PERFORMANCE OF LINSEED (*Linum usitatissimum* L.) VARIETIES UNDER DIFFERENT NUTRIENT MANAGEMENT PRACTICES

THESIS

By

NITIN SOOD
(A-2018-30-021)

Submitted to

CHAUDHARY SARWAN KUMAR HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA PALAMPUR – 176 062 (H.P.) INDIA

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CERTIFICATE – I

This is to certify that the thesis entitled **"Performance of linseed (*Linum usitatissimum* L.) varieties under different nutrient management practices"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Agronomy,** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Nitin Sood (Admission No. A-2018-30-021)** son of **Shri Sudesh Kumar Sood** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place: Palampur
Dated: 18th November, 2020

(Dr. Pankaj Chopra)
Major Advisor

CERTIFICATE- II

This is to certify that the thesis entitled **"Performance of linseed (*Linum usitatissimum* L.) varieties under different nutrient management practices"** submitted by **Nitin Sood (A-2018-30-021)** son of **Shri Sudesh Kumar Sood** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Agronomy** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Needless to mention, errors and omissions are mine.

Place : Palampur ***(Nitin Sood)***
Dated : 18th November, 2020

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LIST OF ABBREVIATIONS USED

Abbreviation	Meaning	Abbreviation	Meaning
BC ratio	Benefit-cost ratio	m^2	Square meter
CFU	Colony forming unit	µg	Microgram
cm	Centimeter	NF	Natural Farming
^{0}C	Degree Celsius	NMR	Net marginal returns
DAS	Days after sowing	N	Nitrogen
et al.	et alii (and other)	No.	Number
Fig.	Figure	*viz.*	Namely
FYM	Farm yard manure	OC	Organic Carbon
gm	Gram	PSB	Phosphorus solubilising bacteria
GMR	Gross marginal returns	P	Phosphorus
ha	Hectare	%	Per cent
i.e	id est (that is)	/	Per
INM	Integrated nutrient management	pH	Potential of hydrogen
K	Potassium	Q	Quintal
kg	Kilogram	RDN	Recommended dose of nutrients
kg/ha	Kilogram per hectare	₹/ha	Rupees per hectare
L	Litre	VC	Vermicompost

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ABSTRACT

To find out the suitable variety of linseed for achieving higher productivity and profitability under different nutrient management practices, a field experiment was conducted during *Rabi* 2018-19 at Palampur. Twelve treatments comprising of four nutrient management practices (*viz.* Inorganic (RDF), Organic, Natural and Integrated Nutrient Management) in main plots and three varieties (*viz*. 'Him Palam Alsi-2', 'Himani' and 'Priyam') in sub plots were evaluated in Split Plot Design with three replications. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.9) and medium in available nitrogen (243.3 kg/ha), phosphorus (24.7 kg/ha) and potassium (145.4 kg/ha). Results, revealed that among different nutrient management practices, Integrated Nutrient Management being at par with inorganic practice resulted in significantly taller plants with more dry matter, yield attributes, higher uptake of nutrients and thereby higher yield (1184 kg/ha) with highest net return of ₹21935/ha. However, INM practice has significant advantage over inorganic practice for enhancing microbial count and other soil properties with 7.53 per cent increase in yield. Among varieties, 'Him Palam Alsi-2' has significantly more dry matter, number of primary branches, capsules/plant, higher uptake of NPK and superseded all other varieties with significantly highest yield (1169 kg/ha) and maximum net return (₹20567/ha). Soil properties were not influenced by different varieties. In integration, variety 'Him Palam Alsi-2' sown under integrated nutrient management practice resulted in significantly higher seed yield (1297 kg/ha) and net return of ₹26429/ha. Thus 'Him Palam Alsi-2' along with INM may be recommended for higher sustainable yield of linseed.

