

**YIELD MAXIMIZATION OF LINSEED (*Linum usitatissimum* L.)
THROUGH DIFFERENT AGRO-TECHNIQUES
IN CHHATTISGARH PLAINS**

M. Sc. (Ag) Thesis

by

Rajkamal Patel

**DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
FACULTY OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (Chhattisgarh)**

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**YIELD MAXIMIZATION OF LINSEED (*Linum usitatissimum* L.)
THROUGH DIFFERENT AGRO-TECHNIQUES
IN CHHATTISGARH PLAINS**

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Rajkamal Patel

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

Master of Science

in

**Agriculture
(Agronomy)**

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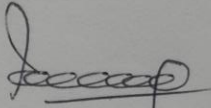
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CERTIFICATE – I

This is to certify that the thesis entitled “**Yield maximization of linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Rajkamal Patel** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

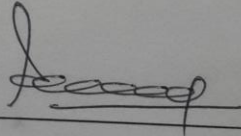
No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.


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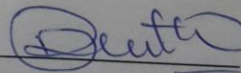
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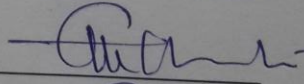
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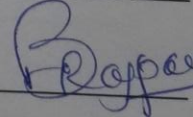
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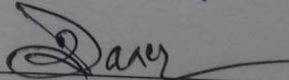
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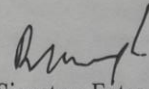


Member (Dr. R.R. Saxena)



CERTIFICATE - II

This is to certify that the thesis entitled “Yield maximization of linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains” submitted by **Rajkamal Patel** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Agronomy** has been approved by the external examiner and Student's Advisory Committee after oral examination.

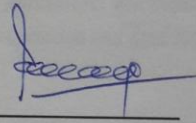


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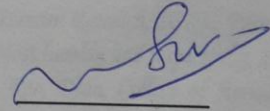
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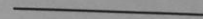
Major Advisor



Head of the Department



Faculty Dean



Approved/Not approved

Director of Instructions



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Research needs the close co-operation of the friends and colleagues and the guidance of experts in the field to achieve something worthwhile with light patience, vigour and dedication of the person.

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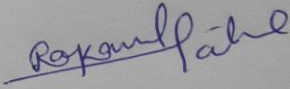
I would like to express thank to Dr. Madhav Pandey (Librarian, Nehru Library, IGKV, Raipur) and all other members of the Nehru Library for giving me their kind help during the study.

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Date -----

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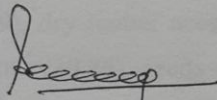
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LIST OF ABBREVIATIONS

Abbreviations	Description	Abbreviations	Description
%	Per cent	m ⁻²	Per metre square
@	At the rate	No.	Number
<i>a.i.</i>	Active ingredient	NS	Non-significant
B:C	Benefit cost ratio	d.f.	Degree of freedom
CD	Critical Difference	etc.	Etcetera
Day ⁻¹	Per day	Q	Quintal
t ha ⁻¹	Ton per hectare	₹	Rupees
⁰ C	Degree Celsius	SEm±	Standard error of mean
DAS	Days after sowing	₹ ha ⁻¹	Rupees per hectare
<i>et al.</i>	And others/ co-worker	<i>viz.</i>	For example
Fig.	Figure	N	Nitrogen
Ha	Hectare	P	Phosphorus
ha ⁻¹	Per hectare	K	Potassium
HI	Harvest index	S	Significant
Hr	Hours	G	Gram
<i>i.e.</i>	That is	FYM	Farm yard manure
Kg	Kilogram	OC	Organic carbon
Kmph	Kilometer per hour	Mm	Millimetre
Cm	Centimeter	M	Metre
cm ²	Centimeter square	L	Litre
max.	Maximum	min.	Minimum

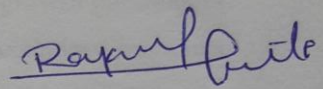
THESIS ABSTRACT

- a) Title of the Thesis: Yield maximization of Linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains
- b) Full Name of the Student : Rajkamal Patel
- c) Major Subject: Agronomy
- d) Name and Address of the Major Advisor: Dr. S.K. Dwivedi
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Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)
- e) Degree to be Awarded: M.Sc. (Ag) Agronomy

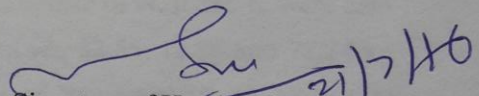


Signature of the Major Advisor

Date: 21-07-2016



Signature of the Student



Signature of Head of the Department

ABSTRACT

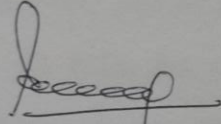
An experiment entitled "Yield maximization of Linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains" was conducted at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (C.G.) during *Rabi* 2015-16. The soil of the experimental field was clay in texture (*Vertisols*), neutral in pH (6.68), normal in EC (0.18 mhos m^{-1} at 25°C), medium in organic carbon (0.50%) and had low in available nitrogen (226 kg ha^{-1}), medium in phosphorus (12.64 kg ha^{-1}), and high in available potassium (367 kg ha^{-1}) contents.

The linseed var. 'RLC-92' sown on 22nd Nov, 2015 using experimental techniques of factorial randomized block design with three replications and eighteen treatments. The treatment consisted of two seed rate *viz.* 25 kg ha⁻¹ (S₁), 30 kg ha⁻¹ (S₂), three nutrient management *viz.* RDF 60:30:30 N, P₂O₅ & K₂O Kg ha⁻¹ (N₁), RDF + Incorporation of FYM @ 5 t ha⁻¹ (N₂), RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) and three foliar of water spray at 15, 40, 65 and 90 DAS (F₁), foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS (F₂) and foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃). Recommended agronomic practices were followed for raising linseed. The crop was harvested on 12th March, 2016 for seed yield purpose.

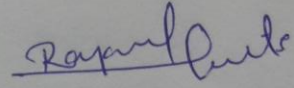
Different agro input management practices had significant effect on growth, yield attributes and yield of linseed. However, seed rates did not give significant influence on seed yield. Whereas, application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded significantly higher growth parameters *viz.* plant height (88.44 cm), primary branches plant⁻¹ (3.83), secondary branches plant⁻¹ (23.39), dry matter accumulation (6.76 g plant⁻¹) and yield attributes *viz.* capsules plant⁻¹ (30.86), seeds capsule⁻¹ (7.63), seeds plant⁻¹ (235.32), seed yield (2100 kg ha⁻¹) and stover yield (4885 kg ha⁻¹). The uptake of N, P and K were also observed significantly higher in the same treatment *viz.* 52.55, 18.36 and 77.24 kg ha⁻¹ respectively. In case of foliar spray application of 2% urea at 15, 40, 65 and 90 DAS (F₃) gave significantly higher growth parameters *viz.* plant height (88.37 cm), primary branches plant⁻¹ (3.82), secondary branches plant⁻¹ (23.68), dry matter accumulation (6.59 g plant⁻¹) and yield attributes *viz.* capsules plant⁻¹ (31.74), seeds capsule⁻¹ (7.63), seeds plant⁻¹ (241.38), seed yield (2089 kg ha⁻¹) and stover yield (4772 kg ha⁻¹). The uptake of N, P and K were also observed significantly higher in the same treatment *viz.* 50.99, 18.13 and 75.57 kg ha⁻¹ respectively. Interaction among seed rate 30 kg ha⁻¹ (S₂) X RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) (S₂ X N₁ X F₃) recorded the highest benefit-cost ratio (4.39).

शोध सारांश

- अ) शोध का शीर्षक : "छत्तीसगढ़ के मैदानी इलाकों में विभिन्न सस्य तकनीकों के माध्यम से अलसी (लाईनम यूसीटैटीसिम एल.) के उपज को अधिकतम बढ़ाना"
- ब) छात्र का पूरा नाम : राजकमल पटेल
- स) मुख्य विषय : सस्य विज्ञान
- द) मुख्य सलाहकार का नाम एवं पता : डॉ. एस.के. द्विवेदी (वैज्ञानिक), सस्य विज्ञान विभाग, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.)
- इ) उपाधि का नाम : स्नातकोत्तर (कृषि), सस्य विज्ञान

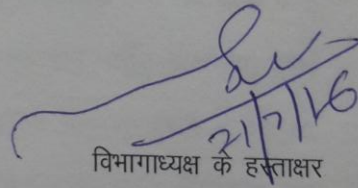


मुख्य सलाहकार के हस्ताक्षर



छात्र के हस्ताक्षर

दिनांक: 21-07-2016



विभागाध्यक्ष के हस्ताक्षर

सारांश

अनुसंधान शीर्षक “ छत्तीसगढ़ के मैदानी इलाकों में विभिन्न सस्य तकनीकों के माध्यम से अलसी के उपज को अधिकतम बढ़ाना” का परीक्षण अनुसंधान सह अनुदेशक प्रक्षेत्र, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) में रबी मौसम में वर्ष 2015–16 के दौरान परीक्षण किया गया। परीक्षण स्थल की मृदा कन्हार (क्ले), पी.एच. मान (6.68), विद्युत चालकता सामान्य (0.18 मिली म्होस प्रति मीटर 25 डिग्री सेल्सियस पर) कार्बनिक पदार्थ मध्यम (0.50 प्रतिशत), उपलब्ध नत्रजन (226 कि.ग्रा. प्रति हेक्टेयर), स्फुर (12.64 कि.ग्रा. प्रति हेक्टेयर), पोटाश (367 कि.ग्रा. प्रति हेक्टेयर) क्रमशः निम्न, मध्यम एवं उच्च थी।

अलसी की किस्म ‘आर.एल.सी.–92’ की बुवाई 22 नवम्बर 2015 को भाज्य यादृच्छिकीकृत भूखण्ड अभिकल्पना की परीक्षण तकनीकी से तीन पुनरावृत्तियों एवं 18 उपचारों में किया गया। उपचारों में, दो बीज दर; 25 कि.ग्रा. प्रति हेक्टेयर (एस 1), 30 कि.ग्रा. प्रति हेक्टेयर (एस 2), तीन पोषक तत्व प्रबंधन; अनुसंधित उर्वरक की मात्रा 60:30:30 एन.पी.के. कि.ग्रा. प्रति हेक्टेयर (एन 1), अनुसंधित उर्वरक की मात्रा + 5 टन गोबर की खाद प्रति हेक्टेयर खेत में मिलाना (एन 2), अनुसंधित उर्वरक की मात्रा + 5 टन गोबर की खाद प्रति हेक्टेयर पंक्तियों में (एन 3) एवं तीन पर्णिय छिड़काव; बुवाई के 15, 40, 65 और 90 दिन बाद जल का पर्णिय छिड़काव (एफ 1), बुवाई के 15, 40, 65 और 90 दिन बाद 0.06 प्रतिशत की दर से नाइट्रोबेंजीन का पर्णिय छिड़काव (एफ 2) तथा बुवाई के 15, 40, 65 एवं 90 दिन बाद यूरिया 2 प्रतिशत की दर से पर्णिय छिड़काव (एफ 3)। अलसी की खेती हेतु सभी अनुसंधित सस्य क्रियाएं अपनायी गयी तथा बीज हेतु फसल की कटाई 12 मार्च 2016 को की गई।

अलसी के बढ़वार, उपज के कारक एवं उपज पर विभिन्न कृषि अदान प्रबंधन क्रियाओं का सार्थक प्रभाव पाया गया। बीज दर उपचार में बीज उपज पर कोई सार्थक

प्रभाव नहीं पाया गया। जबकि अनुसंशित उर्वरक की मात्रा + 5 टन गोबर की खाद प्रति हेक्टेयर पंक्तियों में (एन 3), उपचार के उपयोग से पौधे के विकास मापदण्डों जैसे— पौधे की ऊँचाई (88.44 से.मी.), प्राथमिक शाखाएं प्रति पौधा (3.83), द्वितीयक शाखाएं प्रति पौधा (23.39), शुष्क भार संचय (6.76 ग्रा. प्रति पौधा) एवं उपज विशेषताएं जैसे—संपूटियां प्रति पौधा (30.86), बीज प्रति संपूटि (7.63), बीज प्रति पौधा (235.32), बीज उपज (2100 कि.ग्रा. प्रति हेक्टेयर) एवं शेष अवशेष की उपज (4885 कि.ग्रा. प्रति हेक्टेयर) सांख्यिकीय आधार पर आधिक पाये गये। नत्रजन, स्फुर एवं पोटेश का उद्ग्रहण क्रमशः 52.55, 18.36 एवं 77.24 कि.ग्रा. प्रति हेक्टेयर इसी परीक्षण में सांख्यिकीय आधार पर आधिक पाये गये। बुवाई के 15, 40, 65 और 90 दिन बाद यूरिया 2 प्रतिशत की दर से पर्णीय छिड़काव (एफ 3) प्रति हेक्टेयर उपचार में पौधे के विकास मापदण्डों जैसे— पौधे की ऊँचाई (88.37 से.मी.), प्राथमिक शाखाएं प्रति पौधा (3.82), द्वितीयक शाखाएं प्रति पौधा (23.68), शुष्क भार संचय (6.59 ग्रा. प्रति पौधा) एवं उपज विशेषताएं जैसे— संपूटियां प्रति पौधा (31.74), बीज प्रति संपूटि (7.63), बीज प्रति पौधा (241.38), बीज उपज (2089 कि.ग्रा. प्रति हेक्टेयर) एवं शेष अवशेष की उपज (4772 कि.ग्रा. प्रति हेक्टेयर) सांख्यिकीय आधार पर आधिक पाये गये। नत्रजन, स्फुर एवं पोटेश का उद्ग्रहण क्रमशः 50.99, 18.13 एवं 75.57 कि.ग्रा. प्रति हेक्टेयर इसी उपचार में सांख्यिकीय आधार पर आधिक पाये गये। बीज दर 30 कि.ग्रा. प्रति हेक्टेयर (एस 2) x अनुसंशित उर्वरक की मात्रा 60:30:30 कि.ग्रा. प्रति हेक्टेयर (एन 1) x यूरिया 2 प्रतिशत की दर से पर्णीय छिड़काव (एफ 3) के पारस्परिक प्रभाव से सर्वाधिक लाभ—लागत अनुपात (4.39) प्राप्त हुआ।

CHAPTER-I

INTRODUCTION

Among the oilseeds, linseed or flax (*Linum usitatissimum* L.) is one of the oldest crops, grown in almost all countries of world for oil, fibre and seed purpose. Linseed is unique among oilseeds for its technical grade vegetable oil producing ability and fibre (good quality having high strength and durability) production. Linseed contains 35-45% oil. Linseed oil is suitable for human consumption and is used as a nutritional supplement. It is rich in omega-3 fatty acids, especially alpha-linolenic acid that was beneficial for heart disease, inflammatory bowel disease, arthritis and a variety of other health conditions. It also contains a group of chemicals called lignans that play a significant role in the prevention of cancer (Budwig, 1994). The meal, which remains after oil extraction, is a valuable feed to animals as a protein supplement and is very good manure. Linseed oil is an excellent drying oil used in manufacturing paints, varnishes, soaps, printing inks, oil cloth and linoleum tiles (Rowland *et al.*, 1995). Linseed is also used in making papers and plastics. Linolenic acid omega-3 and omega-6 linoleic acid, essential fatty acids are also found in linseed. Linseed oil contains three times as much omega-3 fatty acid than omega-6 fatty acid (Singh *et al.*, 2013). Its seed has 36 percent protein out of which 85 percent is digestible. Its oil cake is used to feed milch and fattening animals for milk and meat production. Its oil has a lot of uses apart from human consumption *viz.*, oil paint, varnishes, printing ink, oil cloth, soap, patent leather and waterproof fabrics due to its fast volatility feature (Sharma *et al.*, 2015).

Round the globe linseed crop occupies an area of 21.26 lakh ha yielding out 18.67 lakh tones having an average productivity of 877 kg ha⁻¹. Our national production of 1.57 lakh tones is realized from an area of 4.68 lakh ha⁻¹ 2007-08 to 3.03 lakh ha⁻¹ during 2013-14 with low productivity of 413 kg ha⁻¹ to 462 kg ha⁻¹ during the same period in world arena. Linseed is mainly cultivated in the states like Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Rajasthan, West Bengal, Karnataka, Orissa and Bihar. Chhattisgarh is one of the important linseed growing states of India, which accounts for nearly cultivated over 0.26 lakh hectare

area with a production of 0.11 lakh tones and productivity of 423 kg ha⁻¹ (Anonymous, 2015). It occupies 9 per cent of area under oilseeds and 6.29 per cent contribution to the total oilseed production of the country. The important linseed growing districts of Chhattisgarh are Rajnandgaon, Durg, Bilaspur, Kabirdham, Raipur, Dhamtari, Surguja, Kanker and Raigarh. It is mostly grown on marginal and sub marginal soils under rainfed conditions. Maximum area of this crop is grown as *utera* during *rabi* season (Agrawal *et al.*, 2014). Being an important oilseed crop, its average productivity in India as well as in Chhattisgarh is very low in comparison to other country of the world, because of various factors like raising of crop by the resource poor farmers in marginal and sub-marginal areas, non-availability of high yielding varieties having resistance to biotic and abiotic stresses, narrow genetic base, etc (Patial *et al.*, 2014).

The per capita consumption of the vegetable oil is increasing very rapidly (6.2 kg year⁻¹ in 1986-87 to 14.2 kg year⁻¹ during 2012-13) due to increase in population and improved economic status of the population (ISOR, 2015). At present, the demand and supply of edible oil is 18.94 and 10.08 million tons respectively. The gap in demand and supply is about 47% *i.e.* 8.86 million tons being filled by import of edible oil (Anonymous, 2015). ISOR (2015) has projected the demand for the year 2020 and 2050 is 14.57 and 24.10 kg year⁻¹ respectively. To meet this demand, the country will require nearly 21.8 and 45.2 million tons of edible oil. Chhattisgarh having third highest yield gap between improved technology and farmer's practice in irrigated condition is found after Uttar Pradesh and Himachal Pradesh (Singh *et al.*, 2015). Therefore, there is an imbalance between demand and supply in edible oils due to low productivity of oilseeds. The major reason for low productivity of linseed may be due to adoption of primitive sowing method like *Utera* and farmers having poor knowledge with regards to INM and perpetual scarcity of basic agro-inputs like improved seed, fertilizers etc.

Recommended optimum seeding rates for the crop vary depending on environmental and management factors (Hocking and Pinkerton, 1991). The recommended plant population for linseed varies between 350-500 plants m⁻².

Seedling establishment is generally slow and seedlings have poor competitive ability. The germination rate is usually 93-98 % but seedling emergence rates of 50-60 % are obtained under field conditions (Freer, 1993). The significant effects of seed rates were observed on all yield components reflecting the importance of seeding rate for linseed growth, yield and yield components (Delesa and Choferie, 2015).

