33	1.15	2.16	NS
Error II	30	8.50	0.28			

ANOVA TABLE OF POOLED ANALYSIS

Source of Variance	df	SS	MSS	F Cal	F Tab at 5%	S/SN
Years	1	0.13	0.13	0.27	5.32	NS
Replication within years	4	1.09	0.27	0.55	3.48	NS
Tillage system (T)	4	9.97	2.49	5.05	3.84	*
Error I	8	3.95	0.49			
Weed management practices (W)	10	74.49	7.45	30.71	1.99	*
T x W interaction	20	5.98	0.30	1.23	1.75	NS
Pooled Error II	60	14.55	0.24			

*Significant NS-Non significant

14. Analysis of variance on grain potassium uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.19	0.09	0.61	6.94	NS
Tillage system (T)	2	21.85	10.92	70.25	6.94	*
Error I	4	0.62	0.16			
Weed management practices (W)	5	231.26	46.25	416.65	2.53	*
T x W interaction	10	18.43	1.84	16.60	2.16	*
Error II	30	3.33	0.11			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.23	0.11	0.31	6.94	NS
Tillage system (T)	2	17.96	8.98	24.73	6.94	*
Error I	4	1.45	0.36			
Weed management practices (W)	5	252.51	50.50	194.88	2.53	*
T x W interaction	10	13.90	1.39	5.37	2.16	*
Error II	30	7.77	0.26			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.11	0.11	0.44	5.32	NS
Replication within years	4	0.42	0.10	0.40	3.48	NS
Tillage system (T)	4	39.81	9.95	38.38	3.84	*
Error I	8	2.07	0.26			
Weed management practices (W)	10	483.78	48.38	261.39	1.99	*
T x W interaction	20	32.33	1.62	8.73	1.75	*
Pooled Error II	60	11.10	0.19			

*Significant NS-Non significant

15. Analysis of variance on straw potassium uptake (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.008	0.004	0.011	6.94	NS
Tillage system (T)	2	172.83	86.42	243.15	6.94	*
Error I	4	1.42	0.36			
Weed management practices (W)	5	2212.67	442.53	507.50	2.53	*
T x W interaction	10	164.63	16.46	18.88	2.16	*
Error II	30	26.16	0.87			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	11.81	5.91	1.14	6.94	NS
Tillage system (T)	2	246.46	123.23	23.81	6.94	*
Error I	4	20.71	5.18			
Weed management practices (W)	5	2172.11	434.42	145.70	2.53	*
T x W interaction	10	168.29	16.83	5.64	2.16	*
Error II	30	89.45	2.98			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.00008	0.00008	0.00003	5.32	NS
Replication within years	4	11.82	2.95	1.07	3.48	NS
Tillage system (T)	4	419.30	104.82	37.90	3.84	*
Error I	8	22.13	2.77			
Weed management practices (W)	10	4384.78	438.48	227.57	1.99	*
T x W interaction	20	332.92	16.65	8.64	1.75	*
Pooled Error II	60	115.61	1.93			

*Significant NS-Non significant

APPENDIX-VIII

ANOVA for energy analysis

1. Analysis of variance on output energy (MJ ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	32657.35	16328.67	0.01	6.94	NS
Tillage system (T)	2	613054461.13	306527230.56	198.06	6.94	*
Error I	4	6190709.28	1547677.32			
Weed management practices (W)	5	11640638651.15	2328127730.23	3055.91	2.53	*
T x W interaction	10	988027907.36	98802790.74	129.69	2.16	*
Error II	30	22855323.00	761844.10			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1913913.03	956956.52	2.93	6.94	NS
Tillage system (T)	2	620509042.03	310254521.02	948.74	6.94	*
Error I	4	1308070.04	327017.51			
Weed management practices (W)	5	11815721146.56	2363144229.31	3260.43	2.53	*
T x W interaction	10	992551636.14	99255163.61	136.94	2.16	*
Error II	30	21743834.41	724794.48			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	679722.32	679722.32	0.73	5.32	NS
Replication within years	4	1946570.38	486642.59	0.52	3.48	NS
Tillage system (T)	4	1233563503.16	308390875.79	329.00	3.84	*
Error I	8	7498779.32	937347.42			
Weed management practices (W)	10	23456359797.71	2345635979.77	3155.62	1.99	*
T x W interaction	20	1980579543.50	99028977.17	133.23	1.75	*
Pooled Error II	60	44599157.41	743319.29			