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1. INTRODUCTION

Linseed [*Linum usitatissimum* (L.)] occupies a greater importance among oilseeds, owing to its various uses and special qualities. It is a food and fiber crop. The oil crushed from the seeds can either be used for industrial or edible purposes, depending on the fatty acid composition. Linseed is becoming increasingly popular as a nutritional and functional food. Recent advances in medical research have found linseed as best herbal source of Omega-3 fatty acid (α-linolenic acid) and lignan which have immense nutritional/medicinal effect on human body system (Touré and Xueming 2010). In addition, edible linseed oil used for human consumption has high content of other health promoting substances such as soluble and insoluble fibre, complete carbohydrates, proteins, vitamins and minerals (Genser and Morris 2003). The oil content of seeds generally varies from 33-45 per cent. On small scale, the seeds and its oil are directly used for human consumption as linseed oil in cooking or in various value-added edible products. In industries, mostly 80 per cent of linseed oil is used for paints, varnishes, wide range of coating oils, linoleum, pad & printing inks and in leather & soap industries. Linseed oil is also used as a solvent for industrial stains. Modified oils made from linseed find use in the manufacture of water proof materials and patent leathers. Linseed cake obtained as a byproduct of oil extracting industry contains 3% oil, 24-28% protein, 5% nitrogen, 1.4% phosphorus and 1.8% potassium. It is used in animal feed and as organic manure. Linseed mucilage is also used in the preparation of plywood glues, corrosion inhibitor, binding material in water paints, cosmetic and pharmaceutical industry.

Round the globe linseed crop occupies an area of 30.61 lakh ha yielding out 31.56 lakh tonnes having an average productivity of 1031 kg/ha. Our national production of 1.84 lakh tonnes is realized from an area of 3.0 lakh ha with productivity of 613 kg/ha. In Himachal Pradesh, linseed is mostly grown in Kangra and Mandi districts, covering an area of about 800 ha with the production of 240 tonnes and productivity level of 299 kg/ha (Anonymous 2019).

Indiscriminate use of chemical fertilizers and pesticides in any crop are causing serious threats by destroying beneficial soil micro flora, changing soil nature, increasing uptake of heavy metals and enhancing production cost. As linseed is low nutrient requiring crop, it can be well suited for organic, natural farming and Integrated Nutrient Management practices.

Among different nutrient management practices, Natural Farming (NF) is gaining importance. Natural Farming is a new concept introduced with an aim of sustainable development. Natural Farming is low-input, climate-resilient type of farming that encourages farmers to use low cost locally-sourced inputs, eliminating the use of artificial fertilizers and industrial pesticides. Natural Farming replaces use of farm yard manure and compost from organic farming with cover and green manure crops. With the use of such crops, humus formation takes places within field as compared to organic farming in which humus formation takes place at the site of FYM and compost preparation. Natural Farming is based on four aspects *viz*. *beejamrit*, *Jeevamrit/ghanjeevamrit*, *Acchadana* (Mulching) and *Whapasa* (moisture). These practices have a positive effect on the quality of the soil, improving its fertility, water retention capacity and reducing input costs and farmers' exposure to credit risks (Prasada 2016; Kumar 2012).

Organic farming is another production system which avoids the use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives. In organic farming, organic manures (solid and liquid) like vermicompost, FYM, vermiwash, biofertilizers etc. are used. The incorporation of organic manures improves the nutrient content and uptake (Anonymous 2015). Although organic manures contain plant nutrients in small quantities as compared to the fertilizer, the presence of growth promoting principles like enzyme and hormones besides plant materials make them essential for improvement of soil fertility and productivity. The objectives of environmental, social, and economic sustainability are the basics of organic farming (Stockdale et al. 2001). The key characteristics include protecting the long-term fertility of soils by maintaining organic matter levels, fostering soil biological activity, careful mechanical intervention, nitrogen self-sufficiency through biological nitrogen fixation and effective recycling of organic materials (Chhonkar 2002).

