



**EFFECT OF SOWING DATES, PLANTING GEOMETRY
AND FERTILITY LEVELS ON GROUNDNUT (*Arachis
hypogaea* L.) UNDER FOOTHILL CONDITION OF
NAGALAND**

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

By

Zulutemjen Jamir

Admn. No. Ph – 261/18 Regn. No. Ph.D./AGR/00208

**Department of Agronomy,
School of Agricultural Sciences,
Nagaland University,
Medziphema Campus – 797106, Nagaland
December, 2025**



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BY

Name of candidate- Zulutemjen Jamir

Name of Supervisor- Dr. Lanunola Tzudir

Submitted

In partial fulfillment of the requirements for the Degree of Doctor of

Philosophy in

Agronomy of Nagaland University

Dedicated

To

My loving and supportive family

Nagaland University
July, 2024

I, Zulutemjen Jamir, 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 Nagaland University for the degree of Doctor of Philosophy in Agronomy

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CERTIFICATE – I

This is to certify that the thesis entitled “**Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland**” submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Agronomy is the record of research work carried out by Mr. Zulutemjen Jamir, Registration No. Ph.D./AGR/00208 under my personal supervision and guidance.

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

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CERTIFICATE - II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRONOMY

This is to certify that the thesis entitled “**Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland**” submitted by Mr. Zulutemjen Jamir, Admission No. Ph-261/18 Registration No. Ph.D./AGR/00208 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

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LIST OF ABBREVIATIONS

%	-	Percentage
@	-	at the rate of
₹	-	Rupees
⁻¹ or /	-	Per
ai	-	active ingredient
BCR	-	Benefit Cost ratio
CD	-	Critical Difference
cm	-	Centimetre
DAS	-	Days after sowing
df	-	Degree of freedom
<i>et al.</i>	-	<i>et allia</i> (and others/co-workers)
<i>fb</i>	-	Followed by
Fig.	-	Figure
g	-	Gram
ha	-	Hectare
<i>i.e.</i>	-	Id est (that is)
kg	-	Kilogram
m	-	Metre
m ²	-	Metre square
Max.	-	Maximum
Min.	-	Minimum
mm	-	Millimetre
MOP	-	Muriate of Potash
msl	-	Mean sea level
Mss	-	Mean sum of squares
mt	-	Million tonnes
NPK	-	Nitrogen Phosphorus Potassium
NS	-	Not significant
NU	-	Nagaland University

°C	-	Degree Celsius
RDF	-	Recommended Dose of Fertilizers
SAS	-	School of Agricultural Sciences
SEm±	-	Standard error of mean
Sl. No.	-	Serial number
SOV	-	Source of Variation
ss	-	Sum of square
SSP		Single Superphosphate
t	-	tonnes
<i>viz.</i>	-	Videlicet (Namely)

ABSTRACT

The experiment entitled "Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland" was conducted during 2019-2021 in the Agronomy experimental farm of School of Agricultural Sciences (SAS), Medziphema Campus, Nagaland. The experimental field was laid out in split plot randomized design with two main factors: Sowing dates- 20th June (D₁) and 10th July (D₂); Fertility level 75% RDF (F₁); 100% RDF (F₂); 125% RDF (F₃) and sub plot treatments of planting geometry: (S₁) 30 cm × 10 cm; (S₂) 40 cm × 10 cm; (S₃) 50 cm × 10 cm and consisting of 18 treatment D₁F₁S₁; D₁F₁S₂; D₁F₁S₃; D₁F₂S₁; D₁F₂S₂; D₁F₂S₃; D₁F₃S₁; D₁F₃S₂; D₁F₃S₃; D₂F₁S₁; D₂F₁S₂; D₂F₁S₃; D₂F₂S₁; D₂F₂S₂; D₂F₂S₃; D₂F₃S₁; D₂F₃S₂; D₂F₃S₃.

The pooled data results revealed 20th June sowing along with 125% RDF recorded significantly the highest growth and yield attributes of groundnut viz. plant height (32.59 cm), number of primary branches (10.48), number of leaves (75.33), leaf are index (4.81), crop growth rate (6.99 g m⁻² day⁻¹), net assimilation rate (1.48 g day⁻¹m⁻²), shoot dry weight (31.59g), number of pods plant⁻¹ (19.22), seed yield (1.57 t ha⁻¹), stover yield (2.61 t ha⁻¹), shelling percentage (67.44 %) and oil content (43.50%). The pooled data results revealed S³ recorded significantly maximum plant height (33.70 cm), number of primary branches (10.17), number of leaves (74.28), leaf are index (4.09), crop growth rate (7.06 g m⁻² day⁻¹), net assimilation rate (1.35 g day⁻¹m⁻²), shoot dry weight (31.33g), number of pods plant⁻¹ (18.70), seed yield (1.35 t ha⁻¹), stover yield (2.40 t ha⁻¹), shelling percentage (67.31%) and oil content (42.97%).

Application of 20th June sowing along with 125% RDF recorded maximum soil organic carbon (1.48), nitrogen (292.86 kg ha⁻¹), phosphorus (30.60 kg ha⁻¹) and potassium (167.02 kg ha⁻¹) while in terms of total uptake it

followed a similar pattern of D₁F₃ with maximum uptake of total nitrogen (68.86 kg ha⁻¹), phosphorus (8.31 kg ha⁻¹), potassium (51.99 kg ha⁻¹).

Application of S₃ recorded maximum soil organic carbon (1.48), nitrogen (286.71 kg ha⁻¹), phosphorus (25.87 kg ha⁻¹) and potassium (163.96 kg ha⁻¹) while in terms of total uptake it followed a similar pattern of D₁F₃ with maximum uptake of nitrogen (66.53 kg ha⁻¹), phosphorus (8.66 kg ha⁻¹), potassium (51.99 kg ha⁻¹), protein content (21.90%) and oil content (54.42%). The highest gross returns were noted in D₂F₃S₃ (late sowing with 125% RDF, 50 cm × 10 cm spacing) at ₹42,336.67 ha⁻¹ (2019) and D₁F₃S₂ (early sowing with 125% RDF, 40 cm × 10 cm spacing) at ₹57,053.33 ha⁻¹ (2020). The highest net returns were in D₁F₂S₁ (early sowing with 100% RDF, 30 cm × 10 cm spacing) at ₹20,644.25 ha⁻¹ (2019) and D₁F₃S₂ at ₹34,448.63 ha⁻¹ (2020). The highest benefit-cost ratio was 1.67 (2019) for D₁F₁S₂ (early sowing with 75% RDF, 40 cm × 10 cm spacing) and 2.08 (2020) for D₁F₂S₃ (early sowing with 100% RDF, 50 cm × 10 cm spacing).

Keywords: early sowing, fertility levels, spacing and groundnut

CHAPTER I

INTRODUCTION

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the king of oilseed crops, and is believed to be native of Brazil (South America). The groundnut is important oil, food and forage crop generally distributed in tropical, subtropical and warm temperate zones (Hammons, 1994) and belongs to the family *Fabaceae* and sub family papilionaceae. It is known by many other names such as poor man's almond, wonder nut, peanut, earthnut, ground nut, goober pea, monkey nut, pygmy nut and pig nut. Despite its name and appearance, the peanut is not a nut, but rather a legume.

Groundnut is the fourth most important source of edible oil, third most important source of vegetable protein and good nutritional attributes. The groundnut concentrated protein fortified with various cereals in the diets has made a significant contribution in alleviating protein energy malnutrition in many countries which leads to increases in the production of groundnut cultivation (Savage and Keenan, 1994). It contains moisture (5.53 per cent), crude fibre (1.15 per cent), lipid (46.22 per cent), crude protein (25.20 per cent), carbohydrate (21.26 per cent), ash (2.57 per cent), calcium (0.08 per cent), phosphorus (0.29 per cent) and energy (601.86 per cent). The total fatty acid composition was 10.44 and 33.51 per cent for saturated and unsaturated, respectively.

The average annual production of groundnut across the world accounts for 539 lakh tons from an area of 337 lakh hectares (Anonymous, 2022). In India, groundnut occupies an area of 47.07 lakh hectares with production of 101.801 lakh tonnes in 2023-2024 (Anonymous, 2023-2024). where as in Nagaland the groundnut is grown at 0.021 lakh hectares with a

productivity of 0.022 lakh tons (Anonymous, 2023-2024). Major groundnut growing states are Gujarat, Rajasthan, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. In India groundnut occupies first in terms of area and second position in terms of production. China is the largest producer as well as consumer of groundnut in the world followed by India, Nigeria and United States. The average groundnut yield, in India, is around 1 t ha⁻¹, the non-traditional groundnut area in NE states harvest 3-3.5 t ha⁻¹ of pods in about 100-120 days (Singh *et al.*, 2003). In NE states due to cooler climatic conditions and short day nature of growing season, the production system does not support aflatoxin development in groundnut beyond permissible limit and that could be the boon to the farmers. Therefore, there is a huge scope for large scale cultivation of groundnut in NE states for export to ASEAN countries (Anonymous, 2018).

Groundnut plays a pivotal role in the diets of rural populations, has a distinct position among the oilseeds economy of India, can be consumed and utilized in diverse ways. It is valued both for edible oil and confectionery purposes. The groundnut kernels are consumed as raw, boiled, roasted or fried products and also used in a variety of culinary preparations like peanut butter, peanut milk and chocolates.

Groundnut is grown throughout the tropics and its cultivation is extended to the subtropical up to an altitude of 1000 metres. The crop can be grown successfully in places receiving a minimum rainfall of 1250 mm. The rainfall should be well distributed during the flowering and pegging of the crop. The total amount required for pre-sowing operations (preparatory cultivation) is 100 mm; for sowing, it is 150 mm and for flowering and pod development an evenly distributed rainfall of 400-500 mm is required. The groundnut crop, however, cannot stand frost, long and severe drought or water stagnation. Agro-ecological conditions of NEH region are suitable for cultivation of groundnut.

In dry land agriculture, farmers have limited choice for sowing time, but in irrigated situation sowing time is one of the most important non-monetary inputs affecting yield of crops (Sardana and Kandhola, 2007). Major reasons for low groundnut yield in India are the use of low yield potential varieties, maintenance of inadequate plant population, poor soil fertility and water management. Groundnut performs better in terms of yield and quality when good cultivar sown under optimum plant density coupled with efficient nutrient and water management. Several studies indicated that proper crop geometry facilitates sufficient interception of sunlight and satisfactory absorption of nutrients and water from the soil due to proper development of root system. Groundnut being a leguminous crop, it is capable of fixing atmospheric nitrogen by the root nodule bacteria. Application of nitrogenous fertilizer at lower doses would be sufficient and also, application of phosphorus and potassium in adequate quantities become more essential for obtaining higher yields. Several workers have shown that adoption of an improved variety alone can increase the yield by about 20 per cent. There are reports that application of gypsum to peanut increased the seedling vigour, seed yield and quality by altering the soil physical characteristics (Annadurai *et al.* 2009).

An optimum plant density is one of the important factor for increasing crop yield per hectare of groundnut. Higher plant population can be achieved by reducing the distance between two rows and also spacing provides better condition for plant growth which resulted in timely commencement of reproductive phase and formation of more pods. Suitable plant geometry can be obtained by planting the crop at proper row spacing. Therefore, the use of proper row spacing to get appropriate plant stand is a pre-requisite for higher crop yield per unit area (Chaudhari *et al.* 2018).

For obtaining better growth and yield of groundnut crop proper sowing time, spacing and fertility levels have to be studied. Groundnut is

popular among the farmers because it provides greater and assured returns compare to most of competing crops. However, the information on optimum sowing time, spacing and nutrient requirement of groundnut for *kharif* is not available under foothills conditions of Nagaland. Keeping in view these considerations relating to *kharif* groundnut, an experiment will be carried out to study the **“Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland”** with the following objectives.

1. To find out the suitable date of sowing, spacing and fertility level on growth, yield and quality of groundnut.
2. To assess the effect of date of sowing, spacing and fertility levels on nutrient concentration, their uptake and soil fertility status.
3. To study the economics of different treatments under study.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter briefly describes the research works carried out on different date of sowing and the effect of planting geometry and nutrient management on the productivity of groundnut. For convenience of consultation, the findings have been briefly reviewed under the following heads.

2.1 Effect of date of sowing

2.1.1 Effect of different date of sowing on growth and yield attributes

2.1.2 Effect of different date of sowing on quality of groundnut

2.2 Effect of spacing

2.2.1 Effect of different spacing on growth and yield attributes

2.2.2 Effect of spacing on nutrient uptake and nutrient concentration in soil.

2.2.3 Effect of spacing on quality of groundnut.

2.3 Effect of NPK levels

2.3.1 Effect of levels of NPK on growth and yield attributes

2.3.2 Effect of levels of NPK on nutrient uptake and nutrient concentration.

2.3.3 Effect of levels of NPK on quality of groundnuts

2.4 Economics

2.1 Effect of date of sowing.

2.1.1 Effect of different date of sowing on growth and yield attributes.

Kumar *et al.* (2003) conducted a field experiment during the rainy season of 1997 and 1998 at Agricultural Research Station, Durgapura, Jaipur and reported that the crop sown on 1st June recorded significantly higher productivity in term of pod, kernel and haulm yield representing increase of

21.58, 25.88 and 21.50 per cent and 40.23, 49.85 and 48.20 per cent over 16th June and 1st July sowing, respectively.

Sajo and Mohammed (2004) conducted a field trial at Adamawa State, Nigeria with the planting dates early June, late June, early July and late July. It was observed that the tallest plants were produced from the early and late June planting giving the highest value. Similarly, the planting dates of early and late June gave the earliest flowering, higher values for numbers of pods per plant and performed better. Planting groundnut by late June could give earlier flowering and higher pod and grains yield than all the other planting dates investigated and advise to allow the rains to be well established before planting. Delayed planting to the month of July may resulted in lower total grain yield because of lower number of pods per plant and shorter growing period

Banik *et al.* (2009) reported that the number of pods per plant, pod yield, kernel yield and leaf area index significantly varied due to variation in dates of sowing.

Bala *et al.* (2011) observed that sowing date has a very strong influence on groundnut performance, particularly with respect to pod number per plant and pod, seed and haulm yields. In this particular study, NPK fertilizer application had a modest influence on groundnut performance. Sowing of groundnut in mid-June with application of 20 kg N+26 kg P and 29 kg K per ha will produce decent pod, seed and haulm yields in semi-arid parts of Nigeria.

Prathima *et al.* (2012) conducted an experiment at S.V. Agricultural college, Dryland farm, Tirupati, Andhra Pradesh with four dates of sowing (Second fortnight of May, First fortnight of June, Second fortnight of June and First fortnight of July) and four Varieties. The results revealed that sowing during July first fortnight was found to be optimum time for groundnut during

drought year, while during normal year advancing the sowing date by one month favoured good crop provided there were good rains.

Meena *et al.* (2014) conducted an experiment in split-plot design with four dates of sowing (April 20, May 15, June 9 and July 4) and two varieties (HNG 10 and TG 37A) in main-plot and four fertility levels (0, 20 N : 40 P₂O₅, 30 N : 60 P₂O₅ and 40 N : 80 P₂O₅ kg ha⁻¹) in sub-plot. Yield component of semispreading variety 'HNG 10' *i.e.* pods/plant, number of kernel/pod, seed index, shelling percentage and yields *i.e.* pod, kernel, haulm and biological yield were statistically at par with each other from April 20 to June 9 sowing and minimum yield was observed in July 4 sowing, while days to maturity reduced significantly with delay sowing. Variety 'TG 37A' sown at July 4 had higher yield attributes and yields than earlier sowing. Higher yield components and yields were recorded in 30 kg N-60 kg P₂O₅ ha⁻¹ which was at par with 40 kg N-80 kg P₂O₅ ha⁻¹. On the basis of economics, June 9 sowing variety 'HNG 10' of groundnut recorded higher net return.

Kanade *et al.* (2015) conducted a field experiment using groundnut (variety JL-24) during *kharif* season at Department of Agricultural Meteorology Farm, College of Agriculture, Pune, with five sowing dates 22nd June, 29th June, 6th July, 13th July and 20th July. The results indicated that the treatment sown on 6th July significantly influenced various growth attributes, yield attributing characters and yield which were found significantly superior over all the other sowing date treatments.

Anil *et al.* (2017) evaluated the effect of agroclimatic indices and yield in groundnut (*Arachis hypogaea* L.) at different dates of sowing and found that temperature, photoperiod and sunshine hours had positive influence with grain filling stage *i.e.* from days to first pod initiation to physiological maturity. Significant variation was also observed for yield among the varieties and dates

of sowing where June 21st sowing recorded higher yield followed by July 14th sowing and July 30th sowing respectively.

Raagavalli *et al.* (2019) conducted a field experiment at Agricultural & Horticultural Research Station, Shivamogga, Karnataka under rainfed conditions during *kharif* with three varieties sown at three different times. Among the four different times of sowing, second forth night of June recorded higher growth and yield attributes over the other four dates of sowing.

Kumar *et al.* (2020) studied the influence of sowing windows on growth and yield of groundnut cultivars under rainfed conditions during *Kharif* season. The experimental results revealed that, highest mean pod yield was recorded with Kadiri-9 (1866 kg ha⁻¹) over the different dates of sowing and it was at par with Kadiri- harithandra (1790 kg ha⁻¹). While, among different sowing windows, highest mean pod yield was recorded at 1st fortnight of July (1905 kg ha⁻¹) which was at par with 2nd fortnight of June (1804 kg ha⁻¹) and significantly superior over the rest of the dates of sowings i.e., 1st fortnight of June and 2nd fortnight of July.

Sai *et al.* (2022) conducted a field experiment to study the influence of sowing windows on growth and yield of groundnut cultivars under rainfed conditions during *Kharif* season. From the results, it was observed that the growth parameters viz., plant height (63.14 cm), dry weight (55.0 g plant⁻¹), number of nodules plant⁻¹ (50.1), dry matter accumulation (1833.41g m⁻²) were recorded highest in the treatment 2 was recorded with GJG-32+20th July. The yield parameters and yield viz., No. of pods plant⁻¹ (31.72), shelling percentage (69.65%), Seed yield (2.91 t ha⁻¹), Haulm yield (4.77 t ha⁻¹), Seed index (34.07 g), No. of kernels plant⁻¹ (1.93). The experimental results revealed that, highest mean pod yield was recorded with GJG-32 (2.91 t ha⁻¹) over the different dates of sowing and it was at par with GG-14 (2.81 t ha⁻¹).

Yadav and Lunagaria (2022) conducted an experiment to study the influence of varieties and sowing dates on growth and yield of *kharif* groundnut (*Arachis hypogaea* L.). Results showed that first date of sowing (onset of monsoon) proved significantly superior to other dates of sowing in respect of growth and yield characters. Significantly high pod yield (2176 kg ha⁻¹ and 1862 kg ha⁻¹) was recorded during 2019 and 2020 under first date of sowing, respectively which was statistically at par with second date of sowing (1937 kg ha⁻¹ and 1592 kg ha⁻¹) and significantly higher than the third date of sowing (1614 kg ha⁻¹ and 1369 kg ha⁻¹). In case of crop sown at onset of monsoon, rainfall, soil moisture and mean temperature favorable during crop growing period showed significantly higher pod yield. On an average, onset of monsoon (early sowing) gave 13.4% higher pod yield than 10 days after onset of monsoon sowing.

Hiremath *et al.* (2022) conducted a field experiment to study influence of weather on groundnut genotypes under extended sowing window during *Kharif* season. The result revealed that groundnut crop sown during first fortnight of June recorded significantly higher pod yield (3,551 kg ha⁻¹) and haulm yield (4,477 kg ha⁻¹) compared to second fortnight of July and was at par with first fortnight of July and second fortnight of June.

Yadav rao *et al.* (2023) evaluated an experiment to study the impact of yield attributes and yields of groundnut varieties under different sowing windows and reported that amongst all the groundnut varieties, JL-776 (Phule Bharati) is significantly superior under extended sowing windows followed by varieties RHRG-6083, TAG-24 and JL-501. Sowing during 26th MW was observed to be most suitable and optimum for groundnut considering the growth and yield attributes. This sowing window was at par with 27th MW sowing window.

2.1.2 Effect of different date of sowing on quality of groundnut.

Gupta *et al.* (1983) conducted a field experiment at Haryana Agricultural University, Hissar on groundnut crop varieties MH-2 (bunch type) and M-145 sown on four dates between 26th June and 25th July. The result indicated that seed protein content was reduced by 2 per cent with delay in sowing by one month. Protein content was stable until the last sowing dates.

Sardana and Kondhola (2007) conducted a field experiment at Punjab Agricultural University (PAU), Ludhiana and reported that the oil content in treatments of later sowing dates, viz., 10th and 20th June (51.1–51.2 %) were significantly lower than 30th May sowing (52.5 %) which in turn registered significantly lower oil content than 10th and 20th May sowings (53.7–53.8 %).

Sogut *et al.* (2016) investigated the effects of sowing time and cultivar on pod yield, yield components, oil and protein content of peanut crops under irrigated condition in south-eastern of Turkey. Sowing time affected pod yield, pod number plant⁻¹ and oil content in both years. Early sowings resulted in higher pod yields, pod number plant⁻¹ and oil content compared to late sowing for all cultivars. The results also showed that cultivars were different for pod yield in both years. Sultan produced the highest pod yields under both sowing times.

2.2 Effect of spacing

2.2.1 Effect of different spacing on growth and yield attributes.

Howlader *et al.* (2009) conducted a field trial in farmers' field of farming System Research and Development Site, Razakhali, Bangladesh and reported that varieties of different growth habits required different spacing to express their yield potentials. The erect type groundnut variety required closer spacing of 20 cm x 10 cm while semi spreading required wider spacing of 40 cm x 20 cm to produce maximum yield. However, considering seed cost and

oil yield, 30 cm x 10 cm spacing for erect type and 40 cm x 20 cm for semi spreading may be considered as optimum spacing to get maximum benefit.

Konlan *et al.* (2013) conducted an experiment at the Savanna Agricultural Research Institute, Ghana, to assess the effect of spacing arrangement on the growth and yield of groundnut varieties in three (3) spacing arrangements (30 cm x 15 cm, 40 cm x 10 cm and 50 cm x 10 cm). The results showed that groundnut variety and spacing arrangement significantly influenced its growth and yield performance.

Reddy *et al.* (2014) studied the effect of plant spacing on the yield and yield attributes of groundnut varieties. The results showed that plant spacing of 35x20 cm gave higher yield and lowest yield was recorded in plant spacing of 20x15cm. The growth and yield attributes of groundnut were significantly reduced when the crop was provided with less spacing, groundnut required wider plant spacing (35 x 20 cm) to express its maximum yield potentiality.

Awal and Aktar (2015) observed that closing of row spacing on crop stature increased the growth and yield contributing characters such as plant height, number of branches/plant, leaf area index, dry matter accumulation, pod/plant, 1000-seed weight, pod or seed yield, biological yield & harvest index and thereafter the yield decreased gradually with widening of row spacing.

Gunri *et al.* (2015a) reported that the optimum planting geometry for Spanish bunch groundnut variety R 2001-3 would be 30 cm x 10cm. The highest pod and haulm yield were obtained with 20:60:40 kg ha⁻¹ of N: P₂O₅:K₂O (100 per cent RDF) thereafter, no incremental yield advantages and benefit cost ratio were found with further increase in the inorganic fertilizers level.

Ansa and Okon (2016) conducted a field experiment to determine the effect of spacing on growth, yield and weed control in groundnut and reported that groundnuts spaced at 25 x 25 cm had the tallest plant, highest growth rate and leaf area while number of flowers increased with spacing until 50 x 50 cm and declined thereafter. Same trend was observed for seed weight or yield per experimental plot. However, when yield was converted to per hectare basis groundnut yield per hectare reduced as planting distance increased.

Hamakareem *et al.* (2016) revealed that plant spacing 60 cm x 30 cm produced significantly highest leaflet and leaf area. However, lowest leaflet and leaf area were observed in plant spacing 50 cm x 30 cm which was statistically identical with plant spacing 70 cm x 30 cm. The reduced competition and increased availability of resources like nutrients, soil moisture and light paved way for higher leaf area per plant. However, plant spacing 50 cm x 30 cm was found to be inferior to all other plant spacing. All the plant traits positively contributed towards final seeds yield.

Waghmode *et al.* (2017a) reported that groundnut cultivar sown with 30 cm x 10 cm plant spacing (plant population of 3,33,333 plants ha⁻¹) and fertilized with 30:70:00 NPK kg ha⁻¹ noticed significantly highest pod, kernel and haulm yield of groundnut.

Rajitha *et al.* (2018) observed that secondary and micronutrient fertilization is essential for enhancing the productivity of groundnut crop. Calcium, Magnesium and Sulphur requirements are highest in oil seed crops followed by pulses and least in cereals. Combined foliar application of secondary and micronutrients along with RDF recorded significantly highest pod yield of 2654 kg ha⁻¹ and haulm yield of 3603 kg ha⁻¹ as compared to RDF (1500 and 2551 kg ha⁻¹ of pod and haulm yield, respectively) and also the highest uptake of primary nutrients (N, P and K) by haulm and pod at harvest

which might be because of highest dry matter production with the combined application of all thenutrients.

Parmeshwarareddy *et al.* (2019) studied the influence of plant spacing and fertilizer levels on summer groundnut. The results indicated that, plant spacing did not differ significantly on pod yield. Similarly, Application of 125 per cent RDF (39.20 q ha⁻¹) and 150 per cent RDF (38.08 q ha⁻¹) did not differ significantly on pod yield, but was significantly higher than 100 per cent RDF (36.47 q ha⁻¹). However, the combination of plant spacing of 30cm × 10cm with 125 per cent RDF recorded significantly higher pod yield as compared to other combination

Dolie and Nongmaithem (2020) conducted a field experiment to study the influence of spacing and weed management practices on weed, growth and yield of groundnut (*Arachis hypogaea* L.) and found that maintaining plant spacing at 40 × 15cm enhance the growth as well as yield of groundnut. Results showed significant increased in plant dry matter accumulation (48.34 g plant⁻¹), test weight (46.45 g), pod yield (1392.03 kg ha⁻¹), kernel yield (977.64kg ha⁻¹) and stover yield (2942.36 kg ha⁻¹).

Essilfie (2020) conducted a field experiment to determine the influence of row spacing and NPK fertilizer on growth and yield of groundnut under rain-fed condition in transitional zone of Ghana. The result according to the two year cropping seasons showed that the 30×15 and 50×15 cm spacing produced heaviest pod weight and high yield respectively. Interaction effect between variety×spacing and variety×spacing×fertilizer was significant with number of branches, yield and haulm weight at harvest.

Raju *et al.* (2022) reported that plant height (62.91 cm), number of nodules (92.00), dry weight (53.69 g plant⁻¹), No. of pods plant⁻¹ (23.53), no. of kernels pod-1 (2.00), harvest index (51.62%), kernel yield (2917.33 kg ha⁻¹),

haulm yield (2698 kg ha⁻¹) were significantly influenced with treatment combination of 35 × 10 cm spacing + 2.5t ha⁻¹ vermicompost. Maximum CGR (31.10 g m⁻² day⁻¹) were recorded with application of 30 × 10 cm spacing + 2.5t ha⁻¹ vermicompost. However, RGR and seed index were found to be non-significant. Therefore, treatment combination of 35 × 10 cm spacing + 2.5t ha⁻¹ vermicompost was most productive and cost effective

Sowmya *et al.* (2022) studied the performance of groundnut (*Arachis hypogaea* L.) to different land configurations and spacings on sandy loam soils. Results showed that spacing at 30 × 10 cm recorded higher plant height, dry matter accumulation and LAI and higher number of branches were observed with 60 × 10 cm spacing. Higher pod and haulm yields were observed with the land configuration flat bed with crop compaction and 30 × 10 cm spacing.

Yeswanth and Debbarma (2022) reported that treatment 6 (Sulphur at 60 kg/ha + 30 x 10 cm,) was recorded significantly higher plant height (39.09 cm), maximum number of nodules/plant (8.07), higher plant dry weight (22.03 g/plant), crop growth rate (5.33 g/m²/day), maximum number of pods, maximum number of kernels /pod, number of pods/plant (27.46), kernels/pod (2.06), test weight (39.20 g), pod yield (3.63 t/ha), seed yield (1.56 t/ha), haulm yield (5.92 t/ha), harvest index (21.44%) and shelling (69.04%).

Chilakala *et al.* (2023) studied the effect of spacing and varieties on growth, yield and economics of summer groundnut. Results revealed that treatment 9 *i.e.*, combination of Kadiri-6 and Spacing at 30 cm × 10 cm recorded significantly higher plant height (43.48 cm), maximum number of nodules plant⁻¹ (46.53), higher plant dry weight (25.39 g plant⁻¹), and yield attributes namely higher number of pods plant⁻¹ (21.13), higher number of kernals pod⁻¹ (2.01), higher seed index (36.77 g), higher seed yield (2.27 t ha⁻¹),

higher haulm yield (4.44 t ha⁻¹) and higher harvest index (39.23 %) compared to other treatment combinations.

2.2.2 Effect of spacing on nutrient uptake and nutrient concentration in soil.

Hanum (2018) studied the effect of P fertilization, mulching straw and plant spacing on growth, yield and movement of P nutrient on soybean and showed that phosphate fertilizer (200 kg/ha) significantly increased levels of phosphate in the shoot. Plant spacing (50 cm x 25 cm) increased root volume. The interaction of phosphate fertilizer (200 kg/ha) and spacing (50 cm x 25 cm) increased the phosphate level by 93.33% in shoot. Plant spacing (50 cm x 25 cm) produced the largest of 100 grains weight as compared to other plant spacing.

Rajitha *et al.* (2018) carried out an experiment on sandy loam soils of Agricultural College farm, Mahanandi during rabi season of 2015-2016 to study the response of groundnut to secondary and micronutrients. Data collected on yield and nitrogen uptake of groundnut indicated that all the characters studied were significantly higher with application of RDF + foliar application of 1% each of CaNO₃, MgNO₃ and Sulphur + micronutrient mixture @ 0.2% (T10).

Sunilkumar *et al.* (2020) evaluated the yield and quality of groundnut under high density planting (22.5 x 10 cm - 4.44 lakh ha⁻¹ ; 20 x 7.5 cm - 6.66 lakh ha⁻¹ ; 22.5 x 5 cm - 8.88 lakh ha⁻¹ with graded levels of phosphorus (25, 37.5, 50 and 62.5 kg P₂O₅ ha⁻¹). The results disclosed that dry matter production and phosphorus uptake of groundnut at different crop growth stages increased with graded increase in plant density from 4.44 to 8.88 lakh ha⁻¹ and graded increase in phosphorus application from 25 to 62.5 kg P₂O₅ ha⁻¹. All yield parameters *i.e.*, number of pods plant⁻¹, pod yield, kernel yield and shelling percentage was higher at plant density of 4.44 lakh ha⁻¹.

2.2.3 Effect of spacing on quality of groundnut.

Patil *et al.* (2007) reported that maximum yield was produced and found beneficial proposition for achieving higher quality and productivity when crop was shown at 30 cm x 10 cm on broad bed furrow (BBF) where as crop sown in 45 cm x 15 cm spacing reduced the haulm yield of groundnut crop.

Jaiswal *et al.* (2018) observed that the yield attributing characters, number of pods per plant, pod weight per plant and shelling percentage were highest at 30 cm x 15 cm spacing compared to closer spacing of 30 cm x 10 cm and 22.5 cm x 10 cm. The pod yield was significantly higher with 30 cm x 10 cm spacing compared to other spacing and there was no marked difference on oil content among the different spacing.

2.3 Effect of levels of NPK.

2.3.1 Effect of levels of NPK on growth and yield attributes.

Kausale (2009) reported that nodule number, dry matter plant⁻¹, pod and haulm yield of groundnut crop increased with application of 100 % RDF

Priya *et al.* (2009) observed in Tamil Nadu that basal application of 100 per cent fertilisers dose to base crop and basal application of 50 per cent recommended nitrogen with 100 per cent phosphorus and potassium was found superior in increasing the productivity of shelling percentage, pod yield, head diameter, seed yield, oil yield and content of groundnut.

Abraham and Thenua (2010) carried out an investigation to study the influence of organic and inorganic sources of nutrients and their methods of application on groundnut (*Arachis hypogaea* L) and revealed that growth and yield attributes as well as yield improvement could be obtained by root zone placement of manures and fertilizers mainly through a significant improvement in 100 kernel weight. . Basal application of 75% recommended dose of fertiliser [RDF: 20-80-20 (NPK) kg/ha] applied in root zone produced higher

dry matter accumulation and nut yield. Amongst the interaction effects, combination of 13t FYM + 75% RDF, 13t FYM + root zone application and 100% RDF + root zone application recorded the highest nut yield of groundnut as compared to other treatment combinations.

Sharma *et al.* (2013) evaluated sixteen treatment combinations of four fertility levels (control, 50, 75 and 100% RDF) and four bio-fertilizers (control, Rhizobium, phosphate solubilizing bacteria and vesicular arbuscular mycorrhiza) on groundnut. Results indicated that application of fertilizers up to 100% RDF recorded significantly higher number of pods per plant, kernels per pod, yields (pod, haulm and biological) and net returns over its preceding levels. However, seed index and shelling per cent were increased significantly only up to 75% RDF.

Sagvekar *et al.* (2015a) conducted an experiment at Shirgaon, Maharashtra, the result indicated that higher number of pods and dry pod weight were observed in case of application of 75 per cent RDF as basal and 75 per cent RDF at 30 DAS with FYM and was at par with application of 100 per cent RDF as basal + 50 per cent RDF as top dressing at 30 DAS along with FYM.

Sengupta *et al.* (2016) studied the effect of nutrient management strategy on production potentiality of short duration high yielding summer irrigated groundnut variety TG 51. Results revealed that, application of 100 % RDF + 7.5 t/ha FYM as basal increased growth and yield attributes that led to significantly higher productivity (pod yield 3320 kg/ha) besides enrichment of soil available nutrients after harvest of the crop. Pod yield decreased with further increase in NPK fertilizer above 100% RDF. However, maximum haulm yield (3979 kg/ha) was recorded with 150% RDF + 7.5t/ha FYM as

basal. Maximum net return: cost ratio (3.43) was found with 100 % RDF which was closely followed by that of 100 % RDF + 7.5 t/ha FYM.

Bhosale and Pisal (2017) studied the effect of nutrient management on productivity of summer groundnut (*Arachis hypogaea* L.) and revealed that increasing dose of fertilizers up to 125% recommended dose of fertilizers (RDF) significantly increased pod yield (35.42 q ha⁻¹) and haulm yield (29.15 q ha⁻¹). The higher plant height (30.70 cm), number of functional leaves plant⁻¹ (54.64), leaf area (5.59 dm²), number of branches plant⁻¹ (11.73) and dry matter plant⁻¹ (41.33 g) was recorded with 125% RDF and it was comparable with 100% RDF and 75% RDF through inorganic fertilizers + 25% N through vermicomposting. Application of 125% RDF through inorganic fertilizers recorded significantly the highest no. of pods plant⁻¹ (35.00) and weight of pods plant⁻¹ (26.43).

Patil *et al.* (2017) studied the effect of integrated nutrient management on growth and yield of *kharif* Groundnut (*Arachis hypogaea* L.). Results revealed that application of 100 % RDF through inorganic fertilizers + 5 tonne FYM recorded significantly highest plant growth attributes like plant height, plant spread, dry matter, number of branches plant⁻¹, leaf area and number of nodules plant⁻¹ and yield attributes like number of pods plant⁻¹, weight of dry pods plant⁻¹, 100 kernel weight, shelling %, dry pod yield ha⁻¹ and dry haulm yield ha⁻¹.

Satpute *et al.* (2020) conducted an experiment to study the effect of inorganic and bio-fertilizers on growth, yield and quality of summer groundnut (*Arachis hypogaea* L.). The results revealed that the application of 100% of RDF ha⁻¹ was comparable with 125% of RDF ha⁻¹ significantly over 75% RDF ha⁻¹ in respect of recording higher value of the growth attributes viz., plant

height (cm), number of branches plant⁻¹, plant spread plant⁻¹ (cm), dry matter plant⁻¹ (g), number of nodule plant⁻¹ and weight of nodule plant⁻¹ (g).

Senthilkumar and Naveen (2020) studied the effect of integrated nutrients management on growth and yield of groundnut (G-7). The results of this experiment showed that combined application of 100 % RDF + Basal application Rhizobium and Phosphobacteria @ 2 Kg ha⁻¹ recorded highest growth and yield parameters viz., plant height (82.20 cm), leaf area index (2.76), dry matter production (5776.20 kg ha⁻¹), number of pods plant⁻¹ (20.96), 100 kernel weight (49.76 g), shelling percentage (72.83), pod yield (2576.4 kg ha⁻¹), haulm yield (3174.5 kg ha⁻¹) and kernel yield (2044.46 kg ha⁻¹), recorded with significantly higher values.

Tekulu *et al.* (2020) reported that plant growth was significantly affected by separate and combined application of N and P fertilizers. Plant growth parameters such as plant height and number of branches were increased by higher N and P fertilizers application rates. Plant biomass yield significantly increased when higher doses of both N and P fertilizers were separately applied. Haulm yield was only increased by higher rates of N application. Combination of N and P at 15 kg N ha⁻¹ and 46 kg P₂O₅ ha⁻¹ resulted in higher pod yield, grain yield, grain protein content and residual soil N contents after harvest. Nitrogen harvest index was also found to be significantly affected by the main and interaction effect of both N and P fertilizers.

Vasuki (2020) evaluated the impact of split application of fertilizers along with economic feasibility of integrated nutrient combinations and revealed that application of recommended dose of fertilizers (RDF) (100%) as basal + RDF (50 %) as top dressing at 30 DAS + FYM @ 7.5 t ha⁻¹ recorded higher pod yield and net returns (2936 kg ha⁻¹ and Rs. 91789 ha⁻¹, respectively) and were comparable with RDF (75 %) as basal + RDF (75 %) as top dressing

at 30 DAS along with 7.5 t ha⁻¹ of FYM higher pod yield and net returns (2812 kg ha⁻¹ and Rs. 86610 ha⁻¹, respectively). Economic analysis registered that RDF (100 %) as basal + RDF (50 %) as top dressing at 30 DAS along with 7.5 t ha⁻¹ of FYM recorded the maximum return of Rs. 91789 and BCR of 3.10 and was closely followed by RDF (75 %) as basal + RDF (75 %) as top dressing at 30 DAS with a maximum return of Rs. 86610 but with a BCR of 3.05 the additional cost of FYM were not incurred in cost of cultivation.

Singh *et al.* (2021) studied the response of groundnut (*Arachis hypogaea* L.) to biofertilizers and inorganic sources of nutrient. Results showed that an application of RDF resulted in significantly highest number of branches/plant, number of nodules/plant and dry matter accumulation at 30, 60 and 90 days after sowing (DAS). Increasing dose of fertilizers up to RDF resulted in significant increase in haulm, pod yield and net returns.