*Significant NS-Non significant

3. Analysis of variance on energy use efficiency as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.00009	0.00005	0.01	6.94	NS
Tillage system (T)	2	1.59645	0.79823	173.05	6.94	Significant
Error I	4	0.01845	0.00461			
Weed management practices (W)	5	31.71478	6.34296	2805.83	2.53	Significant
T x W interaction	10	2.90804	0.29080	128.64	2.16	Significant
Error II	30	0.06782	0.00226			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.006	0.003	2.88	6.94	NS
Tillage system (T)	2	1.617	0.808	829.87	6.94	*
Error I	4	0.004	0.001			
Weed management practices (W)	5	32.235	6.447	2995.28	2.53	*
T x W interaction	10	2.922	0.292	135.76	2.16	*
Error II	30	0.065	0.002			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.002	0.002	0.72	5.32	NS
Replication within years	4	0.006	0.001	0.51	3.48	NS
Tillage system (T)	4	3.213	0.803	287.56	3.84	*
Error I	8	0.022	0.003			
Weed management practices (W)	10	63.950	6.395	2898.23	1.99	*
T x W interaction	20	5.830	0.292	132.11	1.75	*
Pooled Error II	60	0.132	0.002			

*Significant NS-Non significant

APPENDIX-IX

ANOVA for succeeding weed density, weed dry weight, crop growth and yield

1. Analysis of variance on weed density (no. m^{-2}) at 20 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.82	0.41	1.26	6.94	**NS**
Tillage system (T)	2	2.53	1.27	3.88	6.94	**NS**
Error I	4	1.30	**0.33**			
Weed management practices (W)	5	26.82	5.36	14.30	2.53	**Significant**
T x W interaction	10	3.45	0.34	0.92	2.16	**NS**
Error II	30	11.26	**0.38**			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.11	0.06	4.42	6.94	NS
Tillage system (T)	2	2.72	1.36	107.85	6.94	Significant
Error I	4	0.05	0.01			
Weed management practices (W)	5	27.84	5.57	46.27	2.53	Significant
T x W interaction	10	2.60	0.26	2.16	2.16	NS
Error II	30	3.61	0.12			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.10	0.10	0.59	5.32	NS
Replication within years	4	0.93	0.23	1.38	3.48	NS
Tillage system (T)	4	5.25	1.31	7.75	3.84	*
Error I	8	1.35	0.17			
Weed management practices (W)	10	54.66	5.47	22.06	1.99	*
T x W interaction	20	6.04	0.30	1.22	1.75	NS
Pooled Error II	60	14.87	0.25			

*Significant NS-Non significant

2. Analysis of variance on weed dry weight (g m^{-2}) at 20 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.84	0.42	1.15	6.94	NS
Tillage system (T)	2	0.15	0.07	0.20	6.94	NS
Error I	4	1.45	0.36			
Weed management practices (W)	5	38.51	7.70	8.88	2.53	*
T x W interaction	10	3.87	0.39	0.45	2.16	NS
Error II	30	26.02	0.87			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.09	1.04	3.54	6.94	NS
Tillage system (T)	2	1.02	0.51	1.73	6.94	NS
Error I	4	1.18	0.29			
Weed management practices (W)	5	34.90	6.98	8.47	2.53	*
T x W interaction	10	6.01	0.60	0.73	2.16	NS
Error II	30	24.72	0.82			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.87	0.87	2.63	5.32	NS
Replication within years	4	2.92	0.73	2.22	3.48	NS
Tillage system (T)	4	1.17	0.29	0.89	3.84	NS
Error I	8	2.63	0.33			
Weed management practices (W)	10	73.41	7.34	8.68	1.99	*
T x W interaction	20	9.88	0.49	0.58	1.75	NS
Pooled Error II	60	50.73	0.85			