For better utilization of resources and to produce crops with less expenditure, INM is the best approach. In this approach, all the possible source of plant nutrients are applied based on economic consideration and the balance required for the crop is supplemented with chemical fertilizers. The combined use of organic and inorganic sources of plant nutrient not only pushes the production and profitability of field crops, but also helps in maintaining the permanent fertility status of the soil (Krishnakumar et al. 2013).

As different nutrient sources are used in these management systems, which have different impact on crop productivity and soil properties like physical, chemical & biological, thus need to be assessed. With progress in research, new varieties of linseed are being released for Himachal Pradesh. In the last two years, 'Him Palam Alsi-2' and 'Priyam' have been released under AICRP on linseed programme for Zone-1 comprising H.P, J.K, Punjab, Haryana and Uttrakhand. These varieties respond differently to nutrient management practices because of their genetic characters along with environmental conditions. Thus, there is need to test the response of these newly evolved varieties under different nutrient management practices.

Keeping this in view, present investigation entitled "**Performance of linseed (*Linum usitatissimum* L.) varieties under different nutrient management practices**" has been formulated with the following objectives:

- To find out the suitable variety for achieving higher productivity and profitability under different nutrient management practices, and
- to find out the effect of treatments on soil properties.

2. REVIEW OF LITERATURE

In this chapter an attempt has been made to present a brief account of work pertaining to the problem under study carried out at different locations in India and abroad. The effect of nutrients management practices and varieties on growth, yield attributes, yield, quality and soil properties etc. has been reviewed in this chapter. The relevant work done has been reviewed under the following heads:

2.1 Effect of inorganic/recommended nutrient management practice and varieties

2.2 Effect of organic nutrient management practice and varieties

2.3 Effect of natural farming nutrient management practice and varieties

2.4 Effect of integrated nutrient management practice and varieties

In this crop, a very limited information is available on organic, natural and integrated nutrient management aspect in the published literature, therefore efforts have been made to cite additional references by citing the literature available on other oilseed crops *viz.* groundnut, sunflower and rapeseed & mustard.

2.1 Effect of inorganic/recommended nutrient management practice and varieties

Chemical fertilizers have played a key role in ushering the green revolution. It has been established that there is a positive correlation between usage and agricultural productivity. Much research has established the importance of fertilizers in increasing the fertility of soil and in influencing its productivity. From these fertilizers, the plants can absorb the nutrients quickly and results can be viewed immediately. Chemical fertilizers provide exactly what plants need to grow with minimal fillers and they are highly regulated. It has been observed that applying fertilizers causes many changes in the soil, including chemical changes, that can positively or negatively influence its productiveness. Only a fraction of the fertilizer applied to the soil is taken up by the crop, the rest either remains in the soil or is lost through leaching, physical wash-off, fixation by the soil or release to the atmosphere through chemical and microbiological processes (Anonymous 2013). So these inorganic fertilizers should be used judiciously upto the optimal level. Over use of these fertilizers can degrade the soil, water and environment etc.

Singh (1994) reported that high fertility rate (125% of recommended rate) when applied to dual-purpose linseed at Palampur significantly increased the seed yield, straw yield, retted straw yield and fibre yield by 10.27, 10.30, 11.71 and 9.77%, respectively over recommended rate (90:30:30). They observed 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. Application of 25% higher NPK level over recommended rate considerably reduced the number of days taken to flowering and capsule formation.

Tiwari et al. (1994) found that application of two irrigations and fertilization with 60, 40 and 30 NPK kg/ha resulted in highest seed yield (14.26 q/ha) and net return (₹ 8739/ha) from linseed in Uttar Pradesh.

Dubey et al. (1997) found that application of nitrogen, phosphorus and sulphur up to 80, 40 and 40 kg/ha, respectively, significantly increased the branches/plant, capsules/plant, seeds/capsule and 1000 grain weight in linseed at Kanpur.

Singh and Verma (1997) found that the plant height, primary branches and seeds/capsule significantly increased due to higher fertility levels compared to control. Net profit and BC ratio were also highest under these treatments.