Poonia *et al.* (2022) conducted a two year study to evaluate the efficient tillage and nutrient management practices and their influence on crop yield and nutrient uptake in groundnut. Results indicated that among nutrient management options RDF along with seed inoculation with PSB and AMF recorded significantly higher attributes of yield and pod yield compared to RDF without seed inoculation. This treatment also recorded the maximum N, P, K uptake over rest of nutrient management practices.

2.3.2 Effect of levels of NPK on nutrient uptake and nutrient concentration.

Halevy and Hartzoop (1988) reported that concentrations of N, P and K in nearly all plant parts decreased as the growth and maturation processes progressed, With the exception of mature seeds, in which the concentration increased. Nitrogen concentration in the leaves and stems dropped from 3.3% early in the season to 1.5% in mature plants. In the shell, it dropped from 1.0 to 0.8%, but in the seeds it increased slightly, from 4.8 to 5.0%. Phosphorus

concentration in the stem and leaves dropped from 0.35% P early in the season to 0.10% in mature plants. The concentration of K in the leaves and stems was nearly constant until 128 days after planting, between 3.0 and 3.4%. Only in the last stage did it drop, to 2.8%.

Kharade, *et al.* (2013) observed the total uptake of N ($234.08 \text{ kg ha}^{-1}$), P (20.38 kg ha^{-1}) and K ($104.12 \text{ kg ha}^{-1}$) was recorded with 30 kg N , $50 \text{ kg P}_2\text{O}_5$ and $45 \text{ kg K}_2\text{O}$ along with seed inoculation. A higher N and P uptake under co-inoculation of biofertilizers and K application might be attributed to enhanced nitrogenase and nitrate-reductase, enzyme activity in soil leading to more biological N fixation by *Rhizobium* and increased availability of P in soil due to greater solubilization. The K uptake was greatly improved due to biofertilizers, its need for higher vegetation growth and seed formation.

Chirwa *et al.* (2017) conducted a field study to improve kernel yields by assessing the effect of B, Ca, N, P and K fertilizer application on groundnuts. Results showed that compared to the control (0 kg ha^{-1}), groundnuts responded to the application of $\text{N}_{20}\text{P}_{30}\text{Ca}_{100}\text{K}_{40}\text{B}_1 \text{ kg ha}^{-1}$ to result in an increase of Ca uptake by 21%, N uptake by 55.5% and P uptake by 51%. The response of groundnuts to $\text{N}_{20}\text{P}_{30}\text{Ca}_{100} \text{ kg ha}^{-1}$ resulted in an increase in kernels by 65.5% and haulm yield by 83.4%.

Amruth *et al.* (2018) observed that total uptake of primary and secondary nutrients by different plant parts are due to influence of graded phosphorus levels through integrated nutrient management (INM) packages. The total uptake of N, P, K, Ca, Mg and S significantly showed higher value of uptake due to application of 75 % of $30 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ through CF + 25 % through FYM + PSB.

Arunkumar *et al.* (2020) carried out an experiment to determine the performance of groundnut to different soil fertility amendments in coastal sandy

soil. The result revealed that application of 125% RDF + Press mud @ 10 t ha⁻¹ + Sea weed extract recorded higher values in parameters viz., plant height (63.30cm), Leaf area index (1.48), Number of leaves (45.30), Dry matter production (3816), Pod yield (2157), Kernel yield (1119), nitrogen uptake (68.92), phosphorus uptake(12.64), Potassium uptake (12.64), Calcium uptake (61.57), Magnesium uptake (23.64) and BC ratio (2.88).

Moinuddin and Saren (2023) evaluated the effect of phosphorus management on growth and yield of groundnut varieties and its residual effect on succeeding baby corn. Results showed that highest pod yield (2007 kg/ha), shelling % (67.35%), Oil % (49.97%), number of nuts/plant (23.23) & 100 kernel weight (40.55g) were obtained with groundnut variety TG 51 and application of (100% RDP + PSB + FYM).

2.3.3 Effect of levels of NPK on quality of groundnut

Bhosale and Pisal (2017) reported that application of 125% RDF recorded significantly highest oil yield and it was on par with 100% RDF through inorganic fertilizers due to the increase in oil yield is mainly due to cumulative effect of pod yield.

Sanadi *et al.* (2018) observed the oil and protein contents of groundnut were influenced by application of different potassium treatments which received through MOP and by foliar spray at 60 DAS increases the oil and protein contents by 6.07 and 6.89 per cent respectively due to the enhanced activity of malic dehydrogenase enzyme which helps in the synthesis of fatty acids such as malate and oxaloacetate in groundnut kernels, resulting in the enhanced oil content. Split application of potassium in one split along with foliage nutrition of potassium sulphate increased the protein content in groundnut kernel and was attributed to the role of potassium in facilitating the

uptake as well as assimilation of nitrogen into simple amino acids and amides which enhanced the peptide synthesis and led to protein synthesis.

2.4 Economics

Karunakaran *et al.* (2010) studied the effect of integrated nutrient management on the growth and yield of groundnut (*Arachis hypogaea* L.) and revealed that application of 125% RDF + 5 t/ha EC increased growth and yield attributes that led to its significantly higher productivity (2.25 and 5.00 tonne/ha of mean pod and haulm yield), and nutrient uptake of groundnut besides enriching soil available nutrients after harvest of groundnut. However, due to high cost of manuring, RDF recorded the highest mean net returns (Rs 16,996/ha) and B: C ratio (2.02).

Bala and Nath (2015) observed the different treatments, highest pod yield was recorded by the treatment RDF (100 per cent as basal dose) + FYM (7.5 t ha⁻¹) 2169 kg ha⁻¹ with BC ratio 1:5.45 this improvement was followed by treatment RDF (100 per cent as basal dose) + RDF (50 per cent as top Dressing at 30 DAS) + FYM (7.5 t ha⁻¹) 2006 kg ha⁻¹, 1:4.66 BC ratio and RDF (100 per cent as basal dose) 1966 kg ha⁻¹, BC ratio 1:4.59 and lowest yield recorded by RDF (75 per cent as basal dose) + RDF (75% as top Dressing at 30 DAS) 1721 kg/ha, BC ratio 1:4.58.

Gunri *et al.* (2015b) reported the higher pod yield (₹. 2764 kg ha⁻¹) and haulm yield (₹. 3515 kg ha⁻¹) was obtained with the spacing of 30 x 10 cm. The highest pod yield of groundnut (₹. 2911 kg ha⁻¹) was found with the application of 100% RDF which was followed by 125% RDF with 2910 kg/ha, 75% RDF with 2786 kg/ha and 50% of RDF with 2294 kg/ha. Maximum gross returns (₹ 72950) and net returns (₹. 51570) were recorded with the treatment 100% RDF. Highest benefit cost ratio (3.42) was found with the treatment 75% RDF.

Sagvekar *et al.* (2015b) observed the maximum net returns and benefit cost ratio was observed at application of 100 % RDF as basal + 50% RDF as top dressing (₹. 23018/- and 1.45, respectively).

Waghmode *et al.* (2017b) observed that economics of groundnut cultivar sown with 30 X 10 cm plant spacing and fertilized with 25:50:00 NPK kg ha⁻¹ gives more benefit to cost ratio 2.08 with net returns of ₹. 76561 ha⁻¹.

Desmae *et al.* (2022) conducted an experiment over the main rainy and dry seasons to determine the optimum density for maximum groundnut yield and economic benefits. Results showed that when plant density was increased, dry pod yield, production value, and net economic benefit per hectare increased in a no moisture stress scenario. During the rainy season, the 40 cm × 10 cm spacing gave the highest dry pod yield (1693 kg), production value (\$891.6), and net benefit (\$403.5) per hectare. The highest dry pod yield (3703 kg), production value (\$2173), and net benefit (\$1510.2) per hectare were obtained from 30 cm × 10 cm spacing during the dry season. The number of pods per plant and 100 SW increased with lower plant densities.

Kumar *et al.* (2022) studied the influence of nitrogen and spacing on yield and economics on groundnut. The result showed that *viz.*, significantly higher number of pods per plant, seed yield, haulm yield, net returns and B:C ratio recorded in nitrogen 30kg/ha + 25cm × 10cm.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The concise description of experimental procedure, materials and technique to be adopted during the course of investigation in the field and laboratory are embodied under the appropriate heads.

3.1 General Information

3.1.1 Experimental site

The present investigation entitled, “Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland” was carried out in the Experimental research farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema campus during the *kharif* season of 2019 and 2020. The experimental site is located at 25°45'09.2"N latitude and 93°51'18.6"E longitude with an altitude of 310 meter above mean sea level.

3.1.2 Climate and weather conditions during the experiment period

The climate of the region is sub-tropical having hot and humid summers and cold winters. Monsoon starts from the first week of June and extends to September and the rains gradually decrease from October. The experimental farm lies in the humid sub-tropical zone with an average rainfall ranging from 1800-2500 mm per annum. The mean temperature ranges from 21 to 32 °C during summer and rarely goes below 8°C in the winter season.

The meteorological data recorded during the period of experimentation from the time of field preparation till the final harvest of the crop for two successive years is presented in Table 3.1(a) and 3.1(b) and illustrated in Fig 3.1(a) and 3.1(b)

Table 3.1(a) Meteorological data recorded during the cropping season (2019)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine (hours)
	Max (°C)	Min (°C)	Max (%)	Min (%)			
22	33.3	21.4	92	62	111.3	5	5.6
23	32.5	23.5	91	70	15.9	4	4.5
24	33.2	24.4	91	67	41	2	4.8
25	34.5	24.9	91	73	66	4	5.1
26	34.4	24.6	91	68	21	3	3.8
27	32.5	25.2	94	78	63.7	5	2.6
28	30.8	24.9	94	78	34.1	2	0.2
29	35	24.7	92	61	57.4	1	7.1
30	33.5	24.5	93	70	111.5	5	3.1
31	33.1	24.8	95	72	29.1	4	3.7
32	35.1	25.3	92	68	42.5	3	5.8
33	33.8	24.5	92	74	121.6	4	3.9
34	34	25.1	91	72	24.5	3	5.0
35	33.8	24.7	93	75	64.6	4	5.1
36	34	25.1	94	72	21.2	2	5.2
37	33.1	24.7	94	73	16.3	2	3.1
38	33.9	23.3	92	66	37.3	3	5.2
39	29.6	22.5	95	79	94.6	3	2.2
40	31	22.6	95	77	22.1	2	5.9
41	31.2	23.2	95	69	50.8	4	6.4
42	32.5	21.6	94	65	19	2	7.6
43	26.5	20.1	96	81	152.9	3	2.9
44	30.7	19.2	97	69	0	0	8.3
45	28.7	19.6	97	76	34.9	3	4.2
46	29	16.2	97	59	18	1	8.0
47	27.8	13.3	98	58	0	0	7.6
48	27.9	13.5	98	63	0	0	7.0

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

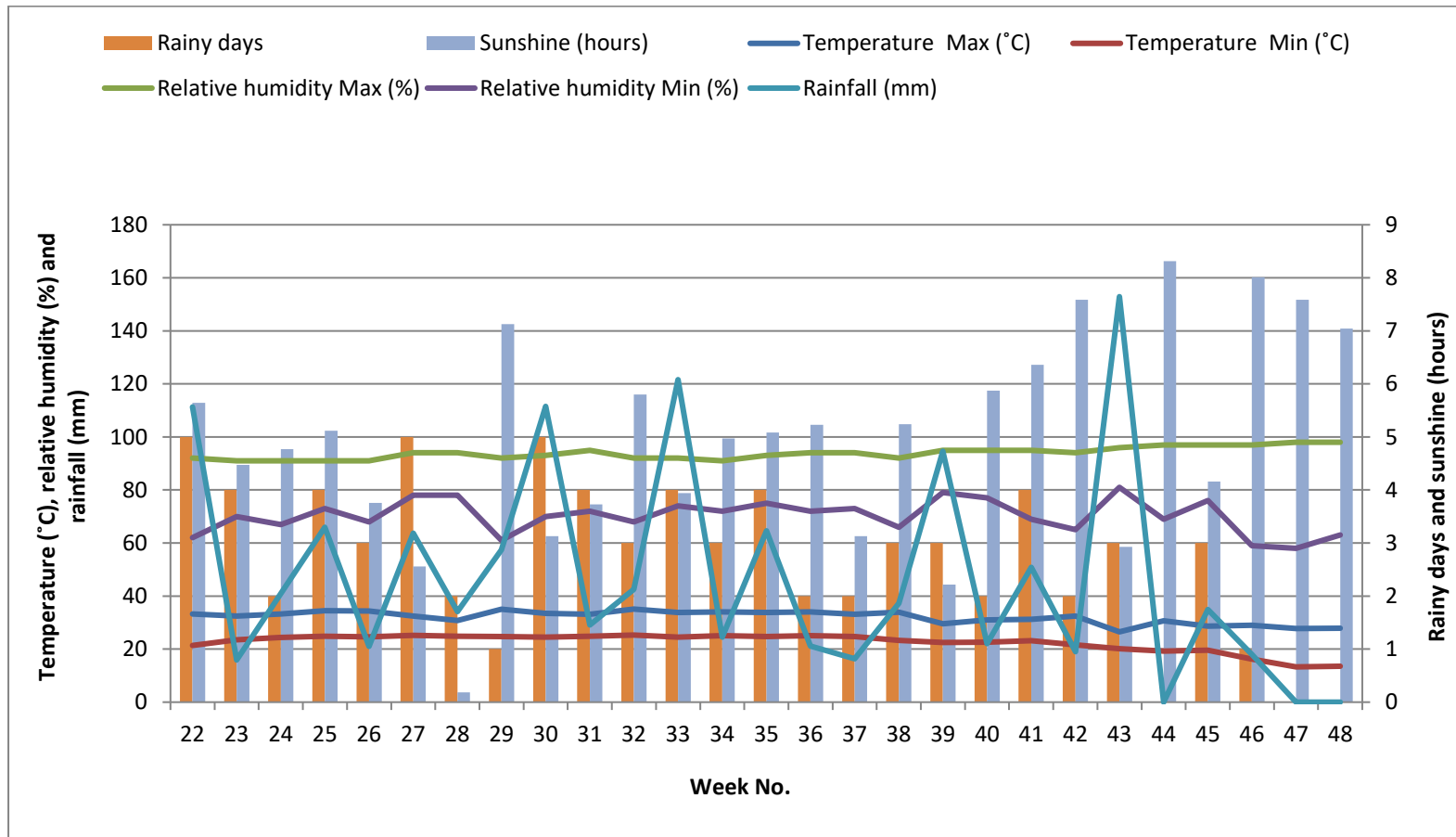


Fig 3.1(a) Meteorological data during the cropping season (2019)

Table 3.1(b) Meteorological data recorded during the cropping season (2020)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine (hours)
	Max (°C)	Min (°C)	Max (%)	Min (%)			
22	30.1	21.2	92	63	74	4	5.7
23	31.9	22.7	94	68	16.5	2	4.1
24	33.2	24.7	92	80	67.1	4	4.0
25	33.1	24.3	92	71	111.9	6	4.9
26	31.8	23.9	92	73	53.6	3	2.3
27	32.9	24.6	94	78	79.5	5	3.7
28	32.9	24.8	93	71	29.7	3	1.9
29	32.3	24.6	93	72	18.5	3	2.8
30	32	23.9	93	76	71.4	6	2.2
31	33.6	25.3	94	70	3.5	0	4.8
32	34.7	25.3	92	71	10.8	3	4.5
33	33.6	25.2	92	67	31.4	2	3.0
34	32.4	24.4	96	74	32.3	3	4.0
35	33.1	24.7	93	71	42.9	2	4.8
36	33.8	24.3	94	64	10.7	1	7.3
37	33.3	24.3	95	72	58.5	1	4.5
38	33.2	24.5	96	76	17.3	2	3.6
39	31.3	24.1	95	80	31.3	4	3.4
40	32.5	23.5	95	80	103.9	4	4.6
41	32.2	23.4	95	71	2.5	0	7.0
42	32.4	23.6	94	64	1.1	0	6.2
43	28.6	22	97	80	68.2	4	3.6
44	30.1	22.5	96	74	34.8	2	4.1
45	29.3	17.7	97	61	0.4	0	7.4
46	29	15.2	98	60	0	0	8.1
47	26.2	14	97	56	0	0	5.7
48	26.3	12.1	97	55	0	0	7.2

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

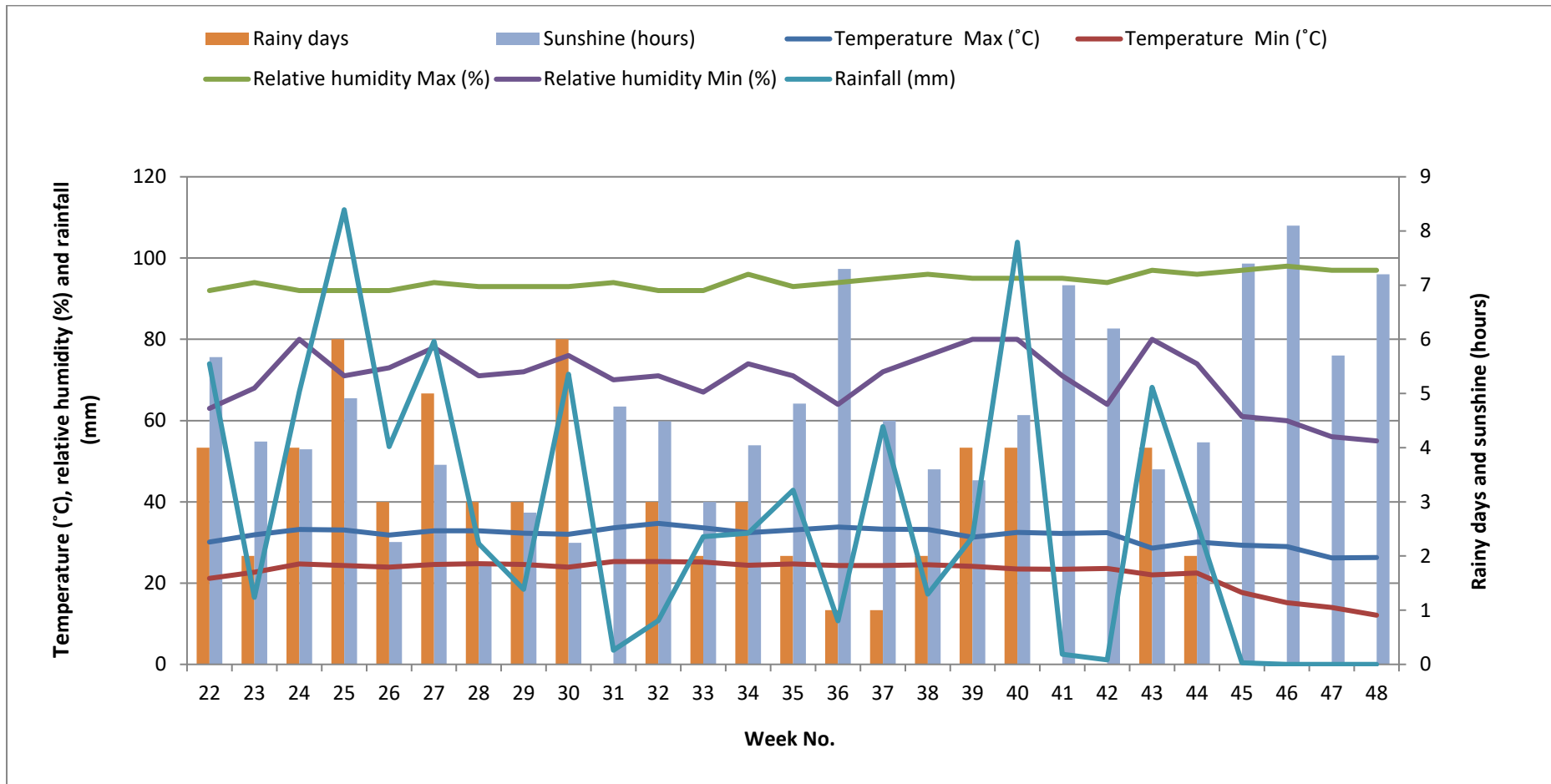


Fig 3.1(b) Meteorological data during the cropping season (2020)

3.1.3 Soil condition

The soil condition of the experimental plot was categorized as sandy loam. The fertility status of soil was ascertained by collecting soil samples randomly from each experimental plot taken at a depth of 0-15 cm. The samples were then mixed, air dried, ground and sieved for analysis following standard procedures as mentioned in Table 3.2.

Table 3.2 Initial soil fertility status of the experimental field

Characteristics	Method followed	2019		2020	
		Content	Interference	Content	Interference
pH	Glass electrode method (Jackson, 1973)	4.85	Acidic	4.93	Acidic
Organic carbon (%)	Titrimetric determination (Walkley and Black, 1934)	1.21	High	1.33	High
Available Nitrogen (kg ha ⁻¹)	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	253	Low	250	Low
Available Phosphorus (kg ha ⁻¹)	Bray's No. 1 method (Bray and Kurtz, 1945)	18.43	Low	20.37	Low
Available Potassium (kg ha ⁻¹)	Neutral normal ammonium acetate method (Hanway and Heidal, 1952)	142.62	Medium	139.25	Medium

3.2 Experimental details

3.2.1 Experimental design

The experiment was conducted in split plot design with three replications, six main treatments and three sub-plot treatment. The whole experimental field was divided into three equal size blocks and each block was subdivided into six main blocks to accommodate the main factors and each main plot was further sub-divided into three sub-plots to accommodate the sub-

factors. Altogether there were 54 plots. The layout plan of the experimental field is presented in Fig 3.2.

Details of the experiment are as follows:

- a. Crop : Groundnut (*Arachis hypogaea* L.)
- b. Cultivar : ICGS 76
- c. Design of the experiment : Split Plot Design (SPD)
- d. Number of replications : 3
- e. Number of main treatments : 6
- f. Number of sub-plots : 3
- g. Total number of plots : 54
- h. Gross area : $5 \text{ m} \times 4 \text{ m} = 20 \text{ m}^2$
- i. Net area : $4 \text{ m} \times 3 \text{ m} = 18 \text{ m}^2$
- j. Distances between replication : 1.5 m
- k. Distances between plot : 1.0 m
- l. Total experimental area : 1065 m^2

3.2.2 Treatment Details

Two sowing dates and three fertility levels were allocated in the main and three planting geometries were allocated in the sub-plot. The classified description of the treatments and their corresponding symbols are shown below:

Treatments	Symbol
1. Main plot treatments	
Sowing dates	
a. 20 th June	D ₁
b. 10 th July	D ₂
Fertility level	
a. 75% RDF	F ₁

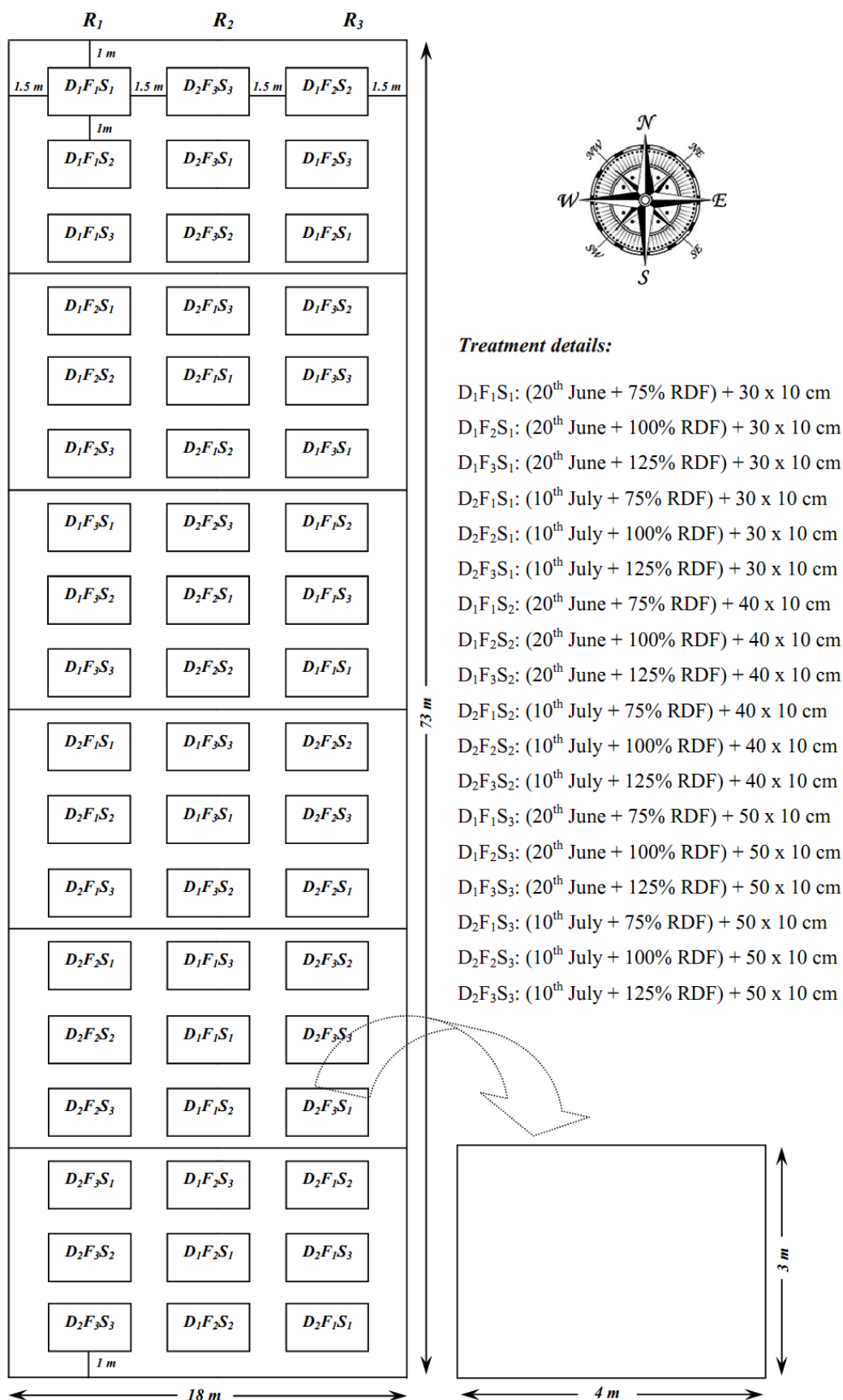


Fig 3.2: Field layout of the experiment in Split Plot Design (SPD)

- | | |
|------------------------|----------------|
| b. 100% RDF | F ₂ |
| c. 125% RDF | F ₃ |
| 2. Sub plot treatments | |
| Planting geometry | |
| a. 30 cm × 10 cm | S ₁ |
| b. 40 cm × 10 cm | S ₂ |
| c. 50 cm × 10 cm | S ₃ |

3.2.3 Treatment Combinations

There were a total of 18 treatment combinations as obtained from the multiplication of six main factors and three sub factors.

T ₁	:	D ₁ F ₁ S ₁	T ₁₀ :	D ₂ F ₁ S ₂
T ₂	:	D ₁ F ₂ S ₁	T ₁₁ :	D ₂ F ₂ S ₂
T ₃	:	D ₁ F ₃ S ₁	T ₁₂ :	D ₂ F ₃ S ₂
T ₄	:	D ₂ F ₁ S ₁	T ₁₃ :	D ₁ F ₁ S ₃
T ₅	:	D ₂ F ₂ S ₁	T ₁₄ :	D ₁ F ₂ S ₃
T ₆	:	D ₂ F ₃ S ₁	T ₁₅ :	D ₁ F ₃ S ₃
T ₇	:	D ₁ F ₁ S ₂	T ₁₆ :	D ₂ F ₁ S ₃
T ₈	:	D ₁ F ₂ S ₂	T ₁₇ :	D ₂ F ₂ S ₃
T ₉	:	D ₁ F ₃ S ₂	T ₁₈ :	D ₂ F ₃ S ₃

3.2.4 Varietal description

ICGS 76: It is a high yielding Virginia bunch variety. It matures in 100-120 days in the rainy season. It is tolerant to bud necrosis. The shelling turnover is 73% and the oil content is 43%. It has good oil quality (oleic/linoleic acid ratio of 1.69).

3.3 Cultivation details

3.3.1 Field preparation

A suitable site was selected to experiment on the experimental farm of the Agronomy department. Primary tillage was done with the help of tractor-drawn disc plough during the last week of May in both years. Final ploughing and breaking of clods were done with the help of a rotavator. Thereafter, all the stubbles, debris and undecomposed plant materials were removed from the entire experimental site and then the plots were laid out according to the plan and design of the experimental field.

3.3.2 Application of manures and fertilizers

Well-decomposed FYM @ 10 t ha⁻¹ was uniformly broadcasted over the field and incorporated thoroughly during the final land preparation. Application of different levels of the recommended dose of fertilizers was done as per the treatment *viz.*, F₁ at 75 % RDF- 15 kg N ha⁻¹+45 kg P ha⁻¹+ 30 kg K ha⁻¹, F₂ at 100% RDF- 20 kg N ha⁻¹+60kg P ha⁻¹+40 kg K ha⁻¹ and F₃ at 125% RDF- 25 kg N ha⁻¹+ 75 kg P ha⁻¹+ 50 kg K ha⁻¹. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash at the time of sowing.

3.3.3 Seed rate and sowing

Healthy seeds were selected and sown as per the treatment on 20th June and 10th July using the recommended seed rate of 75 kg ha⁻¹. Sowing was done in open furrows in lines at the depth of 5 cm maintaining spacing based on the treatment at 30 cm × 10 cm, 40 cm × 10 cm and 50 cm × 10 cm and covered with soil.

3.3.4 Intercultural operation

Gap filling was done at 10 days after sowing to ensure a uniform plant population wherever necessary. Two hand weeding's were performed at the vegetative and reproductive (pegging) stages of crops.

3.3.5 Harvesting

The crop was harvested when it attained physiological maturity as indicated by lower leaves started drying. Harvesting was done using a spade and hand pulling and separating the pods by handpicking. The pods from each treatment were sundried separately and weighed. Groundnut stover was left to be sundried for some time and its weight was recorded with the help of a weighing balance.

3.4 Experimental observation

3.4.1 Growth attributes

Three plants were randomly selected in each plot and tagged. Their growth attributes were recorded.

3.4.1.1 Plant height (cm)

The tagged plants in every plot were measured from ground level to the tip of the longest leaf and recorded at 30, 60 and 90 DAS. The average height of the three tagged plants was recorded as plant height in centimetres.

3.4.1.2 Number of primary branches plant⁻¹

The number of primary branches from each tagged plant was counted at 30, 60 and 90 DAS and the average value was recorded for each plot separately.

3.4.1.3 Number of leaves plant⁻¹

Number of leaves plant⁻¹ was counted from three randomly tagged plants from each plot at 30, 60 and 90 DAS. The values were averaged for each plot.

3.4.1.4 Leaf Area Index (LAI)

Leaf area index at 30, 60 and 90 DAS was calculated using the formula given by Watson, 1952.

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

3.4.1.5 Crop growth rate (g m⁻² day⁻¹)

Crop growth rate is defined as the rate of dry matter production per unit ground area per unit time. It was worked out at 30-60 DAS and 60-90 DAS using the shoot dry weight by adopting the formula given by Watson (1952).

$$\text{CGR} = \frac{W_2 - W_1}{(t_2 - t_1)S} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, W_1 and W_2 are the shoot dry weight at time t_1 and t_2 respectively. S is the land area (m²) over which dry matter was recorded.

3.4.1.6 Net assimilation rate (g day⁻¹ m⁻²)

It is the rate of increase in dry weight per unit leaf area per unit time. The net assimilation rate was estimated by using the formula given by Gregory (1926) at 30-60 DAS and 60-90 DAS and expressed as g day⁻¹ m⁻².

$$\text{Net assimilation rate (NAR)} = \frac{(W_2 - W_1) \times (\ln W_2 - \ln W_1)}{(t_2 - t_1) \times (L_2 - L_1)}$$

Where

W_1 and W_2 are plant dry weight at time t_1 and t_2 respectively

L_1 and L_2 are leaf area at time t_1 and t_2 respectively

3.4.1.7 Relative growth rate (g g⁻¹ day⁻¹)

It is the rate of increase in dry weight per unit dry weight already present and is expressed in g g⁻¹ day⁻¹. It was recorded at 30-60 DAS and 60-90 DAS using the shoot dry weight and calculated by using the formula given by Radford (1967).

$$\text{Relative growth rate (RGR)} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weight of plant at time t_1 and t_2 , respectively.

3.4.1.8 Shoot dry weight (g plant⁻¹)

Shoot dry weight was taken at 30, 60 and 90 DAS by uprooting three randomly selected plants from each treatment plot leaving the border rows. After removal of the root portion, the samples were sundried and then oven dried at 75°C for 48 hours. When the plant samples attained constant weight, the shoot dry weight was recorded in g plant⁻¹.

3.4.2 Phenology

3.4.2.1 Days to 50% flowering

Days to 50% flowering were recorded from each plot by counting the number of days from the date of sowing consecutively till the date when 50% of the plants flower.

3.4.2.2 Days to maturity

Days to maturity were observed visually and recorded from each plot when around 90% of the panicles had matured.

3.4.3 Yield and yield attributes

3.4.3.1 Number of total pods plant⁻¹

Total numbers of pods were counted from three randomly selected plants and the average number of total pods plant⁻¹ was worked out.

3.4.3.2 Length of pods (cm)

The length of pods was worked out by measuring the length (cm) of ten random pods from the tagged plants and the average length was recorded.

3.4.3.3 Number of seeds pod⁻¹

Ten pods were selected randomly from the total number of pods harvested from the tagged plants. The number of seeds pod⁻¹ was counted and average values were recorded and expressed as number of seeds pod⁻¹.

3.4.3.4 Test weight (g)

After shelling the pods, 1000 seeds were counted from each treatment and weighed in gram and the average value was recorded.

3.4.3.5 Seed yield (kg ha⁻¹)

After drying, the pods were shelled, cleaned and weighed separately. The weight of the grain was recorded plot wise and expressed in kg ha⁻¹ using the formula.

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

3.4.3.6 Stover yield (kg ha⁻¹)

The stover collected from each plot after removing pods was sundried properly and the weight was recorded and expressed in kg ha⁻¹ using the formula.

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

3.4.3.7 Harvest index (%)

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

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (seed yield)}}{\text{Biological yield (seed+stover yield)}} \times 100$$

3.4.3.8 Shelling percentage (%)

Shelling percentage was worked out by the following formula

$$\text{Shelling percentage (\%)} = \frac{\text{Weight of seed}}{\text{Weight of pods}} \times 100$$

3.5 Soil analysis

3.5.1 Soil pH

Soil pH was determined in soil:water (1:2) ratio by Glass electrode method (Jackson, 1973).

3.5.2 Organic carbon (%)

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

3.5.3 Available Nitrogen (kg ha^{-1})

The available nitrogen of soil was determined by alkaline potassium permanganate (KMnO_4) method proposed by Subbiah and Asija (1956) with the help of 'Kel Plus' nitrogen distillation machine. The data was calculated in terms of kg ha^{-1} .

3.5.4 Available Phosphorus (kg ha^{-1})

The available soil phosphorus was determined by Bray's No. 1 method proposed by Bray and Kurtz (1945) using 0.03 N NH_4F + 0.025 N HCL (pH 3.5) as an extracting solution. In the filtered extract, phosphorus was estimated colorimetrically by adding ammonium molybdate and stannous chloride. 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, the concentration of P was read from the standard curve. The results were expressed in kg ha^{-1} . This method is primarily meant for soils that are moderate to strong acids with pH of around 5.5 or less.

3.5.5 Available Potassium (kg ha^{-1})

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 through a dry filter paper (Whatman No. 1) and then potassium concentration in the extract was determined using Flame Photometer (Hanway and Heidal, 1952). It was expressed in terms of kg ha^{-1} .

3.6 Plant analysis

3.6.1 N, P and K content and uptake in grain and straw

Randomly selected plant samples were collected treatment wise for chemical estimation. Straw and grains were separated, air-dried and finally oven dried at a temperature of 65°C and grinded. Seed and straw samples were analysed for nitrogen by modified Kjeldahl's method (Jackson, 1973), phosphorus by di-acid digestion and yellow colour development method (Jackson, 1973) and potassium by flame photometric method (Jackson, 1973). The uptake was further calculated by using the formula

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

3.7 Quality parameters

3.7.1 Oil content (%)

The oil content in the seed was determined by Soxhlet's apparatus using petroleum ether (60-80°C) as an extractant.

3.7.2 Protein content (%)

Protein content in grain was worked out by using the formula.

$$\text{Protein content (\%)} = \% \text{ N content} \times 6.25$$

3.8 Economics

The total cost for the system was calculated separately by taking into account all investments (labour and inputs) at prevailing market prices. The value of the main products and by-products in terms of monetary value was calculated separately based on the prevailing market price and was recorded on a unit area basis. Net return was worked out by subtracting the cost of cultivation from the corresponding gross returns and expressed as ₹ ha⁻¹. The benefit cost ratio (BCR) was calculated by using the following formula

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

3.9 Statistical analysis

Data obtained from various studies were statistically analysed in a 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 differences of different groups of treatments and their interactions at 5 per cent probability level were calculated whenever 'F' test was significance.

CHAPTER IV
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The research study on "Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland" was conducted during the foothill seasons of 2019 and 2020. The details about the results and findings are presented below in this section and indicated by using relevant tables and figures at suitable places. The results from the experiment were statistically analyzed and are presented here, including Tables and figures.

4.1 Observations on crop

4.1.1 Growth attributes

4.1.1.1 Plant height (cm)

The data on plant height of groundnut recorded at 30, 60, and 90 DAS are presented in Table 4.1 and 4.2.

4.1.1.1.1 Effect of date of sowing and fertility levels on plant height in groundnut

The date of sowing affected the height of groundnut plants at all stages of growth, as the maximum heights of groundnut plants sown on different dates, with measurements taken at 30, 60, and 90 days after sowing (DAS).

It can be observed from the data presented in Table 4.1 that date of sowing and fertility levels did not show any significant effect on plant height at 30DAS during both the years. Plants sown on 20th June (D₁) consistently exhibited greater heights than those sown on 10th July (D₂). At 60 DAS, in 2019, 2020 and pooled value the maximum plant height was displayed at treatment D₁F₃ (24.73, 24.20 and 24.56cm) which was under the treatment combination of June 20 sowing along with 125% of RDF while the least plant height was exhibited at D₂F₁ (19.58, 19.25 and 19.42 cm). Similarly, at 90

DAS, the maximum height in 2019, 2020 and pooled value was displayed at treatment D₁F₃ (32.49, 32.70 and 32.59 cm) which was under the treatment combination of June 20 sowing along with 125% of RDF while D₂F₁ (32.32, 32.53 and 32.43 cm) was also almost at par with D₁F₃ and the least plant height was exhibited at D₂F₁ (27.51, 27.25 and 27.38 cm). Overall, the early sowing date (20 June) resulted in taller plants throughout the growth stages.