*Significant NS-Non significant

3. Analysis of variance on initial plant population (no. m^{-2}) of sunflower as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	32.93	16.46	1.25	6.94	NS
Tillage system (T)	2	161.59	80.80	6.13	6.94	NS
Error I	4	52.74	13.19			
Weed management practices (W)	5	92.09	18.42	2.20	2.53	NS
T x W interaction	10	67.07	6.71	0.80	2.16	NS
Error II	30	251.67	8.39			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	3.37	1.69	0.16	6.94	NS
Tillage system (T)	2	104.15	52.07	4.89	6.94	NS
Error I	4	42.63	10.66			
Weed management practices (W)	5	64.31	12.86	2.46	2.53	NS
T x W interaction	10	73.19	7.32	1.40	2.16	NS
Error II	30	156.67	5.22			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	6.26	6.26	0.53	5.32	NS
Replication within years	4	36.30	9.07	0.76	3.48	NS
Tillage system (T)	4	265.74	66.44	5.57	3.84	*
Error I	8	95.37	11.92			
Weed management practices (W)	10	156.41	15.64	2.30	1.99	*
T x W interaction	20	140.26	7.01	1.03	1.75	NS
Pooled Error II	60	408.33	6.81			

*Significant NS-Non significant

4 (a) Analysis of variance on chlorophyll content (micro mol m^{-2}) at 25 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.20	0.60	0.93	6.94	NS
Tillage system (T)	2	0.30	0.15	0.23	6.94	NS
Error I	4	2.58	0.65			
Weed management practices (W)	5	19.92	3.98	1.83	2.53	NS
T x W interaction	10	2.80	0.28	0.13	2.16	NS
Error II	30	65.33	2.18			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.68	0.34	1.12	6.94	NS
Tillage system (T)	2	4.87	2.43	8.02	6.94	*
Error I	4	1.21	0.30			
Weed management practices (W)	5	8.72	1.74	2.37	2.53	NS
T x W interaction	10	4.97	0.50	0.68	2.16	NS
Error II	30	22.08	0.74			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.82	0.82	1.72	5.32	NS
Replication within years	4	1.88	0.47	0.99	3.48	NS
Tillage system (T)	4	5.16	1.29	2.72	3.84	NS
Error I	8	3.79	0.47			
Weed management practices (W)	10	28.63	2.86	1.97	1.99	NS
T x W interaction	20	7.77	0.39	0.27	1.75	NS
Pooled Error II	60	87.41	1.46			

*Significant NS-Non significant

4(b) Analysis of variance on chlorophyll content (micro mol m^{-2}) at 50 DAS as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	91.91	45.95	4.49	6.94	NS
Tillage system (T)	2	16.95	8.48	0.83	6.94	NS
Error I	4	40.98	10.24			
Weed management practices (W)	5	145.02	29.00	1.39	2.53	NS
T x W interaction	10	283.25	28.33	1.35	2.16	NS
Error II	30	627.15	20.90			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.85	0.42	0.09	6.94	NS
Tillage system (T)	2	90.29	45.14	9.84	6.94	*
Error I	4	18.36	4.59			
Weed management practices (W)	5	24.73	4.95	1.31	2.53	NS
T x W interaction	10	72.28	7.23	1.92	2.16	NS
Error II	30	113.04	3.77			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	7.08	7.08	0.95	5.32	NS
Replication within years	4	92.76	23.19	3.13	3.48	NS
Tillage system (T)	4	107.24	26.81	3.61	3.84	NS
Error I	8	59.33	7.42			
Weed management practices (W)	10	169.75	16.97	1.38	1.99	NS
T x W interaction	20	355.53	17.78	1.44	1.75	NS
Pooled Error II	60	740.18	12.34			