Among the agro-techniques, judicious application of nutrients, particularly the nitrogen, phosphorus and potash play the important role for increasing linseed productivity (Singh *et al.*, 2013). An application of fertilizer is considered imperative for increasing crop production. Long time studies being carried out at several locations in India indicated that application of all the needy nutrients through chemical fertilizers have deleterious effect on soil health leading to unsustainable yields (Jaga and Upadhyay, 2013). Therefore; there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with FYM. Balanced fertilizer is the application of essential plant nutrients in light proportion and in optimum quantity for a specific soil crop condition. Therefore, future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively, and on sustainable basis. Integrated nutrient management are essential for proper plant growth, water use, soil, and land management that will be critical for the sustaining agriculture productivity over the long period of time.

Besides of integrated nutrient management practices, foliar application response of different nutrient is also importance, hence testing of foliar response has been taken under the investigation. Foliar application of nutrients to the plants has been successfully used in correction of nutrient deficiency especially micronutrients (Hsu and Ashmead, 1984), and quickly counter a mineral unbalance that would inhibit plant metabolism.

Nitrobenzene is an aromatic synthetic nitro compound widely used in industry which can lead to environmental pollution. While the toxicity and

carcinogenicity of nitrobenzene on humans and animals have been studied, less is known about its effects on plants growth. However, the susceptibility of plant to nitrobenzene varies with plants species (Farlane *et al.*, 1990).

Nitrobenzene is a combination of nitrogen and plants growth regulators that act as a plant energizer, flowering stimulant and yield booster (Aziz and Miah, 2009). Nitrobenzene produce best result in combination with plants growth regulators, which have capacity to increase to flowering in plants and also prevent flower shedding due to more number of flower, it increase the yield by considerable ratio with better quality. It is specially recommended for crops like cotton, vegetables like chillies, brinjal, tomato and lady's finger and flowering plants such as rose, crossandra, chrysanthemum etc.

Keeping these points in view, a field experiment was carried out at Instructional Cum Research farm, I.G.K.V., Raipur, during *rabi* season of 2015-16 with the following objectives.

- To find out appropriate quantity of seed for obtaining optimum growth and productivity of linseed,
- To evaluate the performance of FYM under different nutrient management practices on growth and productivity of linseed,
- To study the foliar response of nutrient on growth and yield of linseed and
- To workout the economics of linseed as influenced by different treatments.

CHAPTER-II

REVIEW OF LITERATURE

A review of work pertaining to the research work under investigation with special emphasis on "**Yield maximization of Linseed (*Linum sitatissimum* L.) through different agro-techniques in Chhattisgarh plains**". The review although confirmed the research done on linseed, but relevant information on crops other than linseed is also included.

2.1 Effect of seed rate and plant population on yield attribute and yield of linseed

Husain *et al.* (2009 a) observed that sowing of 'Gaurav', 'Jeevan', 'Nagarkot', 'Shikha', 'Rashmi', 'Meera', and 'Parvati' varieties under irrigated situation (2-3 irrigations) during last week of October to mid November using 50-60 kg seed ha⁻¹ at a row distance of 20 cm, fertilizer application of 60- 90 kg N + 13.2- 17.6 kg P + 25- 33.3 kg K ha⁻¹ along with need based plant protection measures. Development of improved varieties having quality fibre with good seed yield.

Vinogradov *et al.* (2012) observed that the level of mineral fertilizers of N - 90, P₂O₅- 60, and K₂O - 60 kg ha⁻¹ under the rate of sowing of 8 million seeds ha⁻¹ provided maximum seed yield of 1.94 t ha⁻¹.

2.2 Effect of nutrient management on linseed

2.2.1 Effect of FYM on growth of linseed

Deo (1979) reported that a good quality fibre in terms of fibre length, strength and fineness was produced when the jute crop was supplied with FYM + chemical fertiliser than FYM or fertiliser alone.

Thakuria *et al.* (1991) obtained higher yield of white jute treated with FYM and realized that this higher yield was accomplished through significant increase in yield attributes.

Yawalkar *et al.* (1992) Stated that farm yard manure (FYM) which is organic in nature contains 0.5 per cent N, 0.2% P₂O₅ and 0.5% K₂O, and has a significant influence on the physical and chemical properties of soil. These beneficial effects are ultimately reflected in the yields of crop.

Badiyala *et al.* (1998) reported that FYM @ 10 t ha⁻¹ applied to flax crop registered higher seed (664 kg ha⁻¹), stalk (3515 kg ha⁻¹) and fibre (677 kg ha⁻¹) yields than no FYM (279, 1698, and 231 kg ha⁻¹, respectively).

Badiyala and Chopra. (2011) revealed that application of Zn through ZnSO₄ @ 25 kg ha⁻¹ to both the crops + FYM 5 t ha⁻¹ to maize recorded significantly higher growth parameters and yield attributes of linseed crop, resulting in significantly more linseed and linseed equivalent yield 61.3 and 52.9%, respectively.

2.2.2 Effect of integrated nutrient management on growth, yield and yield attribute of linseed

Shekhawat *et al.* (1971) observed that soil application with micronutrients was significant over foliar application of micronutrients on linseed which gave 33.2 kg more seed yield of linseed over control (802.8 kg ha⁻¹).

Working at IARI Regional Station, Coimbatore (TN), Bhatt (1974) tested no fertilizers or 20 mg N, 40 mg P or 20 mg K 100⁻¹ g soil, alone or in all combinations in linseed crop. Plants given P alone flowered 10, 10 and 5 days earlier than those given no fertilizer, K alone and N alone, respectively. Seed yield plant⁻¹ ranged from 1.3 g in plants given no fertilizer or K alone to 3.9 g in those given NPK.

Kolomnikova (1979) conducted trials in the forest steppe zone of Omsk province, W. Siberia and obtained high seed yields by growing linseed and maize, when the contents of available P₂O₅ in soil were higher than NO₃ contents. A marked predominance of NO₃ contents over P₂O₅ content in fallow plots decreased yields; application of 30 kg P₂O₅ ha⁻¹ at sowing improved the soil nutrient regime, accelerated maturation and increased yields by 210 kg ha⁻¹. The nutrient uptake

100 kg⁻¹ seed + associated straw were 5.1-6.3 kg N, 1-1.2 kg P₂O₅ and 4.1-5.5 kg K₂O.

Les (1974) applied various combinations of 0-120 kg each of N and P and 0-150 kg K ha⁻¹ to flax and found that increase in NPK levels resulted in increased stem length and diameter. He reported that average seed and stalk yields of flax increased from 582 and 3890 kg ha⁻¹ without NPK to 658 and 5230 kg ha⁻¹ with NPK 120:120:150 kg ha⁻¹, respectively.

Singh *et al.* (1975) reported that the flax has limited ability to absorb nutrients; therefore, it must have an access to adequate supply of fertilisers throughout the growth period. In general, fertiliser recommendations for flax are 20-60 kg N, 10-30 kg P and 20-30 kg K ha⁻¹.

Afonin and Mikhilova (1976) observed that the application of P and K combined with low N rate (15 kg ha⁻¹) to flax at Belarussia increased lodging resistance and dry matter accumulation.

Reddy (1983) at Dharwad while studying the effect of varying fertility (NPK) levels on linseed observed significant variations in number of capsules per plant (38.8 to 46.6), number of seeds per capsule (6.9 to 7.63) and 1000 seed weight (8.47 to 8.72 g).

Awasti *et al.* (1989) conducted a field experiment on sandy clay loam soil with three levels of phosphorus (0, 10, and 20 kg phosphorus ha⁻¹). They observed that yield attributes and yield of linseed, except 1000 seed weight, improved significantly with each increasing level of phosphorus.

Idani *et al.* (1989) conducted a field experiment at New Delhi for two years and found that application of 20 or 40 kg phosphorus ha⁻¹ increased the dry matter accumulation and stalk yield of linseed.

Khurana *et al.* (1989) studied that the response of linseed to the various levels of nitrogen (0, 15, 30, 45 kg ha⁻¹) and phosphorus (0, 10, 20 kg ha⁻¹) on clay loam soil of M.P. They observed that application of 20 kg phosphorus ha⁻¹ significantly highest seed yield (10.2 q ha⁻¹) of linseed was observed.

Park *et al.* (1989) reported that the application of NPK to flax in Korea delayed crop maturity by 3-4 days.

Tarafdar *et al.* (1989) reported that the high rates of NPK applied to linseed crop significantly increased the plant height, number of branches and dry matter production.

Puri and Jaipurkar (1990) in field trials was given 0-100 kg N, 0-60 kg P and 0-30 kg K ha⁻¹ and path coefficient analysis was used to assess the direct and indirect effect of soil fertility on yield of linseed. The direct effects of soil N, P and K and fertilizer N and P were significant, but indirect effects were negligible except for fertilizer N and P. The direct contributions of the soil fertility variables were in the order: fertilizer N (88%) > fertilizer P (71%) > soil N (67%) > soil P (48%) > soil K (45%) > fertilizer K (44%).

Chaubey *et al.* (1992) carried out a two year field experiment at Kanpur (U.P.) on sandy loam soil with three levels of nitrogen (0, 40 and 80 kg ha⁻¹), three levels of phosphorus (0, 25 and 50 kg ha⁻¹) and three levels of sulphur (0, 30 and 0 kg ha⁻¹) to linseed. They found that the seed yield was increased by 17.3 per cent and 14.1 per cent respectively, over control.

Singh *et al.* (1992) from Jabalpur presented their findings quoting that addition of 15 kg K to 60:30:0 NPK dose increased the number of tillers and capsules per plant of linseed but exerted a depressing effect on 1000 seed weight (8.50 to 8.37 g).

Sarode and Nephade (1993) conducted a two year field experiment on linseed on clayey soil and found that application of 30 kg phosphorus ha⁻¹ increased by 15.09, 26.02 and 19.08 percent over control, respectively. They estimated that 60 kg N ha⁻¹ recorded significant increase in seed and biological yield of linseed.

Vasishtha (1993) conducted a field experiment on linseed in sandy loam soil with different levels of nitrogen (0, 40, 80 and 120 kg ha⁻¹) and phosphorus (0, 20 and 40 kg ha⁻¹) and found that seed yield of linseed increased significantly with increasing levels of nitrogen and phosphorus.

Dwivedi *et al.* (1994) found that linseed yield increased up to 30 kg N and 30 kg P₂O₅ ha⁻¹ level.

Shrivastava *et al.* (1994) found that the linseed seed yield was highest with 90 kg N and was also increased by P application that is 60 kg P₂O₅ ha⁻¹.

Singh (1994) observed that high fertility rate (125% of recommended rate) applied to dual-purpose linseed significantly increased the seed, straw, retted straw, and fibre yields by 10.27, 10.30, 11.71 and 9.77% over recommended rate. They noted that higher NPK level produced significantly higher fibre length (60.4 cm) and cellulose content (73.5%) but fibre fineness was unaffected. They observed 7.69% increases in number of seeds per capsule of dual-purpose linseed with 25% higher NPK over recommended dose. They also reported that application of 25% higher NPK level over recommended rate (90:30:30) to dual purpose linseed at Palampur considerably reduced the number of days taken to flowering and capsule formation.

Patil *et al.* (1995) found that linseed variety kiran produced more seed yield of 0.60 t ha⁻¹ and 0.58 t ha⁻¹ with the application 40 kg P₂O₅ and 40 kg K₂O ha⁻¹, respectively.

Sune (2006) conducted a field experiment on linseed at Nagpur with three levels of phosphorus (20, 30, and 40 kg ha⁻¹) and four levels of sulphur (0, 10, 20, and 30 kg ha⁻¹). She observed that application of phosphorus increased the plant height, number of branches plant⁻¹ and dry matter accumulation plant⁻¹.

Khajani *et al.* (2012) observed that the different levels of nitrogen fertilizer consisted of three levels (N₁=30, N₂=60, N₃=90 kg ha⁻¹) and three levels of phosphorus fertilizer (P₁=40, P₂=80, P₃=120 kg ha⁻¹) and three levels of potassium (K₁=40, K₂=80, K₃=120 kg ha⁻¹), were applied respectively. Traits, like branch number, capsules number, number of seeds capsule⁻¹, weight of 1000 seed and seed yield were studied in this experiment. The results showed that 90, 120, 80 kg ha⁻¹ of nitrogen, phosphorus and potassium significantly increased the branches number, capsules number and seed yield. Based on the results mean grain yield was obtained (2384.28 kg ha⁻¹).

Singh *et al.* (2013) revealed that the increasing levels of NPK application up to highest level resulted in improved growth and yield attributing characters. However, 120:60:60 and 90:45:45 kg NPK ha⁻¹ did not differ significantly with respect to growth and yield parameters. Application of 90:45:45 kg NPK ha⁻¹ significantly improved the growth and yield attributing characters over 60:30:30 kg NPK ha⁻¹ and the percentage increase in dry matter accumulation, capsules plant⁻¹, seeds capsule⁻¹ and 1000 seed weight were 8.6 g, 20.3, 3.1 and 8.2 g under 90:45:45 kg NPK compared to 60:30:30 kg NPK ha⁻¹, respectively.

2.3 Effect of foliar response of nutrient

2.3.1 Effect of foliar application Nitrobenzene on growth and yield of linseed

Abo-El-Saod *et al.* (1975) found that an application of 50 ppm GA₃ at 60 DAS as foliar spray increased plant height and number of branches per plant, esds yield and straw yield of flax, but shoot weight was not affected.

Shaahan *et al.* (1982) in Egypt, sprayed flax crop with GA₃ at 0, 25, 50 or 75 ppm and observed that increasing GA₃ concentration upto 50 ppm resulted in increased plant height and leaf dry weight per plant.

Deb *et al.* (2014) studied the effect of nitrobenzene (a plant growth regulator) on the growth, nutrient content and accumulation of arsenic (As) in the tomato plants (*Solanum lycopersicum*). Seven treatments *viz.*, control (c), nitrobenzene only (N), Full recommended dose of fertilizer (FRD), ½ recommended dose of fertilizer (½ RD), ½ recommended dose of fertilizer + nitrobenzene (½ RD + N), ¾ recommended dose of fertilizer (¾ RD), ¾ recommended dose of fertilizer + nitrobenzene (¾ RD + N). The growth increased with nitrobenzene application. The highest growth was found with ¾ recommended fertilizer doses with nitrobenzene.

2.3.2 Effect of foliar application of urea on growth and yield of linseed

El-Kady *et al.* (2010) studied on soil and foliar fertilization in sunflower. Nitrogen fertilizer rates at 15, 30 and 45 kg N fed⁻¹ were applied alone or along with foliar spray of urea (2%), single superphosphate (4%) and a mixture of

micronutrients (100 ppm Fe + 140 ppm Zn + 120 ppm Mn). Results indicated that vegetative growth traits at 65 days after planting were significantly affected by nitrogen fertilizer rates and foliar spray nutrient application. Plant height, leaf area and dry matter plant⁻¹, as well as chlorophyll A and total photosynthetic pigments in leaves were significantly increased with increasing nitrogen level. Foliar nutrient application of urea remarkably improved growth traits. Flowering date was delayed with increasing nitrogen rates and foliar spraying of micronutrient. Increasing nitrogen fertilizer up to 45 kg N fed⁻¹ led to significant increases in plant height, stem diameter, head diameter, 1000 seed weight, seed yield plant⁻¹ and seed yield fed⁻¹. However, seed oil % was decreased with increasing nitrogen fertilizer rates. Oil yield fed⁻¹ was significantly increased with increasing fertilizer nitrogen rate. It could be concluded that nitrogen applied at of 45 or 30 kg fed⁻¹ with spraying with urea (2%) gave the highest oil yield fed⁻¹.

Dalei *et al.* (2014) find out the suitable combination of soil and foliar application of nutrients (urea and di-ammonium phosphate) for maximizing growth and seed yield of niger. The results revealed that, foliar applications of urea and DAP gave better performance regarding growth and yield attributes. Highest seed yield (417.2 kg ha⁻¹), net monetary return (₹ 4247.00 ha⁻¹) and benefit-cost ratio (1.51), recorded with application of 100% RDF + foliar application of 2% urea twice at flowering and capitula formation stage followed by (RDF + foliar spraying of 2% DAP twice at flowering and capitula formation stage) *i.e.* seed yield 387.7 kg ha⁻¹, net monetary return ₹ 3277.00 ha⁻¹ and benefit-cost ratio 1.39

2.4 Effect of seed rate, integrated nutrient management and foliar application of different agro inputs on nutrient content and uptake of linseed

Aulakh *et al.* (1989) observed that application of 60 kg N, 40 kg P₂O₅ and 30 kg S ha⁻¹ maximized seed yield and oil content in linseed.

Leilah *et al.* (2003) noted that the adding 60 kg N + 15 kg P₂O₅ + 24 kg K₂O fad⁻¹ enhanced most of the studied characters. Oil yield fad⁻¹ and seed oil percentage reached the highest value by adding 60 kg N + 30 kg P₂O₅ fad⁻¹.

Berti *et al.* (2009) reported that flaxseed yield improved as N rates increased. Physical optimum rate (rate at which maximum seed yield is obtained) was different depending on the location and year. Nitrogen rate increased oil content and yield up to 200 kg N ha⁻¹. Oil composition was not affected by N, P and K rates, or their interactions. The P and K nutrients did not have an effect on seed yield, oil content, oil yield and oil composition.

Haldar (2011) observed that the treatment receiving N/P ratio of 1.50 (60 kg N, 40 kg P₂O₅ and 30 kg K₂O ha⁻¹) produced higher seed yield (1957 kg ha⁻¹) and oil yield (775 kg ha⁻¹) as compared to the recommended N/P ratio of 0.75 with 60 kg N, 80 kg P₂O₅ and 30 kg K₂O ha⁻¹ fertilizer level (1753 kg ha⁻¹ and 690 kg ha⁻¹) and control (1581 kg ha⁻¹ and 560 kg ha⁻¹). Further increase in N/P ratio there was no significant increase in the seed yield and oil yield.

Kumar *et al.* (2011) reported that N application increased seed yield (1516.28 kg ha⁻¹) significantly with every increase in the level of nitrogen up to 60 kg N ha⁻¹. The highest seed yield was obtained at 45 kg S ha⁻¹ but this was found statistically superior over 0 and 15 kg S ha⁻¹. The application of N decreased oil content but application of S increased oil content of the linseed in both the years. Protein content in seed increased significantly with every increase in the level of nitrogen, sulphur and Boron up to 90 kg N, 45 kg S and 1.0 kg B ha⁻¹, while N application decreased the iodine value of oil, whereas S application increased the iodine value of oil significantly over control.

Meena *et al.* (2011) reported that increase in seed rate significantly increase grain yield from 20 kg to 30 kg ha⁻¹ but with further increase in seed rate, grain yield decreased while the straw yield was maximum with 40 kg seed rate, further increase in seed rate resulted significant decrease in oil content in grain and total oil yield was increased with increase in seed rate upto 30 kg ha⁻¹ thereafter that it started to decrease. The NPKS content in seed and straw was significantly decreased with increased seed rate and found maximum with 20 kg seed rate.