In a series of field experiments, various studies investigated the impact of sowing dates on groundnut yields. Kanade *et al.* (2015) found that sowing on July 6th resulted in significantly superior growth attributes, yield attributes, and overall yield compared to earlier or later sowing dates. Anil *et al.* (2017) reported that early sowing, specifically on June 21st, generally led to higher yields, with temperature, photoperiod, and sunshine hours positively influencing grain filling stages. Sai *et al.* (2022) observed that sowing on July 20th with the GJG-32 cultivar yielded the highest growth and yield parameters, including seed yield (2.91 t ha⁻¹) and haulm yield (4.77 t ha⁻¹). To maximize yields, it is recommended to sow groundnut early in the season and to apply higher levels of fertilizer, which together enhance growth and yield outcomes where Sharma *et al.* (2013) investigated the effects of different fertility levels and bio-fertilizers on groundnut yield. Their study revealed that applying up to 100% RDF significantly increased the number of pods per plant, kernels per pod, as well as pod, haulm, and biological yields, along with net returns, compared to lower fertility levels and based on these findings, it is recommended to combine early sowing with higher fertilizer application to achieve optimal growth and yield in groundnut cultivation.

4.1.1.1.2 Effect of planting geometry on plant height of groundnut

Significant differences were exhibited in wider spacing of 50 cm x 10 cm (S₃) which generally led to taller plants, with an maximum height at 60 DAS (24.03, 23.91 and 23.97 cm) in 2019, 2020 and pooled data while at 30 DAS,

there was no significant differences found. Plants sown in wider spacing of 50 cm x 10 cm (S₃) consistently exhibited greater heights than those to S₂ and S₁. At 90 DAS, in 2019, 2020 and pooled value the maximum plant height was displayed at treatment S₃ (31.63, 31.78 and 31.70) while S₂ also recorded almost at par values with 30.82, 31.04 and 30.93 cm. Overall, the S₃ resulted in taller plants throughout the growth stages. The S₃ geometry (50 cm x 10 cm) had intermediate results, while the results suggest that a planting geometry of 40 cm x 10 cm (S₂) provides an optimal balance between space and resource utilization, promoting greater plant height while the closer spacing of S₁ (30 cm x 10 cm) might lead to competition for nutrients and light, resulting in shorter plants. This is in compliance with Reddy *et al.* (2014) who concluded that a spacing of 35x20 cm resulted in higher yields, while a closer spacing of 20x15 cm led to significantly lower yields and summarised that groundnut requires wider spacing (35x20 cm) to achieve its maximum growth and yield potential.

4.1.1.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on plant height

The study on the interaction effects on plant height in groundnut plants revealed that 30 DAS had no interaction effect among the various treatments.

The maximum plant height at 60 DAS was achieved with the combination with D₁F₂S₃ during 2019 (27.19 cm), 2020 (27.19 cm) and pooled value (27.19 cm) and similarly maximum height was achieved with the combination with D₁F₂S₃ during 2019 (33.33 cm), 2020 (32.96 cm) and pooled value (33.15cm) at 90DAS. The minimum plant height at 60 DAS was achieved with the combination with D₂F₁S₁ during 2019 (17.86 cm), 2020 (17.86cm) and pooled value (17.86cm) and similarly least height was achieved with the combination with D₂F₁S₁ during 2019 (25.26 cm), 2020 (24.21cm) and pooled value (24.73cm) at 90 DAS. The results indicated that early sowing (D₁: June 20) generally led to better growth compared to late sowing (D₂: July 10). Higher

fertility levels (F_2 : 100% RDF and F_3 : 125% RDF) positively influenced plant height, with the highest fertility level (F_3) being most beneficial. Planting geometry also played a role, with wider spacing (S_2 : 40 cm x 10 cm and S_3 : 50 cm x 10 cm) promoting better growth than closer spacing (S_1 : 30 cm x 10 cm). The best combination for overall plant height was $D_1F_2S_3$, while the worst was $D_1F_1S_1$. Therefore, for optimal groundnut growth, early sowing with 100% RDF and a planting geometry of 50 cm x 10 cm is recommended.

4.1.1.2 Number of primary branches

The data on number of primary branches of groundnut recorded at 30, 60, and 90 DAS are presented in Table 4.3 and Table 4.4.

4.1.1.2.1. Effect of date of sowing and fertility levels on number of primary branches of groundnut

The data on a number of primary branches of groundnut plants at different dates of sowing, measured at 30, 60, and 90 days after sowing (DAS) where crops sown on 20 June (D_1) along with 100% of RDF consistently exhibited a greater number of primary branches compared to the other treatments.

At 30 DAS, the number of primary branches for D_1F_3 exhibited maximum values in both 2019 (4.44), 2020 (4.62) and pooled (4.53) while in contrast, the lowest number of primary branches recorded for treatment D_2F_1 (3.17, 3.44 and 3.30). At 60 DAS, the number of primary branches for D_1F_3 exhibited maximum values in both 2019 (8.23), 2020 (8.19) and pooled (8.21) while in contrast, the lowest number of primary branches recorded for treatment D_2F_1 (6.20, 6.38 and 6.29). At 90 DAS, the number of primary branches for D_1F_3 exhibited maximum values in both 2019 (10.47), 2020 (10.49) and pooled (10.48) while in contrast, the lowest number of primary branches recorded for

Table 4.1 Effect of date of sowing, fertility levels and planting geometry on plant height in groundnut

<i>Treatments</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	13.54	14.26	13.90	22.70	22.26	22.48	30.27	30.80	30.54
D ₁ F ₂	14.35	15.09	14.72	24.51	24.18	24.35	32.32	32.53	32.43
D ₁ F ₃	14.54	15.26	14.90	24.73	24.40	24.56	32.49	32.70	32.59
D ₂ F ₁	12.25	12.98	12.61	19.58	19.25	19.42	27.51	27.25	27.38
D ₂ F ₂	12.44	13.52	12.98	21.28	20.92	21.10	30.08	29.48	29.78
D ₂ F ₃	12.90	13.22	13.06	22.60	22.32	22.46	30.16	30.26	30.21
<i>SEm±</i>	<i>0.76</i>	<i>0.69</i>	<i>0.51</i>	<i>0.67</i>	<i>0.58</i>	<i>0.44</i>	<i>0.57</i>	<i>0.40</i>	<i>0.35</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>2.11</i>	<i>1.83</i>	<i>1.31</i>	<i>1.80</i>	<i>1.26</i>	<i>1.03</i>
<i>Planting geometry</i>									
S ₁	12.50	13.37	12.94	20.34	20.40	20.37	28.96	28.69	28.83
S ₂	13.33	13.55	13.44	23.33	22.36	22.84	30.82	31.04	30.93
S ₃	14.18	15.25	14.71	24.03	23.91	23.97	31.63	31.78	31.70
<i>SEm±</i>	<i>0.46</i>	<i>0.70</i>	<i>0.42</i>	<i>0.34</i>	<i>0.31</i>	<i>0.23</i>	<i>0.25</i>	<i>0.36</i>	<i>0.22</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.99</i>	<i>0.89</i>	<i>0.65</i>	<i>0.73</i>	<i>1.04</i>	<i>0.62</i>

Table 4.2 Interaction effect of date of sowing, fertility levels and planting geometry on plant height in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	11.90	12.60	12.25	19.87	19.57	19.72	29.22	29.55	29.39
D ₁ F ₁ S ₂	12.51	13.10	12.81	22.55	21.55	22.05	29.36	30.85	30.11
D ₁ F ₁ S ₃	16.20	17.07	16.64	25.69	25.66	25.67	32.24	31.99	32.12
D ₁ F ₂ S ₁	12.92	13.18	13.05	21.64	21.64	21.64	31.58	31.96	31.77
D ₁ F ₂ S ₂	13.93	14.88	14.41	24.71	23.71	24.21	32.04	32.68	32.36
D ₁ F ₂ S ₃	16.20	17.20	16.70	27.19	27.19	27.19	33.33	32.96	33.15
D ₁ F ₃ S ₁	14.35	15.17	14.76	25.28	25.91	25.60	31.83	32.36	32.10
D ₁ F ₃ S ₂	13.08	14.16	13.62	22.99	21.99	22.49	32.65	32.56	32.60
D ₁ F ₃ S ₃	16.20	16.45	16.33	25.91	25.28	25.60	32.98	33.17	33.07
D ₂ F ₁ S ₁	11.06	12.17	11.62	17.86	17.86	17.86	25.26	24.21	24.73
D ₂ F ₁ S ₂	12.84	13.43	13.14	21.33	20.33	20.83	28.55	28.78	28.66
D ₂ F ₁ S ₃	12.84	13.34	13.09	19.56	19.56	19.56	28.72	28.77	28.74
D ₂ F ₂ S ₁	10.86	12.20	11.53	19.04	19.04	19.04	28.55	27.98	28.27
D ₂ F ₂ S ₂	13.43	14.04	13.74	22.85	21.85	22.35	30.73	29.45	30.09
D ₂ F ₂ S ₃	13.04	14.33	13.69	21.95	21.89	21.92	30.95	31.02	30.99
D ₂ F ₃ S ₁	13.93	14.90	14.42	18.37	18.37	18.37	27.34	26.10	26.72
D ₂ F ₃ S ₂	14.18	11.70	12.94	25.55	24.71	25.13	31.56	31.92	31.74
D ₂ F ₃ S ₃	10.59	13.07	11.83	23.89	23.89	23.89	31.57	32.74	32.16
<i>SEm±</i>	<i>1.13</i>	<i>1.73</i>	<i>1.03</i>	<i>0.83</i>	<i>0.75</i>	<i>0.56</i>	<i>0.61</i>	<i>0.87</i>	<i>0.53</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>2.43</i>	<i>2.18</i>	<i>1.59</i>	<i>1.79</i>	<i>2.55</i>	<i>1.52</i>

treatment D₂F₁ (8.63, 8.75 and 8.68) however, D₁F₂ also showed at par values with the maximum number of primary branches (10.33, 10.49 and 10.41 respectively). Early sowing, such as on June 20, combined with 100% RDF, optimizes growth conditions and nutrient availability, resulting in more primary branches in groundnut plants and this is due to favourable weather and adequate nutrients, promoting robust development. This is also similar to the results reported by Kumar *et al.* (2003) and Kumar *et al.* (2017) who discovered that applying 30 kg K₂O ha⁻¹ significantly increased the number of branches per plant in mustard compared to 15 kg K₂O ha⁻¹. Balanced nutrient supply (N, P, K) each year improved soil fertility and nutrient availability, leading to enhanced crop growth.

4.1.1.2.2 Effect of planting geometry on number of primary branches of groundnut

The wider spacing of 50 cm x 10 cm (S₃) generally led to a greater number of primary branches, with an average primary branches of 4.36 (2019), 4.54 (2020) and 4.45 (pooled data), while the narrowest spacing (S₁: 30 cm x 10 cm) resulted in lesser number of primary branches, with an average 3.64 at 30DAS respectively.

At 60 DAS, S₃ generally led to maximum number of primary branches with 8.23 (2019), 8.19 (2020) and 8.21 (pooled data), and similarly in 90 DAS S₃ led to maximum number of primary branches with 10.09 (2019), 10.24 (2020) and 10.17 (pooled data), while the narrowest spacing (S₁: 30 cm x 10 cm) resulted in lesser number of primary branches, with 9.21 (2019), 9.29 (2020) and 9.25 (pooled) at 90DAS respectively. The wider spacing of

50cm×10 cm (S₃) leading to a greater number of primary branches in groundnut plants can be attributed to reduced competition for resources such as light, water, and nutrients and the ample space in wider spacing allows for better root expansion and canopy development, facilitating optimal plant growth and branch formation throughout various growth stages.

Gawariya *et al.* (2015) also reported similar results where a field experiment with four sowing dates (1st, 16th, 31st October, and 15th November) and six crop geometries (60 × 15, 45 × 15, 45 × 20, 45 × 25, 30 × 20, and 30 × 25 cm) using a split plot design with four replications. The results showed that the 30 × 20 cm crop geometry recorded significantly higher seed yield (1.8 t ha⁻¹) and better yield attributes (number of primary, secondary, and tertiary branches, and number and weight of siliquae plant⁻¹). This spacing provided better utilization of space, nutrients, water, and sunshine, leading to higher dry matter translocation to yield components compared to the other geometries and this aligns with Pandey *et al.* (2015), Yeswanth and Debbarma (2022) and Sowmya *et al.* (2022)

4.1.1.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on number of primary branches

The combination of early sowing (D₁), the ideal fertility level (F₂), and high planting geometry (S₃) yielded the highest plant growth. In contrast, late sowing (D₂), the lowest fertility level (F₁), and the closest planting geometry (S₁) resulted in the lowest plant growth. Combination of D₁F₂S₃ consistently showed the highest growth across all stages – 30 (pooled 4.77), 60 (pooled 9.02), and 90 DAS (pooled 11.28) where the combination involved early sowing (20 June), 100% fertility level (100% RDF), and a planting geometry of 50 cm x 10 cm while D₂F₁S₁ consistently showed the lowest growth across all stages. This concludes that early sowing ensures that plants benefit from favourable environmental conditions such as adequate sunlight and moderate

Table 4.3 Effect of date of sowing, fertility levels and planting geometry on number of primary branches in groundnut

<i>Treatments</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	3.94	4.09	4.02	7.18	7.23	7.21	9.77	9.84	9.81
D ₁ F ₂	4.19	4.35	4.27	8.07	8.12	8.09	10.33	10.49	10.41
D ₁ F ₃	4.44	4.62	4.53	8.23	8.19	8.21	10.47	10.49	10.48
D ₂ F ₁	3.17	3.44	3.30	6.20	6.38	6.29	8.63	8.73	8.68
D ₂ F ₂	3.61	3.92	3.77	7.13	7.23	7.18	9.37	9.60	9.48
D ₂ F ₃	4.04	4.07	4.06	7.21	7.31	7.26	9.64	9.81	9.73
<i>SEm±</i>	<i>0.21</i>	<i>0.17</i>	<i>0.13</i>	<i>0.28</i>	<i>0.24</i>	<i>0.18</i>	<i>0.20</i>	<i>0.18</i>	<i>0.13</i>
<i>CD at 5%</i>	<i>0.65</i>	<i>0.53</i>	<i>0.39</i>	<i>0.88</i>	<i>0.74</i>	<i>0.54</i>	<i>0.63</i>	<i>0.56</i>	<i>0.39</i>
<i>Planting geometry</i>									
S ₁	3.61	3.68	3.64	6.96	7.08	7.02	9.21	9.29	9.25
S ₂	3.73	4.02	3.88	7.01	7.00	7.00	9.80	9.96	9.88
S ₃	4.36	4.54	4.45	8.05	8.15	8.10	10.09	10.24	10.17
<i>SEm±</i>	<i>0.11</i>	<i>0.11</i>	<i>0.08</i>	<i>0.16</i>	<i>0.15</i>	<i>0.11</i>	<i>0.12</i>	<i>0.12</i>	<i>0.08</i>
<i>CD at 5%</i>	<i>0.31</i>	<i>0.31</i>	<i>0.22</i>	<i>0.47</i>	<i>0.45</i>	<i>0.32</i>	<i>0.34</i>	<i>0.36</i>	<i>0.24</i>

Table 4.4 Interaction effect of date of sowing, fertility levels and planting geometry on number of primary branches

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	3.57	2.97	3.27	6.20	6.43	6.32	9.10	9.17	9.13
D1F1S2	3.57	4.63	4.10	6.83	6.73	6.78	9.80	9.83	9.82
D1F1S3	4.70	4.67	4.68	8.50	8.53	8.52	10.40	10.53	10.47
D1F2S1	3.60	3.92	3.76	7.43	7.77	7.60	9.63	9.70	9.67
D1F2S2	4.23	4.33	4.28	7.73	7.60	7.67	10.13	10.43	10.28
D1F2S3	4.73	4.80	4.77	9.03	9.00	9.02	11.23	11.33	11.28
D1F3S1	4.53	4.77	4.65	8.20	8.37	8.28	10.47	10.20	10.33
D1F3S2	4.13	4.40	4.27	7.67	7.30	7.48	10.07	10.17	10.12
D1F3S3	4.67	4.70	4.68	8.83	8.90	8.87	10.87	11.10	10.98
D2F1S1	2.60	2.90	2.75	5.93	5.97	5.95	7.70	7.88	7.79
D2F1S2	3.37	3.43	3.40	6.20	6.57	6.38	9.40	9.43	9.42
D2F1S3	3.53	3.98	3.76	6.47	6.60	6.53	8.80	8.87	8.83
D2F2S1	2.97	3.87	3.42	6.20	6.23	6.22	8.70	8.80	8.75
D2F2S2	3.73	3.63	3.68	7.53	7.50	7.52	10.03	10.33	10.18
D2F2S3	4.13	4.27	4.20	7.67	7.97	7.82	9.37	9.67	9.52
D2F3S1	4.37	3.67	4.02	7.77	7.73	7.75	9.67	9.97	9.82
D2F3S2	3.37	3.70	3.53	6.07	6.30	6.18	9.37	9.53	9.45
D2F3S3	4.40	4.83	4.62	7.80	7.90	7.85	9.90	9.93	9.92
<i>SEm±</i>	<i>0.26</i>	<i>0.26</i>	<i>0.19</i>	<i>0.39</i>	<i>0.37</i>	<i>0.27</i>	<i>0.28</i>	<i>0.30</i>	<i>0.21</i>
<i>CD at 5%</i>	<i>0.77</i>	<i>0.76</i>	<i>0.53</i>	<i>1.15</i>	<i>1.09</i>	<i>0.77</i>	<i>0.83</i>	<i>0.87</i>	<i>0.59</i>

temperatures. The ideal fertility level (F_2) provides balanced nutrients essential for healthy growth, and the wider planting geometry (S_3) minimizes competition for resources, allowing each plant to access sufficient light, water, and nutrients. This synergy of optimal sowing time, nutrient availability, and spacing results in superior plant growth, as observed in the consistently highest growth metrics across all stages for the $D_1F_2S_3$ combination.

4.1.1.3 Number of leaves

The data on number of leaves of groundnut recorded at 30, 60, and 90 DAS are presented in Table 4.5 and Table 4.6.

4.1.1.3.1 Effect of date of sowing and fertility levels on number of leaves of groundnut

The combination of D_1F_3 [early-sown crops (D_1) along with 125% (F_3)] resulted in the highest number of leaves at 60 DAS and 90 DAS but showed no significant variation at 30DAS. As portrayed from the data in 60 DAS, there was significant variation in the number of leaves plant⁻¹ was obtained under D_1F_3 in the both the years *i.e.* 52.25 in 2019 and 54.10 in 2020 and 53.17 in pooled data. It followed a more or less, similar trend was observed at 90 DAS in Table 4.5, where the number of leaves plant⁻¹ in both 2019 and 2020 years and pooled data exhibited showed significant value of 75.61, 75.04 and 75.33. This may conclude that early sowing allows plants to take advantage of favourable weather conditions, promoting vigorous vegetative growth. The higher fertility level (125% RDF) ensures an ample supply of essential nutrients, which supports the development of more leaves as the plants grow. While the impact of these optimal conditions might not be immediately visible at 30 DAS, the cumulative effect of early sowing and high nutrient levels becomes more pronounced at later stages (60 and 90 DAS), leading to a significant increase in the number of leaves per plant. According to the findings of Kumar *et al.* (2003) and Kumar *et al.* (2017), applying 30 kg of K_2O per hectare significantly increased the number of

mustard leaves and branches per plant compared to applying 15 kg of K₂O per hectare. Providing a balanced annual supply of nutrients (N, P, K) improved soil fertility and enhanced crop growth. Singh *et al.* (2010) also found that mustard plants receiving 150% of the recommended dose of fertilizers (RDF) exhibited greater branch production, height, and dry matter compared to those receiving only 75% of RDF and these improvement are attributed to better nutrition, light interception, and photosynthesis. This is also seconded by the findings of Chitale and Bhambri, (2001) where it was concluded that adequate nutrient supply enhances seed and stover yield by improving the formation of branches per plant, leaves per plant, siliquae per plant, and the length of siliquae. Overall, these results suggest that higher levels of fertilizer application can boost mustard growth and yields.

4.1.1.3.2 Effect of planting geometry on the number of leaves of groundnut

At 60 DAS, S₃ generally led to maximum number of leaves with 51.55 (2019), 52.18 (2020) and 52.18 (pooled data), and similarly in 90 DAS S₃ led to maximum number of leaves with 74.24 (2019), 74.32 (2020) and 72.28 (pooled data) while at 60 DAS, the narrowest spacing (S₁: 30 cm x 10 cm) resulted in least number of leaves plant⁻¹, with 51.55 (2019), 52.81 (2020) and 52.18 (pooled) and at 90 DAS respectively and one probable reason maybe that this tight spacing limits each plant's access to light, water, and nutrients, which are crucial for vegetative growth. The resulting resource scarcity hampers the plants' ability to develop a robust foliage system, leading to a lower number of leaves per plant compared to those grown in wider spacings where resource competition is minimized and these results are in accordance with Yeswanth and Debbarma (2022) and Sowmya *et al.* (2022).

4.1.1.3.3 Interaction effect of date of sowing, fertility levels, and planting geometry on the number of leaves

The interaction effect of the date of sowing, fertility levels, and planting geometry on the number of leaves in groundnut shows a significant influence on plant growth at 60 and 90 DAS). The data indicate that both the date of sowing and fertility levels significantly impact leaf number, with different planting geometries further modifying these effects. Generally, early sowing (D₁, June 20) combined with higher fertility levels (F₃, 125% RDF) and S₃ (50x10 cm) tended to produce a higher number of leaves across all geometries. For instance, the combination of D₁F₃S₃ resulted in a consistently high number of leaves at 60 DAS (53.74, pooled) and 90 DAS (76.04, pooled). This suggests that higher fertility levels enhance leaf development when sown early, and the spacing of 50 cm x 10 cm (S₃) also supports better growth under these conditions. On the other hand, the combination yielding the lowest growth in terms of leaf number was observed with late sowing (D₂, July 10) and lower fertility levels (F₁, 75% RDF), S₁ (30 x10cm) at 60 DAS (49.94 pooled) and 90 DAS (71.04 pooled) compared to other combinations. This indicates that late sowing paired with lower fertility levels and closer planting geometry (30 cm x 10 cm) is less favourable for leaf development. The data imply that timely sowing and adequate fertility are crucial for optimizing groundnut growth, with the combination of early sowing, high fertility, and wider planting geometry being the most beneficial.

4.1.1.4 Leaf area index

The data on leaf area index of groundnut recorded at 30, 60, and 90 DAS are presented in Table 4.7 and Table 4.8

4.1.1.4.1 Effect of date of sowing and fertility levels on leaf area index of groundnut

At 30 DAS, there was no significant response to the effect of date of sowing and fertility levels on leaf area index.

However at 60DAS, significant differences were observed where groundnuts sown on June 20 with 125% RDF (D₁F₃) consistently showed higher LAI values compared to the other treatments at pooled data during 60 DAS in 2019(3.87), 2020 (3.78) and pooled (3.83). Moreover, it followed a similar trend at 90 DAS where D₁F₃ exhibited LAI values in 2019(4.81), 2020 (4.80) and pooled (4.81). Increasing fertilizer with early sowing doses also improved LAI, with the highest values observed in 125% RDF (F₃) treatments while D₂F₁ (July 10th with 75% RDF) had showed least value of LAI during 60 DAS (pooled 2.39), 60 DAS (3.28, pooled) while D₂F₁ also showed at par values during 90DAS (4.58, 4.69 and 4.64) . Increasing fertilizer doses also improved LAI, with the highest values observed in 125% RDF (F₃) treatments and the lowest in 75% RDF (F₁) and these align with Karunakaran *et al.* (2010) who reported similar trends, noting that integrated and synthetic nutrient management produced higher LAI due to the increased number of leaves and these findings suggest that both earlier sowing dates and higher fertility levels positively affect the leaf area index of groundnuts. The association of nutrient elements from inorganic and organics produced a greater number of leaves resulting in higher LAI (Karunakaran *et al.* 2010) and similar results were also obtained by Dhadge and Satpute (2014).

Table 4.5 Effect of date of sowing, fertility levels and planting geometry on number of leaves in groundnut

<i>Treatments</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	26.37	26.13	26.25	51.18	51.92	51.55	73.88	73.80	73.84
D ₁ F ₂	26.40	26.95	26.68	51.81	52.59	52.20	74.61	74.79	74.70
D ₁ F ₃	26.33	27.45	26.89	52.25	54.10	53.17	75.61	75.04	75.33
D ₂ F ₁	25.09	24.78	24.94	50.30	50.97	50.63	71.92	72.01	71.96
D ₂ F ₂	25.94	25.28	25.61	50.79	51.63	51.21	73.40	73.19	73.30
D ₂ F ₃	26.35	25.47	25.91	51.05	51.64	51.35	73.53	73.06	73.30
<i>SEm±</i>	<i>0.56</i>	<i>0.61</i>	<i>0.41</i>	<i>0.20</i>	<i>0.26</i>	<i>0.16</i>	<i>0.31</i>	<i>0.23</i>	<i>0.19</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.63</i>	<i>0.83</i>	<i>0.49</i>	<i>0.98</i>	<i>0.73</i>	<i>0.57</i>
<i>Planting geometry</i>									
S ₁	25.97	25.29	25.63	50.84	51.74	51.29	73.37	72.61	72.99
S ₂	26.02	25.92	25.97	51.30	51.88	51.59	73.87	74.02	73.95
S ₃	26.25	26.82	26.54	51.55	52.81	52.18	74.24	74.32	74.28
<i>SEm±</i>	<i>0.62</i>	<i>0.48</i>	<i>0.39</i>	<i>0.11</i>	<i>0.19</i>	<i>0.11</i>	<i>0.22</i>	<i>0.19</i>	<i>0.15</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.33</i>	<i>0.57</i>	<i>0.32</i>	<i>0.64</i>	<i>0.56</i>	<i>0.41</i>

Table 4.6 Interaction effect of date of sowing, fertility levels and planting geometry on number of leaves in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	27.67	25.33	26.50	50.57	51.23	50.90	72.97	72.63	72.80
D ₁ F ₁ S ₂	25.45	25.81	25.63	51.50	50.71	51.11	74.42	74.66	74.54
D ₁ F ₁ S ₃	26.00	27.24	26.62	51.46	53.82	52.64	74.25	74.09	74.17
D ₁ F ₂ S ₁	26.48	26.87	26.68	52.31	51.21	51.76	74.49	72.86	73.68
D ₁ F ₂ S ₂	25.08	24.54	24.81	50.63	51.65	51.14	73.96	75.00	74.48
D ₁ F ₂ S ₃	27.65	29.44	28.55	52.49	54.91	53.70	75.38	76.50	75.94
D ₁ F ₃ S ₁	26.29	25.59	25.94	52.30	56.25	54.27	75.73	74.73	75.23
D ₁ F ₃ S ₂	27.74	29.04	28.39	51.46	51.56	51.51	74.85	74.57	74.71
D ₁ F ₃ S ₃	24.96	27.71	26.34	52.99	54.49	53.74	76.26	75.82	76.04
D ₂ F ₁ S ₁	24.17	22.97	23.57	49.56	50.33	49.94	70.68	71.40	71.04
D ₂ F ₁ S ₂	26.51	24.69	25.60	50.79	51.07	50.93	73.41	73.05	73.23
D ₂ F ₁ S ₃	24.60	26.68	25.64	50.56	51.50	51.03	71.66	71.57	71.62
D ₂ F ₂ S ₁	25.50	25.82	25.66	50.06	50.56	50.31	73.77	72.15	72.96
D ₂ F ₂ S ₂	25.97	24.74	25.36	51.45	53.55	52.50	72.85	73.75	73.30
D ₂ F ₂ S ₃	26.34	25.26	25.80	50.86	50.79	50.83	73.57	73.68	73.63
D ₂ F ₃ S ₁	25.71	25.16	25.44	50.25	50.84	50.54	72.57	71.87	72.22
D ₂ F ₃ S ₂	25.36	26.68	26.02	51.95	52.74	52.35	73.74	73.08	73.41
D ₂ F ₃ S ₃	27.97	24.58	26.27	50.96	51.35	51.15	74.28	74.24	74.26
<i>SEm±</i>	<i>1.52</i>	<i>1.17</i>	<i>0.96</i>	<i>0.28</i>	<i>0.48</i>	<i>0.27</i>	<i>0.53</i>	<i>0.47</i>	<i>0.36</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.81</i>	<i>1.39</i>	<i>0.78</i>	<i>1.56</i>	<i>1.38</i>	<i>1.01</i>

4.1.1.4.2 Effect of planting geometry on leaf area index of groundnut

Planting geometry also influenced the LAI, with the best results observed in the 50 cm x 10 cm spacing (S_3) as at 60 DAS, in 2019, 2020 and pooled data the LAI were maximum in S_3 with values of 3.09, 3.11 and 3.10; this followed a similar trend in at 90 DAS, in 2019, 2020 and pooled data where in S_3 had the highest values of 4.07, 4.10 and 4.09 this indicates that the 50 cm x 10 cm spacing provided optimal conditions for groundnut growth compared to the other geometries tested. There was no significant effect of planting geometry on LAI at the 30 DAS growth period as maximum of the plant leaves achieved the highest leaf growth. Sowmya *et al.* (2022) in the result showed that spacing at 30×10 cm recorded higher plant height, dry matter accumulation while LAI and higher number of branches were observed with 60×10 cm spacing. Higher pod and haulm yields were observed with the land configuration flat bed with crop compaction and 30×10 cm spacing and was at par with the findings of Irungam *et al* (2016), Singh *et al.* (2008), Dhadge and Satpute (2014).

4.1.1.4.3 Interaction effect of date of sowing, fertility levels and planting geometry on leaf area index in groundnut

There was no interaction effect between date of sowing, fertility levels, and planting geometry on the leaf area index (LAI) in groundnut.

4.1.1.5 Crop Growth Rate

The data on CGR of groundnut recorded at 30-60 and 60-90 DAS are presented in Table 4.9 and Table 4.10.

4.1.1.5.1 Effect of date of sowing and fertility levels on CGR in groundnut

The effect of date of sowing on CGR in groundnut as depicted showed that groundnut with the combination of D_1F_3 (20th June sowing with 125% recommended dose fertilizer, RDF) had a pooled CGR of 7.77 (2019, 7.61 and 2020, 7.93) from 30-60 DAS and similarly at 60-90 DAS D_1F_3 showed highest

CGR with values of 6.87 in 2019, 7.11 in 2020 and 6.99 in pooled data and D₁F₂ also showed close proximity values (5.95, 6.13 and 6.04) . In contrast, D₂F₁ (10th July sowing with 75% RDF) had a pooled CGR of 2.46 in 30-60 and 5.52 for 60-90 DAS. The combination of early sowing (D₁) on June 20 with 125% recommended dose of fertilizer (F₃) resulted in the highest crop growth rate (CGR) in groundnut plants due to optimal growing conditions and enhanced nutrient supply as early sowing allows the plants to benefit from favourable climatic conditions, such as adequate sunlight and moderate temperatures, which are essential for vigorous growth. Additionally, the 125% RDF ensures that the plants receive an ample and balanced supply of nutrients. promoting healthy vegetative and reproductive growth. In contrast, the later sowing date (D₂) on July 10 with a lower fertility level (75% RDF) results in suboptimal conditions, including less favorable weather and insufficient nutrient availability, leading to significantly lower CGR values. This aligns with Patel *et al.* (2019) who reported that LAI, CGR, RGR significantly increased with increased on fertility levels in lentil. The periodical observations recorded on lentil reveal that CGR were increased almost significantly due to application of higher levels of fertility N₄₀P₈₀K₄₀ at every stage. At harvest stage, the CGR recorded a value of 0.36 g/m²/day. The response of NPK in improving seed quality may be attributed to its significant role in regulating the photosynthesis, root-enlargement, and better microbial activities.

Table 4.7 Effect of date of sowing, fertility levels and planting geometry on leaf area index in groundnut

<i>Treatments</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	0.70	0.80	0.75	3.39	3.38	3.38	4.48	4.57	4.53
D ₁ F ₂	0.79	0.85	0.82	3.46	3.53	3.50	4.58	4.69	4.64
D ₁ F ₃	0.82	0.84	0.83	3.87	3.78	3.83	4.81	4.80	4.81
D ₂ F ₁	0.69	0.70	0.69	2.36	2.42	2.39	3.26	3.30	3.28
D ₂ F ₂	0.71	0.72	0.71	2.50	2.53	2.52	3.40	3.46	3.43
D ₂ F ₃	0.74	0.72	0.73	2.64	2.66	2.65	3.52	3.55	3.53
<i>SEm±</i>	<i>0.03</i>	<i>0.06</i>	<i>0.03</i>	<i>0.04</i>	<i>0.03</i>	<i>0.03</i>	<i>0.05</i>	<i>0.03</i>	<i>0.03</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.14</i>	<i>0.10</i>	<i>0.08</i>	<i>0.16</i>	<i>0.09</i>	<i>0.09</i>
<i>Planting geometry</i>									
S ₁	0.71	0.75	0.73	2.97	2.99	2.98	3.94	4.03	3.98
S ₂	0.76	0.79	0.77	3.05	3.05	3.05	4.02	4.06	4.04
S ₃	0.75	0.77	0.76	3.09	3.11	3.10	4.07	4.10	4.09
<i>SEm±</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>	<i>0.03</i>	<i>0.02</i>	<i>0.02</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.10</i>	<i>0.09</i>	<i>0.07</i>	<i>0.10</i>	<i>0.06</i>	<i>0.06</i>

Table 4.8 Interaction effect of date of sowing, fertility levels and planting geometry on leaf area index in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	0.62	0.76	0.69	3.37	3.37	3.37	4.45	4.51	4.48
D1F1S2	0.72	0.82	0.77	3.38	3.37	3.38	4.50	4.57	4.53
D1F1S3	0.75	0.83	0.79	3.43	3.39	3.41	4.51	4.64	4.58
D1F2S1	0.71	0.81	0.76	3.44	3.50	3.47	4.52	4.67	4.60
D1F2S2	0.83	0.86	0.84	3.47	3.53	3.50	4.61	4.69	4.65
D1F2S3	0.84	0.87	0.86	3.48	3.58	3.53	4.61	4.72	4.66
D1F3S1	0.86	0.87	0.86	3.65	3.63	3.64	4.62	4.77	4.69
D1F3S2	0.67	0.78	0.72	3.93	3.77	3.85	4.83	4.79	4.81
D1F3S3	0.94	0.89	0.91	4.02	3.95	3.98	4.99	4.85	4.92
D2F1S1	0.64	0.67	0.65	2.29	2.34	2.32	3.19	3.26	3.22
D2F1S2	0.79	0.75	0.77	2.36	2.46	2.41	3.26	3.32	3.29
D2F1S3	0.64	0.67	0.66	2.44	2.47	2.45	3.33	3.33	3.33
D2F2S1	0.65	0.73	0.69	2.47	2.49	2.48	3.36	3.43	3.40
D2F2S2	0.79	0.74	0.77	2.51	2.51	2.51	3.39	3.46	3.42
D2F2S3	0.68	0.69	0.68	2.51	2.61	2.56	3.46	3.49	3.47
D2F3S1	0.77	0.67	0.72	2.59	2.61	2.60	3.50	3.52	3.51
D2F3S2	0.78	0.79	0.79	2.63	2.68	2.66	3.52	3.53	3.53
D2F3S3	0.66	0.70	0.68	2.68	2.69	2.68	3.53	3.60	3.56
<i>SEm±</i>	<i>0.06</i>	<i>0.07</i>	<i>0.05</i>	<i>0.08</i>	<i>0.08</i>	<i>0.06</i>	<i>0.08</i>	<i>0.05</i>	<i>0.05</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

4.1.1.5.2 Effect of planting geometry on CGR in groundnut

Planting geometry also influenced the CGR where groundnuts planted with a geometry of 50 cm x 10 cm (S₃) consistently exhibited higher growth rates. For instance, the pooled CGR for S₃ was 6.36 for 30-60 DAS (6.24 in 2019 and 6.49 in 2020) and 7.06 for 60-90 DAS (7.00 in 2019 and 7.13 in 2020). On the other hand, the geometry of 50 cm x 10 cm (S₁) showed the least value of pooled CGR of 4.39 30-60 and 5.12 for 60-90 DAS for the respective periods. The higher crop growth rates (CGR) observed in groundnuts planted with a wider geometry of 50 cm x 10 cm can be attributed to reduced competition for essential resources such as light, water, and nutrients. The increased spacing allows each plant to access more resources, promoting better overall growth and development and this optimal resource availability leads to enhanced photosynthetic efficiency and biomass accumulation, reflected in the higher CGR values. In contrast, the narrowest spacing (S₁: 30 cm x 10 cm) results in significant competition among plants, limiting their growth potential and leading to the lowest CGR values for the respective periods. Similar reports were also displayed by Yeswanth and Debbarma (2022) who reported T₆ (Sulphur at 60 kg ha⁻¹ + 30 x 10 cm,) significantly higher crop growth rate (5.33g/m²/day) due to better photosynthetic activity and higher spacing, due to greater exposure of sunlight, and increased availability of nutrients. The results were in accordance with to the findings of Gadade *et al.* (2018) and Chilakala *et al.* (2023).

4.1.1.5.3 Interaction effect of date of sowing, fertility levels and planting geometry on CGR in groundnut

Early sowing (D₁) combined with 100% RDF (F₂) and a planting geometry of 50 cm x 10 cm (S₃) consistently yielded the highest crop growth rates as displayed. The combination D₁F₂S₃ achieved the highest CGR in 2019 (9.16), 2020 (9.43) and pooled value (9.30) during 30-60 DAS and followed a similar trend in 2019 (7.46), 2020 (7.77) and pooled value (7.61) during 60-90

DAS. The closer planting geometry might have led to higher competition for resources among plants, and the late sowing could have subjected the crops to less favourable environmental conditions, thereby limiting growth and thus results highlight the importance of optimizing sowing dates, fertility levels, and planting geometries to achieve groundnut crop growth outcomes.

4.1.1.6 Net assimilation rate

The data on NAR of groundnut recorded at 30-60 and 60-90 DAS are presented in Table 4.11 and Table 4.12.

4.1.1.6.1 Effect of date of sowing and fertility levels on NAR in groundnut

The highest NAR for 30-60 DAS was observed in D₁F₃, with a pooled value of 0.52, (0.70 in 2020) and for 60-90 DAS was 1.49 (2019), 1.46 (2020) and 1.48 (pooled value) indicating that early sowing combined with the highest fertilizer dose (125% RDF) resulted in the most significant growth as shown which highlights that increasing the fertilizer dose to 125% RDF consistently promotes better growth in groundnut plants. Conversely, the lowest growth was observed in the D₂F₁ treatment with a pooled NAR of 0.17 (30-60 DAS) and 0.69 (60-90 DAS) indicating that 75% RDF (F₁) may not be as effective as the higher fertility level. This suggests that early sowing allows the plants to maximize their use of available resources, while the increased nutrient availability from the higher fertilizer dose supports more robust growth and development. Conversely, the lowest growth in the D₂F₁ treatment, with 75% RDF, suggests that a lower fertilizer dose may not provide sufficient nutrients to support optimal plant growth, particularly when sowing is delayed and the result is on par with Patel *et al.* (2019).