Pali and Tripathi (2000) reported that the variety 'Kiran' of linseed had maximum seeds/capsule (7.09), grain (5.45 q/ha) and straw (11.02 q/ha) yield under skip row sowing with recommended seed rate of 18.5 kg/ha and fertilization with 22.5 kg N, 30 kg P_2O_5 and 15 kg K_2O/ha on clay loam soil of Raipur.

Dubey (2001) tested five varieties (SLS-21, SLS-9, SLS-7, RLC-29 and T-397) and four levels of nitrogen (30, 40, 50 and 60 kg/ha) in Madhya Pradesh and found that application of 60 kg N/ha had produced taller plants with more number of capsules per plant in variety RLC-29.

Kumar and Kumar (2001) revealed that variety 'Laxmi 27' out yielded other varieties with a yield of 588.41 kg/ha under rainfed condition which was found to be statistically on a par with varieties ‘Pusa 3’ (550.59 kg/ha) and ‘Kiran’ (524.19 kg/ha) while, economic optimum dose of fertilizer was found to be 40, 20 and 10 N, P and K kg/ha, with a BC ratio of 1.46.

Choubey et al. (2002) reported that among inorganic fertilizers, application of 100% recommended dose of fertilizer *i.e*. 60:30:20 NPK kg/ha was proved to be significantly superior to 75% and 50% RDF by a margin of 21.4 and 11.2%, respectively with respect to seed yield of linseed in Chhattisgarh plains. Positive increase in net monetary return was observed with 100% RDF.

Badiyala and Kumar (2003) reported that application of recommended dose of chemical fertilizers 50:40:20 NPK kg/ha produced plants with more height (68.13 cm), number of primary branches (7.12), capsules/plant (29.23), seeds/capsule (8.70) and 1000 seed weight (8.58 g) as compared to 50 and 75% of the recommended dose of NPK application under mid-hill conditions of Himachal Pradesh. Highest gross and net return (₹ 21900/ha) were also obtained with recommended dose of fertilizer 50:40:20 kg NPK/ha application.

Choubey et al. (2003) obtained significantly highest seed yield of linseed when crop was fertilized with 100% RDF as compared to 75 and 50% RDF at Raipur.

From Egypt, Leilah et al. (2003) showed significant interactions between flax varieties and NPK fertilizers levels for straw, fiber, seed and oil yields. The highest oil yield was produced from ‘Giza 8’ variety fertilized with 60 N, 30 K_2O and 30 P_2O_5 kg/ha.

Malik et al. (2008) found that the application of 90:45:30 NPK kg/ha at Kanpur produced significantly taller plants with more number of branches/plant and capsules/plant in linseed.

Berti et al. (2009) found that flaxseed yield and oil content increased as nitrogen rates increased upto 200 kg/ha in South Central Chile. The phosphorus and potassium nutrients did not have an effect on seed yield, oil content and oil composition.

Haldar (2010) showed that the treatment receiving 60 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha produced higher seed yield (1957 kg/ha) and oil yield

(775 kg/ha) as compared to 60 kg N, 80 kg P_2O_5 and 30 kg K_2O/ha fertilizer level (1753 kg/ha and 690 kg/ha, respectively) and control (1581 kg/ha and 560 kg/ha, respectively).

Meena et al. (2011) revealed that increase in fertility levels upto 60:30:30:30 N, P, K, S kg/ha resulted in significantly higher N, P, K and S concentration in grain and straw, oil content, oil yield, protein content and protein yield at Varanasi. Increase in fertility levels resulted in significant increase in both seed and straw yield.

Ranglal et al. (2011) found that application of 60:30:30:30 kg NPKS/ha resulted in significantly higher seed and straw yield of linseed at Varanasi.