El-Mohsen *et al.* (2013) reported that maximum seed, oil, straw and fiber yields ha⁻¹ was produced when seeding rate was applied at the rate of 180 kg ha⁻¹.

Therefore, early planting time November 15 with seeding rate 180 kg ha^{-1} is recommended to obtain higher yield of flax cultivars Sakha 1 and Sakha 2.

Tripathi *et al.* (2014) observed that the yield attributes, yield, uptake of K and S in grain and stover and oil content of grain were significantly affected by the application of potassium and sulphur both. The content and uptake of K and S increased in linear order with the application of both potassium and sulphur up to their highest levels. However, increment was significant only up to 80 ppm each of potassium and sulphur. The results also exhibited that oil content of grain increased with the application potassium and sulphur up to their highest levels.

Salah and Mohamed (2015) revealed that the seeding rate and phosphorus source affected the straw, seed and oil yields of flax. Therefore, three seeding rates (*i.e.* 1750, 2000 and 2250 seed m^{-2}) and two phosphorus sources (*i.e.* single super phosphate; and rock phosphate) were used in this study to evaluate their effects on flax (variety Sakha-1). Results showed that mean squares of seeding rates were significant for straw, seed and oil yields, indicating different responses of mean performances of flax plants under the experimental seeding rates and phosphorus sources treatment. Increasing seeding rate significantly increased straw, seed and oil yields in most cases in both seasons. The favourable straw yield and its components (*i.e.* plant height, technical length, and number of higher branches plant^{-1} , stem diameter and straw yield plant^{-1}) were observed when flax plants were applied with seeding rate of 2250 seed m^{-2} .

2.5 Effect of seed rate, integrated nutrient management and foliar application of different agro inputs on economics of linseed

Anon. (2005) noted that application of 75% RDF + 5 t FYM ha^{-1} + 5 kg of Zinc ha^{-1} + 25 kg S ha^{-1} or 75% RDF + 5 t FYM ha^{-1} module for higher linseed yield, net returns and good soil health in maize-linseed crop sequence at Palampur.

Naik (2005) found that application of 150% RDF (50:25:00) was economically superior which recorded highest net return ($\text{₹ } 11622 \text{ ha}^{-1}$) and B: C ratio (2.31) than other fertilizer levels in safflower.

Husain *et al.* (2009 b) studied on application of zinc (through zinc sulphate @ 25 kg ha⁻¹) and farmyard manure (FYM) @ 5 t ha⁻¹ to rice in rice-linseed crop sequence and recorded maximum linseed equivalent yield (2.71 t ha⁻¹) and net monetary return (₹ 17,419 ha⁻¹) which were on par with Zn in both the crops + FYM in rice and Zn in linseed + FYM in rice. Like linseed equivalent yield (LEY), oil yield of linseed (mean of 3 years) was also recorded higher with treatment of Zn in both the crops + FYM while other treatments of FYM followed it closely.

Meena *et al.* (2011) reported that the increase in fertility level from F₀ (Control) to F₃ (60:30:30:30 kg NPKS ha⁻¹) significantly increased all growth and yield attributes characters during both years. The significantly marked influence of varying seed rates were also observed and it was found that increase in seed rate significantly decreased in growth and yield attributes of linseed crop. In case of economics, maximum B:C ratio was recorded with the fertility level F₂ (40:20:20:20 kg NPKS ha⁻¹) and seed rate @ 30 kg ha⁻¹. The consumptive use of soil moisture was significantly increased with increase in fertility level and seed rate and it was maximum with the fertility level (NPKS applied @ 60:30:30:30: kg ha⁻¹) and seed rate @ 30 kg ha⁻¹.

Delesa and Choferie (2015) studied the effect of seed rates on yield and yield components of linseed and observed that the highest seed yield was recorded from 40 kg ha⁻¹ (2019 kg ha⁻¹) and 70 kg ha⁻¹ (1908 kg ha⁻¹) for row planting and broadcasting, respectively. This data depicted that 6% (111 kg ha⁻¹) seed yield advantage was obtained by using row planting method as compared to broadcasting. They also reported that 30 kg ha⁻¹ and 40 kg ha⁻¹ seed rates increased seed yield ha⁻¹ by 6% (110 kg ha⁻¹) and 9% (162 kg ha⁻¹), respectively as compared to 15 kg ha⁻¹ in the case of row planting. Similarly, using 70 kg ha⁻¹ seed rate for broadcasting resulted in 6% (102 kg ha⁻¹) and 7% (126 kg ha⁻¹) seed yield advantage as compared to 30 kg ha⁻¹ and 40 kg ha⁻¹ seed rates, respectively. However, the results of economic analysis indicated that the highest net benefits were obtained by using a seed rate of 30 to 40 kg ha⁻¹ for row planting and 70 kg ha⁻¹ for broadcasting.

CHAPTER - III

MATERIALS AND METHODS

The investigation entitled “Yield maximization of Linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains” was conducted during the *Rabi* season of 2015-16. This chapter deals with the concise description of the experimental materials used and the techniques employed in the course of investigation.

3.1 Location of experimental site

The experimental site was located at the Instructional *cum* Research Farm under AICRP on Linseed, Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.).

3.2 Geographical Situation

Raipur is situated in central parts of Chhattisgarh and lies at latitude, longitude and altitude of 21°4' N, 81°35' E and 290.20 meters above mean sea level, respectively.

3.3 Climate

Climatologically, Raipur comes under the seventh Agro-climatic region of India *i.e.* Eastern plateau and hills which is classified as sub-humid with hot summer and cold winter. The source of rainfall is south-western monsoon. It receives an average annual rainfall of 1200-1400 mm, mostly (85%) precipitated during the period of June to September. A few showers are expected during winters and occasionally during summer months. May is the hottest and December is the coolest month of the year. The weekly maximum temperature raised up to 46°C during summer and minimum temperature reaches as low as to 6°C during winter season. The atmospheric humidity is relatively high during the months of June to October.

3.4 Weather condition during crop period

Weekly average meteorological data during the period of experimentation obtained from Meteorological Observatory, IGKV, Raipur are presented in Appendix-I and Fig.3.1.

Agro-climatic conditions especially temperature and cool climate play an important role for seed yield in linseed. The meteorological data, recorded during experimental period showed that crop received 16.1 mm total rainfall during the crop period. The maximum temperature was 25.9°C to 34.4°C, while minimum temperature varied from 10.5°C to 20.7°C during the year. Relative humidity throughout the crop season was varied between 71.9 to 90.7 per cent at morning and 25.1 to 51.3 percentages in evening hours. The open pan evaporation mean values ranged from 2.2 to 4.6 mm day⁻¹, whereas, average sunshine hours varied from 0.5 to 9.3 hours day⁻¹ during the crop period. The average wind velocity for different weeks varied from 1.8 to 3.8 km hr⁻¹ during the crop period.

3.5 Physico-chemical characteristics of the soil

Composite soil samples from 0-20 cm depth were collected from ten randomly selected places in the experimental area, prior to start of the field experiment, to evaluate the nutrient status of the soil, with the help of soil auger. Composite samples remain about 250 g and then it were used for analysis of the initial status of the physical and chemical properties of the soil and results of soil analysis are given in Table 3.1.

The soil of the experimental field was clay-loam in texture (*Vertisols*) locally known as “*Kanhar*”. The soil was neutral in reaction. The available nitrogen, phosphorus and potassium content were low, medium and high, respectively (Table 3.1).

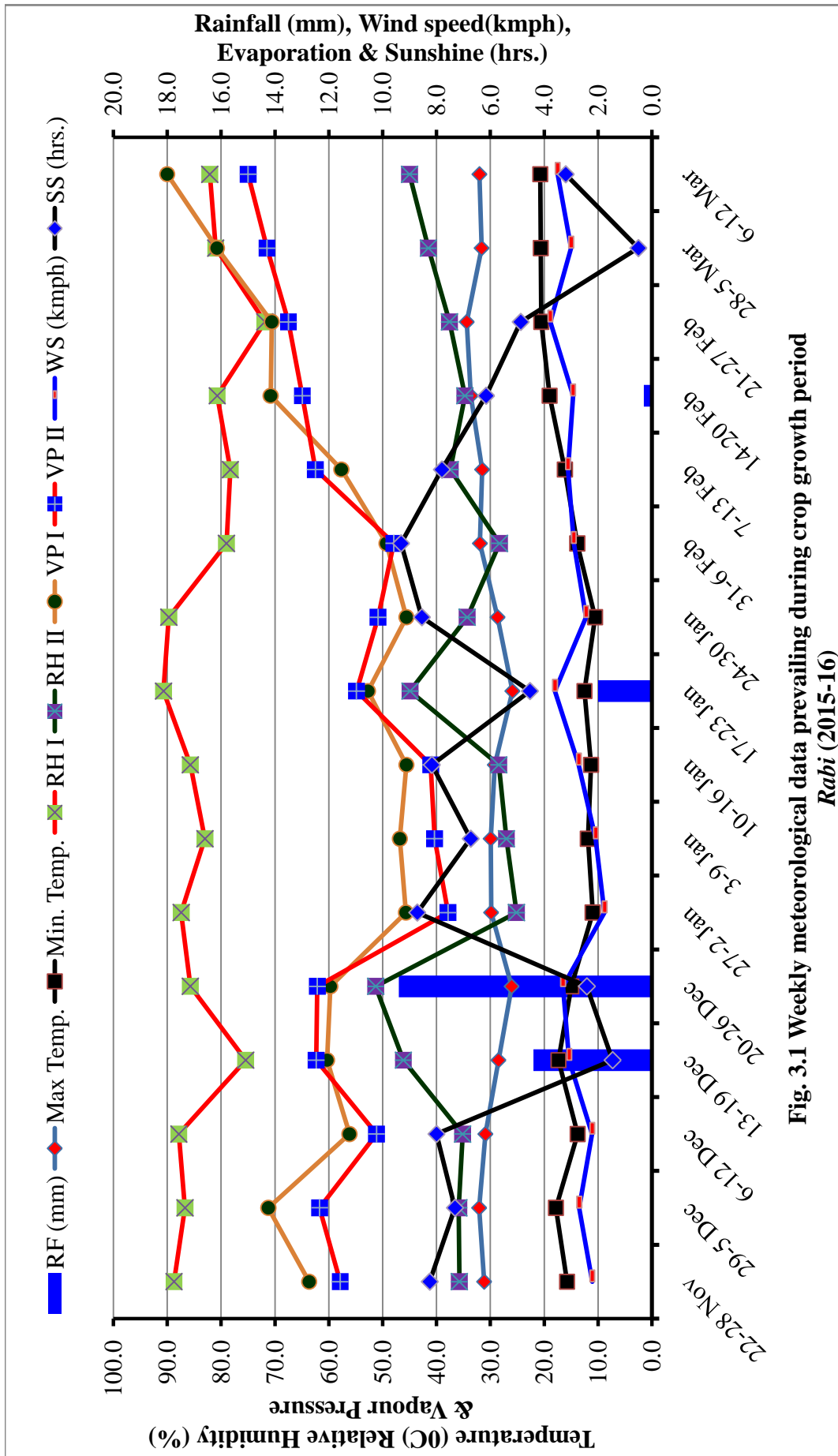


Fig. 3.1 Weekly meteorological data prevailing during crop growth period
Rabi (2015-16)

Table: 3.1: Physico-chemical properties of the experimental site

No.	Particulars	Values		Methods used
A. Physical-mechanical composition				
1.	Sand (%)	20.45		International pipette method (Black, 1965)
2.	Silt (%)	35.36		
3.	Clay (%)	44.19		
4.	Textured class	Clay (<i>Vertisols</i>)		
B. Chemical composition				
1.	Available N (kg ha ⁻¹)	226.0	Low	Alkaline permanganate method (Subbiah & Asija, 1956)
2.	Available P (kg ha ⁻¹)	12.64	Medium	Olsen's method (Olsen, <i>et al.</i> , 1954)
3.	Available K (kg ha ⁻¹)	367.0	High	Flame photometric method (Jackson, 1967)
4.	pH(1:2.5, Soil: water)	6.68	Neutral	Glass electrode pH meter (Piper, 1967)
5.	Organic carbon (%)	0.50	Medium	Walkey and Black method (Black, 1965)
6.	Electrical conductivity (m mhos m ⁻¹ at 25°C)	0.18	Normal	Solubridge method (Black, 1965)

3.6 Cropping history of the experimental field

Year wise cropping history of the experimental field for the past four year has been presented in Table 3.2.

Table 3.2 Season wise cropping history of the experimental field

Year	Crop grown	
	<i>Kharif</i>	<i>Rabi</i>
2011-12	Soybean	Safflower
2012-13	Soybean	Chickpea
2013-14	Soybean	Wheat
2014-15	Soybean	Linseed

3.7 Experimental details

The treatment consisted of two seed rate, three nutrient management and three foliar sprays. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications and eighteen treatments. The details of treatments are given in Table 3.3 and layout plan in Figure 3.2.

3.7.1. Crop and Variety

Linseed variety RLC-92 (Indiravati alsii) was taken as test crop during the course of investigations.

Salient features of RLC-92: It has been released from IGKV, Raipur. The crop mature in about 110-115 days, erect plant upper top branching, non lodging, shattering resistance and responsive to fertilizer. Flowers blue, medium disk shape, petals violet and anthers cream colour. Seeds brown colour, 39% oil content and test weight 6.9 g. Suitable for early, normal and late sown conditions; and average yield 1100-1300 kg ha⁻¹. Resistant to Rust, Wilt and Powdery Mildew; and moderate resistance to *Alternaria* Blight and Bud fly.

3.7.2. Treatment details

A: Seed rate

1. 25 kg ha⁻¹
2. 30 kg ha⁻¹

B: Nutrient Management

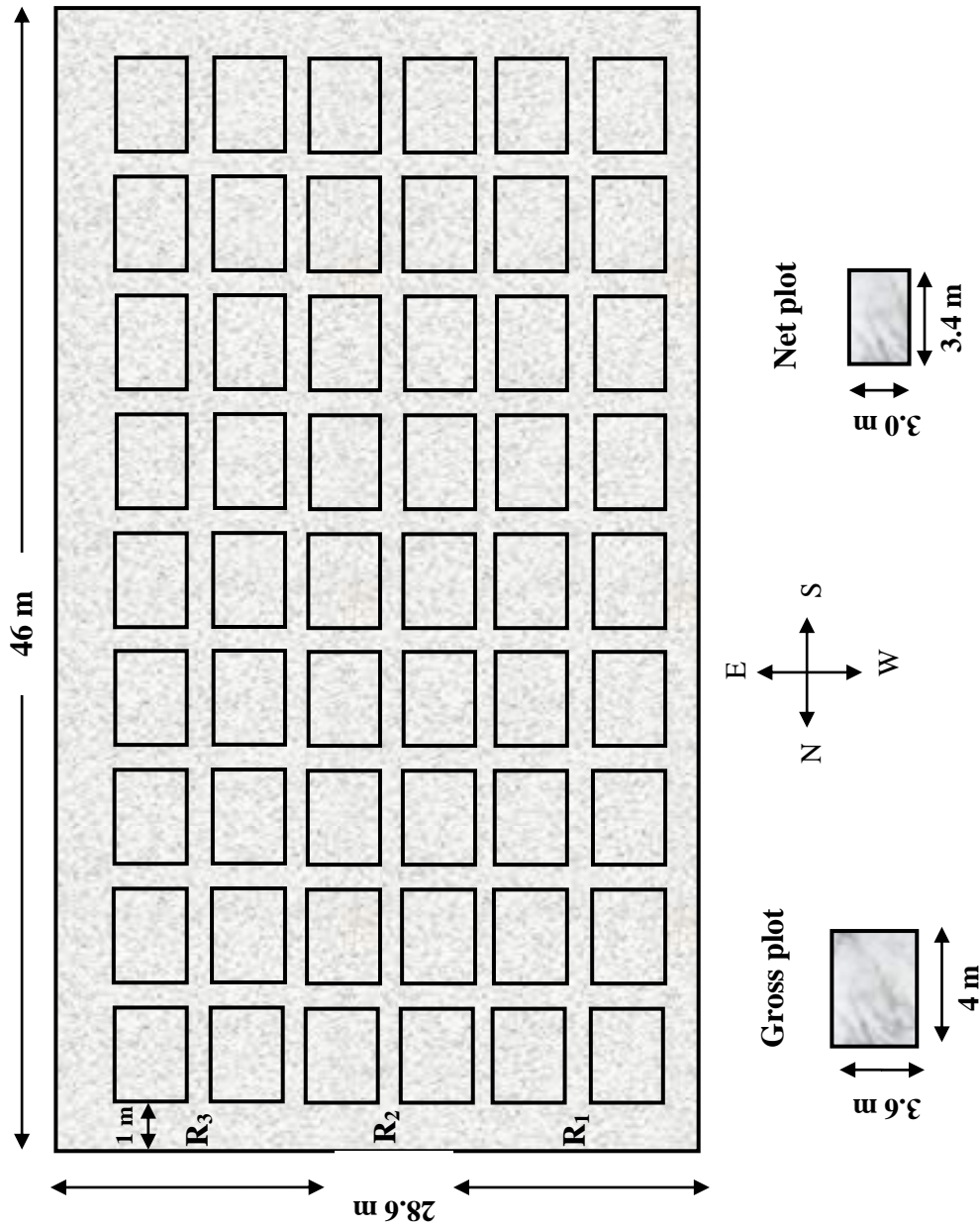
1. RDF (60:30:30 N, P₂O₅ & K₂O Kg ha⁻¹)
2. RDF + Incorporation of FYM @ 5 t ha⁻¹
3. RDF + FYM placement in rows @ 5 t ha⁻¹

C: Foliar spray

1. Water spray
2. Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
3. Foliar spray of 2% urea at 15, 40, 65 and 90 DAS

Table 3.3 Treatment combinations of the experiment:

S. No.	Treatment combinations	Treatment details
1	S ₁ N ₁ F ₁	25 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Water spray
2	S ₁ N ₁ F ₂	25 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
3	S ₁ N ₁ F ₃	25 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS
4	S ₁ N ₂ F ₁	25 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Water spray
5	S ₁ N ₂ F ₂	25 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
6	S ₁ N ₂ F ₃	25 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS
7	S ₁ N ₃ F ₁	25 kg ha ⁻¹ + RDF + FYM placement in rows @ 5 t ha ⁻¹ + Water spray
8	S ₁ N ₃ F ₂	25 kg ha ⁻¹ + FYM placement in rows @ 5 t ha ⁻¹ + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
9	S ₁ N ₃ F ₃	25 kg ha ⁻¹ + FYM placement in rows @ 5 t ha ⁻¹ + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS
10	S ₂ N ₁ F ₁	30 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Water spray
11	S ₂ N ₁ F ₂	30 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
12	S ₂ N ₁ F ₃	30 kg ha ⁻¹ + RDF (60:30:30 N, P ₂ O ₅ & K ₂ O Kg ha ⁻¹) + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS
13	S ₂ N ₂ F ₁	30 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Water spray
14	S ₂ N ₂ F ₂	30 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
15	S ₂ N ₂ F ₃	30 kg ha ⁻¹ + RDF + Incorporation of FYM @ 5 t ha ⁻¹ + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS
16	S ₂ N ₃ F ₁	30 kg ha ⁻¹ + FYM placement in rows @ 5 t ha ⁻¹ + Water spray
17	S ₂ N ₃ F ₂	30 kg ha ⁻¹ + FYM placement in rows @ 5 t ha ⁻¹ + Foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS
18	S ₂ N ₃ F ₃	30 kg ha ⁻¹ + FYM placement in rows @ 5 t ha ⁻¹ + Foliar spray of 2% urea at 15, 40, 65 and 90 DAS



Treatment

Crop	: Linseed
Variety	: RLC-92 (Indiravati alsii)
Design	: FRBD
Replication	: 03
Treatments	: 18
Experimental area	: 1315.60 m ²
Gross plot size	: 3.6 m × 4 m = 14.40 m ²
Net plot size	: 3.0 m × 3.4 m = 10.20 m ²
Seed rate	: 25 and 30 kg ha ⁻¹
Spacing of crop	: 30 cm row to row
Date of sowing	: 22.11.2015
Date of harvesting	: 12.03.2016

Fig. 3.2: Layout of experimental field

3.8 Imposition of treatments

3.8.1 Seed rate

In the experiments 25 and 30 kg ha⁻¹ seed rate was applied per treatment to find out appropriate quantity of seed for obtaining optimum growth and productivity of linseed.