Table 4.9 Effect of date of sowing, fertility levels and planting geometry on CGR in groundnut

<i>Treatments</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D ₁ F ₁	5.81	5.60	5.71	5.91	6.08	5.99
D ₁ F ₂	7.39	7.73	7.56	5.95	6.13	6.04
D ₁ F ₃	7.61	7.93	7.77	6.87	7.11	6.99
D ₂ F ₁	2.40	2.52	2.46	5.48	5.55	5.52
D ₂ F ₂	4.06	4.25	4.15	6.31	5.93	6.12
D ₂ F ₃	4.92	5.13	5.03	6.39	6.22	6.31
<i>SEm±</i>	<i>0.36</i>	<i>0.37</i>	<i>0.26</i>	<i>0.24</i>	<i>0.23</i>	<i>0.17</i>
<i>CD at 5%</i>	<i>1.12</i>	<i>1.17</i>	<i>0.76</i>	<i>0.77</i>	<i>0.74</i>	<i>0.50</i>
<i>Planting geometry</i>						
S ₁	4.40	4.38	4.39	5.25	4.98	5.12
S ₂	5.46	5.71	5.58	6.20	6.40	6.30
S ₃	6.24	6.49	6.36	7.00	7.13	7.06
<i>SEm±</i>	<i>0.27</i>	<i>0.24</i>	<i>0.18</i>	<i>0.13</i>	<i>0.24</i>	<i>0.14</i>
<i>CD at 5%</i>	<i>0.78</i>	<i>0.69</i>	<i>0.51</i>	<i>0.37</i>	<i>0.70</i>	<i>0.38</i>

Table 4.10 Interaction effect of date of sowing, fertility levels and planting geometry on CGR in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	4.89	4.18	4.53	5.06	5.21	5.13
D ₁ F ₁ S ₂	4.54	4.48	4.51	5.30	5.23	5.27
D ₁ F ₁ S ₃	8.01	8.16	8.08	7.36	7.81	7.59
D ₁ F ₂ S ₁	6.21	6.43	6.32	4.28	3.98	4.13
D ₁ F ₂ S ₂	6.80	7.31	7.06	6.11	6.64	6.38
D ₁ F ₂ S ₃	9.16	9.43	9.30	7.46	7.77	7.61
D ₁ F ₃ S ₁	6.53	6.59	6.56	5.46	4.91	5.18
D ₁ F ₃ S ₂	8.43	9.11	8.77	7.34	8.21	7.78
D ₁ F ₃ S ₃	7.88	8.09	7.99	7.79	8.22	8.01
D ₂ F ₁ S ₁	2.46	2.31	2.38	5.12	5.16	5.14
D ₂ F ₁ S ₂	2.66	2.77	2.71	5.34	5.58	5.46
D ₂ F ₁ S ₃	2.08	2.48	2.28	5.98	5.91	5.94
D ₂ F ₂ S ₁	3.23	3.56	3.40	6.00	5.74	5.87
D ₂ F ₂ S ₂	4.54	4.43	4.48	6.34	5.96	6.15
D ₂ F ₂ S ₃	4.41	4.75	4.58	6.59	6.09	6.34
D ₂ F ₃ S ₁	3.11	3.19	3.15	5.60	4.90	5.25
D ₂ F ₃ S ₂	5.76	6.19	5.98	6.77	6.80	6.79
D ₂ F ₃ S ₃	5.88	6.02	5.95	6.81	6.96	6.89
<i>SEm±</i>	<i>0.65</i>	<i>0.58</i>	<i>0.44</i>	<i>0.31</i>	<i>0.58</i>	<i>0.33</i>
<i>CD at 5%</i>	<i>1.91</i>	<i>1.69</i>	<i>1.24</i>	<i>0.91</i>	<i>1.70</i>	<i>0.94</i>

4.1.1.6.2 Effect of planting geometry on NAR in groundnut

When examining the impact of planting geometry, S₃ (50 cm x 10 cm) showed a consistent NAR across the treatments with a pooled value of 0.45 (30-60 DAS) and 1.35 (60-90 DAS), while the S₁ (30 cm x 10 cm) and S₂ (40 cm x 10 cm) geometries had almost at par values of pooled NAR values of around 0.30 (30-60 DAS) and 0.72 (60-90 DAS), respectively. The planting geometry of S₃ (50 cm x 10 cm) resulted in the highest and most consistent NAR values, indicating that this spacing optimizes plant growth by providing ample space for each plant to access light, water, and nutrients efficiently. The wider spacing likely reduces competition among plants, allowing for better root and canopy development, which in turn enhances overall growth. In contrast, the closer spacing of S₁ (30 cm x 10 cm) and S₂ (40 cm x 10 cm) likely increase competition for resources, resulting in lower and less consistent NAR values and this suggests that while closer spacing might accommodate more plants per area, they do not necessarily lead to better individual plant growth.

Yeswanth and Debbarma (2022) reported that T₆ (sulphur at 60 kg ha⁻¹ + 30 x 10 cm spacing) resulted in significantly higher plant height (39.09 cm), maximum number of nodules plant⁻¹ (8.07), higher plant dry weight (22.03 g plant⁻¹), and crop growth rate (5.33 g/m²/day). The highest dry matter production was observed with the 30 x 10 cm spacing, attributed to improved photosynthetic activity due to greater sunlight exposure and increased nutrient availability; these findings align with Gadade *et al.* (2018) and Chilakala *et al.* (2023)

4.1.1.6.3 Interaction effect of date of sowing, fertility levels, and planting geometry on NAR in groundnut

During the 30-60 DAS period, the highest pooled NAR was observed in the D₂F₃S₂ combination, with values of 0.46 in 2019 and 0.65 in the pooled data. However, in 2020, the maximum NAR was recorded in the D₁F₃S₂ combination, which reached 0.90. In contrast, the lowest pooled NAR during this period was

noted in the D₁F₁S₁ combination, with values of 0.17 in 2019, 0.12 in 2020, and a pooled value of 0.14. This combination involved sowing on July 10th with 75% RDF and a planting geometry of 30 cm x 10 cm. During the 60-90 DAS period, the highest pooled NAR was found in the D₁F₂S₃ combination, with values of 1.70 in 2019 and 1.68 in 2020, resulting in a pooled value of 1.69. This combination involved sowing on June 20th with 100% RDF and a planting geometry of 50 cm x 10 cm. The variations in NAR can be attributed to differences in sowing dates, fertilizer application rates, and planting geometries, which significantly influence the growth and assimilation efficiency of the crops.

4.1.1.7 Relative growth rate

The data on RGR of groundnut recorded at 30-60 and 60-90 are presented in Table 4.13 and Table 4.14.

4.1.1.7.1 Effect of date of sowing and fertility levels on RGR in groundnut

A reference on the data presented revealed that there was no effect of date of sowing and fertility levels on RGR in during the two years and pooled value.

4.1.1.7.2 Effect of planting geometry on RGR in groundnut

A reference on the data presented revealed that there was no effect of planting geometry on RGR in groundnut during the two years and pooled value.

Table 4.11 Effect of date of sowing, fertility levels and planting geometry on NAR in groundnut

<i>Treatments</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D1F1	0.24	0.34	0.29	1.17	1.11	1.14
D1F2	0.30	0.66	0.48	1.21	1.16	1.19
D1F3	0.34	0.70	0.52	1.49	1.46	1.48
D2F1	0.20	0.14	0.17	0.67	0.71	0.69
D2F2	0.37	0.38	0.37	0.71	0.77	0.74
D2F3	0.39	0.64	0.52	1.07	0.96	1.02
<i>SEm±</i>	<i>0.01</i>	<i>0.03</i>	<i>0.02</i>	<i>0.08</i>	<i>0.10</i>	<i>0.06</i>
<i>CD at 5%</i>	<i>0.04</i>	<i>0.11</i>	<i>0.05</i>	<i>0.24</i>	<i>0.33</i>	<i>0.19</i>
<i>Planting geometry</i>						
S ₁	0.29	0.32	0.30	0.78	0.67	0.72
S ₂	0.32	0.52	0.42	1.07	1.05	1.06
S ₃	0.31	0.59	0.45	1.32	1.37	1.35
<i>SEm±</i>	<i>0.01</i>	<i>0.04</i>	<i>0.02</i>	<i>0.05</i>	<i>0.07</i>	<i>0.04</i>
<i>CD at 5%</i>	<i>0.02</i>	<i>0.10</i>	<i>0.05</i>	<i>0.16</i>	<i>0.20</i>	<i>0.12</i>

Table 4.12 Interaction effect of date of sowing, fertility levels and planting geometry on NAR in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	0.24	0.20	0.22	1.03	0.99	1.01
D1F1S2	0.21	0.20	0.21	1.29	1.16	1.22
D1F1S3	0.28	0.62	0.45	1.20	1.17	1.19
D1F2S1	0.34	0.51	0.42	0.53	0.50	0.52
D1F2S2	0.30	0.60	0.45	1.39	1.31	1.35
D1F2S3	0.26	0.85	0.56	1.70	1.68	1.69
D1F3S1	0.37	0.51	0.44	1.41	0.85	1.13
D1F3S2	0.30	0.90	0.60	1.46	1.62	1.54
D1F3S3	0.36	0.68	0.52	1.59	1.91	1.75
D2F1S1	0.17	0.12	0.14	0.48	0.43	0.45
D2F1S2	0.22	0.16	0.19	0.50	0.45	0.47
D2F1S3	0.21	0.14	0.17	1.03	1.23	1.13
D2F2S1	0.30	0.27	0.29	0.33	0.32	0.32
D2F2S2	0.45	0.42	0.43	0.67	0.82	0.74
D2F2S3	0.36	0.45	0.40	1.15	1.18	1.16
D2F3S1	0.30	0.31	0.31	0.89	0.91	0.90
D2F3S2	0.46	0.84	0.65	1.09	0.92	1.01
D2F3S3	0.41	0.77	0.59	1.23	1.06	1.14
<i>SEm±</i>	<i>0.02</i>	<i>0.09</i>	<i>0.04</i>	<i>0.13</i>	<i>0.17</i>	<i>0.11</i>
<i>CD at 5%</i>	<i>0.06</i>	<i>0.25</i>	<i>0.13</i>	<i>0.38</i>	<i>0.49</i>	<i>0.30</i>

4.1.1.7.3 Interaction effect of date of sowing, fertility levels and planting geometry on RGR in groundnut

The data presented on the interaction on relative growth rate (RGR) of groundnut plants under varying conditions of sowing dates, fertility levels, and planting geometry revealed that there was no significant variation and interaction

4.1.1.8 Shoot dry weight

The data on shoot dry weight in groundnut recorded at 30, 60, and 90 DAS are presented in Table 4.15 and Table 4.16

4.1.1.8.1 Effect of date of sowing and fertility levels on shoot dry weight in groundnut

The shoot dry weight was higher for groundnuts under the combination of D₁F₃ showed the highest shoot dry weight in 2019 (15.26), 2020 (14.88) and pooled (15.07) for 30 DAS, 24.40 (pooled) for 60 DAS, and 31.59 (pooled) for 90 DAS. This indicates that early sowing (D₁) generally resulted in better growth than late sowing (D₂); these results indicate that early sowing (D₁) generally resulted in better growth compared to late sowing (D₂). This can be attributed to the longer growing season available for early-sown crops, allowing for better establishment, increased photosynthetic activity, and more efficient utilization of resources, ultimately leading to higher biomass accumulation.

4.1.1.8.2 Effect of planting geometry on shoot dry weight in groundnut

Among the different planting geometries, S₃ (50 cm x 10 cm) generally resulted in the highest shoot dry weight. Specifically, S₃ had a shoot dry weight of 15.58 (pooled) for 30 DAS and 23.86 (pooled) for 60 DAS and 31.33 (pooled) for 90DAS which indicates that a planting geometry of 50 cm x 10 cm is optimal for shoot dry weight accumulation in groundnut plants and this result can be attributed to the better spacing, which likely reduces competition for resources

Table 4.13 Effect of date of sowing, fertility levels and planting geometry on RGR in groundnut

<i>Treatments</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D ₁ F ₁	0.005	0.005	0.005	0.004	0.004	0.004
D ₁ F ₂	0.007	0.007	0.007	0.004	0.004	0.004
D ₁ F ₃	0.007	0.007	0.007	0.005	0.005	0.005
D ₂ F ₁	0.003	0.003	0.003	0.005	0.005	0.005
D ₂ F ₂	0.005	0.005	0.005	0.005	0.005	0.005
D ₂ F ₃	0.006	0.006	0.006	0.006	0.006	0.006
<i>SEm±</i>	<i>0.0006</i>	<i>0.0005</i>	<i>0.0004</i>	<i>0.0004</i>	<i>0.0002</i>	<i>0.0002</i>
<i>CD at 5%</i>	<i>0.0019</i>	<i>0.0014</i>	<i>0.0011</i>	<i>0.0013</i>	<i>0.0007</i>	<i>0.0007</i>
<i>Planting geometry</i>						
S ₁	0.005	0.005	0.005	0.004	0.004	0.004
S ₂	0.006	0.006	0.006	0.005	0.005	0.005
S ₃	0.006	0.006	0.006	0.006	0.006	0.006
<i>SEm±</i>	<i>0.0003</i>	<i>0.0004</i>	<i>0.0003</i>	<i>0.0003</i>	<i>0.0002</i>	<i>0.0002</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Table 4.14 Interaction effect of date of sowing, fertility levels and planting geometry on RGR in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30-60 DAS</i>			<i>60-90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	0.005	0.004	0.005	0.003	0.003	0.003
D1F1S2	0.004	0.004	0.004	0.003	0.004	0.004
D1F1S3	0.007	0.007	0.007	0.005	0.005	0.005
D1F2S1	0.006	0.006	0.006	0.003	0.003	0.003
D1F2S2	0.006	0.007	0.006	0.004	0.003	0.004
D1F2S3	0.007	0.008	0.008	0.005	0.005	0.005
D1F3S1	0.006	0.006	0.006	0.003	0.003	0.003
D1F3S2	0.007	0.008	0.008	0.005	0.006	0.006
D1F3S3	0.007	0.007	0.007	0.006	0.006	0.006
D2F1S1	0.003	0.003	0.003	0.004	0.004	0.004
D2F1S2	0.003	0.004	0.004	0.004	0.005	0.004
D2F1S3	0.003	0.003	0.003	0.006	0.005	0.005
D2F2S1	0.004	0.005	0.004	0.005	0.005	0.005
D2F2S2	0.006	0.006	0.006	0.006	0.005	0.005
D2F2S3	0.005	0.006	0.005	0.006	0.006	0.006
D2F3S1	0.004	0.004	0.004	0.006	0.005	0.006
D2F3S2	0.007	0.007	0.007	0.006	0.006	0.006
D2F3S3	0.007	0.007	0.007	0.007	0.007	0.007
<i>SEm±</i>	<i>0.0008</i>	<i>0.0010</i>	<i>0.0006</i>	<i>0.0006</i>	<i>0.0005</i>	<i>0.0004</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

such as light, water, and nutrients, thus promoting more vigorous growth and higher biomass production.

4.1.1.8.3 Interaction effect of date of sowing, fertility levels, and planting geometry on shoot dry weight in groundnut

The interaction effects of sowing date, fertility levels, and planting geometry on shoot dry weight in groundnut reveal significant variations in plant growth at 60 and 90 DAS, as shown in Table 4.16, where the data indicates that the combination of early sowing date (D_1), high fertility levels (F_2), and wider planting geometry (S_3) consistently yields the highest shoot dry weight. Specifically, the $D_1F_2S_3$ combination produced the highest dry weight at 30 DAS (27.19 in 2019, 2020, and pooled), 60 DAS (32.33 in 2019, 31.96 in 2020, and 32.15 in pooled), and 90 DAS (32.33 in 2019). This can be attributed to the optimal conditions provided by early sowing, which allows for a longer growing season, high fertility levels that ensure adequate nutrient supply, and wider planting geometry that reduces intra-plant competition, all of which collectively enhance plant growth and biomass accumulation.

4.1.2 Phenological attributes

4.1.2.1 Days to 50% flowering

The data on 50% flowering in groundnut recorded are presented in Table 4.17 and Table 4.18

4.1.2.1.1 Effect of date of sowing and fertility levels on 50% flowering in groundnut

The effect of date of sowing and fertility levels on 50% flowering in groundnut was found to be non-significant during both the years.

Table 4.15 Effect of date of sowing, fertility levels and planting geometry on shoot dry weight (g plant⁻¹) in groundnut

<i>Treatments</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	15.06	15.09	15.08	22.04	21.82	21.93	30.27	30.35	30.31
D ₁ F ₂	15.31	14.91	15.11	24.18	24.18	24.18	31.32	31.53	31.43
D ₁ F ₃	15.26	14.88	15.07	24.40	24.40	24.40	31.49	31.70	31.59
D ₂ F ₁	14.31	14.14	14.23	17.92	17.92	17.92	27.51	27.25	27.38
D ₂ F ₂	14.52	14.22	14.37	20.61	20.59	20.60	30.08	29.48	29.78
D ₂ F ₃	14.56	14.24	14.40	21.93	21.93	21.93	30.16	30.26	30.21
<i>SEm</i> ±	<i>0.28</i>	<i>0.27</i>	<i>0.20</i>	<i>0.51</i>	<i>0.53</i>	<i>0.37</i>	<i>0.38</i>	<i>0.35</i>	<i>0.26</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>1.59</i>	<i>1.67</i>	<i>1.08</i>	<i>1.20</i>	<i>1.12</i>	<i>0.77</i>
<i>Planting geometry</i>									
S ₁	13.90	13.82	13.86	19.63	19.52	19.57	28.63	28.29	28.46
S ₂	14.85	14.52	14.68	22.04	22.04	22.04	30.48	30.63	30.56
S ₃	15.76	15.40	15.58	23.87	23.85	23.86	31.30	31.37	31.33
<i>SEm</i> ±	<i>0.21</i>	<i>0.27</i>	<i>0.17</i>	<i>0.31</i>	<i>0.34</i>	<i>0.23</i>	<i>0.25</i>	<i>0.34</i>	<i>0.21</i>
<i>CD at 5%</i>	<i>0.62</i>	<i>0.79</i>	<i>0.49</i>	<i>0.91</i>	<i>0.99</i>	<i>0.65</i>	<i>0.73</i>	<i>0.98</i>	<i>0.59</i>

Table 4.16 Interaction effect of date of sowing, fertility levels and planting geometry on shoot dry weight in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>30 DAS</i>			<i>60 DAS</i>			<i>90 DAS</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	14.00	14.23	14.12	19.87	19.24	19.55	29.22	29.10	29.16
D1F1S2	15.10	15.18	15.14	20.55	20.55	20.55	29.36	30.40	29.88
D1F1S3	16.07	15.87	15.97	25.69	25.66	25.67	32.24	31.54	31.89
D1F2S1	14.18	13.92	14.05	21.64	21.64	21.64	30.58	30.96	30.77
D1F2S2	15.55	14.93	15.24	23.71	23.71	23.71	31.04	31.68	31.36
D1F2S3	16.20	15.87	16.04	27.19	27.19	27.19	32.33	31.96	32.15
D1F3S1	14.16	14.08	14.12	21.99	21.99	21.99	30.83	31.36	31.10
D1F3S2	15.17	14.35	14.76	25.28	25.28	25.28	31.65	31.56	31.60
D1F3S3	16.45	16.20	16.33	25.91	25.91	25.91	31.98	32.17	32.07
D2F1S1	13.17	13.40	13.28	16.86	16.86	16.86	25.26	24.21	24.73
D2F1S2	14.34	14.17	14.26	18.33	18.33	18.33	28.55	28.78	28.66
D2F1S3	15.43	14.84	15.14	18.56	18.56	18.56	28.72	28.77	28.74
D2F2S1	14.20	13.69	13.94	19.04	19.04	19.04	28.55	27.98	28.27
D2F2S2	14.04	14.21	14.12	20.85	20.85	20.85	30.73	29.45	30.09
D2F2S3	15.33	14.77	15.05	21.95	21.89	21.92	30.95	31.02	30.99
D2F3S1	13.70	13.59	13.65	18.37	18.37	18.37	27.34	26.10	26.72
D2F3S2	14.90	14.27	14.58	23.55	23.55	23.55	31.56	31.92	31.74
D2F3S3	15.07	14.85	14.96	23.89	23.89	23.89	31.57	32.74	32.16
<i>SEm±</i>	<i>0.52</i>	<i>0.66</i>	<i>0.42</i>	<i>0.76</i>	<i>0.83</i>	<i>0.56</i>	<i>0.61</i>	<i>0.82</i>	<i>0.51</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>2.22</i>	<i>2.42</i>	<i>1.60</i>	<i>1.79</i>	<i>2.40</i>	<i>1.46</i>

4.1.2.1.2 Effect of planting geometry on 50% flowering in groundnut

There was no significant effect of planting geometry on 50% flowering in groundnut.

4.1.2.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on 50% flowering in groundnut

The combination that exhibited the highest growth, indicated by the longest duration to 50% flowering and maturity, was D₁F₂S₂ (early sowing with 100% RDF and 40 cm x 10 cm spacing), which recorded 31.872 days to 50% flowering in pooled data as depicted in Table 4.18. One probable reason to this can be that favourable conditions provided by early sowing, which allows plants to establish well and take full advantage of the growing season. The application of 100% RDF ensures adequate nutrient availability, while the 40 cm x 10 cm spacing provides optimal space for root and shoot development, reducing competition and promoting vigorous growth.

4.1.2.2 Days to maturity

The data on days to maturity in groundnut recorded are presented in Table 4.17 and Table 4.18

4.1.2.1.1 Effect of date of sowing and fertility levels on days to maturity in groundnut

There was no significant effect of date of sowing and fertility levels on days to maturity in groundnut

4.1.2.1.2 Effect of planting geometry on days to maturity in groundnut

There was no significant effect of planting geometry on the days to maturity in groundnut.

4.1.2.1.3 Interaction effect of date of sowing, fertility levels and planting geometry in groundnut

There was no interaction effect of date of sowing, fertility levels and planting geometry in groundnut

4.1.3 Yield and yield attributes in groundnut

4.1.3.1 Number of pods plant⁻¹

The data on yield attributes in groundnut recorded are presented in Table 4.19 and Table 4.20 and illustrated in Fig.4.1 and 4.2.

4.1.3.1.1 Effect of date of sowing and fertility levels in number of pods plant⁻¹ of groundnut

The sowing dates and fertility levels had a noticeable impact on the yield attributes of groundnut. The highest number of pods per plant was recorded under the combination D₁F₂, with values of 19.41 in 2019, 19.04 in 2020, and a pooled value of 19.22. Conversely, the lowest number of pods plant⁻¹ was recorded under the combination D₂F₁, with values of 16.43 in 2019, 15.81 in 2020, and a pooled value of 16.12. D₂F₁ also showed at par values during 2019 (19.15), 2020 (19.04) and pooled value (19.22). This variation can be attributed to the early sowing date (D₁) and higher fertility level (F₂) providing optimal growing conditions, including adequate nutrient supply and a longer growing season, which enhances pod development. In contrast, late sowing (D₂) and lower fertility level (F₁) result in suboptimal conditions, leading to reduced pod formation. Several studies highlight the impact of early sowing dates and fertilizer levels on groundnut yield. Banik *et al.* (2009) found that pod number, pod yield, kernel yield, and leaf area index varied significantly with different sowing dates. Bala *et al.* (2011) noted that mid-June sowing with 20 kg N, 26 kg P, and 29 kg K ha⁻¹ produced good yields in semi-arid Nigeria, though NPK fertilizer alone had a modest effect. Prathima *et al.* (2012) determined that

Table 4.17 Effect of date of sowing, fertility levels and planting geometry on phenological attributes in groundnut

<i>Treatments</i>	<i>Days to 50% flowering</i>			<i>Days to maturity</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D ₁ F ₁	29.69	28.73	29.21	118.38	117.98	118.18
D ₁ F ₂	28.73	30.12	29.43	117.96	117.33	117.64
D ₁ F ₃	28.78	29.99	29.38	116.33	115.44	115.89
D ₂ F ₁	29.09	29.52	29.30	118.68	118.76	118.72
D ₂ F ₂	29.76	29.56	29.66	119.76	119.36	119.56
D ₂ F ₃	29.91	29.42	29.67	119.98	118.47	119.22
<i>SEM±</i>	<i>0.52</i>	<i>0.35</i>	<i>0.31</i>	<i>0.99</i>	<i>0.81</i>	<i>0.64</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
<i>Planting geometry</i>						
S ₁	29.51	29.31	29.41	118.47	117.16	117.81
S ₂	29.63	29.46	29.54	118.58	118.24	118.41
S ₃	28.83	29.90	29.37	118.49	118.27	118.38
<i>SEM±</i>	<i>0.28</i>	<i>0.34</i>	<i>0.22</i>	<i>0.45</i>	<i>0.50</i>	<i>0.34</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Table 4.18 Interaction effect of date of sowing, fertility levels and planting geometry on phenological attributes in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Days to 50% flowering</i>			<i>Days to maturity</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	28.00	27.00	27.50	118.00	116.33	117.17
D ₁ F ₁ S ₂	31.07	31.20	31.13	116.67	120.33	118.50
D ₁ F ₁ S ₃	30.00	28.00	29.00	120.47	117.27	118.87
D ₁ F ₂ S ₁	27.67	30.22	28.94	116.27	116.00	116.13
D ₁ F ₂ S ₂	31.87	31.07	31.47	119.27	116.67	117.97
D ₁ F ₂ S ₃	26.67	29.07	27.87	118.33	119.33	118.83
D ₁ F ₃ S ₁	30.33	29.43	29.88	116.33	115.67	116.00
D ₁ F ₃ S ₂	29.00	30.80	29.90	116.67	114.00	115.33
D ₁ F ₃ S ₃	27.00	29.73	28.37	116.00	116.67	116.33
D ₂ F ₁ S ₁	30.93	29.73	30.33	120.37	119.27	119.82
D ₂ F ₁ S ₂	27.00	28.67	27.83	117.00	120.33	118.67
D ₂ F ₁ S ₃	29.33	30.15	29.74	118.67	116.67	117.67
D ₂ F ₂ S ₁	29.73	29.00	29.37	120.27	118.00	119.13
D ₂ F ₂ S ₂	30.20	28.00	29.10	121.33	120.13	120.73
D ₂ F ₂ S ₃	29.33	31.67	30.50	117.67	119.93	118.80
D ₂ F ₃ S ₁	30.40	30.47	30.43	119.60	117.67	118.63
D ₂ F ₃ S ₂	28.67	27.00	27.83	120.53	118.00	119.27
D ₂ F ₃ S ₃	30.67	30.80	30.73	119.80	119.73	119.77
<i>SEM±</i>	<i>0.67</i>	<i>0.84</i>	<i>0.54</i>	<i>1.10</i>	<i>1.24</i>	<i>0.83</i>
<i>CD at 5%</i>	<i>1.97</i>	<i>2.44</i>	<i>1.53</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

owing in the first fortnight of July was optimal during drought years, while advancing sowing by one month was beneficial in normal years with adequate rain. Meena *et al.* (2014) observed that sowing from April 20 to June 9 produced comparable yields, but July 4 sowing yielded less, although the variety TG 37A showed higher yield attributes when sown in July. Higher yields were achieved with 30 kg N and 60 kg P₂O₅ ha⁻¹, similar to 40 kg N and 80 kg P₂O₅ per ha. Sogut *et al.* (2016) found that early sowing of peanuts in southeastern Turkey led to higher pod yields, pod numbers, and oil content compared to late sowing, regardless of cultivar. Among the cultivars, Sultan consistently produced the highest pod yields in both early and late sowing conditions and for optimal results, it is recommended to use higher fertilizer levels and select the appropriate sowing date based on local conditions.

4.1.3.1.2 Effect of planting geometry on number of pods plant⁻¹ of groundnut

The planting geometry influenced the yield attributes of groundnut, as depicted in Table 4.19. Among the different geometries, S₃ (50 cm x 10 cm) generally produced higher numbers of pods plant⁻¹ and longer pod lengths compared to S₁ and S₂, with 19.04 pods plant⁻¹ in 2019, 18.37 in 2020, and 18.70 in pooled data. The highest number of pods plant⁻¹ (18.70) was observed in the pooled data for S₃, whereas S₁ had the lowest (16.40); the optimal spacing in S₃, which reduces competition for resources like light, water, and nutrients, can be a reason for promoting better pod development and increased pod length. Various studies on groundnut spacing have highlighted its impact on yield. Howlader *et al.* (2009) also reported that erect varieties performed best with 20 cm x 10 cm spacing, Konlan *et al.* (2013) reported that spacing arrangements significantly affected growth and yield, with 30 cm x 15 cm, 40 cm x 10 cm, and 50 cm x 10 cm all influencing performance. Reddy *et al.* (2014) demonstrated that a spacing of 35 cm x 20 cm yielded better results than 20 cm x 15 cm as these findings suggest that wider spacing generally enhances groundnut yield and is at line with

the findings by Dolie and Nongmaithem (2020) ; Parameshwarareddy *et al.* (2019).

4.1.3.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on number of pods plant⁻¹ of groundnut

Early sowing (D₁) with a 100% RDF (F₂) and a planting geometry of 50 cm x 10 cm (S₃) resulted in the highest number of pods per plant in the pooled data, with 21.19 pods, while the least was noted in D₂F₁S₁, with a pooled value of 14.20. This can be attributed to the combination of early sowing, which allows for a longer growing season and better crop establishment, 100% RDF providing sufficient nutrients for optimal growth, and the 50 cm x 10 cm spacing reducing competition among plants for resources. Together, these factors create an ideal environment for pod development, leading to a higher number of pods plant⁻¹. Conversely, late sowing (D₂), lower fertility (F₁), and less optimal spacing (S₁) result in poorer growth conditions, leading to fewer pods per plant.

4.1.3.2 Number of seeds pod⁻¹

The data on yield attributes in groundnut recorded are presented in Table 4.19 and Table 4.20 and illustrated in Fig 4.3 and 4.4.

4.1.3.2.1 Effect of date of sowing and fertility levels in number of seeds pods⁻¹ of groundnut

There was no effect of date of sowing and fertility levels in number of seeds pods⁻¹ of groundnut date of sowing and fertility levels in groundnut.

4.1.3.2.2 Effect of planting geometry in number of seeds pods⁻¹ of groundnut

There was no effect of planting geometry in number of seeds pods⁻¹ in groundnut.

4.1.3.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on number of seeds pods⁻¹ of groundnut

There was no significant interaction between the sowing dates, levels of fertility and planting geometry in number of seeds pods⁻¹ in groundnut.

4.1.3.3 Pod length (cm)

4.1.3.3.1 Effect of date of sowing and fertility levels in pod length of groundnut.

There was no interaction effect of date of sowing and fertility levels in pod length of groundnut.

4.1.3.3.2 Effect of planting geometry in pod length of groundnut

There was no effect of planting geometry in pod length of groundnut

4.1.3.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on pod length of groundnut

There was no interaction effect of date of sowing, fertility levels and planting geometry on pod length of groundnut

4.1.3.4 Test weight

4.1.3.4.1 Effect of date of sowing and fertility levels in test weight of groundnut.

There was no interaction effect of date of sowing and fertility levels in test weight of groundnut.

4.1.3.4.2 Effect of planting geometry in test weight of groundnut

There was no effect of planting geometry in test weight of groundnut

4.1.3.4.3 Interaction effect of date of sowing, fertility levels and planting geometry on test weight of groundnut

There was no interaction effect of date of sowing, fertility levels and planting geometry on test weight of groundnut

4.1.3.4 Seed, stover and biological yield ($t\ ha^{-1}$)

The data on seed yield, stover yield, and biological yield attributes in groundnut recorded are presented in Table 4.21 and Table 4.22 and illustrated in fig 4.5 and 4.6.

4.1.3.4.1 Effect of date of sowing and fertility levels on seed, stover and biological yield of groundnut

Variations in seed, stover, and biological yield were significant with the date of sowing and fertility levels in groundnut.

Specifically, the highest seed yield was observed in the D_1F_3 treatment, with values of $1.65\ t\ ha^{-1}$ in 2019, $1.49\ t\ ha^{-1}$ in 2020, and $1.57\ t\ ha^{-1}$ in pooled data, while the D_2F_1 treatment recorded the lowest seed yield, with $1.02\ t\ ha^{-1}$ in 2019, $1.00\ t\ ha^{-1}$ in 2020, and $1.01\ t\ ha^{-1}$ in pooled data. Similarly, the highest stover yield was achieved with D_1F_3 , showing $2.69\ t\ ha^{-1}$ in 2019, $2.54\ t\ ha^{-1}$ in 2020, and a pooled value of $2.61\ t\ ha^{-1}$. The biological yield was also highest for early sowing combined with high fertility, with D_1F_3 reaching $4.34\ t\ ha^{-1}$ in 2019, $4.03\ t\ ha^{-1}$ in 2020, and $4.18\ t\ ha^{-1}$ in pooled data while on the other hand D_1F_2 showed at par in 2019 (4.16), 2020 (3.99) and pooled (4.07). These results indicate that early sowing (D_1) with high fertility levels (F_3) provides optimal conditions for growth, resulting in greater seed and stover yields, and consequently a higher overall biological yield. This is due to the extended growing season and better nutrient availability enhancing plant development and productivity and the results are also in compliance with the recent studies on groundnut cultivation emphasize the importance of sowing date and fertilizer levels on seed yield where Yadav and

Lunagaria (2022) found that sowing at the onset of the monsoon resulted in significantly higher pod yields compared to later dates, with an average yield increase of 13.4% over sowing 10 days later; similarly, Sai *et al.* (2022) reported that sowing on July 20 achieved the highest pod yield with GJG-32 variety (2.91 t ha⁻¹), outperforming other dates. Meena *et al.* (2014) observed that sowing between April 20 and June 9 provided comparable yields, but July 4 sowing yielded less and reported that higher fertilizer levels (30 kg N and 60 kg P₂O₅ ha⁻¹) were effective, with 40 kg N and 80 kg P₂O₅ ha⁻¹ providing similar results. These findings suggest that early sowing combined with higher fertilizer application leads to increased seed yield in groundnuts. This is also seconded by the findings of Chitale and Bhambri, (2001) where it was concluded that adequate nutrient supply enhances seed and stover yield by improving the formation of branches per plant, leaves per plant, siliquae per plant, and the length of siliquae.

Table 4.19 Effect of date of sowing, fertility levels and planting geometry on yield attributes in groundnut

Treatment	Number of pods plant ⁻¹			Number of seeds pod ⁻¹			Pod length (cm)			Test weight (g)		
	2019	2020	Pooled	2020	Pooled	Pooled	2019	2020	Pooled	2019	2020	Pooled
<i>Date of sowing and fertility levels</i>												
D ₁ F ₁	18.13	17.68	17.90	2.56	2.75	2.66	2.56	2.82	2.69	388.86	385.86	387.36
D ₁ F ₂	19.15	18.94	19.04	2.95	2.80	2.88	2.59	2.41	2.50	383.15	385.80	384.48
D ₁ F ₃	19.41	19.04	19.22	3.00	3.04	3.02	2.91	2.99	2.95	389.41	388.77	389.09
D ₂ F ₁	16.43	15.81	16.12	2.29	1.97	2.13	2.62	2.54	2.58	384.79	383.56	384.18
D ₂ F ₂	17.79	17.38	17.59	2.36	2.32	2.34	2.74	2.51	2.62	386.89	385.02	385.95
D ₂ F ₃	17.57	17.55	17.56	2.39	2.64	2.51	2.58	2.56	2.57	384.01	384.29	384.15
<i>SEm±</i>	<i>0.31</i>	<i>0.26</i>	<i>0.20</i>	<i>0.20</i>	<i>0.21</i>	<i>0.15</i>	<i>0.21</i>	<i>0.26</i>	<i>0.17</i>	<i>3.70</i>	<i>3.67</i>	<i>2.61</i>
<i>CD at 5%</i>	<i>0.97</i>	<i>0.80</i>	<i>0.59</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>
<i>Planting geometry</i>												
S ₁	16.45	16.35	16.40	2.38	2.41	2.40	2.71	2.61	2.66	389.27	386.79	388.03
S ₂	18.75	18.48	18.61	2.57	2.51	2.54	2.63	2.70	2.66	385.75	386.40	386.08
S ₃	19.04	18.37	18.70	2.83	2.84	2.83	2.66	2.61	2.63	383.54	383.46	383.50
<i>SEm±</i>	<i>0.28</i>	<i>0.11</i>	<i>0.15</i>	<i>0.12</i>	<i>0.14</i>	<i>0.09</i>	<i>0.11</i>	<i>0.11</i>	<i>0.08</i>	<i>1.99</i>	<i>2.21</i>	<i>1.49</i>
<i>CD at 5%</i>	<i>0.83</i>	<i>0.32</i>	<i>0.43</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

Table 4.20 Interaction effect of date of sowing, fertility levels and planting geometry on yield attributes in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Number of pods plant⁻¹</i>			<i>Number of seeds pod⁻¹</i>			<i>Pod length (cm)</i>			<i>Test weight (g)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	16.73	16.44	16.59	2.28	2.58	2.43	2.71	3.10	2.90	387.01	389.68	388.34
D1F1S2	18.92	18.60	18.76	2.34	2.65	2.50	2.53	2.59	2.56	386.26	385.54	385.90
D1F1S3	18.73	18.00	18.36	3.05	3.03	3.04	2.43	2.76	2.60	393.32	382.37	387.85
D1F2S1	15.34	17.61	16.48	2.88	2.72	2.80	2.75	2.17	2.46	390.45	385.23	387.84
D1F2S2	19.32	19.62	19.47	2.89	2.62	2.76	2.86	2.12	2.49	384.50	384.40	384.45
D1F2S3	22.79	19.58	21.19	3.08	3.07	3.07	2.17	2.95	2.56	374.49	387.78	381.14
D1F3S1	18.68	17.95	18.32	2.78	2.79	2.79	3.07	2.75	2.91	388.54	392.51	390.53
D1F3S2	19.51	19.34	19.42	2.97	2.91	2.94	2.72	3.55	3.13	387.54	396.00	391.77
D1F3S3	20.03	19.83	19.93	3.26	3.41	3.34	2.94	2.67	2.80	392.16	377.82	384.99
D2F1S1	14.44	13.97	14.20	1.96	1.67	1.82	2.50	2.41	2.46	392.82	381.21	387.02
D2F1S2	17.97	16.61	17.29	2.33	2.07	2.20	2.76	2.68	2.72	386.67	381.27	383.97
D2F1S3	16.87	16.87	16.87	2.59	2.19	2.39	2.62	2.53	2.57	374.88	388.21	381.55
D2F2S1	16.87	16.56	16.72	2.16	2.17	2.16	3.02	2.50	2.76	390.82	389.10	389.96
D2F2S2	18.57	18.01	18.29	2.45	2.22	2.33	2.55	2.71	2.63	386.94	386.51	386.72
D2F2S3	17.94	17.56	17.75	2.47	2.58	2.52	2.63	2.31	2.47	382.92	379.44	381.18
D2F3S1	16.65	15.57	16.11	2.21	2.55	2.38	2.23	2.71	2.47	385.98	383.03	384.51
D2F3S2	18.20	18.71	18.46	2.45	2.59	2.52	2.35	2.53	2.44	382.62	384.71	383.67
D2F3S3	17.87	18.36	18.11	2.51	2.78	2.64	3.15	2.43	2.79	383.44	385.13	384.29
<i>SEm±</i>	<i>0.69</i>	<i>0.27</i>	<i>0.37</i>	<i>0.30</i>	<i>0.34</i>	<i>0.23</i>	<i>0.27</i>	<i>0.28</i>	<i>0.19</i>	<i>4.87</i>	<i>5.41</i>	<i>3.64</i>
<i>CD at 5%</i>	<i>2.02</i>	<i>0.79</i>	<i>1.06</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

4.1.3.4.2 Effect of planting geometry on seed, stover and biological yield of groundnut

The planting geometry significantly influenced yield attributes, with S₃ (50 cm x 10 cm) showing the highest seed yield, reaching 1.40 t ha⁻¹ in 2019, 1.30 t ha⁻¹ in 2020, and a pooled yield of 1.35 t ha⁻¹. In contrast, S₁ (30 cm x 10 cm) had the lowest pooled seed yield at 1.17 t ha⁻¹. Similarly, S₃ achieved the highest stover yield with 2.13 t ha⁻¹ in 2019, 2.40 t ha⁻¹ in 2020, and a pooled yield of 2.48 t ha⁻¹, while S₁ had the lowest stover yield. The biological yield also followed this trend, with S₃ recording the highest pooled yield of 3.83 t ha⁻¹, compared to S₁ which had lowest pooled yield of 3.22 t ha⁻¹ while S₂ showed close at par values (3.80 in 2019; 3.59 in 2020 and 3.69 in pooled value). These results can be attributed to the optimal spacing in S₃, which reduces intra-plant competition for resources, leading to better growth and higher yields compared to the denser spacing of S₁. With recent studies on groundnut cultivation have highlighted the benefits of optimal plant spacing where Waghmode *et al.* (2017a) found that a plant spacing of 30 cm x 10 cm, combined with 30:70:00 NPK kg ha⁻¹, yielded the highest pod, kernel, and haulm outputs. Rajitha *et al.* (2018) emphasized the importance of secondary and micronutrient fertilization, reporting that a combined foliar application of these nutrients with RDF resulted in the highest pod yield (2654 kg ha⁻¹) and haulm yield (3603 kg ha⁻¹), due to increased nutrient uptake and dry matter production. Parameshwarareddy *et al.* (2019) noted that while different plant spacings did not significantly affect pod yield, combining a 30 cm x 10 cm spacing with 125% RDF resulted in significantly higher pod yields compared to other combinations and these findings suggest that wider plant spacing, along with adequate fertilization, enhances seed yield in groundnuts. This is also seconded by the findings of Chitale and Bhambri, (2001) where it was concluded that adequate nutrient supply enhances seed and stover yield by improving the formation of branches per plant, leaves per plant, siliquae per plant, and the length of siliquae.