Khajani et al. (2012) found that application of 90, 120 and 80 kg/ha of nitrogen, phosphorus and potassium, respectively significantly increased the number of branches/plant and number of capsules/plant and thereby seed yield (2384.28 kg/ha) of linseed variety 'Lirina' at Tehran, Iran .

Singh et al. (2013) found that the application of 90:45:45 kg NPK/ha significantly increased growth parameters (such as plant height, branches/plant and dry matter accumulation), yield attributes and seed yield over 60:30:30 kg NPK/ha at Varanasi (U.P). Linseed variety 'Shekhar' had the highest values of growth parameters, yield attributes, yield and removal of nutrients than 'Garima'.

Gupta (2014) reported that application of 60, 30 and 30 NPK kg/ha along with sulphur 20 kg/ha was found remunerative in linseed cultivar 'Garima' under agroclimatic condition of Vindhyan region of Barkachha (U.P.).

Pohare and Raundal (2015) found that application of 80:45:30 NPK kg/ha resulted in significantly higher seed yield, total N, P and K uptake by seed, straw and crop and available N, P and K in soil after linseed harvest over lower levels of fertilizer application in linseed.

Chopra and Badiyala (2016) found that among varieties, 'Nagarkot' had significantly highest plant population/ha, which was followed by 'Himani' and 'Baner' varieties. 'Nagarkot' was found to be significantly superior for higher number of primary and secondary branches and 'Himani' for number of capsules/plant, which have resulted in higher seed yield of 1062 and 1012 kg/ha and BC ratio of 1.62 and 1.50 with ‘Himani’ and ‘Nagarkot’ varieties, respectively.

Kumar and Deka (2016) found that the seed and straw yield of linseed were significantly affected due to different fertility levels and thus yield and economics of linseed crop were significantly increased up to the application of 80:60:60:40 NPKS kg/ha but it was statistically at par with 60:45:45:30 NPKS kg/ha at Jharnapani, Medziphema (Nagaland).

From their study, Kumar et al. (2016) revealed that growth parameters, yield attributes, seed and straw yields were significantly higher under medium level of fertility (75:45:40 kg NPK/ha) as compared to low and higher level of fertility in Linseed. The magnitude of increase in seed yield under medium over low and high levels of fertility was 22.4 and 13.0%, respectively. The maximum oil content (40%) and total NPK removal was observed under 50:30:20 kg and 75:45:40 kg NPK/ha, respectively.

Gupta et al. (2017) while working with four fertility levels of N:P:K in kg/ha *viz.* F_1 - control, F_2 - 37.5:22.5:15, F_3 - 50:30:20 and F_4 - 62.5:37.5:25 allotted to main plots and four varieties (LC-2023, LC-2063, LC-54 and local variety) in sub-plots found that increasing fertilizer dose from F_1 to F_3 significantly increased growth (plant height and number of branches per plant), yield attributes (capsules per plant and seeds per capsule) and seed and straw yield of linseed. However, further increase in fertilizer dose to F_4 did not increase the growth, yield attributes and seed and stover yield significantly. Regarding varietal effect, linseed variety ‘LC-2063’ marked its superiority over other three varieties by recording higher values of growth parameters as well as yield attributes.

Gurjar et al. (2017) revealed that all the growth characters (plant height, dry matter and number of branches/plant) and yield attributes (number of capsules/plant and number of seeds/capsule), seed and straw yield, oil content & oil yield were found promotive with the application of three irrigation and with 75% RDF + two foliar sprays of 19:19:19 at Nagpur.

Pohare and Raundal (2017) revealed that the total N, P and K uptake by seed and straw increased significantly due to application of 80:45:30 NPK kg/ha and available N, P and K in soil after harvest was also higher under this treatment over lower levels of fertilizer application at Pune.