3.8.2 Nutrient managements

In the experiments 60:30:30 N, P₂O₅ and K₂O kg ha⁻¹ fertilizer was applied as recommended dose of fertilizer and incorporation and placement of FYM @ 5t ha⁻¹ was applied. Full P₂O₅, K₂O and half of N at the time of basal, remaining N was applied in two equal split. The application of FYM in the treatment of row placement *i.e.* applied by hand and in incorporation *i.e.* broadcasted in tied by hand.

3.8.3 Foliar spray

Foliar spray of water, 0.06% of Nitrobenzene and 2 % of urea at 15, 40, 65 and 90 DAS were applied with help of Knapsack sprayer as per the treatments.

3.9 Cultural operations

The schedule of various cultural operations carried out during the course of investigation is given below under different headings.

3.9.1 Field preparation

The field was prepared with tractor drawn plough followed by harrowing to obtain a well pulverized seed bed. The weed and crop residues removed to get weed and stubble free seed bed. Finally, it was levelled with the help of tractor driven leveller. The layout of experimental plot was done as per specification mentioned in layout plan (Fig.3.2) with the help of measuring tap, rope, bamboo pegs and manual labour. During lay out, minor bunds were provided all around each plots and replications.

3.9.2 Seed treatment and Sowing

In order to prevent the crop from seed and soil borne diseases, the seeds were treated with Carbendazim @ 3 g kg⁻¹ of seed followed by PSB and *Rhizobium* culture @ 5g kg⁻¹ of seed. Then treated seeds were dried in shade for 3-4 hours before sowing. The crop was sown in November, during *rabi* seasons. The seeds were dibbled in marked lines at 30 cm apart to a depth of 2-3 cm and seeds were slightly covered with soil then come-up irrigation was given. The mortality of seedling was visualized on the field; accordingly gap filing was done within 10-15 DAS to maintain required plant population per unit area.

3.9.3 Manure and Fertilizer application

Well rotted FYM 5 t ha⁻¹ was applied as per treatments. The application of FYM in the treatment of row placement and incorporation treatments by hand. Recommended dose of N, P₂O₅ and K₂O were applied @ 60:30:30 kg ha⁻¹.

The half dose of nitrogen were applied as basal dressing at the time of sowing, while remaining half nitrogen was top dressed in two equal splits during first and second irrigation. The basal dose of fertilizers was applied at the time of sowing with the depth of 6-7 cm and 4 cm away from seed rows.

3.9.4 Water managements

During crop growth period two irrigations was applied *i.e.* at 30 and 60 DAS through pipe for utilization of water.

3.9.5 Weed Management

Weeds were managed in the experimental field with the use of post emergence herbicide *i.e.* Metsulfuron-methyl 20% WP @ 4 g ha⁻¹ at 20 DAS followed by one hand weeding was done at 45 DAS to keep experimental plot weed free.

3.9.6 Plant protection

Plant protection measures were adopted as and when needed during crop growth period. Imidachloprid 200 SL @125 ml a.i. ha⁻¹ was applied at 60 DAS to

reduce the infestation of linseed bud fly and also applied chlorpyrifos dust to control of ants and rates.

3.9.7 Harvesting

Harvesting was done manually from net plot area (10.20 m²) when the seed became hard and leaves turned yellow in colour. The plants were left in plot for few days to sun dry and thereafter bundles were made and the bundle weight plot⁻¹ was recorded.

3.9.8 Threshing and winnowing

Threshing of produce of each net plot was done manually by beating with wooden stick and after manual winnowing seed yield plot⁻¹ was noted. Stover yield was worked out after subtracting the seed yield from bundle weight.

3.10 Observations

In order to record the data on growth and yield attributes five plants per plot were selected randomly in the net plot area and tagged for observations at different time interval for recording growth and yield parameters.

3.10.1 Pre-harvest observations

3.10.1.1 Plant population (No. m⁻²)

Plant population was recorded at initial growth stage (20 DAS) and at harvest. The average plant population was worked out. Plant population was counted randomly from three places from one meter row length. The numbers of plants were counted m⁻² for statistical analysis.

3.10.1.2 Plant height (cm)

Height of five tagged plants in each plot was recorded in cm at an interval of 30, 60, 90 DAS and at harvest and then average was worked out and used for statistical analysis. Height was measured in centimeter from ground surface to the tip of main stem.

3.10.1.3 Number of primary branches plant⁻¹

Number of primary branches were counted from five tagged plants of

each plot at 30, 60, 90 DAS and at harvest. The mean number of primary branches plant^{-1} was obtained by dividing the summation with five and used for statistical analysis.

3.10.1.4 Number of secondary branches plant^{-1}

Number of secondary branches were counted from five tagged plants of each plot at 60, 90 DAS and at harvest. The mean number of secondary branches plant^{-1} was obtained by dividing the summation with five and used for statistical analysis.

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

Dry matter accumulation (g plant^{-1}) was computed at 30, 60, 90 DAS and at harvest. Five randomly selected plants were uprooted carefully along with the roots. Root portion was detached and shoot portion of the plant was sun dried followed by drying in hot air oven at 60°C for 48 hours to record constant dry weight. The samples were weighed on an electronic digital balance and then average was worked out by dividing the summation by five to get dry matter accumulation plant^{-1} .

3.10.2 Post-harvest studies

3.10.2.1 Number of capsules plant^{-1}

To study the influence of different treatment on capsule formation in linseed crop, total number of capsules was recorded from five randomly tagged plants and mean was worked out by dividing the total number of capsules by five and used for statistical analysis.

3.10.2.2 Number of seeds capsule $^{-1}$

Randomly selected capsules of five tagged plants from each plot were picked up and their seeds were counted and it was averaged by capsules of five tagged plants to get mean number of seeds capsule $^{-1}$.

3.10.2.3 Number of seeds plant⁻¹

All capsules of five tagged plants from each plot were picked up and their seeds were counted and it was averaged by seeds of five tagged plants to get mean number of seeds plant⁻¹.

3.10.2.4 1000 seed weight (g)

Randomly seed samples were taken from each net plot. 1000 healthy seeds from the produce of each plot were counted and same were oven dried till constant weight and then weight was recorded in gram accurately by using an electronic digital balance.

3.10.2.5 Seed yield (kg ha⁻¹)

Seed yield of the net plot was noted down, after threshing, winnowing and drying then calculated in kg ha⁻¹ with appropriate multiplication factor.

3.10.2.6 Stover yield (kg ha⁻¹)

The harvested produce from each net plot was tied in bundles separately. Stover yield of plot was calculated after subtraction of seed yield from bundle weight. Bundle weight was recorded with the help of spring balance and converted in to kg ha⁻¹.

3.10.2.7 Harvest index (HI)

The harvest index was determined by using the formula given by Donald (1962).

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

Where,

$$\text{Economic yield} = \text{Seed yield}$$

$$\text{Biological yield} = \text{Seed yield} + \text{Stover yield}$$

3.11 Chemical analysis

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

Nitrogen, phosphorus and potassium content in seed and stover were determined by Kjeldahl method (Jackson, 1967), Vanado Molybdate acid yellow colour method (Jackson, 1967) and Flame photometric method using triacid digestion system (Chapman and Patra, 1967).

3.11.2 Oil content in seed (%)

It was the proportion of oil in the seed to total oven dried seed weight is determined by a nuclear magnetic resonance spectrometer. In this experiment, 22 g seed was prepared from 30 g of submitted seeds sample and dried in an oven for two and half hours at 78 °C cooled for 30 minutes, than oil contents seed were determined by using nuclear magnetic resonance (NMR).

3.11.3 Oil yield (kg ha⁻¹)

The amount of oil in kilogram per hectare was obtained by multiplying the seed yield per hectare by the corresponding seed oil percentage obtained from the oil content analysis.

3.12 Economics

Economics of linseed production was calculated on the prevailing prices of linseed as well as inputs used. The cost of cultivation of linseed crop was calculated on the basis of prevailing prices for different inputs. The production of linseed crop was converted in to gross return (₹ ha⁻¹) on the basis of prevailing prices in the market.

3.12.1 Total gross return (₹ ha⁻¹)

$$\text{Gross return} = \text{linseed yield (kg ha}^{-1}\text{)} \times \text{Price of yield (₹ kg}^{-1}\text{)}$$

3.12.2 Net return (ha⁻¹)

$$\text{Net return (ha}^{-1}\text{)} = \text{Gross return (₹ ha}^{-1}\text{)} - \text{Cost of cultivation (₹ ha}^{-1}\text{)}$$

3.12.3 Benefit cost ratio

$$\text{Benefit: Cost ratio} = \frac{\text{Gross return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.13 Statistical analysis

All the pre and post harvest observation recorded during different period with respect to various growth and yield, were subjected to statistical analysis as per the procedure laid down by Gomez and Gomez (1984). The significance of treatment effects was tested with variance ratio (F-value). Appropriate standard errors and critical difference at 5% probability level to test the statistical significance of the results. Analysis of variance (ANOVA) table was prepared in the following way for each character.

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	(r - 1)	RSS	RMS	RMS/ErMS
Seed rate (s)	(s-1)	SSS	SMS	SMS/ErMS
Nutrient (n)	(n-1)	NSS	NMS	NMS/ErMS
I(s X n)	(s- 1) X (n-1)	ISNSS	ISMS	ISMS/ErMS
Foliar (f)	(f-1)	FSS	FMS	FMS/ErMS
I(s X f)	(s- 1) X (f-1)	ISFSS	ISFMS	ISFMS/ErMS
(n X f)	(n- 1) X (f-1)	INFSS	INFMS	INFMS/ErMS
(S X n X f)	(s- 1) X (n- 1) X (f-1)	ISNFSS	ISNFMS	ISNFMS/ErMS
Error	(r-1) (snf-1)	ErSS	ErMS	-
Total	rsnf - 1	TSS		

In order to compare the mean value of treatments, standard error and critical values were calculated as follows:

1. Standard Error of mean SEm_{\pm}

- a. Comparison of seed rate (s) = $\sqrt{EMS / r \times n \times f}$
- b. Comparison of nutrient (n) = $\sqrt{EMS / r \times s \times f}$
- c. Comparison of interaction (s X n) = $\sqrt{EMS / r \times f}$

- d. Comparison of foliar (f) = $\sqrt{\text{EMS} / r \times s \times n}$
- e. Comparison of interaction (s X f) = $\sqrt{\text{EMS} / r \times n}$
- f. Comparison of interaction (n X f) = $\sqrt{\text{EMS} / r \times s}$
- g. Comparison of interaction (s X n X f) = $\sqrt{\text{EMS} / r}$

2. Standard Error of difference SEd

- 1. Comparison of seed rate (s) = $\sqrt{2\text{EMS} / r \times n \times f}$
- 2. Comparison of nutrient (n) = $\sqrt{2\text{EMS} / r \times s \times f}$
- 3. Comparison of interaction (s X n) = $\sqrt{2\text{EMS} / r \times f}$
- 4. Comparison of foliar (f) = $\sqrt{2\text{EMS} / r \times s \times n}$
- 5. Comparison of interaction (s X f) = $\sqrt{2\text{EMS} / r \times n}$
- 6. Comparison of interaction (n X f) = $\sqrt{2\text{EMS} / r \times s}$
- 7. Comparison of interaction (s X n X f) = $\sqrt{2\text{EMS} / r}$

3. Critical difference (CD)

- 1. Comparison of seed rate (s) = SEd (s) X t at error 5 % d.f
- 2. Comparison of nutrient (n) = SEd (n) X t at error 5 % d.f
- 3. Comparison of interaction (s X n) = SEd I (s X n) X t at error 5 % d.f
- 4. Comparison of foliar (f) = SEd (f) X t at error 5 % d.f
- 5. Comparison of interaction (s X f) = SEd I (s X f) x t at error 5 % d.f
- 6. Comparison of interaction (n X f) = SEd I (n X f) x t at error 5 % d.f
- 7. Comparison of interaction (s X n X f) = SEd I (s X n X f) X t at error 5 % d.f

8. Coefficient of variation (CV)

$$\text{CV} (\%) = \sqrt{\text{EMS} / \text{grand mean}} \times 100$$

CHAPTER - IV

RESULTS AND DISCUSSION

The experimental findings obtained from the present investigation “Yield maximization of Linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains” conducted at the Research *cum* Instructional Farm I.G.K.V., Raipur (C.G.) during *Rabi* season of 2015-16 have been presented in this chapter. Data collected on various growth and yield parameters were subjected to analysis of variance techniques using appropriate statistical package. Experimental results have been discussed through appropriate tables, graphs, figures and appendices in the following pages by justifying the variation among treatments or treatment combinations with scientific reasoning and in comparison with the results of research carried out by the past research workers elsewhere on the subject.

4.1 Pre-harvest observation

Pre-harvest observations were taken on plant population, various growth attributing characters such as plant height, number of primary branches plant⁻¹, secondary branches plant⁻¹ and dry matter accumulation (g plant⁻¹).

4.1.1 Plant population (No. m⁻²)

Data regarding plant population at initial (20 DAS) and at harvest are presented in Table 4.1. It is clear from the data that no significant difference was observed with the application of seed rates in both the stages of linseed crop. However, maximum plant population was observed at the initial and at harvest stage with the application of seed rate 30 kg ha⁻¹.

Among nutrient management practices, no significant difference was observed in both the stages of linseed crop. However, maximum plant population was observed at the initial and at harvest stage with the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) *viz.* 203 m⁻² and 184 m⁻², respectively, whereas the application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) showed the lowest plant population at initial and at harvest stage *viz.* 193 m⁻² and 173 m⁻², respectively. Similarly, in case of foliar spray no significant impact was noticed at both the stage

Table 4.1: Plant population (No. m⁻²) at various growth stages of linseed as influenced by different treatments

Treatment	Plant Population (No. m ⁻²)	
	Initial (20 DAS)	At harvest
Seed rate		
S ₁ 25 kg ha ⁻¹	192	173
S ₂ 30 kg ha ⁻¹	205	185
SE m±	5.63	5.41
CD (P=0.05)	NS	NS
Nutrient Management		
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	193	173
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	199	180
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	203	184
SE m±	6.9	6.63
CD (P=0.05)	NS	NS
Foliar spray		
F ₁ Water spray	199	177
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	198	179
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	198	181
SE m±	6.9	6.63
CD (P=0.05)	NS	NS
Interaction	NS	NS

of linseed crop. However, maximum plant population was observed at the initial stage with the application of water spray (F₁) (199 m⁻²) and at harvest stage with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) (181 m⁻²).

As regards to initial and harvest stage of plant population, initially higher plant population was observed in comparison to later stage. This might be due to wilting and natural phenomena of plant habits of linseed. That data also reveal that in different treatments, 9.81 per cent mean mortality was observed from initial to harvest stage.

4.1.2 Plant height (cm)

The plant height is an important growth character directly linked with the productive potential of plants in terms of biological, and fibre yield in linseed. Plant height of linseed was recorded at 30, 60, 90 DAS and at harvest and the data are presented in Table 4.2. Result revealed that plant height increased with an advancement of crop age and the higher magnitude of increase was observed between 30 and 60 DAS followed by 60 to 90 DAS and thereafter slightly increase in height was observed.

Between seed rates, no significant difference was observed on plant height in all the stages of linseed crop. However, maximum plant height was observed with the seed rate of 30 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows (N₃) registered significantly tallest plants *viz.* 78.92 cm, 87.06 cm, and 88.44 cm at 60 DAS, 90 DAS and at harvest, respectively. However, it was statistically at par with the application of RDF + FYM incorporation (N₂) *viz.* 85.30 cm and 86.41 cm at 90 DAS and at harvest, respectively. Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) showed the shortest plants *viz.* 70.39 cm, 81.96 cm and 83.24 cm at 60 DAS, 90 DAS and at harvest, respectively, at all the stages. At 30 DAS, none of the treatment of nutrient management showed significant impact on plant height. It is due to the higher dose of fertility levels that help in better crop growth and proportionately brought higher production of linseed. Hence, the significantly maximum plant height was recorded at the highest level of fertility application.