4.1.3.4.3 Interaction effect of date of sowing, fertility levels and planting geometry on seed, stover and biological yield of groundnut

Highest growth, in terms of seed yield, was observed for the combination D₁F₃S₃ (early sown on 20th June with 125% recommended dose of fertilizer and planting geometry of 50 cm x 10 cm) with a pooled seed yield of 1.85 t ha⁻¹ in 2019, 1.53 t ha⁻¹ in 2020, giving a pooled yield of 1.69 t ha⁻¹ and this combination consistently provided high stover and biological yields across both years, with stover yields of 23.01 t ha⁻¹ in 2019 and 2.57 t ha⁻¹ in 2020, leading to a pooled stover yield of 2.79 t ha⁻¹ and a biological yield of 4.87 t ha⁻¹ in 2019 and 4.10 t ha⁻¹ in 2020, resulting in a pooled biological yield of 4.49 t ha⁻¹.

Conversely, the lowest growth in seed yield was recorded for the combination D₂F₁S₁ (10 July with 75% recommended dose of fertilizer and planting geometry of 30 cm x 10 cm) with a pooled seed yield of 0.92 t ha⁻¹ across both years. This combination also resulted in relatively lower stover and biological yields, with pooled stover yields of 1.77 t ha⁻¹ and biological yields of 2.69 t ha⁻¹. The data suggests that late sowing with lower fertilizer levels and tighter planting geometry does not favour high yield outcomes in groundnut, emphasizing the importance of optimal sowing time, adequate fertility levels, and appropriate planting geometry to maximize yield attributes.

4.1.3.5 Harvest index and shelling percentage in groundnut

The data on harvest index and shelling percentage in groundnut recorded are presented in Table 4.23 and Table 4.24 and illustrated in Fig 4.7 and 4.8.

4.1.3.5.1 Effect of date of sowing and fertility levels on harvest index and shelling percentage in groundnut

No variations were shown in the effect of date of sowing, fertility levels in harvest index during 2019 and pooled data.

Significant variations in harvest index and shelling percentage were observed between sowing dates and fertility levels in groundnut. The D₁F₃ treatment consistently showed higher values, with the maximum harvest index reaching 37.02% in 2020. Similarly, the shelling percentage was highest in D₁F₃, with values of 67.46% in 2019, 67.41% in 2020, and a pooled value of 67.44%, whereas the lowest was recorded in D₂F₁ with a pooled value of 64.82%.

These trends are consistent with findings by Nayak *et al.* (2023), who reported that early sowing resulted in a higher harvest index of 30.62%, and Halder and Panda (2014), who found that sowing in mid to late February yielded higher peanut pod yields. The higher harvest index and shelling percentage in the D₁F₃ treatment can be attributed to the optimal combination of early sowing, adequate fertility levels, and favourable growing conditions, which enhance pod development and overall seed quality.

Table 4.21 Effect of date of sowing, fertility levels and planting geometry on seed yield, stover yield and biological yield attributes in groundnut

<i>Treatments</i>	<i>Seed yield (t ha⁻¹)</i>			<i>Stover yield (t ha⁻¹)</i>			<i>Biological yield (t ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D1F1	1.27	1.17	1.22	2.41	2.29	2.35	3.68	3.46	3.57
D1F2	1.58	1.48	1.53	2.58	2.51	2.54	4.16	3.99	4.07
D1F3	1.65	1.49	1.57	2.69	2.54	2.61	4.34	4.03	4.18
D2F1	1.02	1.00	1.01	2.10	1.88	1.99	3.12	2.89	3.00
D2F2	1.17	1.14	1.15	2.23	2.08	2.15	3.40	3.21	3.31
D2F3	1.23	1.14	1.18	2.26	2.09	2.17	3.48	3.22	3.35
<i>SEm±</i>	<i>0.02</i>	<i>0.02</i>	<i>0.01</i>	<i>0.04</i>	<i>0.06</i>	<i>0.03</i>	<i>0.05</i>	<i>0.06</i>	<i>0.04</i>
<i>CD at 5%</i>	<i>0.06</i>	<i>0.06</i>	<i>0.04</i>	<i>0.11</i>	<i>0.18</i>	<i>0.10</i>	<i>0.15</i>	<i>0.20</i>	<i>0.12</i>
<i>Planting geometry</i>									
S ₁	1.20	1.14	1.17	2.13	1.98	2.06	3.32	3.12	3.22
S ₂	1.36	1.27	1.32	2.45	2.31	2.38	3.80	3.59	3.69
S ₃	1.40	1.30	1.35	2.56	2.40	2.48	3.96	3.69	3.83
<i>SEm±</i>	<i>0.02</i>	<i>0.01</i>	<i>0.01</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>
<i>CD at 5%</i>	<i>0.05</i>	<i>0.04</i>	<i>0.03</i>	<i>0.09</i>	<i>0.08</i>	<i>0.06</i>	<i>0.09</i>	<i>0.09</i>	<i>0.06</i>

Table 4.22 Interaction effect of date of sowing, fertility levels and planting geometry on seed yield, stover yield and biological yield in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Seed yield (t ha⁻¹)</i>			<i>Stover yield (t ha⁻¹)</i>			<i>Biological yield (t ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	1.17	1.09	1.13	2.35	2.25	2.30	3.52	3.34	3.43
D ₁ F ₁ S ₂	1.30	1.18	1.24	2.37	2.25	2.31	3.67	3.43	3.55
D ₁ F ₁ S ₃	1.33	1.25	1.29	2.52	2.38	2.45	3.85	3.63	3.74
D ₁ F ₂ S ₁	1.48	1.40	1.44	2.48	2.09	2.29	3.96	3.49	3.73
D ₁ F ₂ S ₂	1.57	1.49	1.53	2.60	2.69	2.65	4.17	4.18	4.17
D ₁ F ₂ S ₃	1.69	1.54	1.62	2.65	2.75	2.70	4.34	4.29	4.31
D ₁ F ₃ S ₁	1.42	1.39	1.40	2.22	2.36	2.29	3.64	3.75	3.69
D ₁ F ₃ S ₂	1.68	1.55	1.62	2.83	2.69	2.76	4.51	4.24	4.38
D ₁ F ₃ S ₃	1.85	1.53	1.69	3.01	2.57	2.79	4.87	4.10	4.49
D ₂ F ₁ S ₁	0.86	0.98	0.92	1.81	1.73	1.77	2.67	2.71	2.69
D ₂ F ₁ S ₂	1.11	1.03	1.07	2.08	1.75	1.92	3.19	2.78	2.99
D ₂ F ₁ S ₃	1.10	1.00	1.05	2.40	2.18	2.29	3.50	3.17	3.34
D ₂ F ₂ S ₁	1.10	0.98	1.04	1.97	1.84	1.91	3.07	2.82	2.94
D ₂ F ₂ S ₂	1.19	1.20	1.19	2.39	2.17	2.28	3.57	3.37	3.47
D ₂ F ₂ S ₃	1.23	1.23	1.23	2.33	2.22	2.28	3.56	3.45	3.51
D ₂ F ₃ S ₁	1.16	0.98	1.07	1.93	1.64	1.78	3.09	2.62	2.85
D ₂ F ₃ S ₂	1.29	1.20	1.25	2.40	2.34	2.37	3.69	3.53	3.61
D ₂ F ₃ S ₃	1.23	1.23	1.23	2.44	2.29	2.37	3.67	3.52	3.59
<i>SEM±</i>	<i>0.04</i>	<i>0.03</i>	<i>0.02</i>	<i>0.07</i>	<i>0.07</i>	<i>0.05</i>	<i>0.07</i>	<i>0.08</i>	<i>0.05</i>
<i>CD at 5%</i>	<i>0.11</i>	<i>0.09</i>	<i>0.07</i>	<i>0.21</i>	<i>0.20</i>	<i>0.14</i>	<i>0.21</i>	<i>0.23</i>	<i>0.15</i>

4.1.3.5.2 Effect of date planting geometry on harvest index and shelling percentage in groundnut

There were no variations in the effect of planting geometry on harvest index during 2019 and pooled data; however, in 2020, the maximum harvest index of 36.08% was recorded under S₁ (30 cm x 10 cm).

In terms of shelling percentage, the S₃ treatment (50 cm x 10 cm) showed the highest values, with 67.76% in 2019, 66.86% in 2020, and a pooled value of 67.31%.

These results suggest that while planting geometry had a consistent impact on shelling percentage, it had less influence on harvest index. The higher shelling percentage under S₃ can be attributed to the optimal spacing that reduces intra-plant competition and enhances pod development, while variations in harvest index in 2020 for S₁ might be due to different environmental conditions or management practices affecting the efficiency of resource use. Patil *et al.* (2007) found that a spacing of 30 cm x 10 cm on broad bed furrow (BBF) produced the highest yield and quality in groundnuts, while a spacing of 45 cm x 15 cm resulted in reduced haulm yield. Jaiswal *et al.* (2018) observed that 30 cm x 15 cm spacing yielded the highest number of pods per plant, pod weight, and shelling percentage compared to narrower spacings like 30 cm x 10 cm and 22.5 cm x 10 cm. Although pod yield was significantly higher with 30 cm x 10 cm spacing, oil content remained consistent across different spacings.

4.1.3.5.3 Interaction of effect of fertility levels on harvest index and shelling percentage in groundnut

There was no significant effect due to the interaction of date of sowing, fertility levels and planting geometry on harvest index and test weight attributes in groundnut in 2019.

Highest harvest index percentage was observed for the combination D₁F₂S₁ (early sown on 20th June with 100% recommended dose of fertilizer and planting geometry of 30 cm x 10 cm) with value of 40.04 in 2020 and 38.72 in pooled data.

The maximum shelling percentage was observed for the combination D₁F₃S₃ (early sowing on June 20th with 125% recommended dose of fertilizer and a planting geometry of 50 cm x 10 cm), with values of 67.60% in 2019, 68.04% in 2020, and 67.82% in pooled data and the findings suggests that early sowing, higher fertility levels, and optimal planting density contribute to better seed development and shelling efficiency. The enhanced shelling percentage is likely due to improved nutrient availability from the higher fertilizer application and reduced plant competition due to the wider spacing, which together promote better pod and seed formation.

4.2 Soil parameters

4.2.1 Soil pH and soil organic carbon

The data on soil pH and organic carbon in groundnut recorded are presented in Table 4.25 and Table 4.26 and and illustrated in Fig 4.9 and 4.10.

4.2.1.1 Effect of date of sowing and fertility levels on soil pH and organic carbon

No variations were observed in the effect of sowing date and planting geometry on soil pH.

However, in terms of organic carbon, the combination D₁F₃ (early sowing with 125%RDF) had the highest organic carbon values, with 1.51 in 2019, 1.46 in 2020, and 1.48 in pooled data. Conversely, the D₂F₁ combination (late sowing with 75% recommended dose of fertilizer) recorded the lowest organic carbon values, with 1.40 in 2019, 1.35 in 2020, and 1.37 in pooled data and the results indicate that early sowing combined with higher fertility levels enhances soil

Table 4.23 Effect of date of sowing, fertility levels and planting geometry on harvest index and shelling percentage in groundnut

<i>Treatments</i>	<i>Harvest index</i>			<i>Shelling percentage</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D ₁ F ₁	34.42	33.75	34.09	66.17	65.89	66.03
D ₁ F ₂	37.98	37.27	37.63	67.29	66.51	66.90
D ₁ F ₃	38.12	37.02	37.57	67.46	67.41	67.44
D ₂ F ₁	32.76	34.86	33.81	65.82	63.81	64.82
D ₂ F ₂	34.49	35.34	34.91	65.86	64.46	65.16
D ₂ F ₃	35.30	35.43	35.37	66.00	65.84	65.92
<i>SEm±</i>	0.34	0.60	0.34	0.39	0.32	0.25
<i>CD at 5%</i>	1.07	1.88	1.01	1.23	1.01	0.75
<i>Planting geometry</i>						
S ₁	35.81	36.34	36.08	64.77	64.10	64.43
S ₂	35.58	35.53	35.56	66.77	66.00	66.39
S ₃	35.14	34.97	35.05	67.76	66.86	67.31
<i>SEm±</i>	0.45	0.31	0.27	0.21	0.25	0.16
<i>CD at 5%</i>	NS	0.89	NS	0.61	0.72	0.46

Table 4.24 Interaction effect of date of sowing, fertility levels and planting geometry on harvest index and shelling percentage in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Harvest index (%)</i>			<i>Shelling percentage (%)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	33.20	32.54	32.87	65.33	62.71	64.02
D ₁ F ₁ S ₂	35.58	34.34	34.96	66.24	66.83	66.53
D ₁ F ₁ S ₃	34.49	34.38	34.44	66.94	68.15	67.54
D ₁ F ₂ S ₁	37.39	40.04	38.72	64.81	64.26	64.54
D ₁ F ₂ S ₂	37.61	35.73	36.67	67.05	67.23	67.14
D ₁ F ₂ S ₃	38.94	36.04	37.49	70.00	68.04	69.02
D ₁ F ₃ S ₁	39.04	37.02	38.03	67.22	66.63	66.92
D ₁ F ₃ S ₂	37.24	36.66	36.95	67.56	67.57	67.57
D ₁ F ₃ S ₃	38.07	37.37	37.72	67.60	68.04	67.82
D ₂ F ₁ S ₁	32.02	36.21	34.12	63.76	63.23	63.50
D ₂ F ₁ S ₂	34.80	36.97	35.89	66.52	63.48	65.00
D ₂ F ₁ S ₃	31.45	31.41	31.43	67.19	64.72	65.96
D ₂ F ₂ S ₁	35.74	34.80	35.27	63.21	62.96	63.09
D ₂ F ₂ S ₂	33.22	35.59	34.40	67.05	64.56	65.81
D ₂ F ₂ S ₃	34.50	35.63	35.07	67.32	65.86	66.59
D ₂ F ₃ S ₁	37.47	37.45	37.46	64.26	64.83	64.55
D ₂ F ₃ S ₂	35.05	33.87	34.46	66.22	66.35	66.28
D ₂ F ₃ S ₃	33.40	34.97	34.18	67.53	66.35	66.94
<i>SEm±</i>	<i>1.11</i>	<i>0.75</i>	<i>0.67</i>	<i>0.51</i>	<i>0.60</i>	<i>0.40</i>
<i>CD at 5%</i>	<i>NS</i>	<i>2.19</i>	<i>1.90</i>	<i>1.50</i>	<i>1.76</i>	<i>1.12</i>

organic carbon, likely due to improved plant growth and biomass, which contributes to greater organic matter return to the soil while in contrast, late sowing and lower fertility levels result in reduced plant growth and organic matter, leading to lower organic carbon levels.

4.2.1.2 Effect of planting geometry on soil pH and organic carbon

The Table 4.25 revealed the soil organic carbon tends to increase with wider spacing. S₃ (50 cm × 10 cm) has the highest soil organic carbon percentage at 1.48% in pooled data, 1.51 in 2019 and 1.44 in 2020 and suggested that wider planting geometry may contribute to better soil organic carbon content and the increased spacing reduces plant competition, leading to improved plant growth and higher biomass production, which in turn enhances the return of organic matter to the soil. The greater organic matter from the larger plants improves soil organic carbon levels, promoting better soil health and fertility.

4.2.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on soil pH and organic carbon

The interaction effects of sowing dates, fertility levels, and planting geometry on soil pH could not be proven statistically significant.

The interaction effects on soil organic carbon in groundnut show significant variations across different combinations. The D₁F₃S₃ combination (sown on June 20th with 125% RDF and a planting geometry of 50 cm × 10 cm) resulted in the highest organic carbon content of 1.52%, while the lowest soil organic carbon of 1.30% was found in the D₂F₁S₁ combination (sown on July 10th with 75% RDF and a planting geometry of 30 cm × 10 cm); which indicates that higher fertilizer levels can initially boost plant growth, but their impact on soil organic carbon content may be limited when combined with closer planting geometry. The wider spacing in D₁F₃S₃ likely allows for better plant growth and increased biomass return to the soil, enhancing organic carbon content, whereas the closer spacing

Table 4.25 Effect of date of sowing, fertility levels and planting geometry on soil pH and soil organic carbon in groundnut

<i>Treatments</i>	<i>Soil pH</i>			<i>Soil organic carbon (%)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D1F1	4.92	5.13	5.02	1.44	1.42	1.43
D1F2	4.93	5.15	5.04	1.48	1.43	1.45
D1F3	4.94	5.17	5.05	1.51	1.46	1.48
D2F1	4.86	5.12	4.99	1.40	1.35	1.37
D2F2	4.87	5.11	4.99	1.42	1.41	1.41
D2F3	4.88	5.11	5.00	1.42	1.40	1.41
<i>SEm±</i>	<i>0.06</i>	<i>0.07</i>	<i>0.05</i>	<i>0.01</i>	<i>0.02</i>	<i>0.01</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.04</i>	<i>0.06</i>	<i>0.03</i>
<i>Planting geometry</i>						
S ₁	4.93	5.18	5.05	1.38	1.39	1.38
S ₂	4.89	5.11	5.00	1.44	1.40	1.42
S ₃	4.87	5.10	4.99	1.51	1.44	1.48
<i>SEm±</i>	<i>0.06</i>	<i>0.06</i>	<i>0.04</i>	<i>0.01</i>	<i>0.01</i>	<i>0.01</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.02</i>	<i>0.03</i>	<i>0.02</i>

Table 4.26 Interaction effect of date of sowing, fertility levels and planting geometry on soil pH and soil organic carbon in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Soil pH</i>			<i>Soil organic carbon (%)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	4.92	5.11	5.02	1.40	1.40	1.40
D ₁ F ₁ S ₂	4.95	5.14	5.04	1.43	1.40	1.42
D ₁ F ₁ S ₃	4.90	5.13	5.01	1.50	1.45	1.47
D ₁ F ₂ S ₁	4.86	5.09	4.98	1.40	1.42	1.41
D ₁ F ₂ S ₂	4.98	5.20	5.09	1.48	1.40	1.44
D ₁ F ₂ S ₃	4.94	5.17	5.06	1.55	1.47	1.51
D ₁ F ₃ S ₁	5.02	5.25	5.14	1.46	1.41	1.43
D ₁ F ₃ S ₂	4.93	5.16	5.04	1.50	1.49	1.50
D ₁ F ₃ S ₃	4.86	5.09	4.98	1.55	1.49	1.52
D ₂ F ₁ S ₁	4.87	5.21	5.04	1.29	1.30	1.30
D ₂ F ₁ S ₂	4.79	5.02	4.91	1.39	1.33	1.36
D ₂ F ₁ S ₃	4.91	5.14	5.03	1.51	1.42	1.46
D ₂ F ₂ S ₁	4.98	5.15	5.06	1.38	1.40	1.39
D ₂ F ₂ S ₂	4.87	5.07	4.97	1.41	1.43	1.42
D ₂ F ₂ S ₃	4.77	5.10	4.93	1.45	1.40	1.42
D ₂ F ₃ S ₁	4.92	5.24	5.08	1.34	1.41	1.38
D ₂ F ₃ S ₂	4.84	5.10	4.97	1.42	1.35	1.39
D ₂ F ₃ S ₃	4.87	5.00	4.93	1.51	1.43	1.47
<i>SEM±</i>	<i>0.14</i>	<i>0.15</i>	<i>0.10</i>	<i>0.02</i>	<i>0.02</i>	<i>0.01</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.06</i>	<i>0.06</i>	<i>0.04</i>

in D₂F₁S₁ results in reduced biomass and organic matter input, leading to lower soil organic carbon levels.

4.2.2 Available soil nitrogen

The data on available soil nitrogen recorded are presented in Table 4.27 and Table 4.28 and illustrated in Fig 4.11 and 4.12.

4.2.2.1 Effect of date of sowing and fertility levels on nitrogen

The maximum available soil nitrogen was evident in D₁F₃ with value of 292.25 kg ha⁻¹ (2019), 293.47 kg ha⁻¹ (2020) and 292.86 kg ha⁻¹ (pooled data) while the least value was exhibited D₂F₁ with value of 268.54 kg ha⁻¹ (2019), 268.87 kg ha⁻¹ (2020) and 268.71 kg ha⁻¹ (pooled data) which concludes that early sowing combined with higher fertilizer levels (D₁F₃) contributes to higher soil nitrogen availability. The increased fertilizer application in D₁F₃ likely enhances nutrient supply and retention in the soil, whereas the later sowing date and lower fertility levels in D₂F₁ result in reduced soil nitrogen levels, possibly due to less effective nutrient uptake and soil management.

4.2.2.2 Effect of planting geometry on soil nitrogen

The maximum available soil nitrogen was observed in S₃ (50 cm x 10 cm), with values of 286.38 kg ha⁻¹ in 2019, 287.05 kg ha⁻¹ in 2020, and 286.71 kg ha⁻¹ in pooled data. In contrast, the lowest available soil nitrogen was found in S₁ (30 cm x 10 cm), with values of 280.11 kg ha⁻¹ in 2019, 280.87 kg ha⁻¹ in 2020, and 280.49 kg ha⁻¹ in pooled data. The results suggest that wider planting geometry (S₃) supports higher soil nitrogen levels due to reduced plant competition, allowing for better nutrient uptake and retention. The increased spacing in S₃ likely promotes more vigorous plant growth and higher biomass, which can contribute to greater nitrogen content in the soil. Conversely, the closer spacing in S₁ may lead to increased competition for nutrients, resulting in lower available soil nitrogen. This is also in close proximity with Prathyusha *et al.* (2022) observed

that among the various plant spacings evaluated, the post-harvest soil available nitrogen was significantly higher with a spacing of 22.5 cm × 10 cm (P₁) compared to other geometric alterations. This could be attributed to the lower plant population, which decreased nitrogen uptake and thus elevated the post-harvest soil nitrogen levels and the findings align with the results reported by Sunilkumar *et al.* (2020).

4.2.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on soil nitrogen

There was no interaction effect of date of sowing, fertility levels and planting geometry on available soil nitrogen.

4.2.3 Available phosphorus (kg ha⁻¹)

The data on available soil phosphorus recorded are presented in Table 4.27 and Table 4.28 and illustrated in Fig 4.13 and 4.14.

4.2.3.1 Effect of date of sowing and fertility levels on soil phosphorus

The maximum available soil phosphorus was evident in D₁F₃ with value of 30.52 kg ha⁻¹ (2019), 30.67 kg ha⁻¹ (2020) and 30.60 kg ha⁻¹ (pooled data) while the least value was exhibited D₂F₁ with value of 20.97 kg ha⁻¹ (2019), 21.29 kg ha⁻¹ (2020) and 21.13 kg ha⁻¹ (pooled data). The increased fertilizer application in D₁F₃ likely enhances nutrient supply and retention in the soil, whereas the later sowing date and lower fertility levels in D₂F₁ result in reduced soil phosphorus levels, possibly due to less effective nutrient uptake and soil management. This is also in close proximity with Prathyusha *et al.* (2022) who reported that the application of 150% RDF (N₃) led to the highest soil available phosphorus, followed closely by 125% RDF (N₂), with a significant difference between the two. A substantial amount of phosphorus remained in the soil after the groundnut crop and these findings are consistent with the studies by Suneetha (2013), and Sunilkumar *et al.* (2020).

4.2.2.2 Effect of planting geometry on soil phosphorus

The maximum available soil phosphorus was evident in S₃ with value of 25.79 kg ha⁻¹ (2019), 25.95kg ha⁻¹ (2020) and 25.87 kg ha⁻¹ (pooled data) while the least value was exhibited S₁ with value of 24.29 kg ha⁻¹ (2019), 24.59 kg ha⁻¹ (2020) and 24.44 kg ha⁻¹ (pooled data). The results suggest that wider planting geometry (S₃) supports higher soil phosphorus levels due to reduced plant competition, allowing for better nutrient uptake and retention. The increased spacing in S₃ likely promotes more vigorous plant growth and higher biomass, which can contribute to greater phosphorus content in the soil. This is also consistent with the findings of Prathyusha *et al.* (2022), who reported significantly higher soil available phosphorus with a wider spacing of 22.5 cm × 10 cm (P1) compared to other plant spacings tested. This may be due to lower phosphorus uptake by the crop resulting from the lower plant density, which increased the availability of phosphorus in the soil after the crop harvest. These results align with the findings of Sunilkumar *et al.* (2020).

4.2.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on soil phosphorus

There was no interaction effect of date of sowing, fertility levels and planting geometry on available soil phosphorus.

4.2.4 Available potassium (kg ha⁻¹)

The data on available soil potassium recorded are presented in Table 4.27 and Table 4.28 and illustrated in Fig 4.15 and 4.16.

4.2.4.1 Effect of date of sowing and fertility levels

Table 4.27 and Table 4.28 revealed effect of date of sowing, fertility levels and planting geometry showed significant effect on available potassium in both the years.

In 2019, the maximum soil phosphorus was noted under D₁F₃ treatment with 166.71 kg ha⁻¹, similarly in 2020 (167.34 kg ha⁻¹) and pooled data also (167.02 kg ha⁻¹) while least values were reported in D₂F₁ in 2019 (152.34 kg ha⁻¹), 2020 (152.73 kg ha⁻¹) and pooled data (152.53 kg ha⁻¹). The observed patterns in soil potassium levels across different treatments can be attributed to the combined effects of sowing date, fertility levels, and planting geometry. Later sowing dates and higher fertility levels create favourable conditions for phosphorus availability, while earlier sowing dates and lower fertility levels result in lower phosphorus availability. Understanding these interactions can help in optimizing agricultural practices for better soil nutrient management. This is also in line with the findings of Prathyusha *et al.* (2022), who observed that the application of 150% RDF (N3) resulted in significantly higher post-harvest soil available potassium compared to other nutrient levels tested, both annually and in pooled data. This could be attributed to the increased availability of potassium in the soil after fulfilling the crop's needs. The lowest post-harvest soil available potassium was recorded with 100% RDF which was the least and these results are consistent with the earlier findings of Bunsu *et al.* (2004) and Suneetha (2013).

4.2.4.1 Effect of planting geometry in groundnut

The maximum available soil potassium was evident in S₃ with value of 163.08 kg ha⁻¹ (2019), 164.84 kg ha⁻¹ (2020) and 163.96 kg ha⁻¹ (pooled data) while the least value was exhibited S₁ with value of 159.08 kg ha⁻¹ (2019), 157.49 kg ha⁻¹ (2020) and 158.29 kg ha⁻¹ (pooled data). The results suggest that wider planting geometry (S₃) supports higher soil potassium levels due to reduced plant competition, allowing for better nutrient uptake and retention. The increased spacing in S₃ likely promotes more vigorous plant growth and higher biomass, which can contribute to greater potassium content in the soil. Conversely, the closer spacing in S₁ may lead to increased competition for nutrients, resulting in lower available soil nutrient.

4.2.4.2 Interaction effect of date of sowing, fertility levels and planting geometry on available soil potassium

For available soil potassium, the highest values were recorded for D₁F₃S₃ in 2019 (170.91 kg ha⁻¹), 2020 (171.54 kg ha⁻¹) and pooled data (171.22 kg ha⁻¹), indicating that early sowing with high fertility and maximum geometries optimizes potassium availability. Conversely, the lowest potassium availability was noted in D₂F₁S₁ in 2019 (148.53 kg ha⁻¹), 2020 (149.00 kg ha⁻¹) and pooled data (148.76 kg ha⁻¹), highlighting that the least fertility and late sowing may not support maximum potassium uptake. These results underscore the critical role of adequate fertility and appropriate planting geometry in nutrient availability and overall crop growth, with a significant interaction effect observed for potassium.

4.3 Plant nutrient uptake

4.3.1 Nitrogen content in grain and stover and their uptake

The data on N content in grain and stover and their uptake in groundnut recorded are presented in Table 4.29 and Table 4.30.

4.3.1.1 Effect of date of sowing and fertility on N content in grain and stover and their uptake

Significant variations in nitrogen were observed among date of sowing and fertility on N content in grain and stover and their uptake. The Table 4.29 presents data on the nitrogen (N) content in both grain and stover, as well as their N uptake for groundnut crops sown on two different dates: June 20th (D₁) and July 10th (D₂) and fertility levels. Across the treatments, the highest N content in N% in grain was observed in D₁F₃ in 2019 (3.52%), 2020 (3.48%) and pooled data with 3.5% while minimum values were under D₂F₁ in 2019 (2.72%), 2020 (2.73%) and pooled data with 2.72%.

Across the treatments, the highest N content in N% in stover was observed in D₁F₃ in 2019 (1.54%), 2020 (1.54%) and pooled data with 1.54% while

minimum values were under D₂F₁ in 2019 (1.36%), 2020 (1.36%) and pooled data with 1.36%.

The data from 2019 shows that the significantly highest total nitrogen uptake (grain and stover) was recorded D₁F₃ during 2019 (71.19 kg ha⁻¹) while lowest total nitrogen uptake was recorded in D₂F₁ (52.85 kg ha⁻¹). In 2020, the significant highest total nitrogen uptake was recorded from D₁F₃ (66.53 kg ha⁻¹) and the data pooled analysis also showed that the maximum nitrogen uptake was recorded from groundnut plant which were subjected under D₁F₃ treatment (68.86 kg ha⁻¹). This indicates that early sowing conditions were generally more conducive for nitrogen uptake, and the standard fertilizer rate was adequate to meet the plant's nutrient requirements. The differences in nitrogen uptake can be explained by the interaction between sowing time and fertilizer application rates.

It was reported by Halevy and Hartzoop (1988) that as groundnut plants matured the concentrations of nitrogen (N), phosphorus (P), and potassium (K) in most plant parts decreased, except in the seeds, where N and P concentrations increased. Specifically, N in leaves and stems fell from 3.3% to 1.5%, while P dropped from 0.35% to 0.10%, and K remained stable until the final growth stage. Kharade *et al.* (2013) found that total nutrient uptake of N, P, and K increased significantly with the application of 30 kg N, 50 kg P₂O₅, and 45 kg K₂O, along with seed inoculation, due to enhanced biological nitrogen fixation and nutrient availability. Chirwa *et al.* (2017) observed that applying N, P, Ca, K, and B fertilizers significantly increased nutrient uptake and kernel yields, with N uptake rising by 55.5%, P uptake by 51%, and kernel yield by 65.5% compared to control. These results suggest that higher fertility levels improve nutrient uptake and overall groundnut yield.

Table 4.27 Effect of date of sowing, fertility levels and planting geometry on available nutrients in groundnut

<i>Treatments</i>	<i>Available nitrogen (kg ha⁻¹)</i>			<i>Available phosphorus (kg ha⁻¹)</i>			<i>Available potassium (kg ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>									
D ₁ F ₁	269.46	270.11	269.79	23.71	23.98	23.85	157.48	156.91	157.19
D ₁ F ₂	290.34	290.86	290.60	29.33	29.56	29.44	164.94	165.57	165.25
D ₁ F ₃	292.25	293.47	292.86	30.52	30.67	30.60	166.71	167.34	167.02
D ₂ F ₁	268.54	268.87	268.71	20.97	21.29	21.13	152.34	152.73	152.53
D ₂ F ₂	288.89	289.08	288.98	22.59	22.90	22.75	160.86	161.49	161.17
D ₂ F ₃	289.26	289.68	289.47	22.66	23.08	22.87	161.02	161.56	161.29
<i>SEm±</i>	<i>2.31</i>	<i>2.42</i>	<i>1.67</i>	<i>0.35</i>	<i>0.38</i>	<i>0.26</i>	<i>1.70</i>	<i>0.94</i>	<i>0.97</i>
<i>CD at 5%</i>	<i>7.27</i>	<i>7.64</i>	<i>4.93</i>	<i>1.09</i>	<i>1.20</i>	<i>0.76</i>	<i>5.36</i>	<i>2.97</i>	<i>2.87</i>
<i>Planting geometry</i>									
S ₁	280.11	280.87	280.49	24.29	24.59	24.44	159.08	157.49	158.29
S ₂	282.88	283.12	283.00	24.82	25.19	25.01	159.51	160.47	159.99
S ₃	286.38	287.05	286.71	25.79	25.95	25.87	163.08	164.84	163.96
<i>SEm±</i>	<i>1.60</i>	<i>1.66</i>	<i>1.15</i>	<i>0.36</i>	<i>0.18</i>	<i>0.20</i>	<i>1.13</i>	<i>0.55</i>	<i>0.63</i>
<i>CD at 5%</i>	<i>4.68</i>	<i>4.83</i>	<i>3.28</i>	<i>1.05</i>	<i>0.51</i>	<i>0.57</i>	<i>3.30</i>	<i>1.61</i>	<i>1.79</i>

Table 4.28 Interaction effect of date of sowing, fertility levels and planting geometry on available nutrients in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Available nitrogen (kg ha⁻¹)</i>			<i>Available phosphorus (kg ha⁻¹)</i>			<i>Available potassium (kg ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	265.64	266.67	266.16	23.19	23.42	23.31	165.43	153.00	159.22
D ₁ F ₁ S ₂	267.37	267.97	267.67	23.35	23.69	23.52	152.51	155.12	153.81
D ₁ F ₁ S ₃	275.36	275.70	275.53	24.60	24.83	24.71	154.49	162.62	158.55
D ₁ F ₂ S ₁	289.78	290.75	290.27	28.89	29.12	29.00	157.51	158.14	157.83
D ₁ F ₂ S ₂	290.54	290.67	290.60	28.93	29.16	29.05	167.19	167.82	167.51
D ₁ F ₂ S ₃	290.71	291.16	290.93	30.16	30.39	30.27	170.11	170.74	170.42
D ₁ F ₃ S ₁	292.55	293.08	292.81	29.03	29.52	29.27	164.23	164.86	164.54
D ₁ F ₃ S ₂	293.51	293.47	293.49	30.86	31.09	30.97	164.99	165.62	165.30
D ₁ F ₃ S ₃	290.71	293.85	292.28	31.69	31.41	31.55	170.91	171.54	171.22
D ₂ F ₁ S ₁	264.11	265.08	264.60	20.73	20.96	20.85	148.53	149.00	148.76
D ₂ F ₁ S ₂	270.32	267.66	268.99	20.84	21.34	21.09	152.49	153.12	152.80
D ₂ F ₁ S ₃	271.19	273.87	272.53	21.33	21.56	21.45	155.99	156.08	156.04
D ₂ F ₂ S ₁	284.80	284.98	284.89	22.16	22.39	22.27	159.03	159.66	159.35
D ₂ F ₂ S ₂	288.20	290.70	289.45	22.54	22.91	22.73	160.13	160.76	160.44
D ₂ F ₂ S ₃	293.66	291.55	292.61	23.08	23.39	23.24	163.41	164.04	163.73
D ₂ F ₃ S ₁	283.78	284.65	284.21	21.72	22.15	21.93	159.75	160.30	160.03
D ₂ F ₃ S ₂	287.34	288.21	287.78	22.40	22.98	22.69	159.76	160.38	160.07
D ₂ F ₃ S ₃	296.65	296.18	296.41	23.87	24.10	23.99	163.55	164.01	163.78
<i>SEM±</i>	<i>3.93</i>	<i>4.06</i>	<i>2.82</i>	<i>0.88</i>	<i>0.43</i>	<i>0.49</i>	<i>2.77</i>	<i>1.35</i>	<i>1.54</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>8.08</i>	<i>3.94</i>	<i>4.38</i>

4.3.1.2 Effect of planting geometry on N content in grain and stover and their uptake

Different planting geometries influenced N uptake in grain and stover. S₃ (40 cm × 10 cm) consistently showed the highest N uptake in grain, stover and total N uptake respectively where in 2019, 2020 the maximum total N uptake was 68.62, 64.44 kg ha⁻¹ and pooled data was 66.53 kg ha⁻¹ while the least was noted in S₁ (30 × 10cm) with pooled value of 53.36 kg ha⁻¹. The spacing (S₃: 50 cm × 10 cm) provides an optimal balance between resource competition and space utilization, leading to better N uptake in both grain and stover. This spacing likely allows plants to access sufficient light, nutrients, and water while minimizing the negative effects of overcrowding. The consistent performance of this spacing across different years underscores its effectiveness in promoting higher biomass and nutrient uptake.