*Significant NS-Non significant

5. Analysis of variance on plant height at harvest (cm) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.15	1.08	0.04	6.94	NS
Tillage system (T)	2	45.25	22.63	0.84	6.94	NS
Error I	4	108.02	27.01			
Weed management practices (W)	5	94.42	18.88	1.54	2.53	NS
T x W interaction	10	103.23	10.32	0.84	2.16	NS
Error II	30	367.45	12.25			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	5.64	2.82	1.15	6.94	NS
Tillage system (T)	2	34.79	17.40	7.09	6.94	Significant
Error I	4	9.81	2.45			
Weed management practices (W)	5	51.95	10.39	2.45	2.53	NS
T x W interaction	10	23.54	2.35	0.56	2.16	NS
Error II	30	127.02	4.23			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	3.52	3.52	0.24	5.32	NS
Replication within years	4	7.79	1.95	0.13	3.48	NS
Tillage system (T)	4	80.04	20.01	1.36	3.84	NS
Error I	8	117.84	14.73			
Weed management practices (W)	10	146.37	14.64	1.78	1.99	NS
T x W interaction	20	126.77	6.34	0.77	1.75	NS
Pooled Error II	60	494.47	8.24			

*Significant NS-Non significant

6. Analysis of variance on head diameter (cm) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.18	0.09	0.40	6.94	NS
Tillage system (T)	2	0.56	0.28	1.21	6.94	NS
Error I	4	0.92	0.23			
Weed management practices (W)	5	2.75	0.55	1.55	2.53	NS
T x W interaction	10	0.57	0.06	0.16	2.16	NS
Error II	30	10.67	0.36			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.07	0.03	0.20	6.94	NS
Tillage system (T)	2	1.22	0.61	3.44	6.94	NS
Error I	4	0.71	0.18			
Weed management practices (W)	5	3.14	0.63	2.48	2.53	NS
T x W interaction	10	1.19	0.12	0.47	2.16	NS
Error II	30	7.61	0.25			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.51	0.51	2.53	5.32	NS
Replication within years	4	0.25	0.06	0.31	3.48	NS
Tillage system (T)	4	1.77	0.44	2.18	3.84	NS
Error I	8	1.62	0.20			
Weed management practices (W)	10	5.90	0.59	1.94	1.99	NS
T x W interaction	20	1.77	0.09	0.29	1.75	NS
Pooled Error II	60	18.28	0.30			

*Significant NS-Non significant

7. Analysis of variance on number of seeds head^{-1} as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	291.99	145.99	0.96	6.94	NS
Tillage system (T)	2	8330.32	4165.16	27.26	6.94	Significant
Error I	4	611.21	152.80			
Weed management practices (W)	5	8456.67	1691.33	2.02	2.53	NS
T x W interaction	10	3596.14	359.61	0.43	2.16	NS
Error II	30	25179.75	839.32			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	466.38	233.19	0.44	6.94	NS
Tillage system (T)	2	7598.88	3799.44	7.21	6.94	*
Error I	4	2107.38	526.85			
Weed management practices (W)	5	3474.44	694.89	1.39	2.53	NS
T x W interaction	10	4378.87	437.89	0.87	2.16	NS
Error II	30	15047.27	501.58			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	2044.55	2044.55	6.02	5.32	*
Replication within years	4	758.37	189.59	0.56	3.48	NS
Tillage system (T)	4	15929.20	3982.30	11.72	3.84	*
Error I	8	2718.59	339.82			
Weed management practices (W)	10	11931.10	1193.11	1.78	1.99	NS
T x W interaction	20	7975.01	398.75	0.59	1.75	NS
Pooled Error II	60	40227.02	670.45			

*Significant NS-Non significant

8. Analysis of variance on seed yield (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	24.33	12.17	0.81	6.94	NS
Tillage system (T)	2	697.43	348.72	23.18	6.94	*
Error I	4	60.18	15.04			
Weed management practices (W)	5	399.94	79.99	2.44	2.53	NS
T x W interaction	10	167.00	16.70	0.51	2.16	NS
Error II	30	984.95	32.83			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	196.94	98.47	1.07	6.94	NS
Tillage system (T)	2	2868.16	1434.08	15.62	6.94	*
Error I	4	367.18	91.79			
Weed management practices (W)	5	2093.86	418.77	1.71	2.53	NS
T x W interaction	10	1337.73	133.77	0.55	2.16	NS
Error II	30	7328.33	244.28			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	259.10	259.10	4.85	5.32	NS
Replication within years	4	221.27	55.32	1.04	3.48	NS
Tillage system (T)	4	3565.59	891.40	16.69	3.84	*
Error I	8	427.35	53.42			
Weed management practices (W)	10	2493.80	249.38	1.80	1.99	NS
T x W interaction	20	1504.73	75.24	0.54	1.75	NS
Pooled Error II	60	8313.28	138.55			