Table 4.2: Plant height (cm) at various growth stages of linseed as influenced by different treatments

Treatment	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	At harvest	
Seed rate					
S ₁ 25 kg ha ⁻¹	16.91	74.55	84.56	85.63	
S ₂ 30 kg ha ⁻¹	17.57	75.67	84.98	86.43	
SE m±	0.30	0.72	0.89	0.83	
CD (P=0.05)	NS	NS	NS	NS	
Nutrient Management					
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	17.15	70.39	81.96	83.24	
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	17.26	75.98	85.30	86.41	
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	17.99	78.92	87.06	88.44	
SE m±	0.37	0.88	1.09	1.01	
CD (P=0.05)	NS	2.55	3.15	2.93	
Foliar spray					
F ₁ Water spray	17.15	70.68	82.51	83.63	
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	17.26	75.69	84.93	86.10	
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	17.99	78.92	86.89	88.37	
SE m±	0.37	0.88	1.09	1.01	
CD (P=0.05)	NS	2.55	3.15	2.93	
Interaction	NS	NS	NS	NS	

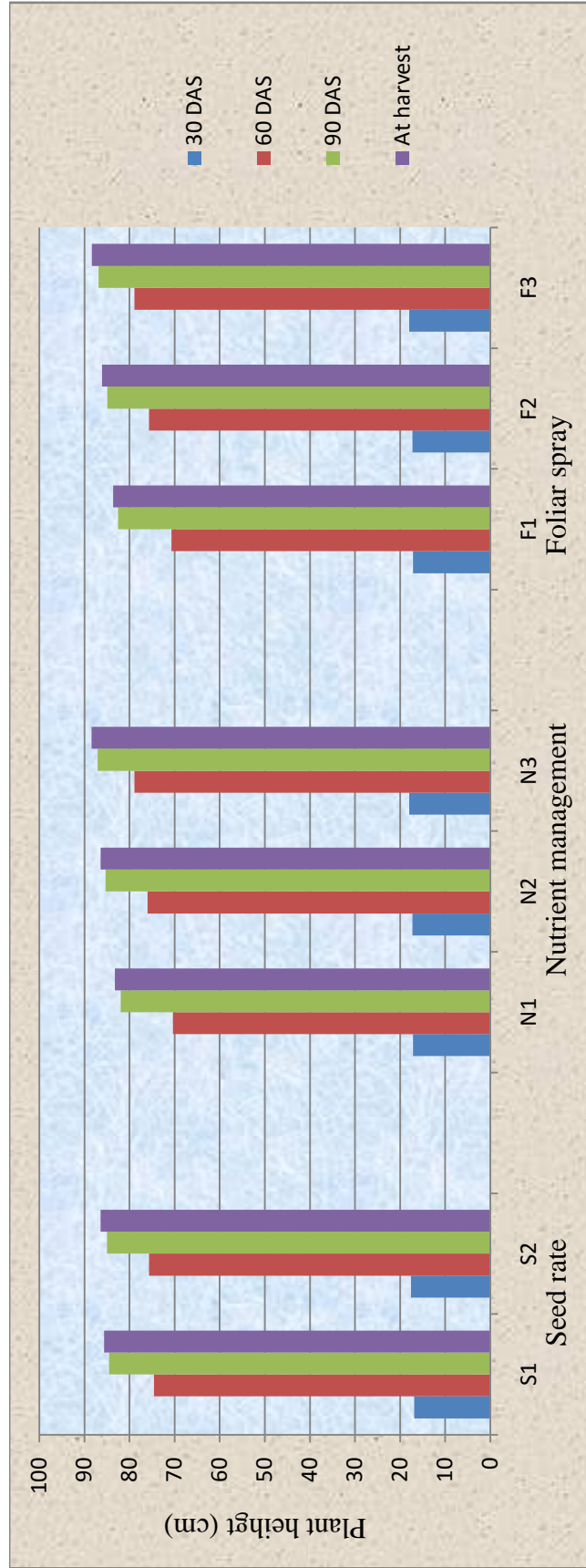


Fig 4.1: Plant height (cm) at various growth stages of linseed as influenced by different treatments

these might be possible because balance application of NPK and FYM enhance the cell division, cell multiplication and tissue differentiation, which ultimately increase the plant height. These results were corroborated with finding of Meena *et al.* (2011).

As regard to foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly tallest plants *viz.* 78.92 cm, 86.89 cm and 88.37 cm at 60 DAS, 90 and at harvest, respectively. However, it was statistically at par with the application of foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂) *viz.* 84.93 cm and 86.10 cm at 90 DAS and at harvest, respectively. Application of water spray (F₁) showed the shortest plants *viz.* 70.68 cm, 82.51 cm and 83.63 cm at 60 DAS, 90 DAS and at harvest, respectively, at all the stages. At 30 DAS, effect of foliar spray on plant height was found non-significant. Application of foliar spray of urea 2% at 15, 40, 65 and 90 DAS (F₃) gave significantly higher plant height as compared to foliar spray of nitrobenzene @ 0.06 % at 15, 40, 65 and 90 DAS (F₂) and water spray (F₁) because foliar spraying with urea at 2% at 15, 40, 65 and 90 DAS, such effect may be attributed to the fact that N is essential for building up the protoplasm and protein which increase cell number and size leading to an overall increase in plant height and stem diameter. Similar results were obtained by El-kady *et al.* (2010).

4.1.3 Number of primary branches plant⁻¹

Primary branches are an important component of linseed yield because they have the potential to develop seed-bearing capsules. The number of primary branches plant⁻¹ at 30, 60 and 90 DAS as influenced by nutrient management, foliar spray and their interaction effect has been summarized in Table 4.3 and 4.4, respectively. It is evident from the data that there was visible difference in number of primary branches plant⁻¹ due to nutrient management and foliar spray. The number of primary branches plant⁻¹ was increased sharply up to 90 DAS thereafter; there was no increase in primary branches up to maturity.

Between seed rates, no significant difference was observed on number of primary branches plant⁻¹ in all the stages of linseed crop. However, maximum primary branches were observed with the seed rate of 25 kg ha⁻¹. As a result of

lower plant population at 25 kg ha⁻¹ seed rate, the individual plant could have utilized more soil moisture, nutrient and solar radiation and hence their growth and development was better leading to higher, both primary and secondary branch plant⁻¹. Similar results have been reported by Meena *et al.* (2011).

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded significantly highest number of primary branches plant⁻¹ (3.83) at 90 DAS and at harvest stage. Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) showed minimum number of primary branches plant⁻¹ (3.52) both at 90 DAS and at harvest. At 30 and 60 DAS, no significant difference was observed due to nutrient management.

In case of foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest number of primary branches plant⁻¹ (3.82) at 90 DAS and at harvest stage. Application of water spray (F₁) showed minimum number of primary branches plant⁻¹ (3.48) at 90 DAS and at harvest stage. At 30 and 60 DAS, the effect of foliar spray was found non-significant. More number of primary branches might be due to the more availability of nitrogen, which plays a vital role in cell division. Several workers have reported marked superiority in growth parameters like plant height due to adequate nutrient supply in niger. These findings are similar to Dalei *et al.* (2014).

Interaction effects of nutrient managements and foliar spray on number of primary branches plant⁻¹ were found non-significant during 30 DAS and 60 DAS. However significant impact was found at 90 DAS and at harvest stage. Among different interaction of nutrient management and foliar spray at harvest, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) and application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher number of primary branches plants⁻¹ (4.10) than others but it was found at par to interaction between application of RDF + FYM placement in rows @ 5 t ha⁻¹ X spray of 0.06 % Nitrobenzene at 15, 40, 65 and 90 DAS N₃ X F₂. The lower number of primary branches plant⁻¹ (3.45) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray N₁ X F₁. The similar results were obtained at 90 DAS.

Table 4.3: Number of primary branches plant⁻¹ at various growth stages of linseed as influenced by different treatments

Treatment	Number of primary branches plant ⁻¹			
	30 DAS	60 DAS	90 DAS	At harvest
Seed rate				
S ₁ 25 kg ha ⁻¹	3.26	3.39	3.70	3.70
S ₂ 30 kg ha ⁻¹	3.17	3.37	3.63	3.63
SE m±	0.03	0.04	0.03	0.04
CD (P=0.05)	NS	NS	NS	NS
Nutrient Management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	3.20	3.41	3.52	3.52
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	3.18	3.33	3.65	3.65
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	3.27	3.40	3.83	3.83
SE m±	0.04	0.05	0.04	0.04
CD (P=0.05)	NS	NS	0.13	0.13
Foliar spray				
F ₁ Water spray	3.21	3.37	3.48	3.48
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	3.24	3.38	3.60	3.60
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	3.21	3.37	3.82	3.82
SE m±	0.37	0.04	0.05	0.04
CD (P=0.05)	NS	NS	0.13	0.13
Interaction	NS	NS	S	S

Table 4.4: Interaction effect of nutrients and foliar spray on primary branches plant⁻¹ of linseed at harvest

Treatment	Primary branches plant ⁻¹ at harvest			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	3.45	3.46	3.66	3.52
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	3.52	3.75	3.70	3.65
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	3.51	3.90	4.10	3.83
Mean	3.48	3.69	3.81	
SE m±	0.08			
CD (P=0.05)	0.23			

4.1.4 Number of secondary branches plant⁻¹

Secondary branches are an important component of linseed yield because they have the potential to develop seed-bearing capsules. The number of secondary branches plant⁻¹ at 60, 90 DAS and at harvest as influenced by nutrient management, foliar spray and their interaction effect has been summarized in Table 4.5 and 4.6. It is evident from the data that there was visible difference in number of secondary branches plant⁻¹ due to nutrient management and foliar spray. The number of secondary branches plant⁻¹ were increased sharply up to 90 DAS, thereafter; there was no increase in branches up to maturity.

Between seed rates, no significant difference was observed on secondary branch plant⁻¹ in all the stages of linseed crop. However, maximum number of secondary branches plant⁻¹ were observed with the seed rate of 25 kg ha⁻¹. The primary and secondary branches plant⁻¹ was markedly reduced with increasing plant population (Meena *et al.*, 2011).

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) gave significantly highest number of secondary branches plant⁻¹ *i.e.* 16.80, 23.39, and 23.39 at 60, 90 DAS and at harvest, respectively.

Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) showed minimum number of secondary branches plant⁻¹ *i.e.* 12.72, 20.07 and 20.07 at 60, 90 DAS and at harvest, respectively. There was increase in number of secondary branches with the application of RDF + FYM placement in rows @ 5 t ha⁻¹ this might be due to higher uptake of nutrient by plants. When balance nutrients applied in soil, their availability increase for to enhance for proper growth and development. Application of FYM to linseed crop improve the overall fertility status of the soil with respect to N, P and K (Meena *et al.*, 2011).

As regards to foliar spray application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest number of secondary branches plant⁻¹ *viz.* 16.80, 23.68 and 23.68 at 60, 90 DAS and at harvest, respectively. Application of water spray (F₁) showed minimum number of secondary branches plant⁻¹ *i.e.* 13.03, 19.95 and 19.95 at 60, 90 DAS and at harvest, respectively. More number of secondary branches might be due to the more availability of nitrogen in the form of urea as a foliar, which plays a vital role in cell division, cell elongation which is ultimately increase number of secondary branches plant⁻¹. Several workers have reported marked superiority in growth parameters like plant height due to adequate nutrient supply in niger. These findings are similar to Dalei *et al.* (2014).

Interaction effects of nutrient managements and foliar spray on number of secondary branches plant⁻¹ were found significant during 60, 90 DAS and at harvest stage. Among different interaction of nutrient management and foliar spray at 60, 90 DAS and at harvest stage, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher number of secondary branches plant⁻¹ *i.e.* 18.42, 25.72 and 25.72, respectively, than others. The lowest number of secondary branches plant⁻¹ *i.e.* 10.87, 18.78 and 18.78 was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray N₁ X F₁ at 60, 90 DAS and at harvest, respectively.

Table 4.5: Number of secondary branches plant⁻¹ at various growth stages of linseed as influenced by different treatments

Treatment	Number of secondary branches plant ⁻¹			
	60 DAS	90 harvest	At harvest	
Seed rate				
S ₁ 25 kg ha ⁻¹	15.21	21.96	21.96	21.96
S ₂ 30 kg ha ⁻¹	14.77	21.66	21.66	21.66
SE m±	0.15	0.22	0.22	0.22
CD (P=0.05)	NS	NS	NS	NS
Nutrient Management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	12.72	20.7	20.7	20.7
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	15.44	21.97	21.97	21.97
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	16.80	23.39	23.39	23.39
SE m±	0.19	0.27	0.27	0.27
CD (P=0.05)	0.55	0.79	0.79	0.79
Foliar spray				
F ₁ Water spray	13.03	19.95	19.95	19.95
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	15.13	21.81	21.81	21.81
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	16.80	23.68	23.68	23.68
SE m±	0.19	0.27	0.27	0.27
CD (P=0.05)	0.55	0.79	0.79	0.79
Interaction	S	S	S	S

Table 4.6: Interaction effect of nutrients and foliar spray on secondary branches plant⁻¹ of linseed at 60, 90 DAS and at harvest

Treatment	Secondary branches plant ⁻¹ at 60 DAS				Secondary branches plant ⁻¹ at 90 DAS and at harvest			
	Foliar spray				Foliar spray			
	F1	F2	F3	Mean	F1	F2	F3	Mean
Nutrient management								
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	10.87	11.98	15.33	12.72	18.78	19.32	22.13	20.07
N ₂ RDF + Incorporation of FYM	13.45	16.23	16.65	15.44	19.95	22.79	23.18	21.97
N ₃ RDF + FYM placement in rows	14.80	17.20	18.42	16.80	21.13	23.34	25.72	23.39
Mean	13.03	15.13	16.80		19.95	21.81	23.67	
SE m±	0.33				0.48			
CD (P=0.05)	0.95				1.37			

4.1.5 Dry matter accumulation (g plant⁻¹)

Dry matter production during various growth stages of any crop is an important pre-requisite for higher yields as it signifies photosynthetic ability of the crop. It is presented in Table 4.7 and 4.8. Increase of dry matter accumulation was slow at the early stages of plant growth but increased rapidly with the advancement of up to 90 DAS thereafter slightly increment was observed. At early growth stages, the root and shoot development are less, therefore, dry matter accumulation is also less up to harvest stage. The cause of rapid increment in dry matter accumulation at 90 DAS was possibly due to emergence of considerable number of new branches plant⁻¹ and filled capsules plant⁻¹.

Between seed rates, no significant difference was observed on dry matter accumulation plant⁻¹ in all the stages of linseed crop. However, maximum dry matter accumulation was observed with the seed rate of 25 kg ha⁻¹ at 60, 90 DAS and at harvest stage. As a result of lower plant population at 25 kg ha⁻¹ seed rate, the individual plant could have utilized more soil moisture, nutrient and solar radiation, hence their growth and development of plant was better leading to higher dry matter accumulation. These findings are in agreements with the reports of Meena *et al.* (2011).

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded significantly higher dry matter accumulation *viz.* 2.58 g, 6.27 g, and 6.76 g at 60, 90 DAS and at harvest, respectively as compared to others. Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) showed the lower dry matter accumulation *viz.* 2.28 g, 5.27 g, and 5.82 g at 60, 90 DAS and at harvest, respectively. At 30 DAS, no significant difference was observed due to nutrient management. The increment in dry matter accumulation plant⁻¹ with the application of RDF + FYM placement in rows @ 5 t ha⁻¹ due to higher uptake of nutrient by plants. When balance nutrients was applied in soil, the availability was increased, hence proper growth, development and ultimately primary and secondary branches plant⁻¹ which is responsible for increasing dry matter accumulation. The application of FYM to linseed improve the overall fertility status of the soil with respect to N, P and K uptake (Meena *et al.*, 2011).

In case of foliar spray, application of urea 2% (F₃) recorded significantly more dry matter accumulation *viz.* 2.58 g, 6.13 g, and 6.59 g at 60 DAS, 90 DAS and at harvest, respectively. However it was statistically at par with the application of foliar spray of 0.06% Nitrobenzene (F₂) *viz.* 6.39 g at harvest stage. Application of water spray (F₁) showed the lower dry matter accumulation *viz.* 2.25 g, 5.33 g and 5.83 g at 60, 90 DAS and at harvest, respectively, At 30 DAS, no significant difference was observed due to foliar spray. Dry matter accumulation increase with the application of foliar spray of urea 2% (F₃) treatment due to increase in number of secondary branches might be due to the more availability of nitrogen in the form of urea as a foliar, which plays a vital role in cell division, cell elongation which is ultimately increase number of secondary branches plant⁻¹ as well as plant height, number of leaves, number of capsules plant⁻¹, seeds capsule⁻¹ and seeds plant⁻¹ which is directly responsible for dry matter accumulation. Several researchers have reported marked superiority in growth parameters like plant height due to adequate nutrient supply in niger. These findings are similar to Dalei *et al.* (2014).

Interaction effects of nutrient managements and foliar spray on dry matter accumulation plant⁻¹ were found non-significant during 30 DAS and 60 DAS, however, it was found significant at 90 DAS and at harvest stage. Among different interaction of nutrient management and foliar spray at 90 DAS and at harvest, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) and foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher dry matter accumulation plant⁻¹ 6.85 and 7.37 than others, except the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) X water spray (F₂) which was found at par at 90 DAS only. The lower dry matter accumulation plant⁻¹ 4.98 and 5.57 was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁) at 90 DAS and at harvest stage, respectively.