4.3.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on N content in grain and stover

The results from 2020, as well as the pooled data, indicate that the highest total N uptake was observed in the combination of D₁F₃S₃ (sown on 20th June, 125% RDF, 50 cm × 10 cm), with pooled total N uptake values of 83.57 in 2019, 73.03 in 2020 and pooled value of 78.30 kg ha⁻¹ which lead to enhanced growth and N accumulation in groundnut plants this may be due to the synergy of optimal environmental conditions, adequate nutrient supply, and balanced planting geometry. On the other hand, the combination with the lowest growth in terms of total N uptake was D₂F₁S₁ (sown on July 10, 75% RDF, 30 cm x 10 cm), which had pooled total N uptake values of 48.04 kg ha⁻¹. The results indicate that lower fertility levels and late sowing, even with closer planting geometry, do not support optimal N uptake and growth, highlighting the importance of adequate fertilization for maximizing groundnut productivity. The variations across the different treatments underline the critical role of optimizing sowing dates, fertility levels,

and planting geometry to achieve higher growth and nutrient uptake in groundnut crops.

4.3.2 P content in grain and stover and their uptake

The data on P content in grain and stover and their uptake in groundnut recorded are presented in Table 4.31 and Table 4.32.

4.3.2.1 Effect of date of sowing and fertility on P content in grain and stover and their uptake

The result presents data on the P content in both grain and stover, as well as their P uptake for groundnut crops sown on two different dates: June 20th (D₁) and July 10th (D₂) and fertility levels. Across the treatments, the highest N content in P% in grain was observed in D₁F₃ in 2019 (0.371%), 2020 (0.372%) and pooled data with 0.371% while minimum values were under D₂F₁ in 2019 (0.335%), 2020 (0.329%) and pooled data with 0.332%.

The data shows that the significantly highest total phosphorus uptake (grain and stover) was recorded D₁F₃ during 2019 (8.78 kg ha⁻¹) while lowest total phosphorus uptake was recorded in D₂F₁ (7.44 kg ha⁻¹). In 2020, the significant highest total nitrogen uptake was recorded from D₁F₃ (7.84 kg ha⁻¹) and the data pooled analysis also showed that the maximum nitrogen uptake was recorded from groundnut plant which were subjected under D₁F₃ treatment (8.31 kg ha⁻¹). This indicates that early sowing conditions were generally more conducive for nitrogen uptake, and the standard fertilizer rate was adequate to meet the plant's nutrient requirements. The differences in nitrogen uptake can be explained by the interaction between sowing time and fertilizer application rates. It was reported by Kharade *et al.* (2013) found that total nutrient uptake of N, P, and K increased significantly with the application of 30 kg N, 50 kg P₂O₅, and 45 kg K₂O, along with seed inoculation, due to enhanced biological nitrogen fixation and nutrient availability. Chirwa *et al.* (2017) observed that applying N,

Table 4.29 Effect of date of sowing, fertility levels and planting geometry on N content in grain and stover and their uptake

Treatments	N content in grain (%)			N content in stover (%)			N uptake in Grain (kg ha ⁻¹)			N uptake in stover (kg ha ⁻¹)			Total N uptake (grain + stover) (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Date of sowing and fertility levels															
D ₁ F ₁	3.09	3.11	3.10	1.44	1.43	1.43	37.68	35.66	36.67	24.33	21.96	23.15	62.01	57.63	59.82
D ₁ F ₂	3.44	3.40	3.42	1.52	1.52	1.52	39.40	39.81	39.60	26.87	25.09	25.98	66.27	64.90	65.58
D ₁ F ₃	3.52	3.48	3.50	1.54	1.54	1.54	43.06	39.95	41.51	28.13	26.58	27.36	71.19	66.53	68.86
D ₂ F ₁	2.72	2.73	2.72	1.35	1.36	1.36	31.17	31.56	31.36	21.68	19.96	20.82	52.85	51.52	52.18
D ₂ F ₂	2.95	3.01	2.98	1.39	1.40	1.40	34.47	33.41	33.94	24.81	22.76	23.79	59.28	56.17	57.73
D ₂ F ₃	3.07	3.04	3.06	1.43	1.43	1.43	36.14	34.59	35.36	24.49	23.79	24.14	60.63	58.37	59.50
SEm±	0.08	0.03	0.04	0.02	0.02	0.02	1.66	0.90	0.94	0.76	0.64	0.49	2.22	1.10	1.24
CD at 5%	0.25	0.11	0.12	0.07	0.07	0.05	5.24	2.83	2.79	2.38	2.00	1.46	6.99	3.48	3.66
Planting geometry															
S ₁	2.93	2.99	2.96	1.38	1.39	1.39	32.88	31.96	32.42	21.53	20.34	20.94	54.41	52.30	53.36
S ₂	3.14	3.12	3.13	1.45	1.44	1.44	37.13	36.40	36.77	25.95	24.42	25.19	63.08	60.82	61.95
S ₃	3.32	3.27	3.30	1.50	1.50	1.50	40.95	39.13	40.04	27.68	25.30	26.49	68.62	64.44	66.53
SEm±	0.05	0.04	0.03	0.01	0.01	0.01	0.71	0.44	0.42	0.49	0.48	0.34	0.84	0.68	0.54
CD at 5%	0.15	0.13	0.10	0.04	0.04	0.02	2.09	1.29	1.19	1.42	1.40	0.97	2.45	1.98	1.53

Table 4.30 Interaction effect of date of sowing, fertility levels and planting geometry on N content in grain and stover in groundnut

<i>Treatments</i>	<i>N content in grain (%)</i>			<i>N content in stover (%)</i>			<i>N uptake in grain (kg ha⁻¹)</i>			<i>N uptake in stover (kg ha⁻¹)</i>			<i>Total N uptake (grain + stover) (kg ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	2.90	2.92	2.91	1.33	1.34	1.33	34.38	31.21	32.79	21.78	21.50	21.64	56.16	52.71	54.43
D1F1S2	2.95	3.17	3.06	1.49	1.44	1.46	37.00	35.89	36.44	22.92	21.95	22.44	59.92	57.84	58.88
D1F1S3	3.41	3.23	3.32	1.49	1.51	1.50	41.65	39.90	40.78	28.28	22.43	25.36	69.93	62.34	66.13
D1F2S1	3.29	3.31	3.30	1.46	1.47	1.47	34.32	35.94	35.13	20.63	19.08	19.86	54.95	55.02	54.99
D1F2S2	3.34	3.33	3.34	1.54	1.53	1.54	38.46	41.51	39.98	29.46	27.11	28.28	67.92	68.61	68.27
D1F2S3	3.69	3.55	3.62	1.55	1.54	1.54	45.41	41.98	43.70	30.52	29.08	29.80	75.94	71.06	73.50
D1F3S1	3.32	3.39	3.35	1.45	1.44	1.44	34.84	33.12	33.98	22.06	21.81	21.94	56.91	54.93	55.92
D1F3S2	3.62	3.47	3.55	1.49	1.49	1.49	42.06	42.11	42.09	31.03	29.52	30.28	73.10	71.63	72.36
D1F3S3	3.63	3.59	3.61	1.67	1.69	1.68	52.28	44.63	48.45	31.30	28.40	29.85	83.57	73.03	78.30
D2F1S1	2.65	2.63	2.64	1.33	1.34	1.34	29.11	28.98	29.05	20.69	17.30	18.99	49.80	46.28	48.04
D2F1S2	2.75	2.64	2.70	1.36	1.37	1.36	31.91	31.55	31.73	21.73	20.65	21.19	53.64	52.21	52.92
D2F1S3	2.76	2.91	2.84	1.36	1.37	1.37	32.48	34.14	33.31	22.62	21.93	22.28	55.10	56.07	55.58
D2F2S1	2.73	2.87	2.80	1.34	1.35	1.34	29.25	29.71	29.48	20.24	20.09	20.16	49.49	49.80	49.65
D2F2S2	3.05	2.99	3.02	1.41	1.41	1.41	37.07	33.84	35.45	26.44	23.98	25.21	63.51	57.82	60.67
D2F2S3	3.09	3.17	3.13	1.43	1.44	1.44	37.08	36.70	36.89	27.76	24.20	25.98	64.84	60.90	62.87
D2F3S1	2.72	2.81	2.77	1.39	1.38	1.39	35.36	32.80	34.08	23.79	22.27	23.03	59.15	55.07	57.11
D2F3S2	3.13	3.14	3.13	1.39	1.41	1.40	36.28	33.51	34.89	24.11	23.31	23.71	60.38	56.82	58.60
D2F3S3	3.36	3.17	3.27	1.50	1.48	1.49	36.78	37.46	37.12	25.58	25.77	25.68	62.36	63.23	62.79
<i>SEM±</i>	<i>0.13</i>	<i>0.11</i>	<i>0.08</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>	<i>1.75</i>	<i>1.08</i>	<i>1.03</i>	<i>1.20</i>	<i>1.17</i>	<i>0.84</i>	<i>2.05</i>	<i>1.66</i>	<i>1.32</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>0.09</i>	<i>0.09</i>	<i>0.06</i>	<i>5.11</i>	<i>3.16</i>	<i>2.93</i>	<i>3.49</i>	<i>3.43</i>	<i>2.38</i>	<i>6.00</i>	<i>4.85</i>	<i>3.76</i>

P, Ca, K, and B fertilizers significantly increased nutrient uptake and kernel yields, with N uptake rising by 55.5%, P uptake by 51%, and kernel yield by 65.5% compared to control. These results suggest that higher fertility levels improve nutrient uptake and overall groundnut yield.

4.3.2.2 Effect of planting geometry on P content in grain and stover and their uptake

Different planting geometries influenced N uptake in grain and stover. S₃ (40 cm x 10 cm) consistently showed the highest N uptake in grain, stover and total N uptake respectively where in 2019, 2020 the maximum total P uptake was 8.91, 8.40 kg ha⁻¹ and pooled data was 8.66 kg ha⁻¹ while the least was noted in S₁ (30 x 10cm) with pooled value of 7.11 kg ha⁻¹. The spacing (S₃: 50 cm x 10 cm) provides an optimal balance between resource competition and space utilization, leading to better N uptake in both grain and stover. This spacing likely allows plants to access sufficient light, nutrients, and water while minimizing the negative effects of overcrowding. The consistent performance of this spacing across different years underscores its effectiveness in promoting higher biomass and nutrient uptake.

4.3.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on P content in grain and stover

There was no interaction effect of date of sowing, fertility levels and planting geometry on P content in grain, stover and total uptake.

4.3.3 K content in grain and stover and their uptake

The data on K content in grain and stover and their uptake in groundnut recorded are presented in Table 4.33 and Table 4.34

4.3.3.1 Effect of date of sowing and fertility levels on K content in grain and stover and their uptake in groundnut

The data reveals that the sowing date and fertility levels had no influence on the potassium (K) content in grain and stover, grain uptake but showed significant effect on the K uptake in stover and total K uptake respectively. The highest total K uptake in grain was observed in the D₁F₃ treatment (Early sowing with 125% RDF) with a pooled value of 51.99 kg ha⁻¹; 2019 with 54.41 kg ha⁻¹ and 2020 with 49.57 kg ha⁻¹, while the lowest K uptake in stover was found in the D₂F₁ treatment (late sowing with 75% RDF) with a pooled value of 47.67 kg ha⁻¹. Overall, the total K uptake was highest in the D₁F₃ treatment indicating that early sowing with higher fertility rate tends to enhance K uptake in both grain and stover. The timing may also provide a longer growing period before adverse weather conditions set in, allowing for extended nutrient absorption and accumulation in the plant tissues and additionally, higher fertility levels (125% RDF) ensure an abundant supply of nutrients, including potassium, in the soil. This increased availability promotes higher nutrient uptake efficiency and stimulates better root growth and expansion, allowing plants to access and absorb more nutrients from the soil. This synergy of enhanced environmental conditions and increased nutrient availability explains the higher potassium uptake observed in the D₁F₃ treatment and the result is at par with Alam *et al.*, (2022).

Table 4.31 Effect of date of sowing, fertility levels and planting geometry on P content in grain and stover and their uptake groundnut

Treatments	P content in grain (%)			P content in stover (%)			P uptake in grain (kg ha ⁻¹)			P uptake in stover (kg ha ⁻¹)			Total P uptake (grain + stover) (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Date of sowing and fertility levels															
D1F1	0.342	0.343	0.343	0.249	0.249	0.249	4.34	3.96	4.15	4.19	3.83	4.01	8.19	7.79	7.99
D1F2	0.366	0.366	0.366	0.251	0.249	0.250	4.36	3.96	4.16	4.34	3.84	4.09	8.61	7.79	8.20
D1F3	0.371	0.372	0.371	0.252	0.253	0.252	4.38	4.01	4.19	4.40	3.84	4.12	8.78	7.84	8.31
D2F1	0.335	0.329	0.332	0.243	0.242	0.243	3.66	3.77	3.72	3.83	3.52	3.67	7.44	7.29	7.37
D2F2	0.356	0.355	0.356	0.247	0.246	0.247	3.92	3.85	3.88	3.97	3.68	3.83	7.89	7.53	7.71
D2F3	0.361	0.362	0.362	0.248	0.247	0.248	4.12	3.88	4.00	3.98	3.81	3.89	8.10	7.69	7.89
SEm±	0.003	0.003	0.002	0.002	0.005	0.003	0.21	0.17	0.14	0.30	0.26	0.20	0.37	0.29	0.23
CD at 5%	0.010	0.010	0.006	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting geometry															
S ₁	0.347	0.349	0.348	0.250	0.249	0.250	3.83	3.60	3.72	3.67	3.29	3.48	7.33	6.89	7.11
S ₂	0.351	0.353	0.352	0.249	0.241	0.245	4.11	3.97	4.04	4.21	3.71	3.96	8.26	7.68	7.97
S ₃	0.367	0.363	0.365	0.246	0.252	0.249	4.45	4.14	4.30	4.47	4.25	4.36	8.91	8.40	8.66
SEm±	0.002	0.004	0.002	0.002	0.004	0.002	0.15	0.13	0.10	0.17	0.18	0.13	0.26	0.20	0.16
CD at 5%	0.006	0.011	0.006	NS	NS	NS	0.43	0.37	0.28	0.50	0.53	0.36	0.76	0.58	0.47

Table 4.32 Interaction effect of date of sowing, fertility levels and planting geometry on P content in grain and stover an in groundnut

<i>Treatments</i>	<i>P content in grain (%)</i>			<i>P content in stover (%)</i>			<i>P uptake in grain (kg ha⁻¹)</i>			<i>P uptake in stover (kg ha⁻¹)</i>			<i>Total P uptake (grain + stover) (kg ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D1F1S1	0.335	0.339	0.337	0.249	0.243	0.246	4.13	3.55	3.84	3.85	3.19	3.52	6.90	6.74	6.82
D1F1S2	0.336	0.343	0.339	0.256	0.240	0.248	4.15	4.09	4.12	3.94	3.42	3.68	8.15	7.51	7.83
D1F1S3	0.357	0.347	0.352	0.242	0.263	0.253	4.75	4.24	4.49	4.77	4.88	4.83	9.52	9.12	9.32
D1F2S1	0.360	0.362	0.361	0.243	0.259	0.251	3.76	3.65	3.71	3.49	3.51	3.50	7.25	7.16	7.21
D1F2S2	0.369	0.366	0.367	0.254	0.242	0.248	4.29	4.11	4.20	4.75	3.79	4.27	8.76	7.90	8.33
D1F2S3	0.371	0.371	0.371	0.255	0.246	0.250	5.02	4.11	4.57	4.79	4.21	4.50	9.81	8.32	9.07
D1F3S1	0.365	0.369	0.367	0.253	0.245	0.249	4.12	3.80	3.96	3.76	3.06	3.41	7.88	6.86	7.37
D1F3S2	0.367	0.372	0.370	0.257	0.244	0.251	4.30	4.08	4.19	4.63	4.03	4.33	8.93	8.11	8.52
D1F3S3	0.380	0.374	0.377	0.245	0.268	0.256	4.71	4.13	4.42	4.82	4.42	4.62	9.53	8.55	9.04
D2F1S1	0.326	0.323	0.324	0.241	0.255	0.248	3.34	3.68	3.51	3.56	3.17	3.36	6.90	6.85	6.87
D2F1S2	0.331	0.328	0.330	0.239	0.238	0.238	3.75	3.70	3.72	3.85	3.56	3.70	7.45	7.26	7.35
D2F1S3	0.348	0.337	0.343	0.250	0.234	0.242	3.90	3.92	3.91	4.06	3.85	3.96	7.97	7.77	7.87
D2F2S1	0.347	0.345	0.346	0.254	0.252	0.253	3.66	3.29	3.48	3.55	3.16	3.36	7.21	6.46	6.83
D2F2S2	0.351	0.354	0.353	0.246	0.245	0.245	4.00	4.13	4.07	4.10	3.64	3.87	8.10	7.77	7.93
D2F2S3	0.371	0.367	0.369	0.242	0.242	0.242	4.09	4.12	4.11	4.27	4.24	4.26	8.37	8.36	8.36
D2F3S1	0.351	0.354	0.353	0.258	0.242	0.250	3.99	3.61	3.80	3.84	3.68	3.76	7.82	7.29	7.56
D2F3S2	0.354	0.354	0.354	0.245	0.238	0.242	4.16	3.70	3.93	4.02	3.82	3.92	8.17	7.53	7.85
D2F3S3	0.378	0.379	0.378	0.242	0.260	0.251	4.21	4.33	4.27	4.08	3.92	4.00	8.29	8.25	8.27
<i>SEm±</i>	<i>0.005</i>	<i>0.009</i>	<i>0.005</i>	<i>0.005</i>	<i>0.009</i>	<i>0.005</i>	<i>0.36</i>	<i>0.31</i>	<i>0.24</i>	<i>0.42</i>	<i>0.44</i>	<i>0.31</i>	<i>0.64</i>	<i>0.49</i>	<i>0.40</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>

4.3.3.2 Effect of planting geometry on K content in grain and stover and their uptake in groundnut

The Table reveals that the planting geometry has no influence on the potassium (K) content in grain and stover, grain uptake but showed significant effect on the K uptake in stover and total K uptake respectively. The planting geometry S₃ (50 cm × 10 cm) generally resulted in higher K uptake compared to S₁ (30 cm × 10 cm) and S₂ (40 cm × 10 cm). The S₃ treatment showed the highest total K uptake with a pooled value of 54.42 kg ha⁻¹. Although the differences among planting geometries were not as pronounced as those for sowing dates and fertility levels, S₃ still showed a slight edge in terms of total K uptake. The wider spacing of 50 cm × 10 cm in the S₃ treatment reduces competition among plants for essential resources such as light, water, and nutrients, allowing each plant to access more resources and leading to better overall growth and nutrient uptake, including potassium. With more space available, plants in the S₃ treatment can develop more extensive root systems, enhancing root growth and allowing the plants to explore a larger soil volume. This improved root expansion improves the uptake of potassium and other nutrients, as the larger root system can access nutrients from deeper soil layers, contributing to higher overall K uptake. The 50 cm × 10 cm spacing strikes a balance between too wide and too narrow spacing, allowing for efficient utilization of available space and resources, maximizing nutrient absorption without the drawbacks of excessive competition or underutilization of space.

4.3.3.3 Interaction effect of date of sowing, fertility levels and planting geometry on K content in grain and stover in groundnut

The interaction of these factors had no significant impact on K content in grain and stover but significantly affected the K uptake. The combination of D₁F₃S₃ (Early sown on 20th June, 125% RDF, and 50 cm × 10 cm spacing) yielded the highest total K uptake in both years, in 2019 (64.19 kg ha⁻¹), 2020 (56.89 kg

ha⁻¹) and pooled values of 60.54 kg ha⁻¹ . This suggests that higher fertility levels combined with wider spacing and early sowing dates can optimize nutrient uptake, possibly due to reduced competition for resources among plants and extended nutrient availability. This indicates that lower fertility levels and certain planting geometries may not be sufficient to meet the nutrient demands of groundnut plants, leading to suboptimal growth.

4. 4 Quality attribute in groundnut

4.4.1 Protein content in groundnut

The data on protein content in groundnut recorded are presented in Table 4.35 and Table 4.36 and illustrated in Fig 4.17 and 4.18.

4.4.1.1 Effect of date of sowing and fertility levels on protein content in groundnut

The data revealed that the sowing date and fertility levels significant variation influencing on the protein content respectively. In 2019, the maximum protein content was reported in D₁F₃ with value of 22.03% in 2019, 21.77% in 2020 and 21.90% in pooled value, while the least pooled value was noted in D₂F₁ with 17.03%. The variation in protein content can be attributed to several factors, including sowing date, fertility levels, and yearly environmental conditions. The timing of sowing affects plant growth and oil production by influencing exposure to optimal conditions such as temperature and sunlight.

Moinuddin and Saren (2023) found that the groundnut variety TG 51, when treated with 100% RDF plus phosphate-solubilizing bacteria (PSB) and farmyard manure (FYM), achieved the highest results in pod yield (2007 kg ha⁻¹), shelling percentage (67.35%), oil content (49.97%), number of nuts per plant (23.23), and 100-kernel weight (40.55 g). These findings indicate that enhanced phosphorus management and higher fertility levels improve both the yield and quality of groundnuts.

Table 4.33 Effect of date of sowing, fertility levels and planting geometry on K content in grain and stover and their uptake groundnut

<i>Treatments</i>	<i>K content in grain (%)</i>			<i>K content in stover (%)</i>			<i>K uptake in grain (kg ha⁻¹)</i>			<i>K uptake in stover (kg ha⁻¹)</i>			<i>Total K uptake (grain + stover) (kg ha⁻¹)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>															
D1F1	1.44	1.42	1.43	2.16	2.16	2.16	17.01	15.92	16.46	34.91	32.58	33.74	51.92	48.49	50.21
D1F2	1.45	1.43	1.44	2.21	2.19	2.20	17.61	16.67	17.14	36.58	33.46	35.02	54.19	50.13	52.16
D1F3	1.45	1.49	1.47	2.27	2.29	2.28	18.77	16.79	17.78	35.64	32.77	34.21	54.41	49.57	51.99
D2F1	1.35	1.30	1.32	2.05	2.09	2.07	15.66	15.23	15.45	32.75	31.70	32.23	48.41	46.93	47.67
D2F2	1.35	1.32	1.34	2.10	2.10	2.10	15.68	15.79	15.73	32.52	31.81	32.17	48.20	47.60	47.90
D2F3	1.38	1.36	1.37	2.13	2.15	2.14	15.80	15.85	15.82	35.42	32.48	33.95	51.21	48.33	49.77
<i>SEm±</i>	<i>0.08</i>	<i>0.05</i>	<i>0.05</i>	<i>0.09</i>	<i>0.05</i>	<i>0.05</i>	<i>0.50</i>	<i>0.31</i>	<i>0.29</i>	<i>1.15</i>	<i>0.97</i>	<i>0.75</i>	<i>1.23</i>	<i>0.44</i>	<i>0.65</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>1.58</i>	<i>0.97</i>	<i>0.87</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>3.86</i>	<i>1.40</i>	<i>1.92</i>
<i>Planting geometry</i>															
S ₁	1.34	1.34	1.34	2.04	2.07	2.06	15.49	15.28	15.38	32.16	30.09	31.12	47.65	45.36	46.50
S ₂	1.36	1.38	1.37	2.13	2.13	2.13	16.39	15.91	16.15	33.84	31.72	32.78	50.23	47.63	48.93
S ₃	1.51	1.44	1.47	2.29	2.28	2.29	18.39	16.94	17.66	37.91	35.60	36.75	56.30	52.53	54.42
<i>SEm±</i>	<i>0.03</i>	<i>0.03</i>	<i>0.02</i>	<i>0.05</i>	<i>0.04</i>	<i>0.03</i>	<i>0.23</i>	<i>0.18</i>	<i>0.14</i>	<i>0.79</i>	<i>0.67</i>	<i>0.52</i>	<i>0.76</i>	<i>0.56</i>	<i>0.47</i>
<i>CD at 5%</i>	<i>0.08</i>	<i>0.08</i>	<i>0.06</i>	<i>0.14</i>	<i>0.11</i>	<i>0.09</i>	<i>0.66</i>	<i>0.52</i>	<i>0.41</i>	<i>2.31</i>	<i>1.97</i>	<i>1.48</i>	<i>2.23</i>	<i>1.64</i>	<i>1.35</i>

Table 4.34 Interaction effect of date of sowing, fertility levels and planting geometry on K content in grain and stover and uptake in groundnut

Treatments	K content in grain (%)			K content in stover (%)			K uptake in grain (kg ha ⁻¹)			K uptake in stover (kg ha ⁻¹)			Total K uptake (grain + stover) (kg ha ⁻¹)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
D1F1S1	1.40	1.36	1.38	1.95	2.11	2.03	15.62	15.20	15.41	32.35	31.65	32.00	47.97	46.85	47.41
D1F1S2	1.43	1.44	1.43	2.07	2.15	2.11	16.28	15.44	15.86	34.39	31.75	33.07	50.68	47.18	48.93
D1F1S3	1.51	1.46	1.48	2.44	2.21	2.33	19.13	17.12	18.12	38.00	34.33	36.16	57.12	51.45	54.29
D1F2S1	1.40	1.33	1.37	2.14	2.06	2.10	16.73	15.15	15.94	28.50	27.50	28.00	45.24	42.65	43.94
D1F2S2	1.41	1.45	1.43	2.23	2.16	2.19	16.80	16.14	16.47	38.83	34.16	36.50	55.63	50.30	52.96
D1F2S3	1.54	1.50	1.52	2.25	2.34	2.29	19.31	18.73	19.02	42.41	38.72	40.56	61.71	57.46	59.59
D1F3S1	1.40	1.47	1.44	2.14	2.10	2.12	17.85	15.36	16.60	31.45	29.17	30.31	49.29	44.53	46.91
D1F3S2	1.41	1.48	1.44	2.16	2.23	2.19	18.09	17.34	17.71	31.67	29.93	30.80	49.76	47.27	48.52
D1F3S3	1.54	1.54	1.54	2.52	2.53	2.53	20.37	17.67	19.02	43.82	39.22	41.52	64.19	56.89	60.54
D2F1S1	1.26	1.24	1.25	1.92	2.03	1.98	12.69	12.39	12.54	36.15	32.30	34.22	48.84	44.69	46.77
D2F1S2	1.26	1.24	1.25	2.08	2.04	2.06	16.27	15.62	15.95	31.64	30.06	30.85	47.91	45.67	46.79
D2F1S3	1.53	1.41	1.47	2.16	2.20	2.18	18.02	17.68	17.85	30.47	32.75	31.61	48.49	50.43	49.46
D2F2S1	1.26	1.30	1.28	2.01	2.04	2.03	15.02	15.28	15.15	28.19	27.93	28.06	43.21	43.21	43.21
D2F2S2	1.27	1.31	1.29	2.12	2.05	2.08	15.12	15.33	15.23	32.59	31.88	32.24	47.71	47.21	47.46
D2F2S3	1.53	1.36	1.45	2.16	2.20	2.18	16.89	16.77	16.83	36.79	35.61	36.20	53.68	52.38	53.03
D2F3S1	1.32	1.34	1.33	2.06	2.10	2.08	15.01	18.27	16.64	36.31	31.97	34.14	51.33	50.24	50.78
D2F3S2	1.41	1.37	1.39	2.12	2.14	2.13	15.76	15.61	15.68	33.94	32.54	33.24	49.70	48.15	48.93
D2F3S3	1.41	1.37	1.39	2.21	2.21	2.21	16.61	13.67	15.14	36.00	32.93	34.47	52.61	46.60	49.61
<i>SEm</i> ±	0.07	0.06	0.05	0.11	0.10	0.07	0.55	0.44	0.35	1.94	1.65	1.27	1.87	1.37	1.16
<i>CD at 5%</i>	NS	NS	NS	NS	NS	NS	1.62	1.28	1.01	5.66	4.82	3.62	5.45	4.01	3.30

4.4.1.2 Effect of planting geometry on protein content in groundnut

Among the planting geometries, S₃ (50 cm × 10 cm) exhibited the highest protein content, with a pooled value of 20.60%, 20.77% in 2019, and 20.43% in 2020, while S₁ (30 cm × 10 cm) showed the lowest protein content, with 18.34% in 2019, 18.68% in 2020, and 18.51% in pooled data and the results suggests that wider planting geometry (S₃) enhances protein content in groundnut due to reduced plant competition, allowing for better nutrient uptake and more optimal growth conditions. The increased spacing in S₃ likely leads to higher biomass and better seed development, contributing to higher protein levels. Conversely, the closer spacing in S₁ results in increased competition for nutrients and resources, leading to lower protein content in the seeds.

4.4.1.3 Interaction effect of date of sowing, fertility levels and planting geometry on protein content in groundnut

There were no interaction effects of the date of sowing, fertility levels, and planting geometry on the protein content in groundnut.

4.4.2 Oil content in groundnut

The data on oil content in groundnut recorded are presented in Table 4.35 and Table 4.36 and illustrated Fig 4.17 and 4.18.

4.4.2.1 Effect of date of sowing and fertility levels on oil content in groundnut

The data revealed that the sowing date and fertility levels significant variation influencing on the oil content respectively.

In 2019, the maximum oil content was reported in D₁F₃ with value of 43.31% in 2019, 43.68 % in 2020 and 43.50% in pooled value, while the least pooled value was noted in D₂F₁ with 40.51%. The variation in oil content can be attributed to several factors, including sowing date, fertility levels, and yearly environmental conditions. The timing of sowing affects plant growth and oil

production by influencing exposure to optimal conditions such as temperature and sunlight. The variation in oil content can be attributed to several factors, including sowing date, fertility levels, and yearly environmental conditions. The timing of sowing affects plant growth and oil production by influencing exposure to optimal conditions such as temperature and sunlight. Different sowing dates can thus result in varying oil accumulation in seeds. Soil fertility plays a crucial role as well, with higher fertility levels generally supporting better plant health and increased oil content due to better nutrient availability. Additionally, yearly variations in weather and environmental conditions can significantly impact crop yields and oil content, leading to differences observed between years. In summary, the interplay of sowing dates, fertility levels, and annual environmental factors contributes to the observed variations in oil content.

4.4.2.2 Effect of planting geometry on oil content in groundnut

The data revealed that the planting geometry had significant variation influencing on the oil content respectively.

The planting geometry S₃ (50 cm × 10 cm) exhibited the highest oil content, with a pooled value of 42.97 %, 42.90% in 2019 and 41.35% in 2020 and the least oil content was noted in S₁ (41.27% in 2019, 41.35 in 2020 and 41.31% in pooled value). These variations reflect how each planting geometry affects resource distribution among plants and responds to annual environmental factors, ultimately impacting oil production efficiency.

4.4.2.3 Interaction effect of date of sowing, fertility levels and planting geometry on oil content in groundnut

The interaction effects of the date of sowing, fertility levels, and planting geometry on oil content in groundnut showed that, the highest value (44.37% in 2019, 44.69% in 2020 and 44.53% in pooled value) was found in the combination of early sowing (D₁), 125% recommended dose fertilizer (F₃), and 50 cm x 10 cm

planting geometry (S₃). This suggests that wider spacing allows plants to access more resources and optimize oil production when high fertility levels are provided. Conversely, the lowest oil content (39.97% in 2020) was recorded in the combination of late sowing (D₂), 75% recommended dose fertilizer (F₁), and 30 cm x 10 cm planting geometry (S₁), showing that closer spacing might lead to competition for nutrients and light, thereby reducing oil accumulation. Overall, early sowing with higher fertility levels generally leads to better protein and oil content, but the optimal planting geometry varies depending on the specific nutritional outcome desired.

4.5 Economic analysis

4.5.1 Cost of cultivation (₹ ha⁻¹)

The data on cost of cultivation of groundnut was calculated and recorded in both the cropping season and are presented in Table 4.37.

From the data, it is observed that all treatments under planting geometry F₃ (125% RDF), regardless of sowing date and spacing, recorded the highest and identical cost of cultivation at ₹29,205.58 ha⁻¹. This uniformity in cost can be attributed to the fact that the application of 125% RDF involves a consistent and higher level of input costs, such as fertilizers and other resources, which contribute to the overall expense. Since the cost is directly associated with the quantity of fertilizer applied, it remains the same across different sowing dates and planting geometries within the F₃ treatment, reflecting the significant investment required for enhanced fertility management and is in accordance with Karunakaran *et al.* (2010); Bala and Nath (2015).

Table 4.35 Effect of date of sowing, fertility levels and planting geometry on protein and oil content in groundnut

<i>Treatments</i>	<i>Protein content (%)</i>			<i>Oil content (%)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
<i>Date of sowing and fertility levels</i>						
D ₁ F ₁	19.28	19.41	19.35	42.17	42.22	42.19
D ₁ F ₂	21.49	21.24	21.36	42.68	43.61	43.15
D ₁ F ₃	22.03	21.77	21.90	43.31	43.68	43.50
D ₂ F ₁	17.01	17.04	17.03	40.16	40.86	40.51
D ₂ F ₂	18.47	18.82	18.64	41.58	41.39	41.49
D ₂ F ₃	19.20	19.00	19.10	41.61	42.19	41.90
<i>SEm±</i>	<i>0.49</i>	<i>0.21</i>	<i>0.26</i>	<i>0.21</i>	<i>0.21</i>	<i>0.15</i>
<i>CD at 5%</i>	<i>1.53</i>	<i>0.66</i>	<i>0.78</i>	<i>0.67</i>	<i>0.65</i>	<i>0.44</i>
<i>Planting geometry</i>						
S ₁	18.34	18.68	18.51	41.27	41.35	41.31
S ₂	19.63	19.53	19.58	41.59	42.59	42.09
S ₃	20.77	20.43	20.60	42.90	43.04	42.97
<i>SEm±</i>	<i>0.33</i>	<i>0.27</i>	<i>0.21</i>	<i>0.15</i>	<i>0.11</i>	<i>0.09</i>
<i>CD at 5%</i>	<i>0.96</i>	<i>0.79</i>	<i>0.61</i>	<i>0.43</i>	<i>0.33</i>	<i>0.26</i>

Table 4.36 Interaction effect of date of sowing, fertility levels and planting geometry on protein and oil content in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Protein content (%)</i>			<i>Oil content (%)</i>		
	<i>2019</i>	<i>2020</i>	<i>Pooled</i>	<i>2019</i>	<i>2020</i>	<i>Pooled</i>
D ₁ F ₁ S ₁	18.10	18.24	18.17	41.12	40.51	40.82
D ₁ F ₁ S ₂	18.42	19.83	19.12	41.40	43.08	42.24
D ₁ F ₁ S ₃	21.33	20.16	20.75	43.98	43.07	43.52
D ₁ F ₂ S ₁	20.55	20.71	20.63	42.08	42.89	42.49
D ₁ F ₂ S ₂	20.89	20.84	20.86	42.33	43.96	43.14
D ₁ F ₂ S ₃	23.03	22.17	22.60	43.63	43.99	43.81
D ₁ F ₃ S ₁	20.73	21.16	20.95	42.72	42.52	42.62
D ₁ F ₃ S ₂	22.64	21.72	22.18	42.84	43.84	43.34
D ₁ F ₃ S ₃	22.71	22.42	22.56	44.37	44.69	44.53
D ₂ F ₁ S ₁	16.58	16.42	16.50	39.74	40.20	39.97
D ₂ F ₁ S ₂	17.21	16.50	16.85	40.35	40.64	40.49
D ₂ F ₁ S ₃	17.25	18.21	17.73	40.38	41.75	41.06
D ₂ F ₂ S ₁	17.05	17.96	17.50	41.37	40.66	41.02
D ₂ F ₂ S ₂	19.04	18.68	18.86	41.46	41.44	41.45
D ₂ F ₂ S ₃	19.31	19.81	19.56	41.93	42.08	42.00
D ₂ F ₃ S ₁	17.02	17.57	17.29	40.56	41.29	40.93
D ₂ F ₃ S ₂	19.57	19.61	19.59	41.18	42.60	41.89
D ₂ F ₃ S ₃	21.00	19.83	20.41	43.09	42.67	42.88
<i>SEm±</i>	<i>0.80</i>	<i>0.66</i>	<i>0.52</i>	<i>0.36</i>	<i>0.27</i>	<i>0.22</i>
<i>CD at 5%</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>1.04</i>	<i>0.80</i>	<i>0.64</i>

4.5.2 Gross returns (₹ ha⁻¹)

The combination D₂F₃S₃ (late sown on July 10th with 125% RDF and 50 cm × 10 cm spacing) exhibited the highest gross returns of ₹42,336.67 ha⁻¹ in 2019, while in 2020, D₁F₃S₂ (early sown on June 20th with 125% RDF and 40 cm × 10 cm spacing) achieved the highest gross returns of ₹52,393.33 ha⁻¹. Conversely, the least gross returns were recorded in D₂F₁S₃ (late sown on July 10th with 75% RDF and 50 cm x 10 cm spacing) with ₹33,756.67 ha⁻¹ in 2019 and D₂F₃S₁ (late sown on July 10th with 125% RDF and 30 cm × 10 cm spacing) with ₹32,996.67 ha⁻¹ in 2020. These variations in gross returns can be attributed to the combined effects of sowing date, fertilizer levels, and planting geometry. Early sowing and optimal fertility levels (D₁F₃) generally lead to better growth and higher yields, resulting in greater gross returns. The higher spacing in D₂F₃S₃ also contributed to better yields, while the lower returns in combinations with late sowing and reduced fertility (D₂F₁) reflect the negative impact of suboptimal growing conditions and resource limitations on overall productivity.

4.5.3 Net returns (₹ ha⁻¹)

The data on net returns was calculated in both the cropping season and are presented in Table 4.37.

The combination D₁F₂S₁ (early sown on June 20th with 100% RDF and 30 cm x 10 cm spacing) recorded the highest net returns of ₹20,644.25 ha⁻¹ in 2019, while D₁F₃S₂ (early sown on June 20th with 125% RDF and 40 cm × 10 cm spacing) achieved the highest net returns of ₹29788.63 ha⁻¹ in 2020. The higher net returns in these combinations can be attributed to the optimal combination of early sowing and adequate fertilizer application, which enhances crop growth and yields. The reduced spacing in D₁F₂S₁ may have led to higher yields per unit area, while the increased fertilizer levels in D₁F₃S₂ further boosted productivity. These factors combined to maximize gross returns and, after accounting for cultivation costs, resulted in the highest net returns in their respective years.

4.5.4 B-C ratio

The data on B-C ratio for the two-cropping season was calculated and presented in Table 4.37.