*Significant NS-Non significant

9. Analysis of variance on stover yield (kg ha^{-1}) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	33853.19	16926.59	0.71	6.94	NS
Tillage system (T)	2	30346.09	15173.05	0.63	6.94	NS
Error I	4	95852.06	23963.01			
Weed management practices (W)	5	234730.66	46946.13	1.88	2.53	NS
T x W interaction	10	128253.29	12825.33	0.51	2.16	NS
Error II	30	749739.20	24991.31			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	48793.16	24396.58	0.64	6.94	NS
Tillage system (T)	2	33938.89	16969.45	0.44	6.94	NS
Error I	4	153556.31	38389.08			
Weed management practices (W)	5	225684.77	45136.95	2.02	2.53	NS
T x W interaction	10	119137.53	11913.75	0.53	2.16	NS
Error II	30	668962.95	22298.77			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	1894.47	1894.47	0.06	5.32	NS
Replication within years	4	82646.35	20661.59	0.66	3.48	NS
Tillage system (T)	4	64284.98	16071.25	0.52	3.84	NS
Error I	8	249408.37	31176.05			
Weed management practices (W)	10	460415.42	46041.54	1.95	1.99	NS
T x W interaction	20	247390.82	12369.54	0.52	1.75	NS
Pooled Error II	60	1418702.15	23645.04			

*Significant   NS-Non significant

10. Analysis of variance on test weight (g) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	0.03	0.02	0.08	6.94	NS
Tillage system (T)	2	0.09	0.05	0.24	6.94	NS
Error I	4	0.78	0.19			
Weed management practices (W)	5	1.55	0.31	2.23	2.53	NS
T x W interaction	10	1.38	0.14	0.99	2.16	NS
Error II	30	4.16	0.14			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	1.57	0.78	1.28	6.94	NS
Tillage system (T)	2	0.29	0.15	0.24	6.94	NS
Error I	4	2.46	0.61			
Weed management practices (W)	5	5.00	1.00	2.51	2.53	NS
T x W interaction	10	3.25	0.33	0.82	2.16	NS
Error II	30	11.95	0.40			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	1.11	1.11	2.75	5.32	NS
Replication within years	4	1.60	0.40	0.99	3.48	NS
Tillage system (T)	4	0.38	0.10	0.24	3.84	NS
Error I	8	3.23	0.40			
Weed management practices (W)	10	6.55	0.65	2.44	1.99	*
T x W interaction	20	4.63	0.23	0.86	1.75	NS
Pooled Error II	60	16.10	0.27			

*Significant NS-Non significant

11. Analysis of variance on harvest index (%) as influenced by different tillage system and weed management practices.

ANOVA table for first year 2021						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	2.70	1.35	0.67	6.94	NS
Tillage system (T)	2	1.66	0.83	0.41	6.94	NS
Error I	4	8.01	2.00			
Weed management practices (W)	5	18.66	3.73	1.67	2.53	NS
T x W interaction	10	11.04	1.10	0.49	2.16	NS
Error II	30	66.96	2.23			

ANOVA table for second year 2022						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Replication	2	4.95	2.48	0.80	6.94	NS
Tillage system (T)	2	1.28	0.64	0.21	6.94	NS
Error I	4	12.43	3.11			
Weed management practices (W)	5	14.49	2.90	1.50	2.53	NS
T x W interaction	10	11.45	1.14	0.59	2.16	NS
Error II	30	57.91	1.93			

ANOVA TABLE OF POOLED ANALYSIS						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/SN**
Years	1	0.02	0.02	0.01	5.32	NS
Replication within years	4	7.65	1.91	0.75	3.48	NS
Tillage system (T)	4	2.94	0.74	0.29	3.84	NS
Error I	8	20.45	2.56			
Weed management practices (W)	10	33.14	3.31	1.59	1.99	NS
T x W interaction	20	22.49	1.12	0.54	1.75	NS
Pooled Error II	60	124.87	2.08			

*Significant NS-Non significant