Table 4.7: Dry matter accumulation (g plant⁻¹) at various growth stages of linseed as influenced by different treatments

Treatment	Dry matter accumulation (g plant ⁻¹)				
	30 DAS	60 DAS	90 DAS	At harvest	
Seed rate					
S ₁ 25 kg ha ⁻¹	0.56	2.43	5.85	6.32	
S ₂ 30 kg ha ⁻¹	0.56	2.39	5.68	6.22	
SE m±	0.02	0.03	0.06	0.07	
CD (P=0.05)	NS	NS	NS	NS	NS
Nutrient Management					
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	0.56	2.28	5.27	5.82	
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	0.59	2.38	5.77	6.24	
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	0.56	2.58	6.27	6.76	
SE m±	0.03	0.03	0.07	0.09	
CD (P=0.05)	NS	0.09	0.20	0.27	
Foliar spray					
F ₁ Water spray	0.55	2.25	5.33	5.83	
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	0.57	2.42	5.84	6.39	
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	0.59	2.58	6.13	6.59	
SE m±	0.03	0.03	0.07	0.09	
CD (P=0.05)	NS	0.09	0.20	0.27	
Interaction	NS	NS	S	S	S

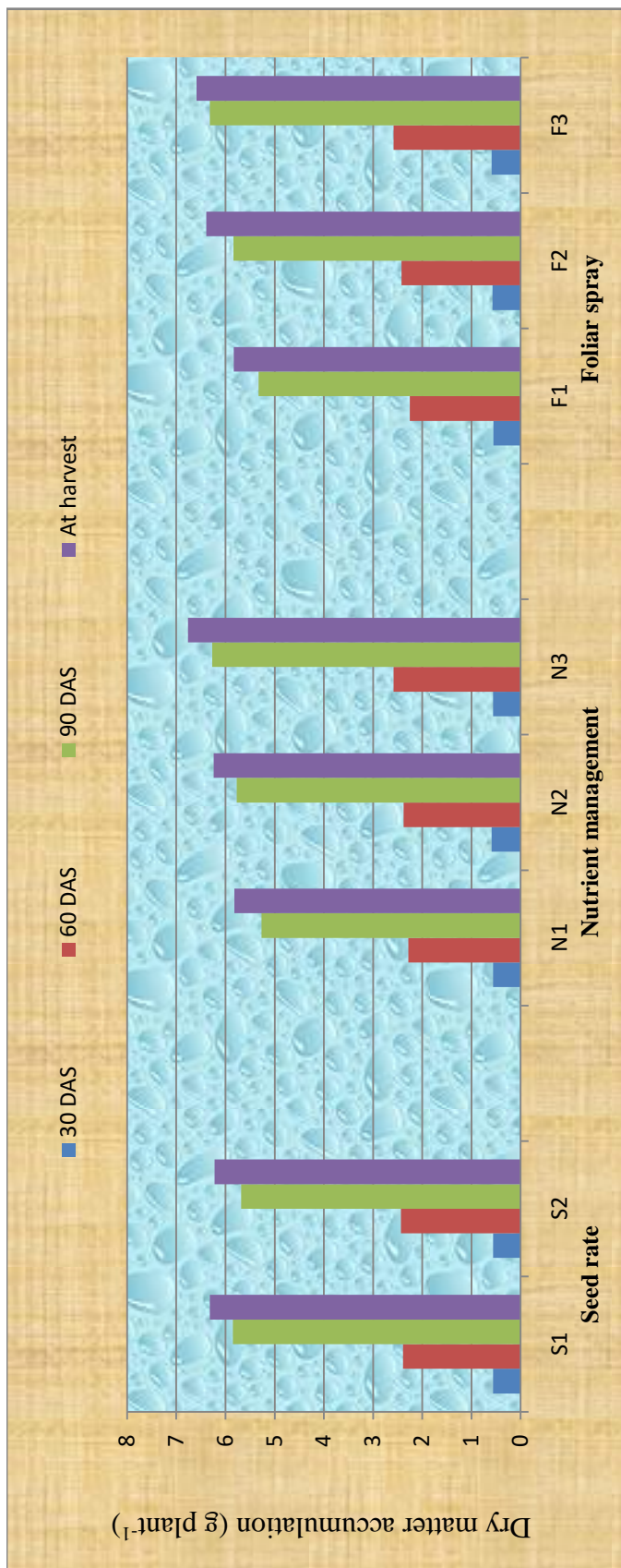


Fig 4.2: Dry matter accumulation (g plant⁻¹) at various growth stages of linseed as influenced by different treatments

Table 4.8: Interaction effect of nutrients and foliar spray on dry matter accumulation (g plant^{-1}) of linseed at 90 DAS and at harvest

Treatment	Dry matter accumulation (g plant^{-1}) at 90 DAS				Dry matter accumulation (g plant^{-1}) at harvest				
	Foliar spray				Foliar spray				
	F1	F2	F3	Mean	F1	F2	F3	Mean	
Nutrient management									
N ₁	RDF (60:30:30 N:P:K kg ha^{-1})	4.98	5.24	5.59	5.27	5.57	5.81	6.10	5.82
N ₂	RDF + Incorporation of FYM	5.41	5.93	5.96	5.76	5.91	6.50	6.31	6.24
N ₃	RDF + FYM placement in rows	5.60	6.37	6.85	6.27	6.04	6.88	7.37	6.76
Mean		5.32	5.84	6.13		5.83	6.39	6.59	
SE $m \pm$		0.12				0.17			
CD (P=0.05)		0.35				0.48			

4.2 Post harvest observation

The data presented in Table 4.9 reveal significant effects of nutrient management and foliar spray on post harvest observations included on various yield attributing characters such as number of capsules plant⁻¹, number of seeds capsule⁻¹, number of seeds plant⁻¹, test weight (g), seed yield (kg ha⁻¹) and stover yield (kg ha⁻¹).

4.2.1 Number of capsules plant⁻¹

The number of filled capsules plant⁻¹ is the most important yield contributing component in linseed. As the number of capsules plant⁻¹ increases, the yield (ha⁻¹) also increases.

Between seed rates, no significant difference was observed on number of capsules plant⁻¹. However, maximum number of capsules plant⁻¹ was observed with the seed rate of 25 kg ha⁻¹. It is due to increased production of secondary branches plant⁻¹ at lower seed rate. The individual plant could have utilized more soil moisture, nutrient and solar radiation and hence their growth and development was better leading to the production of higher number of capsules plant⁻¹ (Meena *et al.*, 2011).

Among nutrient management, the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) recorded significantly highest number of capsules plant⁻¹ (30.86). However, it was statistically at par with the application of RDF + incorporation of FYM @ rate of 5 t ha⁻¹ (N₂). Application of RDF (N₁) gave the lowest number of capsules plant⁻¹ (23.30). The application of adequate quantity of fertilizer through organic and inorganic sources leads to cell division, cell elongation and tissue differentiation. The increase in yield attributing characters of linseed with the application of major nutrient and secondary nutrient (S) has been reported by Khare *et al.* (1996)

As regards to foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest number of capsules plant⁻¹ (31.74). However, it was statistically at par with the application of foliar spray of 0.06% Nitrobenzene

Table 4.9: Yield attributing characters of linseed as influenced by different treatments

Treatment	Capsules plant ⁻¹ (No.)	Seeds capsule ⁻¹ (No.)	Seeds plant ⁻¹ (No.)	1000 – seeds weight (g)
Seed rate				
S ₁ 25 kg ha ⁻¹	28.61	7.46	215.00	7.24
S ₂ 30 kg ha ⁻¹	26.80	7.40	198.45	7.18
SE m±	0.81	0.07	6.22	0.07
CD (P=0.05)	NS	NS	NS	NS
Nutrient Management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	23.30	7.28	169.81	7.09
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	28.96	7.38	215.04	7.20
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	30.86	7.63	235.32	7.34
SE m±	1.00	0.08	7.62	0.08
CD (P=0.05)	2.88	0.25	21.97	NS
Foliar spray				
F ₁ Water spray	21.48	7.20	155.12	7.03
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	29.91	7.46	223.69	7.28
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	31.74	7.63	241.38	7.32
SE m±	1.00	0.08	7.62	0.08
CD (P=0.05)	2.88	0.25	21.97	NS
Interaction	S	S	S	NS

at 15, 40, 65 and 90 DAS (F₂). Application of water spray (F₁) gave the minimum number of capsules plant⁻¹ (21.48).

Interaction effect of nutrient management and foliar spray on capsules plant⁻¹ was found significant and data are presented in Table 4.10. The interaction of application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) with foliar of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher capsules plant⁻¹ (36) than other treatments but it was found at par to interaction between the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ X foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (N₃ X F₂), application of RDF + Incorporation of FYM @ rate of 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS N₂ X F₃ and application of RDF + Incorporation of FYM @ rate of 5 t ha⁻¹ X foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (N₂ X F₂). The lowest capsule plant⁻¹ (20.13) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁).

Table 4.10: Interaction effect of nutrients and foliar spray on capsules plant⁻¹ of linseed

Treatment	Capsules plant ⁻¹			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	20.13	22.72	26.07	22.97
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	22.37	31.37	33.17	28.96
N ₃ RDF + FYM placement in rows@ 5 t ha ⁻¹	21.95	35.65	36.00	31.02
Mean	21.48	29.91	31.74	
SE m±	1.73			
CD (P=0.05)	4.99			

4.2.2 Number of seeds capsule⁻¹

Between seed rates, no significant difference was observed on number of seeds capsules⁻¹. However, maximum number of number of seeds capsule⁻¹ was observed with the seed rate of 25 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) recorded significantly highest number of seeds capsule⁻¹ (7.63). However, it was statistically at par with the application of RDF + incorporation of FYM @ rate of 5 t ha⁻¹ (N₂). Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) gave the minimum number of seeds capsule⁻¹ (7.28). It is because the application of FYM to linseed which improves the overall fertility status of the soil. Similar results were also noted by Leilah *et al.* (2003).

In case of the foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) showed significantly highest number of seeds capsule⁻¹ (7.63). However, it was statistically at par with the application of foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂). Application of water spray (F₁) showed the minimum number of seeds capsule⁻¹ (7.20).

Interaction effects of nutrient managements and foliar spray on seeds capsule⁻¹ were found significant and data are presented in Table 4.11. Among different interaction of nutrient management and foliar spray, the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) with application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest seeds capsule⁻¹ (8.05) than others but it was found at par to interaction between RDF + FYM placement in rows @ rate of 5 t ha⁻¹ X foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (N₃ X F₂) and application of RDF + Incorporation of FYM @ rate of 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (N₂ X F₃). The lowest seeds capsule⁻¹ (7.18) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁).

Table 4.11: Interaction effect of nutrients and foliar spray on seeds capsule⁻¹ of linseed

Treatment	Seeds capsule ⁻¹			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	7.18	7.48	7.18	7.28
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	7.22	7.27	7.67	7.38
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	7.23	7.66	8.05	7.64
Mean	7.21	7.46	7.63	
SE m±	0.01			
CD (P=0.05)	0.44			

4.2.3 Number of seeds plant⁻¹

The number of seeds plant⁻¹ is an important yield-determining component of linseed. The data shown in Table 4.9 reveal that number of seeds plant⁻¹ was significantly affected due to nutrient management and foliar spray.

Between seed rates, no significant difference was observed on number of seeds plant⁻¹. However, maximum number of seeds plant⁻¹ was observed with the seed rate of 25 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) gave significantly highest number of seeds plant⁻¹ (235.32). However, it was statistically at par with the application of RDF + incorporation of FYM @ rate of 5 t ha⁻¹ (N₂). Application of RDF (N₁) gave the lowest number of seeds plant⁻¹ (169.81).

As regards to foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest number of seeds plant⁻¹ (241.38). However, it was statistically at par with the application of foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂). Application of water spray (F₁) gave the lowest number of seeds plant⁻¹ (155.12).

Interaction effects of nutrient managements and foliar spray on seeds plant⁻¹ were found significant and data are presented in Table 4.12. The application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) with application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest seeds plant⁻¹ (282.52) than others but it was found at par to interaction between RDF + FYM placement in rows @ rate of 5 t ha⁻¹ X foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (N₃ X F₂) and application of RDF + Incorporation of FYM @ rate of 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (N₂ X F₃). The lowest seeds plant⁻¹ (150.68) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁).

Table 4.12: Interaction effect of nutrients and foliar spray on seeds plant⁻¹ of linseed

Treatment	Seeds plant ⁻¹			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	150.68	170.08	186.69	169.15
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	161.93	228.28	254.92	215.04
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	152.76	272.71	282.52	235.78
Mean	155.12	223.69	241.37	
SE m±	13.21			
CD (P=0.05)	38.05			

4.2.4 Test weight (g)

As regards to test weight of linseed seed, no significant difference was observed with the use of different agro input management practices *viz.* seed rate, nutrient management and foliar spray in linseed crop. The maximum test weight was recorded under seed rate 25 kg ha⁻¹ (S₁) and RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃). As regards to foliar spray, relatively higher value of test weight was recorded with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃). The results are in accordance with the findings of Meena *et al.* (2011).

4.2.5 Seed yield (kg ha⁻¹)

The seed yield, ultimate result of various interacting growth, development and yield contributing character. The data shown in Table 4.13 and 4.14 reveal that seed yield ha⁻¹ was significantly affected due to nutrient management and foliar spray.

Between seed rates, no significant difference was observed on seed yield. However, maximum number of seeds yield was observed with the seed rate of 30 kg ha⁻¹. Emam and Dewdar, (2015), revealed that the increment in seed rate of linseed seed rate was also increased. Similar results were recorded by Delesa and Choferie (2015).

Among nutrient management, the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ (N₃) gave significantly highest seed yield (2100 kg ha⁻¹). Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) recorded lowest seed yield (1794 kg ha⁻¹). It is possible with the application of RDF + FYM placement in rows @ rate of 5 t ha⁻¹ due to that NPK application along with FYM placement with rows, application of FYM to linseed improving the overall fertility status of the soil, vigorous plant growth might have produced more photosynthetic. Efficient partitioning of accumulated photosynthesis, enhanced yield attributes which ultimately increased the seed yield. Similar observations were noted by Delesa and Choferie (2015).

In case of the foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest seed yield (2089 kg ha⁻¹). Whereas application of water spray (F₁) gave the lowest seed yield (1806 kg ha⁻¹).

Interaction effects of nutrient managements and foliar spray on seed yield were found significant difference. The application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest seed yield (2325 kg ha⁻¹) than other treatments. The lowest seed yield (1695 kg ha⁻¹) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁).

Interaction effects of seed rate, nutrient managements and foliar spray on seeds yield were found significant and data are presented in Table 4.15. The interaction of application of seed rate 30 kg ha⁻¹ (S₂), RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) with foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest seed yield (2344 kg ha⁻¹) than other treatments. But it was found at par to interaction between applications of seed rate 25 kg ha⁻¹ X application of RDF + FYM placement in rows @ 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₁ X N₃ X F₃). The lowest seed yield (1533 kg ha⁻¹) was noted under applications of seed rate 25 kg ha⁻¹ X RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (S₁ X N₁ X F₁).

Table 4.13: Seed yield, stover yield and harvest index of linseed as influenced by different treatments

Treatment	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index (%)
Seed rate			
S ₁ 25 kg ha ⁻¹	1934	4340	45
S ₂ 30 kg ha ⁻¹	1971	4470	44
SE m±	21.11	63.28	0.92
CD (P=0.05)	NS	NS	NS
Nutrient Management			
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	1794	3978	45
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	1963	4351	46
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	2100	4885	43
SE m±	25.85	77.50	1.13
CD (P=0.05)	74.48	223.28	NS
Foliar spray			
F ₁ Water spray	1806	4022	45
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	1961	4420	45
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	2089	4772	44
SE m±	25.85	77.50	1.13
CD (P=0.05)	74.4	223.28	NS
Interaction			
	S	S	NS

Table 4.14: Interaction effect of nutrients and foliar spray on seed yield of linseed

Treatment	Seed yield (kg ha ⁻¹)			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	1695	1806	1881	1794
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	1850	1978	2062	1963
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	1873	2099	2325	2100
Mean	1806	1961	2090	
SE m±	44.78			
CD (P=0.05)	129.00			

Table 4.15: Interaction effect of seed rate, nutrients and foliar spray on seed yield of linseed

Treatment	Seed yield (kg ha ⁻¹)			
	Foliar spray			
	F1	F2	F3	Mean
Seed rate X Nutrient management				
S ₁ X N ₁ 25 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	1533	1881	1838	1751
S ₁ X N ₂ 25 kg ha ⁻¹ X RDF + Incorporation of FYM	1880	1927	2035	1948
S ₁ X N ₃ 25 kg ha ⁻¹ X RDF + FYM placement in rows	1910	2091	2306	2102
S ₂ X N ₁ 30 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	1858	1731	1923	1837
S ₂ X N ₂ 30 kg ha ⁻¹ X RDF + Incorporation of FYM	1820	2028	2089	1979
S ₂ X N ₃ 30 kg ha ⁻¹ X RDF + FYM placement in rows	1836	2107	2344	2096
Mean	1806	1961	2089	
SE m±	63.33			
CD (P=0.05)	182.44			

4.2.6 Stover yield (kg ha⁻¹)

Between seed rates, no significant difference was observed on stover yield. However, maximum stover yield was observed with the seed rate of 30 kg ha⁻¹. The data on stover yield as affected by different treatments are presented in Table 4.13.

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded significantly highest stover yield (4885 kg ha⁻¹). Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) gave the lowest stover yield (3978 kg ha⁻¹). The highest stover yield was recorded due to balance nutrient management and FYM placement in rows. These results corroborate with the findings of Meena *et al.* (2011).

As regards to foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) gave significantly highest stover yield (4772 kg ha⁻¹). Application of water spray (F₁) recorded the lowest stover yield (4022 kg ha⁻¹).

Interaction effects of nutrient managements and foliar spray on stover yield were found significant. The interaction of application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) with application of 2% urea at 15, 40, 65 and 90 DAS (F₃) gave significantly highest stover yield (5431 kg ha⁻¹) than other interactions. The lowest stover yield⁻¹ (3707 kg ha⁻¹) was noted under RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (N₁ X F₁).

Table 4.16: Interaction effect of nutrients and foliar spray on stover yield of linseed

Treatment	Stover yield (kg ha ⁻¹)			
	Foliar spray			
	F1	F2	F3	Mean
Nutrient management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	3707	3953	4273	3978
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	4130	4361	4562	4351
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	4229	4945	5431	4868
Mean	4022	4420	4755	
SE m±	134.24			
CD (P=0.05)	386.73			

4.2.6 Harvest index (%)

The data on harvest index for different treatments have been presented in Table 4.13. Harvest index is a measure of physiological productivity potential of crop. It is the ability of a plant to convert the dry matter into economic yield.

Between seed rates, no significant difference was observed on harvest index. However, maximum harvest index was observed with the seed rate of 25 kg ha⁻¹.

Among nutrient management, no significant difference was observed for harvest index. However, maximum harvest index was observed with the application of RDF + Incorporation of FYM @ 5 t ha⁻¹ (N₂). Application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded the lowest harvest index.

In case of foliar spray no significant effect was observed for harvest index. However, maximum harvest index was observed with foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂) and water spray (F₁). Application of foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) showed the lowest harvest index.

4.3 Chemical studies

4.3.1 NPK content (%) and uptake (kg ha⁻¹) by crop

Data regarding N, P, and K content (%) in seed and stover and N, P, and K uptake (kg ha⁻¹) by seed and stover at harvest are presented in Table 4.17, 4.18 and 4.19.

4.3.1.1 Nitrogen content (%) and uptake (kg ha⁻¹) by seed and stover

Between seed rates, no significant difference was found on N content and uptake by seed and stover. However, maximum nitrogen content and uptake was found with the application of seed rate 30 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows (N₃) gave significantly higher total uptake of nitrogen as compared to others. However, content of nitrogen in seed and stover was found non-significant.

Among the foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) gave significantly higher total uptake of nitrogen as compared to others. However, content of nitrogen in seed and stover was found non-significant.

4.3.1.2 Phosphorus content (%) and uptake (kg ha⁻¹) by seed and stover

It is clear from the table 4.18 that seed rates could not give significant difference on P content and uptake by seed and stover. However, maximum P content and uptake was found with the seed rate of 30 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) gave significantly higher total uptake of P as compared to others. Whereas, content of P in seed and stover was found non-significant.

Among foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest total uptake of P. However, it was statistically at par with the total uptake of P with the foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂). The content of P in seed and stover was found non-significant.

4.3.1.3 Potassium content (%) and uptake (kg ha⁻¹) by seed and stover

The data given in table 4.19 reveal that between seed rates, no significant effect was observed on K content and uptake by seed and stover. However, maximum K content and uptake was found with the application of seed rate of 30 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) recorded significantly higher total uptake of K as compared to others. However, content of K in seed and stover was found non-significant.

Among foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest total uptake of K. However, content of K in seed and stover was found non-significant.