The combination $D_1F_1S_2$ (early sown on June 20th with 75% RDF and 40 cm × 10 cm spacing) exhibited the highest benefit-cost (B-C) ratio of 1.67 in 2019, while $D_1F_2S_3$ (early sown on June 20th with 100% RDF and 50 cm × 10 cm spacing) achieved the maximum B-C ratio of 1.91 in 2020. These high B-C ratios are attributed to the optimal balance between input costs and returns, where efficient use of fertilizer and favourable planting geometry maximize profitability. Conversely, $D_1F_3S_1$ and $D_2F_3S_1$, both with high input costs due to 125% RDF and closer spacing, had lower B-C ratios, with values of 1.26 in 2019 and 1.23 in 2020 for $D_2F_3S_1$. The lower B-C ratios in these treatments reflect higher cultivation costs that may not be proportionately offset by increased returns, thereby reducing overall profitability.

Table 4.37 Economics of treatments in groundnut

<i>Date of sowing and fertility levels x Planting geometry</i>	<i>Cost of cultivation (Rs/ ha)</i>	<i>Gross returns (Rs/ ha)</i>		<i>Net returns (Rs/ ha)</i>		<i>Benefit cost ratio</i>	
		<i>2019</i>	<i>2020</i>	<i>2019</i>	<i>2020</i>	<i>2019</i>	<i>2020</i>
D1F1S1	25148.95	37446.67	37023.33	16780.92	16357.58	1.49	1.47
D1F1S2	25148.95	42046.67	39903.33	19441.97	17298.63	1.67	1.59
D1F1S3	25148.95	39320.00	42276.67	14791.10	17747.77	1.56	1.68
D1F2S1	27177.14	41310.00	46786.67	20644.25	26120.92	1.52	1.72
D1F2S2	27177.14	42066.67	50370.00	19461.97	27765.30	1.55	1.85
D1F2S3	27177.14	37423.33	52026.67	12894.43	27497.77	1.38	1.91
D1F3S1	29205.58	36776.67	46733.33	16110.92	26067.58	1.26	1.60
D1F3S2	29205.58	37926.67	52393.33	15321.97	29788.63	1.30	1.79
D1F3S3	29205.58	37786.67	51636.67	13257.77	27107.77	1.29	1.77
D2F1S1	25148.95	38826.67	33086.67	18160.92	12420.92	1.54	1.32
D2F1S2	25148.95	41443.33	34603.33	18838.63	11998.63	1.65	1.38
D2F1S3	25148.95	33756.67	34070.00	9227.77	9541.10	1.34	1.35
D2F2S1	27177.14	36640.00	33196.67	15974.25	12530.92	1.35	1.22
D2F2S2	27177.14	39826.67	40463.33	17221.97	17858.63	1.47	1.49
D2F2S3	27177.14	41263.33	41583.33	16734.43	17054.43	1.52	1.53
D2F3S1	29205.58	36703.33	32996.67	16037.58	12330.92	1.26	1.13
D2F3S2	29205.58	38773.33	40630.00	16168.63	18025.30	1.33	1.39
D2F3S3	29205.58	42336.67	41646.67	17807.77	17117.77	1.45	1.43

CHAPTER V
SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

The present research entitled “Effect of sowing dates, planting geometry and fertility levels on groundnut (*Arachis hypogaea* L.) under foothill condition of Nagaland” was carried out during *kharif* season of 2019 and 2020 in the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema with the following objectives:

1. To find out the suitable date of sowing, spacing and fertility level on growth, yield and quality of groundnut.
2. To assess the effect of date of sowing, spacing and fertility levels on nutrient concentration, their uptake and soil fertility status.
3. To study the economics of different treatments under study.

The salient findings of the present experiment have been summarized below:

1. Early sowing on June 20th consistently resulted in taller groundnut plants at 60 and 90 days after sowing (DAS) compared to late sowing on July 10th. Maximum plant height of groundnut was notably higher with early sowing on June 20 (D₁) compared to July 10 (D₂), with the maximum height recorded at 90 DAS being 32.59 cm for the combination of D₁ with 125% RDF (F₃) and 50 cm × 10 cm spacing (S₃).
2. Groundnut plants sown on June 20th with 125% RDF exhibited the highest number of primary branches at 30, 60, and 90 DAS. The number of primary branches increased with early sowing and higher fertility, with the highest values at 90 DAS reaching 10.48 branches plant⁻¹ under the same treatment combination of D₁F₃S₃. The highest number of primary branches was observed with early sowing, higher fertility, and wider planting geometry.
3. For the number of leaves, early sowing on June 20 combined with 125% RDF (F₃) and wider spacing of 50 cm × 10 cm (S₃) led to the maximum number of leaves, which peaked at 76.04 leaves per plant at 90 DAS. Wider spacing of 50 cm × 10 cm also resulted in a greater number of leaves (74.28). Early sowing and

higher fertility levels significantly enhanced leaf development, with the optimal number of leaves achieved under these conditions.

4. At 60 and 90 DAS, the highest LAI was observed in groundnut plants sown on June 20th with 125% RDF. The 50 cm x 10 cm spacing provided the highest LAI values. Early sowing and higher fertility levels were most effective in increasing the leaf area index, with the best results obtained with wider planting geometry.
5. The highest CGR in groundnut was achieved with early sowing on June 20 (D₁) combined with 125% recommended dose of fertilizer (F₃), and planting geometry of 50 cm x 10 cm (S₃). Specifically, D₁F₃ had a pooled CGR of 7.77 from 30-60 DAS and 6.99 from 60-90 DAS, while S₃ geometry consistently exhibited higher growth rates, with a pooled CGR of 6.36 (30-60 DAS) and 7.06 (60-90 DAS). In contrast, later sowing on July 10 (D₂) with 75% RDF (F₁) and a narrower spacing of 30 cm x 10 cm (S₁) resulted in significantly lower CGR values.
6. The highest NAR was observed with early sowing and the highest fertilizer dose (D₁F₃), achieving a pooled NAR of 0.52 (30-60 DAS) and 1.48 (60-90 DAS). The optimal planting geometry of 50 cm × 10 cm (S₃) also resulted in the highest and most consistent NAR values, with a pooled value of 0.45 (30-60 DAS) and 1.35 (60-90 DAS).
7. Relative Growth Rate (RGR) did not show significant differences due to varying sowing dates, fertility levels, or planting geometries.
8. For shoot dry weight, the combination of early sowing (D₁) with 125% RDF (F₃) and a planting geometry of 50 cm × 10 cm (S₃) resulted in the highest biomass accumulation, with pooled shoot dry weights of 15.07 g (30 DAS), 24.40 g (60 DAS), and 31.59 g (90 DAS). This optimal combination provided the best conditions for growth, leading to the highest shoot dry weight at all stages of plant development.
9. No significant effect on days to 50% flowering was observed, however, combination of early sowing (D₁), 100% RDF (F₂), and 40 cm × 10 cm spacing (S₂) resulted in the highest duration to 50% flowering (31.87 days in pooled data).
10. The highest number of pods plant⁻¹ was recorded under the combination of early sowing with high fertility (D₁F₂), yielding 19.41 in 2019, 19.04 in 2020, and a pooled value of 19.22. Regarding planting geometry, the S₃ (50 cm × 10 cm)

spacing resulted in the highest number of pods per plant, with 19.04 in 2019, 18.37 in 2020, and a pooled value of 18.70, whereas S_1 had the lowest (16.40). The interaction effect showed that early sowing with 100% RDF and optimal spacing ($D_1F_2S_3$) produced the highest number of pods per plant, with a pooled value of 21.19, while the least was observed in $D_2F_1S_1$, with 14.20.

11. The analysis indicated no significant effect of sowing dates, fertility levels, or planting geometry on the number of seeds per pod in groundnut. Additionally, the interaction between these factors did not significantly influence the number of seeds per pod.
12. There was no significant effect of sowing dates, fertility levels, or planting geometry on the pod length of groundnut. The interaction between these factors also did not show any significant impact on pod length.
13. The test weight of groundnut was not significantly affected by sowing dates, fertility levels, or planting geometry. Furthermore, the interaction between these factors did not result in any significant variations in test weight.
14. The highest seed yield was observed in the D_1F_3 treatment, with values of 1.65 t ha⁻¹ in 2019, 1.49 t ha⁻¹ in 2020, and a pooled value of 1.57 t ha⁻¹, while the lowest was recorded in D_2F_1 , with 1.02 t ha⁻¹ in 2019, 1.00 t ha⁻¹ in 2020, and a pooled value of 1.01 t ha⁻¹. For stover yield, D_1F_3 also showed the highest values, with 2.69 t ha⁻¹ in 2019, 2.54 t ha⁻¹ in 2020, and a pooled value of 2.61 t ha⁻¹. In terms of planting geometry, S_3 (50 cm × 10 cm) had the highest seed yield, reaching 1.40 t ha⁻¹ in 2019, 1.30 t ha⁻¹ in 2020, and a pooled value of 1.35 t ha⁻¹, while S_1 had the lowest pooled seed yield at 1.17 t ha⁻¹. The combination of early sowing with high fertility and optimal spacing ($D_1F_3S_3$) resulted in the highest seed yield, with a pooled value of 1.69 t ha⁻¹, stover yield of 2.79 t ha⁻¹, and biological yield of 4.49 t ha⁻¹, whereas $D_2F_1S_1$ had the lowest seed yield at 0.92 t ha⁻¹, stover yield of 1.77 t ha⁻¹, and biological yield of 2.69 t ha⁻¹.
15. The D_1F_3 treatment showed the highest harvest index, with a maximum of 37.02% in 2020, and the highest shelling percentage, with values of 67.46% in 2019, 67.41% in 2020, and a pooled value of 67.44%. In terms of planting geometry, S_3 (50 cm × 10 cm) had the highest shelling percentage, with 67.76% in 2019, 66.86% in 2020, and a pooled value of 67.31%. The combination of early sowing with high

fertility and optimal spacing ($D_1F_3S_3$) resulted in the highest shelling percentage, with values of 67.60% in 2019, 68.04% in 2020, and a pooled value of 67.82%, while the highest harvest index was observed in $D_1F_2S_1$, with 40.04% in 2020 and 38.72% in pooled data.

16. The study revealed that soil pH remained unaffected by different sowing dates, fertility levels, and planting geometries. However, organic carbon content varied significantly, with early sowing combined with higher fertility levels (D_1F_3) yielding the highest organic carbon values of 1.51% in 2019, 1.46% in 2020, and 1.48% in pooled data. Wider planting geometry (S_3 : 50 cm x 10 cm) also resulted in higher organic carbon content, with pooled data showing 1.48%. The combination of early sowing, higher fertility levels, and wider spacing ($D_1F_3S_3$) produced the highest organic carbon content of 1.52%.
17. Early sowing with higher fertility levels (D_1F_3) led to the highest available soil nitrogen, with values of 292.25 kg ha⁻¹ in 2019, 293.47 kg ha⁻¹ in 2020, and 292.86 kg ha⁻¹ in pooled data. Wider planting geometry (S_3 : 50 cm × 10 cm) also showed higher nitrogen levels, with pooled data indicating 286.71 kg ha⁻¹. No significant interaction effects were found among sowing dates, fertility levels, and planting geometry on soil nitrogen.
18. The highest available soil phosphorus was recorded in the D_1F_3 treatment, with values of 30.52 kg ha⁻¹ in 2019, 30.67 kg ha⁻¹ in 2020, and 30.60 kg ha⁻¹ in pooled data. Wider planting geometry (S_3) also supported higher phosphorus levels, with pooled data showing 25.87 kg ha⁻¹. The interaction effects on soil phosphorus were not significant.
19. Significant effects on available soil potassium were observed, with D_1F_3 showing the highest values of 166.71 kg ha⁻¹ in 2019, 167.34 kg ha⁻¹ in 2020, and 167.02 kg ha⁻¹ in pooled data. Wider planting geometry (S_3) resulted in higher potassium levels, with pooled data indicating 163.96 kg ha⁻¹. The interaction effect revealed that the combination of early sowing, higher fertility levels, and wider spacing ($D_1F_3S_3$) yielded the highest potassium availability with pooled values of 171.22 kg ha⁻¹.
20. Early sowing combined with higher fertility levels (D_1F_3) resulted in the highest nitrogen content and uptake, with pooled values of 3.5% in grain and 1.54% in

stover. The total nitrogen uptake was highest in D₁F₃, with pooled data showing 68.86 kg ha⁻¹. Wider planting geometry (S₃: 50 cm × 10 cm) also promoted higher nitrogen uptake, with pooled values of 66.53 kg ha⁻¹. The combination of early sowing, higher fertility levels, and wider spacing (D₁F₃S₃) resulted in the highest total nitrogen uptake of 78.30 kg ha⁻¹.

21. The highest phosphorus content and uptake were observed in the D₁F₃ treatment, with pooled values of 0.371% in grain and a total phosphorus uptake of 8.31 kg ha⁻¹. Wider planting geometry (S₃: 50 cm × 10 cm) also led to higher phosphorus uptake, with pooled data showing 8.66 kg ha⁻¹. Interaction effects on phosphorus content and uptake were not significant.
22. Sowing date and fertility levels did not significantly affect potassium content in grain and stover, the D₁F₃ treatment showed the highest total potassium uptake, with pooled values of 51.99 kg ha⁻¹. Wider planting geometry (S₃) resulted in higher total potassium uptake, with pooled data indicating 54.42 kg ha⁻¹. The combination of early sowing, higher fertility levels, and wider spacing (D₁F₃S₃) yielded the highest total potassium uptake, with pooled values of 60.54 kg ha⁻¹.
23. The study revealed that the highest protein content in groundnut was observed in the combination of early sowing (D₁) with 125% recommended dose fertilizer (F₃), yielding a maximum of 22.03% in 2019, 21.77% in 2020, and a pooled value of 21.90%. In contrast, the lowest pooled value was 17.03% for late sowing (D₂) with 75% recommended dose fertilizer (F₁). Among planting geometries, the widest spacing (S₃: 50 cm × 10 cm) resulted in the highest protein content, with pooled values of 20.60%, 20.77% in 2019, and 20.43% in 2020. The narrowest spacing (S₁: 30 cm × 10 cm) showed the lowest protein content, with pooled values of 18.51%, 18.34% in 2019, and 18.68% in 2020.
24. The highest oil content was found in the combination of early sowing (D₁) with 125% recommended dose fertilizer (F₃), recording 43.31% in 2019, 43.68% in 2020, and a pooled value of 43.50%. The lowest pooled value was 40.51% for late sowing (D₂) with 75% recommended dose fertilizer (F₁). The planting geometry of 50 cm × 10 cm (S₃) resulted in the highest oil content, with pooled values of 42.97%, 42.90% in 2019, and 41.35% in 2020, while the narrowest spacing (S₁: 30 cm × 10 cm) recorded the lowest pooled oil content, with values of 41.31%,

41.27% in 2019, and 41.35% in 2020. The highest oil content overall was achieved with the combination of early sowing, 125% recommended dose fertilizer, and 50 cm × 10 cm planting geometry, showing pooled values of 44.53%.

25. The cost of cultivation was highest and identical across all treatments under planting geometry F₃ (125% RDF) at ₹29,205.58 ha⁻¹. The highest gross returns were noted in D₂F₃S₃ (late sowing with 125% RDF and 50 cm × 10 cm spacing) with ₹42,336.67 ha⁻¹ in 2019 and D₁F₃S₂ (early sowing with 125% RDF and 40 cm x 10 cm spacing) with ₹52,393.33 ha⁻¹ in 2020. The highest net returns were recorded in D₁F₂S₁ (early sowing with 100% RDF and 30 cm × 10 cm spacing) with ₹20,644.25 ha⁻¹ in 2019 and D₁F₃S₂ (early sowing with 125% RDF and 40 cm x 10 cm spacing) with ₹39,788.63 ha⁻¹ in 2020. The highest benefit-cost (B-C) ratio was 1.67 in 2019 for D₁F₁S₂ (early sowing with 75% RDF and 40 cm × 10 cm spacing) and 1.91 in 2020 for D₁F₂S₃ (early sowing with 100% RDF and 50 cm x 10 cm spacing).

Recommendation

From the results of two years experiments, groundnut is recommended to sow on 20th June maintaining 50 cm × 10 cm planting geometry along with application of 125% RDF for enhancing groundnut productivity and efficient utilization of nutrients. However, for profitable production of groundnut, early sowing on 20th June with 125% RDF at 40 cm × 10 cm spacing or 100% RDF at 50 cm x 10 cm spacing could be recommended under foothill condition of Nagaland.

CHAPTER VI

Appendices

APPENDICES

ANOVA- 1: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on plant height (cm) at 30 DAS

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	13.32	6.66	1.29	4.10	NS
Factor A	5	42.30	8.46	1.64	3.33	NS
Error I	10	51.47	5.15			
Factor B	2	25.32	12.66	3.33	3.40	NS
A x B interaction	10	81.06	8.11	2.13	2.25	NS
Error II	24	91.25	3.80			
Total	53	304.73				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	5.16	2.58	0.60	4.10	NS
Factor A	5	42.22	8.44	1.95	3.33	NS
Error I	10	43.20	4.32			
Factor B	2	38.50	19.25	2.15	3.40	NS
A x B interaction	10	56.38	5.64	0.63	2.25	NS
Error II	24	214.46	8.94			
Total	53	399.93				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	13.92	13.92	2.94	4.35	NS
Replication	4	18.49	4.62	0.98	2.87	NS
Factor A	10	84.53	8.45	1.79	2.35	NS
Error I	20	94.67	4.73			
Factor B	4	63.82	15.96	2.51	2.57	NS
A x B interaction	20	137.44	6.87	1.08	1.79	NS
Error II	48	305.71	6.37			
Total	107	718.58				

ANOVA- 2: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on plant height (cm) at 60 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	27.62	13.81	3.41	4.10	NS
Factor A	5	171.48	34.30	8.48	3.33	S
Error I	10	40.45	4.05			
Factor B	2	138.22	69.11	33.20	3.40	S
A x B interaction	10	99.96	10.00	4.80	2.25	S
Error II	24	49.96	2.08			
Total	53	527.68				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	12.73	6.37	2.10	4.10	NS
Factor A	5	171.84	34.37	11.33	3.33	S
Error I	10	30.34	3.03			
Factor B	2	111.59	55.79	33.24	3.40	S
A x B interaction	10	117.04	11.70	6.97	2.25	S
Error II	24	40.29	1.68			
Total	53	483.82				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	3.22	3.22	0.91	4.35	NS
Replication	4	40.35	10.09	2.85	2.87	NS
Factor A	10	343.32	34.33	9.70	2.35	S
Error I	20	70.80	3.54			
Factor B	4	249.80	62.45	33.22	2.57	S
A x B interaction	20	216.99	10.85	5.77	1.79	S
Error II	48	90.25	1.88			
Total	107	1014.73				

ANOVA- 3: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on plant height (cm) at 90 DAS

ANOVA TABLE First Year						
Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	5.16	2.58	0.88	4.10	NS
Factor A	5	148.87	29.77	10.10	3.33	S
Error I	10	29.49	2.95			
Factor B	2	67.32	33.66	29.68	3.40	S
A x B interaction	10	26.28	2.63	2.32	2.25	S
Error II	24	27.22	1.13			
Total	53	304.34				

ANOVA TABLE Second Year						
Source of Variance	Degree of Freedom	Sum of Square	Mean Sum of Square	F Cal	F Tab at 5%	S/NS
Replication	2	1.12	0.56	0.39	4.10	NS
Factor A	5	186.22	37.24	25.91	3.33	S
Error I	10	14.38	1.44			
Factor B	2	93.18	46.59	20.34	3.40	S
A x B interaction	10	52.55	5.25	2.29	2.25	S
Error II	24	54.98	2.29			
Total	53	402.44				

ANOVA TABLE OF POOLED ANALYSIS						
SOV	df	SS	MSS	F Cal	F Tab at 5%	S/NS
Years	1	0.03	0.03	0.01	4.35	NS
Replication	4	6.29	1.57	0.72	2.87	NS
Factor A	10	335.09	33.51	15.28	2.35	S
Error I	20	43.86	2.19			
Factor B	4	160.50	40.13	23.43	2.57	S
A x B interaction	20	78.83	3.94	2.30	1.79	S
Error II	48	82.21	1.71			
Total	107	706.81				

ANOVA- 4: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of primary branches at 30 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.96	0.98	2.53	4.10	NS
Factor A	5	9.22	1.84	4.76	3.33	S
Error I	10	3.87	0.39			
Factor B	2	5.89	2.94	14.07	3.40	S
A x B interaction	10	4.74	0.47	2.27	2.25	S
Error II	24	5.02	0.21			
Total	53	30.70				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.38	0.19	0.75	4.10	NS
Factor A	5	7.23	1.45	5.70	3.33	S
Error I	10	2.54	0.25			
Factor B	2	6.77	3.38	16.62	3.40	S
A x B interaction	10	5.32	0.53	2.61	2.25	S
Error II	24	4.89	0.20			
Total	53	27.13				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	0.89	0.89	2.78	4.35	NS
Replication	4	2.34	0.59	1.83	2.87	NS
Factor A	10	16.44	1.64	5.13	2.35	S
Error I	20	6.41	0.32			
Factor B	4	12.66	3.16	15.33	2.57	S
A x B interaction	20	10.07	0.50	2.44	1.79	S
Error II	48	9.91	0.21			
Total	107	58.72				

ANOVA- 5: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of primary branches at 60 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.75	0.87	1.24	4.10	NS
Factor A	5	24.40	4.88	6.92	3.33	S
Error I	10	7.06	0.71			
Factor B	2	13.75	6.87	14.84	3.40	S
A x B interaction	10	11.38	1.14	2.46	2.25	S
Error II	24	11.12	0.46			
Total	53	69.45				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.42	0.71	1.43	4.10	NS
Factor A	5	20.26	4.05	8.12	3.33	S
Error I	10	4.99	0.50			
Factor B	2	14.80	7.40	17.57	3.40	S
A x B interaction	10	10.66	1.07	2.53	2.25	S
Error II	24	10.11	0.42			
Total	53	62.25				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.15	0.15	0.25	4.35	NS
Replication	4	3.17	0.79	1.32	2.87	NS
Factor A	10	44.67	4.47	7.42	2.35	S
Error I	20	12.05	0.60			
Factor B	4	28.55	7.14	16.14	2.57	S
A x B interaction	20	22.04	1.10	2.49	1.79	S
Error II	48	21.23	0.44			
Total	107	131.85				

ANOVA- 6: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of primary branches at 90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.82	0.41	1.15	4.10	NS
Factor A	5	20.21	4.04	11.32	3.33	S
Error I	10	3.57	0.36			
Factor B	2	7.28	3.64	15.02	3.40	S
A x B interaction	10	7.79	0.78	3.21	2.25	S
Error II	24	5.82	0.24			
Total	53	45.49				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.33	1.16	4.07	4.10	NS
Factor A	5	19.22	3.84	13.43	3.33	S
Error I	10	2.86	0.29			
Factor B	2	8.61	4.30	16.08	3.40	S
A x B interaction	10	7.46	0.75	2.79	2.25	S
Error II	24	6.43	0.27			
Total	53	46.91				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.42	0.42	1.31	4.35	NS
Replication	4	3.15	0.79	2.45	2.87	NS
Factor A	10	39.42	3.94	12.26	2.35	S
Error I	20	6.43	0.32			
Factor B	4	15.89	3.97	15.58	2.57	S
A x B interaction	20	15.26	0.76	2.99	1.79	S
Error II	48	12.24	0.26			
Total	107	92.82				

ANOVA- 7: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of leaves at 30 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	12.11	6.06	2.18	4.10	NS
Factor A	5	11.86	2.37	0.85	3.33	NS
Error I	10	27.76	2.78			
Factor B	2	0.81	0.41	0.06	3.40	NS
A x B interaction	10	51.17	5.12	0.74	2.25	NS
Error II	24	165.91	6.91			
Total	53	269.63				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.37	1.18	0.36	4.10	NS
Factor A	5	47.84	9.57	2.89	3.33	NS
Error I	10	33.11	3.31			
Factor B	2	21.25	10.62	2.59	3.40	NS
A x B interaction	10	68.36	6.84	1.67	2.25	NS
Error II	24	98.51	4.10			
Total	53	271.43				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.14	0.14	0.05	4.35	NS
Replication	4	14.48	3.62	1.19	2.87	NS
Factor A	10	59.70	5.97	1.96	2.35	NS
Error I	20	60.87	3.04			
Factor B	4	22.06	5.51	1.00	2.57	NS
A x B interaction	20	119.53	5.98	1.08	1.79	NS
Error II	48	264.42	5.51			
Total	107	541.20				

ANOVA- 8: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of leaves at 60 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.75	0.38	1.05	4.10	NS
Factor A	5	22.26	4.45	12.47	3.33	S
Error I	10	3.57	0.36			
Factor B	2	4.70	2.35	10.30	3.40	S
A x B interaction	10	16.72	1.67	7.32	2.25	S
Error II	24	5.48	0.23			
Total	53	53.48				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	3.57	1.79	2.87	4.10	NS
Factor A	5	53.62	10.72	17.21	3.33	S
Error I	10	6.23	0.62			
Factor B	2	12.25	6.13	9.02	3.40	S
A x B interaction	10	87.00	8.70	12.81	2.25	S
Error II	24	16.30	0.68			
Total	53	178.98				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	22.41	22.41	45.74	4.35	S
Replication	4	4.32	1.08	2.21	2.87	NS
Factor A	10	75.88	7.59	15.49	2.35	S
Error I	20	9.80	0.49			
Factor B	4	16.96	4.24	9.34	2.57	S
A x B interaction	20	103.72	5.19	11.43	1.79	S
Error II	48	21.78	0.45			
Total	107	254.88				

ANOVA- 9: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of leaves at 90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.49	0.25	0.29	4.10	NS
Factor A	5	69.45	13.89	16.08	3.33	S
Error I	10	8.64	0.86			
Factor B	2	6.85	3.42	4.00	3.40	S
A x B interaction	10	20.49	2.05	2.40	2.25	S
Error II	24	20.53	0.86			
Total	53	126.45				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.38	1.19	2.48	4.10	NS
Factor A	5	58.43	11.69	24.39	3.33	S
Error I	10	4.79	0.48			
Factor B	2	29.99	14.99	22.39	3.40	S
A x B interaction	10	17.67	1.77	2.64	2.25	S
Error II	24	16.07	0.67			
Total	53	129.34				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.84	0.84	1.26	4.35	NS
Replication	4	2.87	0.72	1.07	2.87	NS
Factor A	10	127.88	12.79	19.05	2.35	S
Error I	20	13.43	0.67			
Factor B	4	36.83	9.21	12.08	2.57	S
A x B interaction	20	38.17	1.91	2.50	1.79	S
Error II	48	36.60	0.76			
Total	107	256.63				

ANOVA- 10: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on LAI at 30 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.03	0.02	1.91	4.10	NS
Factor A	5	0.13	0.03	3.29	3.33	NS
Error I	10	0.08	0.01			
Factor B	2	0.03	0.01	1.32	3.40	NS
A x B interaction	10	0.24	0.02	2.15	2.25	NS
Error II	24	0.27	0.01			
Total	53	0.79				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.01	0.00	0.12	4.10	NS
Factor A	5	0.20	0.04	1.35	3.33	NS
Error I	10	0.30	0.03			
Factor B	2	0.01	0.01	0.47	3.40	NS
A x B interaction	10	0.06	0.01	0.48	2.25	NS
Error II	24	0.32	0.01			
Total	53	0.91				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.03	0.03	1.34	4.35	NS
Replication	4	0.04	0.01	0.49	2.87	NS
Factor A	10	0.34	0.03	1.76	2.35	NS
Error I	20	0.38	0.02			
Factor B	4	0.04	0.01	0.87	2.57	NS
A x B interaction	20	0.31	0.02	1.25	1.79	NS
Error II	48	0.59	0.01			
Total	107	1.72				

ANOVA- 11: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on LAI at 60 DAS

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.01	0.01	0.35	4.10	NS
Factor A	5	17.14	3.43	195.46	3.33	S
Error I	10	0.18	0.02			
Factor B	2	0.14	0.07	3.48	3.40	S
A x B interaction	10	0.14	0.01	0.70	2.25	NS
Error II	24	0.48	0.02			
Total	53	18.09				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.05	0.03	3.03	4.10	NS
Factor A	5	15.21	3.04	348.01	3.33	S
Error I	10	0.09	0.01			
Factor B	2	0.14	0.07	3.66	3.40	S
A x B interaction	10	0.09	0.01	0.49	2.25	NS
Error II	24	0.45	0.02			
Total	53	16.03				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.01	0.01	0.46	4.35	NS
Replication	4	0.07	0.02	1.24	2.87	NS
Factor A	10	32.35	3.24	246.20	2.35	S
Error I	20	0.26	0.01			
Factor B	4	0.28	0.07	3.57	2.57	S
A x B interaction	20	0.23	0.01	0.60	1.79	NS
Error II	48	0.93	0.02			
Total	107	34.12				

ANOVA- 12: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on LAI at 90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.02	0.01	0.49	4.10	NS
Factor A	5	21.34	4.27	174.84	3.33	S
Error I	10	0.24	0.02			
Factor B	2	0.16	0.08	3.73	3.40	S
A x B interaction	10	0.12	0.01	0.56	2.25	NS
Error II	24	0.50	0.02			
Total	53	22.38				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.06	0.03	3.81	4.10	NS
Factor A	5	21.68	4.34	550.90	3.33	S
Error I	10	0.08	0.01			
Factor B	2	0.05	0.03	3.57	3.40	S
A x B interaction	10	0.01	0.00	0.12	2.25	NS
Error II	24	0.18	0.01			
Total	53	22.06				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.08	0.08	4.94	4.35	S
Replication	4	0.08	0.02	1.30	2.87	NS
Factor A	10	43.03	4.30	266.53	2.35	S
Error I	20	0.32	0.02			
Factor B	4	0.21	0.05	3.69	2.57	S
A x B interaction	20	0.12	0.01	0.44	1.79	NS
Error II	48	0.68	0.01			
Total	107	44.53				

ANOVA- 13: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on CGR at 30-60 DAS

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	7.32	3.66	3.21	4.10	NS
Factor A	5	180.47	36.09	31.64	3.33	S
Error I	10	11.41	1.14			
Factor B	2	30.48	15.24	11.91	3.40	S
A x B interaction	10	30.15	3.02	2.36	2.25	S
Error II	24	30.72	1.28			
Total	53	290.56				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.52	1.26	1.02	4.10	NS
Factor A	5	193.25	38.65	31.30	3.33	S
Error I	10	12.35	1.23			
Factor B	2	41.11	20.55	20.49	3.40	S
A x B interaction	10	31.90	3.19	3.18	2.25	S
Error II	24	24.08	1.00			
Total	53	305.20				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.70	0.70	0.59	4.35	NS
Replication	4	9.84	2.46	2.07	2.87	NS
Factor A	10	373.72	37.37	31.46	2.35	S
Error I	20	23.76	1.19			
Factor B	4	71.59	17.90	15.68	2.57	S
A x B interaction	20	62.05	3.10	2.72	1.79	S
Error II	48	54.80	1.14			
Total	107	596.45				

ANOVA- 14: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on CGR at 60-90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.35	0.17	0.32	4.10	NS
Factor A	5	10.27	2.05	3.81	3.33	S
Error I	10	5.39	0.54			
Factor B	2	27.48	13.74	46.80	3.40	S
A x B interaction	10	11.11	1.11	3.78	2.25	S
Error II	24	7.05	0.29			
Total	53	61.64				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.98	0.49	0.99	4.10	NS
Factor A	5	12.06	2.41	4.86	3.33	S
Error I	10	4.96	0.50			
Factor B	2	42.88	21.44	21.00	3.40	S
A x B interaction	10	24.10	2.41	2.36	2.25	S
Error II	24	24.50	1.02			
Total	53	109.48				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.01	0.01	0.02	4.35	NS
Replication	4	1.33	0.33	0.64	2.87	NS
Factor A	10	22.33	2.23	4.31	2.35	S
Error I	20	10.36	0.52			
Factor B	4	70.36	17.59	26.77	2.57	S
A x B interaction	20	35.21	1.76	2.68	1.79	S
Error II	48	31.54	0.66			
Total	107	171.14				

ANOVA- 15: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on NAR at 30-60 DAS

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.01	0.01	3.82	4.10	NS
Factor A	5	0.25	0.05	29.59	3.33	S
Error I	10	0.02	0.00			
Factor B	2	0.01	0.01	5.64	3.40	S
A x B interaction	10	0.08	0.01	6.98	2.25	S
Error II	24	0.03	0.00			
Total	53	0.40				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.03	0.02	1.48	4.10	NS
Factor A	5	2.22	0.44	41.10	3.33	S
Error I	10	0.11	0.01			
Factor B	2	0.69	0.34	15.39	3.40	S
A x B interaction	10	0.63	0.06	2.84	2.25	S
Error II	24	0.54	0.02			
Total	53	4.22				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.77	0.77	123.88	4.35	S
Replication	4	0.04	0.01	1.79	2.87	NS
Factor A	10	2.47	0.25	39.56	2.35	S
Error I	20	0.12	0.01			
Factor B	4	0.70	0.18	14.89	2.57	S
A x B interaction	20	0.72	0.04	3.05	1.79	S
Error II	48	0.57	0.01			
Total	107	5.40				

ANOVA- 16: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on NAR at 60-90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.15	0.08	1.39	4.10	NS
Factor A	5	4.43	0.89	16.34	3.33	S
Error I	10	0.54	0.05			
Factor B	2	2.62	1.31	25.79	3.40	S
A x B interaction	10	1.52	0.15	2.98	2.25	S
Error II	24	1.22	0.05			
Total	53	10.48				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.14	0.07	0.75	4.10	NS
Factor A	5	3.49	0.70	7.24	3.33	S
Error I	10	0.96	0.10			
Factor B	2	4.50	2.25	26.47	3.40	S
A x B interaction	10	1.99	0.20	2.34	2.25	S
Error II	24	2.04	0.09			
Total	53	13.13				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.02	0.02	0.23	4.35	NS
Replication	4	0.29	0.07	0.98	2.87	NS
Factor A	10	7.91	0.79	10.51	2.35	S
Error I	20	1.51	0.08			
Factor B	4	7.12	1.78	26.22	2.57	S
A x B interaction	20	3.51	0.18	2.58	1.79	S
Error II	48	3.26	0.07			
Total	107	23.62				

ANOVA- 17: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on RGR at 30-60 DAS

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Dof</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2.00	0.000019	0.000009	2.90	4.102	NS
Factor A	5.00	0.000075	0.000015	4.8	3.325835	S
Error I	10.00	0.000031	0.000003			
Factor B	2.00	0.000010	0.000005	2.75	3.402	NS
A x B interaction	10.00	0.000021	0.000002	1.1	2.25	NS
Error II	24.00	0.000042	0.000002			
Total	53.0	0.000198				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Dof</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2.00	0.000002	0.000001	0.462	4.102821	NS
Factor A	5.00	0.000084	0.000017	8.891	3.32	S
Error I	10.00	0.000019	0.000002			
Factor B	2.00	0.000017	0.000008	2.975	3.40282	NS
A x B interaction	10.0	0.000022	0.000002	0.796	2.254	NS
Error II	24.0	0.000067	0.000003			
Total	#####	0.000211				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1.00	0.00000	0.00000	0.56965	4.35124	NS
Replication	4.00	0.00002	0.00001	2.02555	2.86608	NS
Factor A	10.0	0.00016	0.00002	6.36717	2.34788	S
Error I	20.0	0.00005	0.00000			
Factor B	4.00	0.00003	0.00001	2.87989	2.56524	S
A x B interaction	20.0	0.00004	0.00000	0.95228	1.79320	NS
Error II	48.0	0.00011	0.00000			
Total	107.	0.00041				

ANOVA- 18: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on RGR at 60-90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.000005	0.000003	1.64	4.10	<i>NS</i>
Factor A	5	0.000043	0.000009	5.60	3.33	<i>S</i>
Error I	10	0.000015	0.000002			
Factor B	2	0.000021	0.000010	8.22	3.40	<i>S</i>
A x B interaction	10	0.000011	0.000001	0.86	2.25	<i>NS</i>
Error II	24	0.000030	0.000001			
Total	53	0.000125				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.000003	0.000002	4.08	4.10	<i>NS</i>
Factor A	5	0.000026	0.000005	12.52	3.33	<i>S</i>
Error I	10	0.000004	0.000000			
Factor B	2	0.000021	0.000010	13.49	3.40	<i>S</i>
A x B interaction	10	0.000013	0.000001	1.68	2.25	<i>NS</i>
Error II	24	0.000019	0.000001			
Total	53	0.000086				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.0000001	0.0000001	0.05	4.35	<i>NS</i>
Replication	4	0.0000084	0.0000021	2.16	2.87	<i>NS</i>
Factor A	10	0.0000687	0.0000069	7.06	2.35	<i>S</i>
Error I	20	0.0000195	0.0000010			
Factor B	4	0.0000417	0.0000104	10.22	2.57	<i>S</i>
A x B interaction	20	0.0000239	0.0000012	1.17	1.79	<i>NS</i>
Error II	48	0.0000489	0.0000010			
Total	107	0.0002111				

ANOVA- 19: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on shoot dry weight at 30 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	3.02	1.51	2.13	4.10	NS
Factor A	5	8.13	1.63	2.29	3.33	NS
Error I	10	7.09	0.71			
Factor B	2	31.10	15.55	19.10	3.40	S
A x B interaction	10	3.67	0.37	0.45	2.25	NS
Error II	24	19.54	0.81			
Total	53	72.56				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.46	0.73	1.09	4.10	NS
Factor A	5	8.12	1.62	2.42	3.33	NS
Error I	10	6.70	0.67			
Factor B	2	22.65	11.32	8.60	3.40	S
A x B interaction	10	2.42	0.24	0.18	2.25	NS
Error II	24	31.60	1.32			
Total	53	72.95				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	1.81	1.81	2.62	4.35	NS
Replication	4	4.49	1.12	1.63	2.87	NS
Factor A	10	16.24	1.62	2.36	2.35	S
Error I	20	13.79	0.69			
Factor B	4	53.75	13.44	12.61	2.57	S
A x B interaction	20	6.09	0.30	0.29	1.79	NS
Error II	48	51.14	1.07			
Total	107	147.32				

ANOVA- 20: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on shoot dry weight at 60 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	16.83	8.42	3.66	4.10	NS
Factor A	5	260.69	52.14	22.67	3.33	S
Error I	10	23.00	2.30			
Factor B	2	162.74	81.37	46.90	3.40	S
A x B interaction	10	47.35	4.73	2.73	2.25	S
Error II	24	41.64	1.73			
Total	53	552.25				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	16.26	8.13	3.23	4.10	NS
Factor A	5	260.73	52.15	20.74	3.33	S
Error I	10	25.15	2.51			
Factor B	2	170.07	85.03	41.24	3.40	S
A x B interaction	10	47.72	4.77	2.31	2.25	S
Error II	24	49.48	2.06			
Total	53	569.40				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.04	0.04	0.02	4.35	NS
Replication	4	33.09	8.27	3.44	2.87	S
Factor A	10	521.42	52.14	21.66	2.35	S
Error I	20	48.15	2.41			
Factor B	4	332.81	83.20	43.83	2.57	S
A x B interaction	20	95.06	4.75	2.50	1.79	S
Error II	48	91.12	1.90			
Total	107	1121.69				