Table 4.17: Nitrogen content in seed and stover and nitrogen uptake by linseed as influenced by different treatments

Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha ⁻¹)		Total uptake (kg ha ⁻¹) (seed+stover)
	Seed	Stover	Seed	Stover	
Seed rate					
S ₁ 25 kg ha ⁻¹	1.65	0.33	32.50	14.62	47.12
S ₂ 30 kg ha ⁻¹	1.67	0.34	33.07	15.24	48.32
SE m±	0.02	0.01	0.54	0.43	0.62
CD (P=0.05)	NS	NS	NS	NS	NS
Nutrient Management					
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	1.61	0.32	29.82	12.99	42.81
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	1.65	0.33	32.88	14.91	47.79
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	1.70	0.35	35.66	16.88	52.55
SE m±	0.02	0.01	0.66	0.52	0.75
CD (P=0.05)	NS	NS	1.91	1.51	2.18
Foliar spray					
F ₁ Water spray	1.64	0.33	30.53	12.99	44.60
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	1.66	0.33	32.96	14.91	47.57
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	1.67	0.34	34.87	16.88	50.99
SE m±	0.02	0.1	0.66	0.52	0.75
CD (P=0.05)	NS	NS	1.91	1.51	2.18
Interaction	NS	NS	NS	NS	NS

Table 4.18: Phosphorus content in seed and stover and phosphorus uptake by linseed as influenced by different treatments

Treatment	Phosphorus content (%)		Phosphorus uptake (kg ha ⁻¹)		Total uptake (kg ha ⁻¹) (seed+stover)
	Seed	Stover	Seed	Stover	
Seed rate					
S ₁ 25 kg ha ⁻¹	0.38	0.21	7.34	9.07	16.49
S ₂ 30 kg ha ⁻¹	0.40	0.22	7.83	9.67	17.50
SE m±	0.00	0.00	0.18	0.21	0.37
CD (P=0.05)	NS	NS	NS	NS	NS
Nutrient Management					
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	0.39	0.21	7.13	8.60	15.85
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	0.38	0.21	7.48	9.29	16.78
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	0.40	0.22	8.13	10.23	18.36
SE m±	0.00	0.00	0.22	0.26	0.46
CD (P=0.05)	NS	NS	0.65	0.76	1.33
Foliar spray					
F ₁ Water spray	0.37	0.20	6.88	8.33	15.33
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	0.39	0.21	7.75	9.78	17.53
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	0.40	0.22	8.12	10.00	18.13
SE m±	0.00	0.00	0.22	0.26	0.46
CD (P=0.05)	NS	NS	0.65	0.76	1.33
Interaction					
	NS	NS	NS	NS	NS

Table 4.19: Potassium content in seed and stover and potassium uptake by linseed as influenced by different treatments

Treatment	Potassium content (%)		Potassium uptake (kg ha ⁻¹)		Total uptake (seed+stover) (kg ha ⁻¹)
	Seed	Stover	Seed	Stover	
Seed rate					
S ₁	0.86	1.18	16.85	51.50	68.36
S ₂	0.94	1.19	18.50	53.14	71.27
SE m±	0.03	0.01	0.67	0.79	1.12
CD (P=0.05)	NS	NS	NS	NS	NS
Nutrient Management					
N ₁	0.87	1.17	15.80	46.80	62.61
N ₂	0.90	1.19	17.70	51.90	69.60
N ₃	0.92	1.19	19.53	58.26	77.24
SE m±	0.03	0.01	0.82	0.96	1.37
CD (P=0.05)	NS	NS	2.36	2.78	3.96
Foliar spray					
F ₁	0.88	1.17	16.04	48.25	64.30
F ₂	0.89	1.18	17.41	52.17	69.59
F ₃	0.93	1.19	19.59	56.54	75.57
SE m±	0.03	0.01	0.82	0.96	1.37
CD (P=0.05)	NS	NS	2.36	2.78	3.96
Interaction	NS	NS	NS	NS	NS

4.3.2 Oil analysis

4.3.2.1 Oil content (%) and oil yield (kg ha⁻¹)

The data on oil content (%) and oil yield (kg ha⁻¹) are presented in Table 4.20. Between seed rates, no significant difference was observed on oil content and oil yield of linseed. However, maximum content of oil was observed with the application seed rate of 30 kg ha⁻¹.

Among nutrient management, the application of RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) gave significantly highest oil content and oil yield *viz.* 39.53 %, 831.37 kg ha⁻¹ respectively. However oil content was statistically at par with the application of RDF + incorporation of FYM @ 5 t ha⁻¹ (N₂). Application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) recorded the lowest amount of oil content and oil yield *viz.* 37.35 %, 670.29 kg ha⁻¹, respectively, Meena *et al.* (2011) reported that oil yield, which was the product of seed yield and seed oil content, was found to increase significantly between 20 and 30 kg ha⁻¹ seed rate.

Among the foliar spray, application of 2% urea at 15, 40, 65 and 90 DAS (F₃) gave significantly highest amount of oil content and oil yield *viz.* 39.44 %, 824.85 kg ha⁻¹, respectively. However, oil content was found statistically at par with the application of foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂). Application of water spray (F₁) gave the lowest amount of oil content and oil yield *viz.* 37.36 %, 675.35 kg ha⁻¹, respectively.

Table 4.20: Oil content (%) and oil yield (kg ha^{-1}) of linseed as influenced by different treatments

Treatment	Oil content (%)	Oil yield (kg ha^{-1})
Seed rate		
S ₁ 25 kg ha^{-1}	38.33	743.40
S ₂ 30 kg ha^{-1}	39.69	763.91
SE $m \pm$	0.42	10.05
CD (P=0.05)	NS	NS
Nutrient Management		
N ₁ RDF (60:30:30 N:P:K kg ha^{-1})	37.35	670.29
N ₂ RDF + Incorporation of FYM @ 5 t ha^{-1}	38.66	759.30
N ₃ RDF + FYM placement in rows @ 5 t ha^{-1}	39.53	831.37
SE $m \pm$	0.52	12.31
CD (P=0.05)	1.51	35.46
Foliar spray		
F ₁ Water spray	37.36	675.35
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	38.73	760.77
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	39.44	824.85
SE $m \pm$	0.52	12.31
CD (P=0.05)	1.51	35.46
Interaction	NS	NS

4.4. Economic analysis

Economics is the final criteria to evaluate the best treatment which are economically sound and that can be accepted by the farming community. A simple economic analysis such as cost of cultivation, gross return, net return and benefit-cost ratio for linseed for different seed rate, nutrient management, foliar spray and their interaction effect are shown in Table 4.21, 4.22, 4.23 and 4.24, respectively.

Between seed rates, use of 30 kg ha⁻¹ (S₂) had more cost (₹ 22947 ha⁻¹) towards linseed production than seed rate of 25 kg ha⁻¹ (S₁) (₹ 22647 ha⁻¹), this might be due to higher price with higher quantity of seed cost hence, higher cost of cultivation was observed with the application of 30 kg ha⁻¹ seed rate.

Among nutrient management, RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) incurred more cost (₹ 24497 ha⁻¹) towards linseed production followed by RDF + incorporation of FYM @ 5 t ha⁻¹ (N₂) (₹ 23897 ha⁻¹). It is because of higher cost of FYM and labour imposed on placement in rows. The lower cost on production (₹ 19997 ha⁻¹) was recorded with the application of in RDF (N₁) treatment. The treatment RDF + FYM placement in rows (N₃) gave the highest gross return (₹ 93045 ha⁻¹), net return (₹ 68548 ha⁻¹) but the application of RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) incurred low cost of cultivation (₹ 19997 ha⁻¹), which have low gross return (₹ 79325 ha⁻¹), net return (₹ 59328 ha⁻¹) but they gave high benefit-cost ratio (3.98). It is because due to no cost of FYM and labour imposed on it.

Among the foliar spray, application of 2 % urea at 15, 40, 65 and 90 DAS (F₃) incurred low cost of cultivation (₹ 22012 ha⁻¹), and gave the highest gross return (₹ 92514 ha⁻¹), net return (₹ 70502 ha⁻¹) and highest benefit-cost ratio (4.21). This was followed by foliar application of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (F₂), gross return (₹ 86775 ha⁻¹) and net return (₹ 62122 ha⁻¹), but application of water spray (F₁) which had lowest gross return (₹ 79891 ha⁻¹) and net return (₹ 58163 ha⁻¹) gave highest benefit-cost ratio (3.69) compared to foliar spray of nitrobenzene (3.53) due to high cost of nitrobenzene as compared to water spray.

Table 4.21: Economics of linseed as influenced by different treatments

Treatment	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	Benefit: cost Ratio
Seed rate				
S ₁ 25 kg ha ⁻¹	22647	85550	62903	3.79
S ₂ 30 kg ha ⁻¹	22947	87236	64288	3.82
SE m±	-	881	881	0.04
CD (P=0.05)	-	NS	NS	NS
Nutrient Management				
N ₁ RDF (60:30:30 N:P:K kg ha ⁻¹)	19997	79325	59328	3.98
N ₂ RDF + Incorporation of FYM @ 5 t ha ⁻¹	23897	86808	62911	3.64
N ₃ RDF + FYM placement in rows @ 5 t ha ⁻¹	24497	93045	68548	3.81
SE m±	-	1079	1079	0.05
CD (P=0.05)	-	3108	3108	0.14
Foliar spray				
F ₁ Water spray	21728	79891	58163	3.69
F ₂ Foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS	24653	86775	62122	3.53
F ₃ Foliar spray of 2% urea at 15, 40, 65 and 90 DAS	22012	92514	70502	4.21
SE m±	-	1079	1079	0.05
CD (P=0.05)	-	3108	3108	0.14
Interaction	-	S	S	S
□ Marketable price: seed = ₹ 4200 q ha ⁻¹ and stover = 100 kg ha ⁻¹				

Interaction effects of seed rates, nutrient managements and foliar spray on gross return were found significant. The interaction among seed rate 30 kg ha⁻¹ (S₂) X RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher gross return (₹ 104045 ha⁻¹) than others. But it was found at par to interaction among applications of seed rate 25 kg ha⁻¹ X application of RDF + FYM placement in rows @ 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₁ X N₃ X F₃). The lowest gross return (₹ 67997 ha⁻¹) was noted under interaction among applications of seed rate 25 kg ha⁻¹ X RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (S₁ X N₁ X F₁).

Table 4.22: Interaction effect of seed rate, nutrients and foliar spray on gross return (₹ ha⁻¹) of linseed

Treatment	Gross return (₹ ha ⁻¹)				
	Foliar spray			Mean	
	F1	F2	F3		
Seed rate X Nutrient management					
S ₁ X N ₁	25 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	67997	82929	81481	77469
S ₁ X N ₂	25 kg ha ⁻¹ X RDF + Incorporation of FYM	83064	85255	89938	86085
S ₁ X N ₃	25 kg ha ⁻¹ X RDF + FYM placement in rows	84473	92620	102197	93097
S ₂ X N ₁	30 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	81834	76671	85042	81182
S ₂ X N ₂	30 kg ha ⁻¹ X RDF + Incorporation of FYM	80624	89588	92381	87531
S ₂ X N ₃	30 kg ha ⁻¹ X RDF + FYM placement in rows	81349	93588	104045	92994
Mean		79890	86775	92514	
SE m±		2642.60			
CD (P=0.05)		7612.68			

Interaction effects of seed rates, nutrient managements and foliar spray on net return were found significant. The interaction among seed rate 30 kg ha⁻¹ (S₂) X RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly higher gross return (₹ 80183 ha⁻¹) than others. But it was found at par to interaction among applications of seed rate 25 kg ha⁻¹ X application of RDF + FYM placement in rows @ 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₁ X N₃ X F₃). The lowest net return (₹ 49219 ha⁻¹) was noted under interaction among applications of seed rate 25 kg ha⁻¹ X RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (S₁ X N₁ X F₁).

Table 4.23: Interaction effect of seed rate, nutrients and foliar spray on net return (₹ ha⁻¹) of linseed

Treatment	Net return (₹ ha ⁻¹)				
	Foliar spray				
	F1	F2	F3	Mean	
Seed rate X Nutrient management					
S ₁ X N ₁	25 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	49219	61227	62419	57622
S ₁ X N ₂	25 kg ha ⁻¹ X RDF + Incorporation of FYM	60386	59652	66976	62338
S ₁ X N ₃	25 kg ha ⁻¹ X RDF + FYM placement in rows	61195	66417	78636	68749
S ₂ X N ₁	30 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	62756	54668	65680	61035
S ₂ X N ₂	30 kg ha ⁻¹ X RDF + Incorporation of FYM	57647	63685	69119	63484
S ₂ X N ₃	30 kg ha ⁻¹ X RDF + FYM placement in rows	57772	67086	80183	68347
Mean		58163	62122	70502	
SE m±		2642.60			
CD (P=0.05)		7612.68			

Interaction effects of seed rate, nutrient managements and foliar spray on benefit-cost ratio were found significant. The interaction among seed rate 30 kg ha⁻¹ (S₂) X RDF 60:30:30 N:P:K kg ha⁻¹ (N₁) X application of 2% urea at 15, 40, 65 and 90 DAS (F₃) recorded significantly highest benefit-cost ratio (4.39) than other interactions. But it was found at par to interaction among applications of seed rate 30 kg ha⁻¹ X application of RDF + FYM placement in rows @ 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₂ X N₃ X F₃), applications of seed rate 25 kg ha⁻¹ X application of RDF + FYM placement in rows @ 5 t ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₁ X N₃ X F₃), applications of seed rate 30 kg ha⁻¹ X RDF 60:30:30 N:P:K kg ha⁻¹ X water spray (S₂ X N₁ X F₁) and applications of seed rate 25 kg ha⁻¹ X RDF 60:30:30 N:P:K kg ha⁻¹ X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (S₁ X N₁ X F₃). The lowest benefit-cost ratio (3.33) was noted under interaction among applications of seed rate 25 kg ha⁻¹ X application of RDF + Incorporation of FYM @ 5 t ha⁻¹ X foliar spray of 0.06% Nitrobenzene at 15, 40, 65 and 90 DAS (S₁ X N₂ X F₂).

Table 4.24: Interaction effect of seed rate, nutrients and foliar spray on benefit: cost ratio of linseed

Treatment	Benefit: cost ratio			
	Foliar spray			
	F1	F2	F3	Mean
Seed rate X Nutrient management				
S ₁ X N ₁ 25 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	3.62	3.82	4.27	3.91
S ₁ X N ₂ 25 kg ha ⁻¹ X RDF + Incorporation of FYM	3.66	3.33	3.92	3.64
S ₁ X N ₃ 25 kg ha ⁻¹ X RDF + FYM placement in rows	3.63	3.53	4.34	3.83
S ₂ X N ₁ 30 kg ha ⁻¹ X RDF (60:30:30 N:P:K kg ha ⁻¹)	4.29	3.48	4.39	4.06
S ₂ X N ₂ 30 kg ha ⁻¹ X RDF + Incorporation of FYM	3.51	3.46	3.97	3.65
S ₂ X N ₃ 30 kg ha ⁻¹ X RDF + FYM placement in rows	3.45	3.53	4.36	3.78
Mean	3.69	3.53	4.21	
SE m±	0.12			
CD (P=0.05)	0.35			



Plate I : A view of experimental field from initial to flowering stage

(Rabi 2015-16)



Plate II : A view of experimental field from peak flowering to maturity stage (*Rabi 2015-16*)

CHAPTER – V

SUMMARY AND CONCLUSIONS

The experimental findings obtained from the present investigation “**Yield maximization of Linseed (*Linum usitatissimum* L.) through different agro-techniques in Chhattisgarh plains**” was carried out during *rabi* season of 2015-16 at the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyala, Raipur. The experiment was laid out in factorial randomized block design with three replications and eighteen treatments. The treatment comprised of two seed rate *viz.* 25 kg ha⁻¹ (S₁), 30 kg ha⁻¹ (S₂), and three nutrient management *viz.* RDF 60:30:30 N:P:K kg ha⁻¹ (N₁), RDF + Incorporation of FYM @ 5 t ha⁻¹ (N₂) and RDF + FYM placement in rows @ 5 t ha⁻¹ (N₃) and three foliar spray *viz.* water spray (F₁), foliar spray of Nitrobenzene @ 0.06% at 15, 40, 65 and 90 DAS (F₂) and foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F₃).

The soil of the experimental field was clayey in texture (*Vertisols*) with low N, medium P and high K content. Climate of the region receives an average annual rainfall of 1200-1400 mm, mostly (85%) precipitated during the period of June to September. A few showers are expected during winters and occasionally during summer months. May is the hottest and December is the coolest month of the year. The weekly maximum temperature raised up to 46°C during summer and minimum temperature reaches as low as to 6°C during winter season. The atmospheric humidity is relatively high during the months of June to October.

The objective of experiment were (i) To find out appropriate quantity of seed for obtaining optimum growth and productivity of linseed, (ii) To evaluate the performance of FYM under different nutrient management practices on growth and productivity of linseed, (iii) To study the foliar response of nutrient on growth and yield of linseed and (iv) To work out the economics of linseed as influenced by different treatments.

Pre-harvest observations like plant population, plant height plant⁻¹, number of primary branches plant⁻¹, secondary branches plant⁻¹, dry matter accumulation (g

plant⁻¹), and post-harvest observations like- number of capsule plant⁻¹, number of seeds capsule⁻¹, number of seeds plant⁻¹, test weight (g), seed yield (kg ha⁻¹) and stover yield (kg ha⁻¹) were recorded and statistically analysed. The statistical analysis were done NPK content seed and stover, oil content and oil yield in seed after harvest of the crop and economics were also worked out.

The results of investigation are highlighted below:

- No significant difference was observed with the application of seed rates, nutrient managements and foliar applications on the plant population at the initial and at harvest stage.
- Between seed rates, no significant difference was observed on plant height. Among nutrient management, application of RDF + FYM placement in rows (N₃) and in case of foliar spray, application of urea 2% (F₃) gave significantly highest plant height.
- Between seed rates, no significant difference was observed on primary and secondary branches. Among nutrient management, application of RDF + FYM placement in rows (N₃) and among foliar spray, application of urea 2% (F₃) gave significantly highest primary and secondary branches plant⁻¹.
- Interaction among RDF + FYM placement in rows (N₃) X foliar application of urea 2% (F₃) recorded significantly maximum number of primary branches plant⁻¹ than other interactions. But it was found at par to interaction among N₃ X F₂.
- Interaction among RDF + FYM placement in rows (N₃) X foliar application of 2% urea (F₃) recorded significantly higher number of secondary branches plant⁻¹ than other interactions.
- Between seed rates, no significant difference was observed on dry matter accumulation. Among nutrient management, application of RDF + FYM placement in rows (N₃) and among foliar spray, application of urea 2% (F₃) gave significantly more dry matter accumulation.

- Interaction among RDF + FYM placement in rows (N_3) X foliar application of urea 2% (F_3) recorded significantly higher dry matter accumulation plant^{-1} than other interactions.
- Between seed rates, no significant difference was observed on capsules plant^{-1} . Among nutrient management, application of RDF + FYM placement in rows (N_3) and in case of foliar spray, application of urea 2% (F_3) gave significantly more capsules plant^{-1} .
- Interaction among RDF + FYM placement in rows (N_3) X foliar application of urea 2% (F_3) gave significantly higher capsules plant^{-1} than other interactions. But it was found at par to interaction among N_3 X F_2 , N_2 X F_3 and N_2 X F_2 .
- Between seed rates, no significant difference was observed on seeds capsule⁻¹. Among nutrient management, application of RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) gave significantly more seeds capsule⁻¹.
- Interaction among RDF + FYM placement in rows (N_3) X foliar application of urea 2% (F_3) recorded significantly highest seeds capsule⁻¹ than other interactions. But it was found at par to interactions among N_3 X F_2 , and N_2 X F_3 .
- Between seed rates, no significant difference was observed on seeds plant^{-1} . Among nutrient management, application of RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) gave significantly more seeds plant^{-1} .
- Interaction among RDF + FYM placement in rows (N_3) X foliar application of urea 2% (F_3) produced significantly highest seeds plant^{-1} than other interactions. But it was found at par to interactions among N_3 X F_2 , and N_2 X F_3 .

- No significant difference was observed with the application of seed rates, nutrient managements and foliar applications on test weight (g).
- Between seed rates, no significant difference was observed on seed yield. Among nutrient management, application of RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) gave significantly more seed yield¹.
- Interaction among seed rate 30 kg ha⁻¹ (S_2) X RDF + FYM placement in rows (N_3) X foliar application of 2% urea (F_3) gave significantly highest seed yield than other interactions. But it was found at par to interaction among seed rate 25 kg ha⁻¹ (S_1) X RDF + FYM placement in rows @ 5 t ha⁻¹ (N_3) X foliar spray of 2% urea at 15, 40, 65 and 90 DAS (F_3) (S_1 X N_3 X F_3). The lowest seed yield was noted under interaction among seed rate 25 kg ha⁻¹ (S_1) X RDF 60:30:30 N:P:K kg ha⁻¹ (N_1) X water spray (F_1) (S_1 X N_1 X F_1).
- Between seed rates, no significant difference was observed on stover yield. Among nutrient management, application of RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) gave significantly more stover yield.
- Interaction among RDF + FYM placement in rows (N_3) X foliar application of urea 2 % (F_3) gave significantly higher stover yield than other interactions. The lowest stover yield was noted under interaction among RDF 60:30:30 N:P:K kg ha⁻¹ (N_1) X water spray (F_1) (N_1 X F_1).
- No significant difference was observed with the application of seed rates, nutrient managements and foliar applications on harvest index.
- No significant difference was observed with the application of seed rates, nutrient managements and foliar applications on N, P, and K content in seed and stover.
- Between seed rates, no significant difference was observed on N, P and K uptake by seed and stover. Among nutrient management, application of

RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) recorded significantly more total uptake of N, P and K.

- Between seed rates, no significant difference was observed on oil content and oil yield of linseed. Among nutrient management, application of RDF + FYM placement in rows (N_3) and among foliar spray, application of urea 2% (F_3) gave significantly more oil content and oil yield.
- Interaction among seed rate 30 kg ha^{-1} (S_2) X RDF + FYM placement in rows (N_3) X foliar application of 2% urea (F_3) ($S_2 \times N_3 \times F_3$) recorded significantly higher gross return than other interactions. But it was found at par to interaction among seed rate 25 kg ha^{-1} (S_1) X application of RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) X foliar application of 2% urea at 15, 40, 65 and 90 DAS (F_3) ($S_1 \times N_3 \times F_3$). The lowest gross return was noted under interaction among seed rate 25 kg ha^{-1} (S_1) X RDF 60:30:30 N:P:K kg ha^{-1} (N_1) X water spray (F_1) ($S_1 \times N_1 \times F_1$).
- Interaction among seed rate, nutrient managements and foliar spray on net return were found significant. The application of seed rate 30 kg ha^{-1} (S_2) X RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) X foliar application of 2% urea at 15, 40, 65 and 90 DAS (F_3) ($S_2 \times N_3 \times F_3$) recorded higher net return than other interaction. However, it was found at par to interaction among applications of seed rate 25 kg ha^{-1} (S_1) X application of RDF + FYM placement in rows @ 5 t ha^{-1} (N_3) X foliar application of 2% urea at 15, 40, 65 and 90 DAS (F_3) ($S_1 \times N_3 \times F_3$). The lowest net return was noted under interaction among seed rate 25 kg ha^{-1} (S_1) X RDF 60:30:30 N:P:K kg ha^{-1} (N_1) X water spray (F_1) ($S_1 \times N_1 \times F_1$).

- **CONCLUSIONS**

On the basis of results obtained, it can be concluded that

- Seed yield of linseed was recorded maximum when crop was sown with higher seed rate i.e. 30 kg ha^{-1} and applied with RDF + FYM placement in rows combined with foliar application of 2% urea.
- In terms of economics the maximum Benefit: Cost ratio was obtained with interaction among seed rate 30 kg ha^{-1} (S_2) X RDF 60:30:30 N:P:K kg ha^{-1} (N_1) X application of 2% urea at 15, 40, 65 and 90 DAS (F_3) gave significantly highest benefit-cost ratio than other ($S_2 \times N_1 \times F_3$).

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APPENDIX - A

Table : Weekly meteorological data during crop growth period (22 Nov 2015 to 12 March 2016)

Week	Date	Temperature (°C)		Rainfall (mm)	Rainy Days	Relative Humidity (%)		Vapour Pressure (mm)		Wind velocity (Kmph)	Evaporation (mm day ⁻¹)	Sunshine (hour day ⁻¹)
		Max.	Min.			I	II	I	II			
47	22-28 Nov	31.1	15.8	0.0	0	88.8	35.8	12.7	11.6	2.2	3.1	8.3
48	29-5 Dec	32.1	17.8	0.0	0	86.7	35.9	14.2	12.3	2.7	3.2	7.3
49	6-12 Dec	30.9	13.8	0.0	0	87.9	35.1	11.2	10.2	2.2	2.8	8.0
50	13-19 Dec	28.5	17.3	4.4	2	75.4	46.1	12.1	12.5	3.1	2.6	1.5
51	20-26 Dec	26.0	14.9	9.4	2	85.7	51.3	11.9	12.4	3.3	2.2	2.4
52	27-2 Jan	29.8	11.0	0.0	0	87.4	25.1	9.1	7.6	1.8	2.8	8.7
1	3-9 Jan	29.9	11.9	0.0	0	83.0	27.0	9.4	8.1	2.1	2.8	6.7
2	10-16 Jan	29.1	11.3	0.0	0	85.7	28.4	9.1	8.2	2.7	3.2	8.2
3	17-23 Jan	25.9	12.5	2.0	1	90.7	44.9	10.5	11.0	3.6	2.6	4.5
4	24-30 Jan	28.6	10.5	0.0	0	89.7	34.3	9.1	10.2	2.4	3.1	8.5
5	31-6 Feb	31.9	13.8	0.0	0	79.0	28.3	9.9	9.6	2.9	3.9	9.3
6	7-13 Feb	31.5	16.1	0.0	0	78.3	37.4	11.5	12.5	3.1	4.1	7.8
7	14-20 Feb	33.6	19.0	0.3	1	80.7	34.7	14.2	13.0	2.9	4.0	6.2
8	21-27 Feb	34.4	20.5	0.0	0	71.9	37.6	14.1	13.5	3.8	4.6	4.9
9	28-5 Mar	31.6	20.6	0.0	0	81.0	41.5	16.2	14.3	3.0	3.5	0.5
10	6-12 Mar	32.0	20.7	0.0	0	82.1	45.0	18.0	15.0	3.5	4.2	3.2
Average		30.4	15.5			83.4	36.8	12.1	11.4	2.8	3.3	6.0
Total				16.1	6							

APPENDIX - B

Table : Fixed cost of linseed cultivation

S. No.	Particulars	Input	Price (Rs)	Total cost (Rs ha ⁻¹)
1.	Land preparation			
a.	Deep ploughing	1 tractor (1 hrs) ha ⁻¹	750 ₹ hrs ⁻¹	750
b.	Harrowing	1 tractor (2 hrs) ha ⁻¹	600 ₹ hrs ⁻¹	1200
c.	Planking	1 tractor (1 hrs) ha ⁻¹	600 ₹ hrs ⁻¹	600
2.	Sowing			
a.	Carbendazim	3 g kg ⁻¹ seed	11.30 ₹ g ⁻¹	34
b.	Seed treatment and sowing	4 man days	200 ₹ man day ⁻¹	800
3.	Fertilizer			
a.	Urea	130.2	5.68 ₹ kg ⁻¹	740
b.	SSP	187.5 kg ha ⁻¹	7.20 ₹ kg ⁻¹	1350
c.	MOP	50.1 kg ha ⁻¹	17.86 ₹ kg ⁻¹	894
d.	fertilizer application	1 man days	200 ₹ man day ⁻¹	200
4.	Irrigation			
a.	No. of irrigation	2 irrigation	900 ₹ irrigation	1800
b.	Labour cost	3 man day	600 ₹ man day ⁻¹	600
5.	Weeding			
a.	Metsulfuron-methyl	2.5 packet	110 ₹ packet ⁻¹	275
b.	Application cost	1 man days	200 ₹ man day ⁻¹	200
c.	Hand weeding	11 man days	200 ₹ man day ⁻¹	2200
6.	Harvesting	10 man days	200 ₹ man day ⁻¹	2000
7.	Threshing and winnowing	6 man days	200 ₹ man day ⁻¹	1200
8.	Common cast	Land revenue	500 ₹ ha ⁻¹	500
A.	Total cost			
B.	Miscellaneous	10 % common cost		1534
	Grand Total(A+B)			16877

₹ = Rupees, ha⁻¹ = Hectare, hrs⁻¹ = Per hour, g = Gram, kg⁻¹ = Per kilogram, % = Percent.

APPENDIX - C

Table : Variable cost of linseed cultivation

S.No.	Particulars	Input	Price (Rs)	Cost (₹ ha ⁻¹)	Total cost (₹ ha ⁻¹)
1.	Seed rate				
A.	S1-25 kg ha ⁻¹	25	60 kg ha ⁻¹	1500	1500
B.	S2- 30 kg ha ⁻¹	30	60 kg ha ⁻¹	1800	1800
2.	Nutrient management				
A.	N1- only RDF	-	-	-	-
B.	a. N2- RDF + FYM incorporation	5	700 ₹ t ⁻¹	3500	3500
	b. Labour cost	2	200 Rs man day ⁻¹	400	400
C.	a. N3- RDF + FYM row placement	5	700 ₹ t ⁻¹	3500	3500
	b. Labour cost	5	200 ₹ man day ⁻¹	1000	1200
3.	Foliar spray				
A.	a. F1- water spray				
	b. Labour cost	2	200 ₹ man day ⁻¹	400	400
B.	a. F2- Nitrobenzene spray	7.5	390 ₹ ha ⁻¹	2925	2925
	b. Labour cost	2	200 ₹ man day ⁻¹	400	400
C.	a. Urea spray	50	5.68 kg ha ⁻¹	284	284
	b. Labor cost	2	200 ₹ man day ⁻¹	400	400

APPENDEX - DTable : Total cost of cultivation as per treatment combination (₹ ha⁻¹)

Treatment combination	Fixed Cost (X)	Variable Cost (Y)	Total Cost (X+Y)
S ₁ N ₁ F ₁	20510	3100	23610
S ₁ N ₁ F ₂	20510	6025	26535
S ₁ N ₁ F ₃	20510	3384	23894
S ₁ N ₂ F ₁	20510	7000	27510
S ₁ N ₂ F ₂	20510	9925	30435
S ₁ N ₂ F ₃	20510	7284	27794
S ₁ N ₃ F ₁	20510	7800	28310
S ₁ N ₃ F ₂	20510	10725	31235
S ₁ N ₃ F ₃	20510	8084	28594
S ₂ N ₁ F ₁	20510	3400	23910
S ₂ N ₁ F ₂	20510	6325	26835
S ₂ N ₁ F ₃	20510	3684	24194
S ₂ N ₂ F ₁	20510	7300	27810
S ₂ N ₂ F ₂	20510	10225	30735
S ₂ N ₂ F ₃	20510	7584	28094
S ₂ N ₃ F ₁	20510	8100	28610
S ₂ N ₃ F ₂	20510	11025	31535
S ₁ N ₁ F ₁	20510	8384	28894

ANOVA TABLE

Plant population at 20 DAS

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	339.853	169.927	0.198
Seed rate (s)	1	2166.279	2166.279	2.526
Nutrient (n)	2	936.565	468.283	0.546
I(s x n)	2	1641.868	820.934	0.957
Foliar (f)	2	20.584	10.292	0.012
I(s x f)	2	309.111	154.555	0.180
(n x f)	4	2909.389	727.347	0.848
(S x n x f)	4	490.180	122.545	0.143
Error	34	29163.196	857.741	
Total	53	37977.024		

Plant population at harvest

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	449.914	224.957	0.284
Seed rate (s)	1	1788.752	1788.752	2.260
Nutrient (n)	2	1094.377	547.188	0.691
I(s x n)	2	1035.149	517.575	0.654
Foliar (f)	2	86.870	43.435	0.055
I(s x f)	2	255.426	127.713	0.161
(n x f)	4	3509.329	877.332	1.108
(S x n x f)	4	471.445	117.861	0.149
Error	34	26910.177	791.476	
Total	53	35601.439		

Plant height (cm) at harvest

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	11.811	5.905	0.316
Seed rate (s)	1	8.560	8.560	0.459
Nutrient (n)	2	247.805	123.902	6.638
I(s x n)	2	2.546	1.273	0.068
Foliar (f)	2	202.614	101.307	5.427
I(s x f)	2	4.551	2.275	0.122
(n x f)	4	25.150	6.287	0.337
(S x n x f)	4	8.695	2.174	0.116
Error	34	634.676	18.667	
Total	53	1146.407		

Primary branches plant⁻¹ (No.) at harvest

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	0.087	0.044	1.053
Seed rate (s)	1	0.056	0.056	1.351
Nutrient (n)	2	0.897	0.448	10.804
I(s x n)	2	0.243	0.122	2.932
Foliar (f)	2	1.001	0.501	12.066
I(s x f)	2	0.070	0.035	0.848
(n x f)	4	0.444	0.111	2.678
(S x n x f)	4	0.079	0.020	0.474
Error	34	1.411	0.041	
Total	53	4.289		

Secondary branches plant⁻¹ (No.) at harvest

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	1.995	0.997	0.733
Seed rate (s)	1	1.206	1.206	0.886
Nutrient (n)	2	99.867	49.934	36.684
I(s x n)	2	0.727	0.363	0.267
Foliar (f)	2	124.732	62.366	45.818
I(s x f)	2	1.267	0.633	0.465
(n x f)	4	14.525	3.631	2.668
(S x n x f)	4	1.101	0.275	0.202
Error	34	46.280	1.361	
Total	53	291.699		

Capsules plant⁻¹ (No.)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	0.280	0.140	0.008
Seed rate (s)	1	44.282	44.282	2.451
Nutrient (n)	2	556.971	278.486	15.412
I(s x n)	2	27.803	13.902	0.769
Foliar (f)	2	1078.074	539.037	29.831
I(s x f)	2	18.763	9.382	0.519
(n x f)	4	285.251	71.313	3.947
(S x n x f)	4	44.430	11.108	0.615
Error	34	614.366	18.070	
Total	53	2670.221		

Seeds capsule⁻¹ (No.)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	0.161	0.080	0.565
Seed rate (s)	1	0.061	0.061	0.427
Nutrient (n)	2	1.143	0.572	4.025
I(s x n)	2	0.008	0.004	0.028
Foliar (f)	2	1.699	0.850	5.983
I(s x f)	2	0.015	0.008	0.054
(n x f)	4	1.584	0.396	2.788
(S x n x f)	4	0.222	0.056	0.392
Error	34	4.828	0.142	
Total	53	9.722		

Seeds plant⁻¹ (No.)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	424.008	212.004	0.202
Seed rate (s)	1	3699.008	3699.008	3.533
Nutrient (n)	2	40490.135	20245.06	19.337
I(s x n)	2	1025.914	512.957	0.490
Foliar (f)	2	74720.267	37360.134	35.684
I(s x f)	2	531.137	265.569	0.254
(n x f)	4	20924.789	5231.197	4.997
(S x n x f)	4	3970.118	992.530	0.948
Error	34	35596.925	1046.968	
Total	53	181382.301		

1000 seed weight (g)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	0.105	0.052	0.381
Seed rate (s)	1	0.042	0.042	0.303
Nutrient (n)	2	0.567	0.284	2.059
I(s x n)	2	0.034	0.017	0.125
Foliar (f)	2	0.885	0.442	3.213
I(s x f)	2	0.001	0.001	0.004
(n x f)	4	0.907	0.227	1.647
(S x n x f)	4	0.278	0.069	0.504
Error	34	4.682	0.138	
Total	53	7.501		

Seed yield (kg ha⁻¹)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	1364.600	682.300	0.057
Seed rate (s)	1	18516.296	18516.296	1.539
Nutrient (n)	2	840894.805	420447.403	34.943
I(s x n)	2	19875.302	9937.651	0.826
Foliar (f)	2	721419.315	360709.657	29.978
I(s x f)	2	15776.541	7888.270	0.656
(n x f)	4	130136.235	32534.059	2.704
(S x n x f)	4	185020.982	46255.245	3.844
Error	34	409104.031	12032.472	
Total	53	2342108.107		

Stover yield (kg ha⁻¹)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	317218.481	158609.241	1.467
Seed rate (s)	1	228020.019	228020.019	2.109
Nutrient (n)	2	7489180.037	3744590.019	34.629
I(s x n)	2	26978.259	13489.130	0.125
Foliar (f)	2	5064900.926	2532450.463	23.419
I(s x f)	2	15776.704	7888.352	0.073
(n x f)	4	1193459.519	298364.880	2759
(S x n x f)	4	97667.519	24416.880	0.226
Error	34	3676598.185	108135.241	
Total	53	18109799.648		

Harvest index (HI)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F calculated value
Replication	2	35.539	17.770	0.770
Seed rate (s)	1	5.776	5.776	0.250
Nutrient (n)	2	57.421	28.710	1.244
I(s x n)	2	29.486	14.743	0.639
Foliar (f)	2	5.286	2.643	0.115
I(s x f)	2	16.895	8.447	0.366
(n x f)	4	26.252	6.563	0.284
(S x n x f)	4	93.309	23.327	1.011
Error	34	784.438	23.072	
Total	53	1054.402		

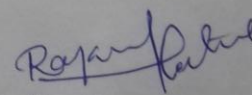
RESUME

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Academic Qualifications:

Degree	Year	University/Institute
High School	2006	CGBSE, Raipur
Higher Secondary	2008	CGBSE, Raipur
B.Sc. (Ag.)	2014	IGKV, Raipur (C.G.)
M.Sc. (Ag.) Agronomy	2016	IGKV, Raipur (C.G.)

Professional Experience (If any) : RAWE (Rural Agricultural Work Experience Programme)
Membership of Professional Societies (If any) : Nil
Awards / Recognitions (If any) : Nil
Publications (If any) :


Signature