ANOVA- 21: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on shoot dry weight at 90 DAS

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.13	1.07	0.82	4.10	NS
Factor A	5	91.34	18.27	13.97	3.33	S
Error I	10	13.08	1.31			
Factor B	2	67.32	33.66	29.73	3.40	S
A x B interaction	10	26.28	2.63	2.32	2.25	S
Error II	24	27.18	1.13			
Total	53	227.34				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	3.24	1.62	1.43	4.10	NS
Factor A	5	118.64	23.73	21.03	3.33	S
Error I	10	11.28	1.13			
Factor B	2	93.18	46.59	23.06	3.40	S
A x B interaction	10	52.55	5.25	2.60	2.25	S
Error II	24	48.48	2.02			
Total	53	327.37				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.05	0.05	0.04	4.35	NS
Replication	4	5.37	1.34	1.10	2.87	NS
Factor A	10	209.98	21.00	17.24	2.35	S
Error I	20	24.37	1.22			
Factor B	4	160.50	40.13	25.46	2.57	S
A x B interaction	20	78.83	3.94	2.50	1.79	S
Error II	48	75.66	1.58			
Total	107	554.76				

ANOVA- 22: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry at 50% flowering

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	6.04	3.02	1.24	4.10	NS
Factor A	5	12.30	2.46	1.01	3.33	NS
Error I	10	24.30	2.43			
Factor B	2	6.69	3.34	2.45	3.40	NS
A x B interaction	10	102.11	10.21	7.48	2.25	S
Error II	24	32.76	1.36			
Total	53	184.18				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	8.62	4.31	3.96	4.10	NS
Factor A	5	10.78	2.16	1.98	3.33	NS
Error I	10	10.88	1.09			
Factor B	2	3.45	1.73	0.82	3.40	NS
A x B interaction	10	86.21	8.62	4.11	2.25	S
Error II	24	50.29	2.10			
Total	53	170.23				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	1.42	1.42	0.81	4.35	NS
Replication	4	14.66	3.67	2.08	2.87	NS
Factor A	10	23.08	2.31	1.31	2.35	NS
Error I	20	35.18	1.76			
Factor B	4	10.14	2.53	1.46	2.57	NS
A x B interaction	20	188.31	9.42	5.44	1.79	S
Error II	48	83.04	1.73			
Total	107	355.84				

ANOVA- 23: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry at maturity

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.11	1.05	0.12	4.10	NS
Factor A	5	79.17	15.83	1.80	3.33	NS
Error I	10	87.80	8.78			
Factor B	2	0.12	0.06	0.02	3.40	NS
A x B interaction	10	76.79	7.68	2.11	2.25	NS
Error II	24	87.34	3.64			
Total	53	333.32				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	5.74	2.87	0.48	4.10	NS
Factor A	5	85.75	17.15	2.89	3.33	NS
Error I	10	59.39	5.94			
Factor B	2	14.52	7.26	1.58	3.40	NS
A x B interaction	10	78.36	7.84	1.71	2.25	NS
Error II	24	110.12	4.59			
Total	53	353.89				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	10.52	10.52	1.43	4.35	NS
Replication	4	7.84	1.96	0.27	2.87	NS
Factor A	10	164.92	16.49	2.24	2.35	NS
Error I	20	147.19	7.36			
Factor B	4	14.64	3.66	0.89	2.57	NS
A x B interaction	20	155.15	7.76	1.89	1.79	S
Error II	48	197.47	4.11			
Total	107	697.73				

ANOVA- 24: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on number of pods per plant

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.71	0.86	1.00	4.10	NS
Factor A	5	53.82	10.76	12.52	3.33	S
Error I	10	8.60	0.86			
Factor B	2	72.21	36.10	25.08	3.40	S
A x B interaction	10	50.85	5.08	3.53	2.25	S
Error II	24	34.54	1.44			
Total	53	221.73				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	1.32	0.66	1.13	4.10	NS
Factor A	5	62.98	12.60	21.50	3.33	S
Error I	10	5.86	0.59			
Factor B	2	51.72	25.86	116.34	3.40	S
A x B interaction	10	5.89	0.59	2.65	2.25	S
Error II	24	5.33	0.22			
Total	53	133.11				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	3.25	3.25	4.50	4.35	S
Replication	4	3.03	0.76	1.05	2.87	NS
Factor A	10	116.80	11.68	16.16	2.35	S
Error I	20	14.46	0.72			
Factor B	4	123.92	30.98	37.29	2.57	S
A x B interaction	20	56.74	2.84	3.42	1.79	S
Error II	48	39.88	0.83			
Total	107	358.08				

ANOVA- 25: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on seed yield

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.01	0.00	1.44	4.10	NS
Factor A	5	2.69	0.54	175.96	3.33	S
Error I	10	0.03	0.00			
Factor B	2	0.43	0.21	49.68	3.40	S
A x B interaction	10	0.15	0.01	3.44	2.25	S
Error II	24	0.10	0.00			
Total	53	3.41				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.01	0.00	1.56	4.10	NS
Factor A	5	1.82	0.36	119.94	3.33	S
Error I	10	0.03	0.00			
Factor B	2	0.27	0.14	48.76	3.40	S
A x B interaction	10	0.07	0.01	2.52	2.25	S
Error II	24	0.07	0.00			
Total	53	2.27				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	0.19	0.19	62.52	4.35	S
Replication	4	0.02	0.00	1.50	2.87	NS
Factor A	10	4.51	0.45	148.06	2.35	S
Error I	20	0.06	0.00			
Factor B	4	0.70	0.18	49.32	2.57	S
A x B interaction	20	0.22	0.01	3.08	1.79	S
Error II	48	0.17	0.00			
Total	107	5.87				

ANOVA- 26: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on stover yield

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.02	0.01	0.67	4.10	NS
Factor A	5	2.27	0.45	37.99	3.33	S
Error I	10	0.12	0.01			
Factor B	2	1.79	0.90	56.25	3.40	S
A x B interaction	10	0.65	0.06	4.08	2.25	S
Error II	24	0.38	0.02			
Total	53	5.23				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.02	0.01	0.38	4.10	NS
Factor A	5	3.07	0.61	20.51	3.33	S
Error I	10	0.30	0.03			
Factor B	2	1.72	0.86	62.90	3.40	S
A x B interaction	10	0.83	0.08	6.03	2.25	S
Error II	24	0.33	0.01			
Total	53	6.27				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.57	0.57	27.30	4.35	S
Replication	4	0.04	0.01	0.47	2.87	NS
Factor A	10	5.34	0.53	25.49	2.35	S
Error I	20	0.42	0.02			
Factor B	4	3.52	0.88	59.32	2.57	S
A x B interaction	20	1.48	0.07	4.98	1.79	S
Error II	48	0.71	0.01			
Total	107	12.07				

ANOVA- 27: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on biological yield

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.03	0.02	0.85	4.10	NS
Factor A	5	9.80	1.96	99.97	3.33	S
Error I	10	0.20	0.02			
Factor B	2	3.97	1.99	126.50	3.40	S
A x B interaction	10	1.06	0.11	6.78	2.25	S
Error II	24	0.38	0.02			
Total	53	15.44				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.04	0.02	0.55	4.10	NS
Factor A	5	9.44	1.89	50.86	3.33	S
Error I	10	0.37	0.04			
Factor B	2	3.37	1.68	88.38	3.40	S
A x B interaction	10	1.02	0.10	5.38	2.25	S
Error II	24	0.46	0.02			
Total	53	14.70				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	1.42	1.42	50.15	4.35	S
Replication	4	0.07	0.02	0.66	2.87	NS
Factor A	10	19.24	1.92	67.83	2.35	S
Error I	20	0.57	0.03			
Factor B	4	7.34	1.83	105.60	2.57	S
A x B interaction	20	2.09	0.10	6.01	1.79	S
Error II	48	0.83	0.02			
Total	107	31.57				

ANOVA- 28: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on harvest index

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.98	1.49	1.43	4.10	NS
Factor A	5	204.56	40.91	39.11	3.33	S
Error I	10	10.46	1.05			
Factor B	2	4.14	2.07	0.56	3.40	NS
A x B interaction	10	67.23	6.72	1.82	2.25	NS
Error II	24	88.86	3.70			
Total	53	378.23				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	3.99	1.99	0.62	4.10	NS
Factor A	5	79.73	15.95	4.98	3.33	S
Error I	10	32.04	3.20			
Factor B	2	17.27	8.64	5.13	3.40	S
A x B interaction	10	100.73	10.07	5.98	2.25	S
Error II	24	40.40	1.68			
Total	53	274.17				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Years	1	0.27	0.27	0.13	4.35	NS
Replication	4	6.97	1.74	0.82	2.87	NS
Factor A	10	284.28	28.43	13.38	2.35	S
Error I	20	42.50	2.13			
Factor B	4	21.41	5.35	1.99	2.57	NS
A x B interaction	20	167.96	8.40	3.12	1.79	S
Error II	48	129.26	2.69			
Total	107	652.67				

ANOVA- 29: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on available soil nitrogen

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	11.53	5.76	0.12	4.10	NS
Factor A	5	5451.20	1090.24	22.77	3.33	S
Error I	10	478.70	47.87			
Factor B	2	355.11	177.55	3.84	3.40	S
A x B interaction	10	293.76	29.38	0.63	2.25	NS
Error II	24	1110.93	46.29			
Total	53	7701.22				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	45.04	22.52	0.43	4.10	NS
Factor A	5	5543.06	1108.61	20.97	3.33	S
Error I	10	528.60	52.86			
Factor B	2	352.48	176.24	3.57	3.40	S
A x B interaction	10	199.75	19.97	0.40	2.25	NS
Error II	24	1185.06	49.38			
Total	53	7853.98				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	8.34	8.34	0.17	4.35	NS
Replication	4	56.57	14.14	0.28	2.87	NS
Factor A	10	10994.26	1099.43	21.83	2.35	S
Error I	20	1007.30	50.37			
Factor B	4	707.58	176.90	3.70	2.57	S
A x B interaction	20	493.51	24.68	0.52	1.79	NS
Error II	48	2295.98	47.83			
Total	107	#####				

ANOVA- 30: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on available soil phosphorus

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	8.42	4.21	3.88	4.10	NS
Factor A	5	705.40	141.08	130.02	3.33	S
Error I	10	10.85	1.09			
Factor B	2	20.86	10.43	4.51	3.40	S
A x B interaction	10	6.10	0.61	0.26	2.25	NS
Error II	24	55.55	2.31			
Total	53	807.18				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	9.56	4.78	3.66	4.10	NS
Factor A	5	679.52	135.90	103.98	3.33	S
Error I	10	13.07	1.31			
Factor B	2	16.53	8.27	14.98	3.40	S
A x B interaction	10	3.87	0.39	0.70	2.25	NS
Error II	24	13.25	0.55			
Total	53	735.80				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	2.11	2.11	1.76	4.35	NS
Replication	4	17.98	4.50	3.76	2.87	S
Factor A	10	1384.92	138.49	115.79	2.35	S
Error I	20	23.92	1.20			
Factor B	4	37.40	9.35	6.52	2.57	S
A x B interaction	20	9.97	0.50	0.35	1.79	NS
Error II	48	68.79	1.43			
Total	107	1545.09				

ANOVA- 31: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on total nitrogen uptake

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	5.99	3.00	0.07	4.10	NS
Factor A	5	1761.71	352.34	7.96	3.33	S
Error I	10	442.84	44.28			
Factor B	2	1847.05	923.53	72.96	3.40	S
A x B interaction	10	706.95	70.70	5.59	2.25	S
Error II	24	303.79	12.66			
Total	53	5068.34				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	6.65	3.32	0.30	4.10	NS
Factor A	5	1418.11	283.62	25.82	3.33	S
Error I	10	109.84	10.98			
Factor B	2	1397.44	698.72	84.40	3.40	S
A x B interaction	10	251.60	25.16	3.04	2.25	S
Error II	24	198.69	8.28			
Total	53	3382.34				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	219.43	219.43	7.94	4.35	S
Replication	4	12.64	3.16	0.11	2.87	NS
Factor A	10	3179.83	317.98	11.51	2.35	S
Error I	20	552.68	27.63			
Factor B	4	3244.50	811.12	77.48	2.57	S
A x B interaction	20	958.55	47.93	4.58	1.79	S
Error II	48	502.48	10.47			
Total	107	8670.11				

ANOVA- 32: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on total phosphorus uptake

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.08	0.04	0.03	4.10	NS
Factor A	5	10.60	2.12	1.76	3.33	NS
Error I	10	12.04	1.20			
Factor B	2	22.84	11.42	9.38	3.40	S
A x B interaction	10	5.78	0.58	0.48	2.25	NS
Error II	24	29.22	1.22			
Total	53	80.56				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.85	0.43	0.55	4.10	NS
Factor A	5	1.98	0.40	0.51	3.33	NS
Error I	10	7.77	0.78			
Factor B	2	20.38	10.19	14.23	3.40	S
A x B interaction	10	3.70	0.37	0.52	2.25	NS
Error II	24	17.19	0.72			
Total	53	51.88				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	7.06	7.06	7.13	4.35	S
Replication	4	0.93	0.23	0.24	2.87	NS
Factor A	10	12.58	1.26	1.27	2.35	NS
Error I	20	19.81	0.99			
Factor B	4	43.23	10.81	11.18	2.57	S
A x B interaction	20	9.49	0.47	0.49	1.79	NS
Error II	48	46.41	0.97			
Total	107	139.50				

ANOVA- 33: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on protein content

ANOVA TABLE First Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.20	1.10	0.52	4.10	NS
Factor A	5	159.16	31.83	14.96	3.33	S
Error I	10	21.28	2.13			
Factor B	2	53.35	26.67	13.76	3.40	S
A x B interaction	10	18.50	1.85	0.95	2.25	NS
Error II	24	46.52	1.94			
Total	53	301.01				

ANOVA TABLE Second Year						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	3.17	1.58	4.01	4.10	NS
Factor A	5	134.15	26.83	67.95	3.33	S
Error I	10	3.95	0.39			
Factor B	2	27.79	13.89	10.48	3.40	S
A x B interaction	10	5.55	0.56	0.42	2.25	NS
Error II	24	31.81	1.33			
Total	53	206.41				

ANOVA TABLE OF POOLED ANALYSIS						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.03	0.03	0.03	4.35	NS
Replication	4	5.36	1.34	1.06	2.87	NS
Factor A	10	293.30	29.33	23.25	2.35	S
Error I	20	25.23	1.26			
Factor B	4	81.14	20.28	12.43	2.57	S
A x B interaction	20	24.05	1.20	0.74	1.79	NS
Error II	48	78.32	1.63			
Total	107	507.45				

ANOVA- 34: Analysis of variance as influenced by effect of date of sowing, fertility levels and planting geometry on oil content

<i>ANOVA TABLE First Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	2.04	1.02	2.47	4.10	NS
Factor A	5	28.88	5.78	14.00	3.33	S
Error I	10	4.13	0.41			
Factor B	2	26.78	13.39	35.02	3.40	S
A x B interaction	10	9.09	0.91	2.38	2.25	S
Error II	24	9.18	0.38			
Total	53	80.09				

<i>ANOVA TABLE Second Year</i>						
<i>Source of Variance</i>	<i>Degree of Freedom</i>	<i>Sum of Square</i>	<i>Mean Sum of Square</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/NS</i>
Replication	2	0.22	0.11	0.29	4.10	NS
Factor A	5	23.25	4.65	12.28	3.33	S
Error I	10	3.79	0.38			
Factor B	2	27.78	13.89	62.00	3.40	S
A x B interaction	10	5.33	0.53	2.38	2.25	S
Error II	24	5.38	0.22			
Total	53	65.75				

<i>ANOVA TABLE OF POOLED ANALYSIS</i>						
<i>SOV</i>	<i>df</i>	<i>SS</i>	<i>MSS</i>	<i>F Cal</i>	<i>F Tab at 5%</i>	<i>S/SN</i>
Years	1	0.23	0.23	0.57	4.35	NS
Replication	4	2.26	0.56	1.43	2.87	NS
Factor A	10	52.13	5.21	13.17	2.35	S
Error I	20	7.91	0.40			
Factor B	4	54.56	13.64	44.99	2.57	S
A x B interaction	20	14.42	0.72	2.38	1.79	S
Error II	48	14.55	0.30			
Total	107	146.06				

CHAPTER VII

References

REFERENCES

- Abraham, T., and Thenua, O. V. 2010. Influence of organic and inorganic sources of nutrients and their methods of application on growth and yield attributes of groundnut (*Arachis hypogaea* L.). *Indian Journal of Agricultural Research*. **44**(3): 216-220.
- Alam, M., Kumar, R and Patel, J. 2022. Effect of sowing dates and varieties on the nutrient uptake and economics of Wheat crop (*Triticum aestivum* L.) under changing climate. *The Pharma Innovation Journal*. **11**(2): 533-538.
- Amruth, B., Thippeshappa, G.N., Chidanandappa, H.M. and Bhogi, B. 2018. Effect of phosphorus levels through integrated nutrient management packages on nutrient uptake by groundnut (*Arachis hypogaea* L.). *International Journal of Chemical Studies*. **6**(3): 93-96.
- Anil, A. I., Sudhakar, P., Umamahesh, V. and Prathima, T. 2017. Effect of agroclimatic indices and yield in groundnut (*Arachis Hypogaea* L.) at different dates of sowing. *Andhra Pradesh Journal of Agricultural Science*. **3**(4): 261-264.
- Annadurai, K., Puppala, N., Angadi, S., and Masilamani, P. 2009. Agronomic management technologies for peanut production: a review. *Agricultural Reviews*. **30**(4): 235-261.
- Anonymous. 2018. Impact of technologies on oilseeds production in north eastern region. ICAR-Agricultural Technology Application Research Institute (ATARI) Umiam, Meghalaya. pp. 3.
- Anonymous. 2022. Crop outlook reports of Andhra Pradesh, Groundnut, January to December, 2022. Centre for Agricultural and Rural Development Policy Research(CARP), ANGRAU, Lam, Guntur.
- Anonymous. 2023-2024. Area, production and yield of oilseeds crop. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Govt. India.
- Ansa. and Okon. J. 2016. Effects of groundnut spacing on yield and weed control in the rainforest agro-ecological zone of Nigeria. *Direct Research Journal of Agriculture and Food Science*. **4** (12): 374-377
- Arunkumar, S., Arivazhagan, K., and Sriramachandrsekharan, M. 2020. Performance of groundnut to different soil fertility amendments in coastal sandy soil. *International Research Journal on Advanced Science Hub* **2**(12): 93-97.
- Awal, M.A. and Aktar, L. 2015. Effect of row spacing on the growth and yield of peanut (*Arachis hypogaea* L.) stands. *International Journal of Agriculture, Forestry and Fisheries*. **3**(1): 7-11.
- Bala, H.M.B., Ogunlela, V.B., Kuchinda, N.C. and Tanimu, B. 2011. Response of two groundnut (*Arachis hypogaea* L.) varieties to sowing date and NPK fertilizer

- rate in a semi-arid environment: yield and yield attributes. *Asian Journal of Crop Science*. **3**: 130-140.
- Bala, M. and Nath, K. 2015. Maximization of groundnut (*Arachis hypogaea* L) yield by nutrient management practices. *Journal of Experimental Biology and Agricultural Sciences*. **3**(3): 241-245.
- Banik, N.C., Nath, R. and Chakraborty, P.K. 2009. Effect of dates of sowing on growth and yield of groundnut crop. *Journal of Crop and Weed*. **5**(2): 59-62.
- Bhosale, N. A. and Pisal, A. A. 2017. Effect of nutrient management on productivity of summer groundnut (*Arachis hypogaea* L.) in Maharashtra. *Advanced Agricultural Research & Technology Journal*. **1**(1): 88-91.
- Bray, R. H. and Kurtz, L. T. 1945. Determination of soil organic and available form of phosphorus in soil. *Soil Science*. **59**: 39-45.
- Bunsa, P.B., Golakiya, B.A and Polaraj, V. 2004. Influence of potassium along with nitrogen and phosphorus on yield and nutrient uptake by groundnut. *Proceeding of National Symposium on Enhancing Productivity of Groundnut for Sustaining Food and Nutritional Security*. Pp: 11-13.
- Hanum, C. 2018. Growth, yield and movement of phosphate nutrients in soybean on P fertilizer, straw mulch and difference of plant spacing. IOP Conf. Series: Earth and Environmental Science. **122**.
- Chilakala, S., Debbarma, V. and Reddy, P. P. 2023. Effect of spacing and varieties on growth, yield and economics of summer groundnut (*Arachis hypogaea* L.). *Biological Forum – An International Journal*. **15**(3): 605-609.
- Chitale S. and Bhambri, M.C. 2001. Response of Rapeseed mustard to crop geometry, nutrient supply, farmyard manure and interculture- A review. *Ecology, Environment and Conservation*. **7**(4):387-396.
- Chirwa, M., Mrema, J. P., Mtakwa, P. W., Kaaya, A. and Lungu, O. I. 2017. Yield response of groundnut (*Arachis hypogaea* L.) to boron, calcium, nitrogen, phosphorus and potassium fertilizer application. *International Journal of Soil Science*. **12**: 18-24.
- Desmae, H., Sako, D. and Konate, D. 2022. Optimum plant density for increased groundnut pod yield and economic benefits in the Semi-Arid Tropics of West Africa. *Agronomy*. **12**: 1474.
- Dhadge, S. M. and Satpute, N. R. 2014. Integrated nutrient management in groundnut (*Arachis hypogaea* L.) – maize (*Zea mays*) cropping system. *International Journal of Agricultural Science*. **10**(1), 365-368.
- Dolie, S. and Nongmaithem, D. 2020. Influence of spacing and weed management practices on weed, growth and yield of groundnut (*Arachis hypogaea* L.). *Journal of Crop and Weed*. **16**: 256-259.
- Donald, C. M. 1962. In search of yield. *Journal of the Australian Institute of Agricultural Science*. **28**: 171-178.

- Essilfie, M. E. 2020. Influence of row spacing and NPK fertilizer on the growth and yield of two groundnut (*Arachis hypogaea* L.) varieties under rain-fed condition in the transitional zone of Ghana. *International Journal of Agricultural Research*. **15**: 28-40.
- Gadade GD, Dhopte RV, Khodke UM. 2018. Effect of Different Spacing on Growth and Yield of BBF Raised Summer Groundnut (*Arachis hypogaea* L.) under Drip Irrigation. *International Journal of Current Microbiology and Applied Sciences*. Special Issue-**6**:593-597.
- Gawariya, S. C., Chopra, N. K., Chopra, N. and Harika, A. S. 2015. Effect of date of sowing and crop geometry on growth and yield parameters of forage mustard (var. *Chinese Cabbage*). *African Journal of Agricultural Research*. **10**(33): 3292-3295.
- Gregory, F. G. 1926. The effects of climatic conditions on the growth of barley. *Annals of Botany*. **40**: 1-26.
- Gunri, S.K., Nath, R., Puste, A.M., Bera, P.S. and Saha, D. 2015ab. Performance of groundnut (*Arachis hypogaea* L.) variety under different planting geometry and fertility levels in new alluvial zone of West Bengal. *Karnataka Journal of Agricultural Sciences*. **28**(1): 102-103.
- Gupta, S.K., Dhawan, K., Bhole, A.L. and Yadav, T.P. 1983. Effect of dates of sowing and variety on oil content, protein content, iodine value and fatty acid composition in groundnut. *Indian Journal of Agricultural Research*. **53**(9): 859-86.
- Halder, D. and Panda, R. 2014. Determination of appropriate sowing date and phosphorus fertilization strategy for peanut in Eastern India. *African Journal of Agricultural Research* **9**(32): 2475-2487
- Halevy, J., and Hartzoop, A. 1988. Dry matter accumulation and nutrient uptake of high-yielding peanut (*Arachis hypogaea* L.) grown in a sandy soil. *Peanut Science*. **15**: 5-8.
- Hamakareem, H.F., Hamahasan, B.M. and Ali, S.H.S. 2016. Influence of Plant Spacing on the Growth and Yield of Groundnut (*Arachis hypogaea* L.) *International Journal of Current Research in Biosciences and Plant Biology*. **3**(10): 7-12
- Hammons, R.O. 1994. The origin and history of the groundnut. **In**: Smartt J. (ed.) *The Groundnut Crop*. World Crop Series. Springer. pp 24-42.
- Hanway, J. and Heidal, H. S. 1952. Soil testing laboratories procedures, *Jowa Agriculture*. **57**:1-31.
- Hiremath, I., Yenagi, B. S., Alagundagi, S. C., and Patil, H. Y. 2022. Influence of weather on groundnut genotypes under extended sowing window during *Kharif* season. *International Journal of Environment and Climate Change*. **12**(10): 1222-1232.
- Howlader, S. H., Bashar, H.M.K., Islam, M.S., Mamun, M.H. and Jahan, S.M.H. 2009. Effect of plant spacings on the yield and yield attributes of groundnut. *International Journal of Sustainable Crop Production*. **4**(1): 41-44.

- Jackson, M. L. 1973. Soil chemical analysis. Prentice hall of India, Pvt. Ltd., New Delhi.
- Jaiswal, A.B., Gourkhede, P.H. and Narale, S.H. 2018. Studies of different plant geometry on yield and quality of groundnut genotypes drought prone area of Marathwada region. *International Journal of Chemical Studies*. **6**(2): 312-316.
- Kanade, S.G., Shaikh, A.A. and Jadhav, J.D. 2015. Effect of sowing dates in groundnut (*Arachis hypogaea* L.) on growth, yield attributing characters and yield. *Advance Research Journal of Crop Improvement*. **6**(1): 5-11.
- Karunakaran, V., Rammohan, J., Chellamuthu, V., and Poonghuzhalan, R. 2010. Effect of integrated nutrient management on the growth and yield of groundnut (*Arachis hypogaea*) in coastal region of Karaikal. *Indian Journal of Agronomy*. **55**. 128-132.
- Kausale, S.P., Shinde, S.B., Patel, L.K. and Borse. N.S. 2009. Effect of integrated nutrient management on nodulation, dry matter accumulation and yield of summer groundnut at south Gujarat conditions. *Legume Research*. **32**(3): 227-229.
- Kharade, S.B., Kasture M.C. and Palsande, V.N., 2013. Response of groundnut to different levels of N and K with and without biofertilizers in relation to yield, quality and nutrient uptake. *An Asian Journal of Soil Science*. **8**(2): 241-244.
- Konlan, S., Sarkodie-Addo, J., Asare, E. and Kombiok M. J. 2013. Groundnut (*Arachis hypogaea* L.) varietal response to spacing in the Guinea savanna agro-ecological zone of Ghana: growth and yield. *African Journal of Agricultural Research*. **8**(22): 2769-2777.
- Kumar, A., Mahapatra, B.S., Yadav, A., Usha Kumari, Singh, S.P. and Verma, G. 2017. Effect of different fertility levels on growth, yield attributes, yield and quality of Indian mustard (*Brassica juncea* L.) *Ann. Agric. Res. New Series*. **38** (1): 98-103.
- Kumar, D. S., Anitha, D. and Prathyusha, C. 2020. Effect of dates of sowings on growth and productivity of different cultivars of groundnut (*Arachis hypogaea* L.). *Journal of Pharmacognosy and Phytochemistry*. **9**(5): 2211-2213.
- Kumar, N., Singh, R. and Chauhan, R. S. 2022. Effect of nitrogen and spacing on yield and economics of summer groundnut (*Arachis hypogaea* L.). *The Pharma Innovation*. **11**(3): 1277-1279.
- Kumar, Y., Shakhawat, M.S., Singh, S. and Gill, O.P. 2003. Effect of sowing dates and weed control method in yield attributes and yield of groundnut (*Arachis hypogaea* L.). *Indian Journal of Agronomy*. **48**(1): 56-58.
- Karunakaran V, Rammohan J, Chellamuthu V and Poonghuzhalan R. 2010. Effect of integrated nutrient management on the growth and yield of groundnut (*Arachis hypogaea*) in coastal region of Karaikal. *Indian Journal of Agronomy*. **55** (2) : 128-132.

- Meena, R.S., Yadav, R.S. and Meena, V.S. 2014. Response of groundnut (*Arachis hypogaea* L.) varieties to sowing dates and NP fertilizers under western dry zone of India. *Bangladesh Journal Botany* **43**(2): 169-173.
- Moinuddin, G. and Saren, B. K. 2023. Response of groundnut varieties to phosphorus management and its residual effect on succeeding baby corn. *Biological Forum – An International Journal*. **15**(4): 603-608.
- Nayak, R.D., Singh, R., Pradhan, A. and Thakur, I. 2023. Effect of Date of Sowing and Integrated Nitrogen Management on Growth and Yield of Summer Groundnut (*Arachis hypogaea* L.). *International Journal of Plant & Soil Science* **35** (19): 1559-1565
- Pandey, N., Kumar, S. and Singh, G. 2015. Effect of planting geometry on growth and yield of mustard varieties. *Int. J. of Farm Sci.*, **5**(2): 47-52.
- Parameshwarareddy, R., Angadi, S. S. and Yenagi, B. S. 2019. Influence of plant spacing and fertilizer levels on growth and yield of summer groundnut. *Journal of Pharmacognosy and Phytochemistry*. **8**(3): 3745-3748.
- Patel, A, R., Patel, M., Patel, R and Mote, B. 2019. Effect of different sowing date on phenology, growth and yield of rice– A review. *Plant Archives*. **19**(1): 12-16
- Patil, D. B., Pawar, P. P., Wadile, S. C. and Patil, H. M. 2017. Effect of integrated nutrient management on growth and yield of *kharif* groundnut (*Arachis hypogaea* L.). *International journal of Horticulture, Agriculture and Food science*. **1**(1): 21-23.
- Patil, H.M., Kolekar, P.T. and Shete, B.T. 2007. Effect of layouts and spacing on yield and quality of bold seeded summer groundnut (*Arachis hypogaea* L.) *International Journal of Agricultural Science*. **3**(2): 210-213.
- Poonia, T., Kumar, S. and Kumawat, S. M. 2022. Effect of tillage and integrated nutrient management on yield and nutrient uptake in groundnut (*Arachis hypogaea* L.). *Biological Forum – An International Journal*. **14**(1): 565-570.
- Prathima, T., Reddy, Y., Dakshina, M., Murali, K., Devaki K., Naga, M. and Parameswari, P. 2012. Influence of sowing date and crop variety on phenology, growth and yield of rainfed groundnut (*Arachis hypogaea* L.) in southern zone of Andhra Pradesh, India. *International Journal of Applied Biology and Pharmaceutical Technology*. **3**(1): 26-39.
- Prathyusha, C., Subramanyam, D., Karuna sagar, G., Sudhakar, P. and Naidu, G. 2022. Post-harvest soil nutrient status as influenced by varied dates of sowing, plant spacing and nutrient levels in groundnut. *Andhra Pradesh Journal of Agricultural Science*. **8**(4): 267-271.
- Priya, S., Mohammed, R., Maheswari, Y.M. and Sangeetha, J. 2009. Influence of NPK fertilization on productivity and oil yield of groundnut and sunflower in intercropping system under irrigated conditions. *International Journal of Agricultural Research*. **4**(2): 97-106.
- Raagavalli, K., Soumya, T.M., Veeranna, H.K., Nataraju, S.P. and Narayanswamy, H. 2019. Effect of sowing windows on growth and yield of groundnut genotypes.

- International Journal of Current Microbiology and Applied Sciences*. **8**(3): 59-67.
- Radford, P. J. 1967. Growth analysis formulae, their use abuse. *Crop Science*. **8**: 171-175.
- Rajitha, G., Reddy, M.S., Babu, P.V.R. and Maheshwari, V.U. 2018. Influence of secondary and micronutrients on primary nutrient uptake by groundnut (*Arachis hypogaea* L.) *Agricultural Science Digest*. **38**(4): 285-288
- Rajitha, G., Reddy, M.S., Babu, P.V.R. and Maheshwari, V.U. 2018. Nitrogen uptake and yield of groundnut as influenced by secondary and micronutrients *International Journal of Chemical Studies*. **6**(5): 307-310.
- Raju, G. V., Umesha, C., Reddy, S. M., Krishna, P. V. 2022. Effect of spacing and organic manures on growth and yield of groundnut (*Arachis hypogaea* L.). *Pharma Innovation*. **11**(4): 291-294.
- Reddy, K. H., Kumar, J. S. A. and Ghosh, G. 2014. Effect of plant spacings on the yield and yield attributes of groundnut varieties. *International Journal of Agricultural Sciences*. **10**(1): 79-81.
- Sagvekar, V.V., Waghmode, B.D., Chavan, A.P., and Mahadkar, U.V. 2015ab. Yield maximization of *rabi*-summer groundnut through nutrient management practices in the Konkan region of Maharashtra. *Journal of Farming Systems Research & Development*. **21**(1): 20-26.
- Sai, J., Singh, S. and Kumari, S. 2022. Effect of sowing dates on performance of groundnut (*Arachis hypogaea* L.) cultivars in *Kharif* season under Prayagraj condition. *Pharma Innovation*. **11**(4): 546-549.
- Sajo and Mohammed 2004. Effect of date of planting on the performance of groundnut (*Arachis Hypogaea*) in Yola Adamawa state. *Nigerian Journal of Biotechnology*. **15**(I): 72-82.
- Sanadi, U., Math, K.K., Bidari. B.I., and Yenagi, B.S. 2018. Effect of potassium nutrition on yield, quality and economics in groundnut (*Arachis hpogaea* L.) in a vertisol. *Journal of Pharmacognosy and Phytochemistry*. **7**(2): 220-222.
- Sardana, V. and Kandhola, S.S. 2007. Productivity of semi-spreading and bunch type varieties of groundnut as influenced by sowing dates. *An Open Access Journal, ICRISAT*. **5**:1-3.
- Satpute, A. V., Shinde, T. S. and Shende, S. M. 2020. Effect of inorganic and bio-fertilizers on growth of summer groundnut (*Arachis hypogaea* L.). *Pharma Innovation*. **9**(12): 310-313.
- Savage, G. and Keenan J.I. 1994. The composition and nutritive value of groundnut kernels. **In**: *The Groundnut Crop: A scientific basis for improvement*. pp 173-213.
- Sengupta, A., Gunri, S. K. and Basu, T. K. 2016. Performance of short duration groundnut (*Arachis hypogaea* L.) variety (TG 51) as influenced by nutrient management strategy under new alluvial zone of West Bengal. *Legume Research*. **39**(1): 91-95.

- Senthilkumar, N. and Naveen, S. 2020. Effect of INM on growth and yield of groundnut. *Plant Archives Volume*. **20**(2): 6367-6370.
- Sharma, S., Jat, N. L., Shivran, A. C., Choudhary, S., Puniya, M. M. and Jeetarwal, R. L. 2013. Effect of fertility levels and bio-fertilizers on yield and economics of groundnut. *Annals of Agricultural Research*. **34**(4): 353-356.
- Singh, A.L., Basu M. S. and Singh, N.B. 2003. Potential of groundnut in north eastern states of India. National Research Centre for groundnut (ICAR), Junagadh, India. pp 75.
- Singh, K. R., Singh, R.K., Singh, Y., Singh, A.K., Kumar, R and Singh, V.K. 2010. Productivity and economics of mustard (*Brassica juncea*) varieties as influenced by different fertility levels under late sown condition. *Indian Journal of Soil Conservation*. **38** (2): 121-124.
- Singh, N., Joshi, E., Sasode, D. S., Rawat, G. S. and Tiwari, S. 2021. Response of rainy-season groundnut (*Arachis hypogaea*) to varying fertility levels and bioformulations. *Indian Journal of Agronomy*. **66**(2): 241-245.
- Sogut, T., Ozturk, F. and Kizil, S. 2016. Effect of sowing time on peanut (*Arachis hypogaea* L.) cultivars: I. yield, yield components, oil and protein content. *Scientific Papers. Series A. Agronomy*. **59**: 415-420.
- Sowmya, N., Babu, P. V. R., Reddy, U., Vijaya, B. and Kavitha, P. 2022. Effect of land configurations and spacing on growth and yield of groundnut (*Arachis hypogaea* L.) in scarce rainfall zone of Andhra Pradesh. *Farming and Managment*. **7**(1): 9-13.
- Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science*. **25**: 259-60.
- Suneetha. 2013. Nutrient management for sustained productivity of newly developed groundnut genotypes. *M.Sc.(Ag.) Thesis*. Acharya N.G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh.
- Sunilkumar, T., Sumathi, V., ReddiRamu, Y., Kumar, N. A. R. and Sagar, G. K. 2020. Evaluation of yield and quality of groundnut under high density plantations with graded levels of phosphorus. *Indian Journal of Pure and Applied Bioscience*. **8**(4): 184-189.
- Tekulu, K., Gebeyehu, T. and Dereje, A. 2020. Effect of starter nitrogen and phosphorus fertilizer rates on yield and yield components, grain protein content of groundnut (*Arachis Hypogaea* L.) and residual soil nitrogen content in a semiarid north Ethiopia. *Heliyon*. **6**(10): 1-12.
- Vasuki, V. 2020. Maximizing yield in irrigated groundnut through increased fertilizer levels, split application along with organic sources. *International Journal Current Microbiology and Applied Science*. **9**(12): 2170-2174.
- Waghmode, B.D., Kambale, A.S., Navhale, V.C., Chendge, P.D. and Mahadkar, U.V. 2017. Agronomic management practices for promising groundnut cultivar RTNG-29 (*Konkan Bhuratna*). *Journal of Pharmacognosy and Phytochemistry*. **6**(6): 963-966.

- Walkley, A. and Black, I. A. 1934. An examination of the degtjariff method for determining soil organic matter, and a proposed modification of the chronic acid titration method. *Soil Science*. **34**: 29-38.
- Watson, D. J. 1952. The physiological basis for variation in yield. *Advances in Agronomy*. **4**: 101-145.
- Yadav, S. T. and Lunagaria, M. M. 2022. Influence of varieties and sowing dates on growth and yield of *kharif* groundnut (*Arachis hypogaea* L.). *Annals of Plant and Soil Research*. **24**(1): 65-68.
- Yadavrao, W. S., Bhambhar , K. S., Satish , M. S., Dadaji , J. J., Shaikh , A. A., and Atmaram , S. V. 2023. Impact on yield attributes and yields of groundnut varieties under different sowing windows in western Maharashtra, India. *International Journal of Environment and Climate Change*. **13**(8): 242-251.
- Yeswanth, J. and Debbarma, V. 2022. Effect of sulphur and spacing on growth and yield of groundnut (*Arachis hypogea* L.). *Pharma Innovation*. **11**(10): 1255-1258.