2.2 Effect of organic nutrient management practice and varieties

With the increase in population our compulsion would be not only to stabilize agricultural production but to increase it further in sustainable manner. The demand for high quality and safe food is increasing day by day. The unscientific use of agrochemicals in crop cultivation has led to several hazards related to human health, soil health and environment degradation (Lampking 1990). It has been realized that the 'Green Revolution' with high input use has reached a plateau and is now sustained with diminishing return of falling dividends. Therefore, the concept organic farming aims at being climate friendly with respect to conventional farming, by granting a lower carbon footprint and reduced environmental impacts (Anonymous 2009).

Singh and Singh (1997) found that the application of FYM @ 5 and 10 t/ha has resulted in significantly more plant height, dry matter and leaf area per plant, yield attributes, seed and stalk yields over no FYM and *Azotobacter* inoculation at Hisar. Both the levels of FYM, were statistically at par with each other for the above said parameters except dry matter which was significantly more with FYM @10t/ha than 5t/ha. The increase in seed yield was 10.0 and 16.0% with 5 and 10 t FYM/ha, respectively over no FYM in sunflower.

Patel et al. (1998) found that among organics, FYM applied at 20 t/ha significantly increased seed, stover yield and P&S uptake by Indian mustard.

Patel and Shelke (2000) found that that application of FYM 10 t/ha increased the mean seed yield (7.83%), net return (11.6%), oil yield (67 kg/ha), protein yield (53 kg/ha) and nutrient content of mustard. Total N, P and S uptake were also higher in FYM-treated versus FYM-untreated plants, by 19.48, 3.99 and 3.55 kg/ha, respectively. An increase of 1.88 and 4.20 kg/ha available P and S, respectively, in the post-harvest soil was also observed.

Choubey et al. (2002) found that among organics, application of farm yard manure @ 5 t/ha increased the growth, yield attributes, seed yield and economics of linseed over no FYM under limited irrigations in Chhattisgarh plains. The extent of increase in seed yield was calculated to be 9.6%.

Rao (2003) found that application of organic manures had significant effect on available N content in soil. Application of farmyard manure 10 t/ha and poultry manure 5 t/ha brought significant improvement in the post harvest available N content in the soil over control.

Badiyala and Kumar (2003) while studying the effect of organic fertilizers at Palampur found that in linseed, application of FYM @ 5 tonnes/ha resulted in better growth, yield attributes as well as yield.

Verma et al. (2005) found that improved management technologies consisting of line or seed drill sowing, application of FYM @ 2 t/ha a month before sowing and use of straw mulch after sowing was proved superior to traditional practices adopted by the farmers for achieving higher seed yield in linseed. 'Padmini' variety followed by 'Sweta' and proved superior to 'Bijuri Local' with improved management technology.

Kumar et al. (2006) reported that organic manuring with FYM 10 t/ha resulted in significant improvement in yield and yield attributes of mustard.

In sesame crop, Ravusaheb (2008) found that application of organic manures FYM (1/3) + vermicompost (1/3) + green manure (1/3) along with organic spray of *panchagavya* resulted in significantly higher microbial population of bacteria, fungi and actinomycetes (15.97×10^7, 8.63×10^3 and 2.57×10^3 cfu/g of soil) over RDF alone due to cumulative effect of both organic manures in increasing organic carbon content of soil which acted as carbon and energy sources for microbes and fermented organics in quick build-up of microflora and fauna.

Manjunatha et al. (2009) reported that application of FYM @ 7.5 t/ha + 100% RDF resulted in significantly higher seed yield of sunflower (1774 kg/ha) which was at par with the application of FYM @ 7.5 t/ha + *jeevamrit* (1733 kg/ha).

Ramesh et al. (2009) observed that application of different combinations of organic manures resulted in higher uptake of nutrients, higher soil organic carbon, higher available soil N, P, K and soil biological parameters (dehydrogenase, phosphatase and microbial biomass carbon) when compared with recommended dose of fertilizers and control in mustard (*Brassica juncea*). Cattle dung manure @ 4 t/ha + poultry manure @ 2.0 t/ha recorded higher number of siliquae per plant (177.2) and number of seeds per siliqua (14.5) compared to the recommended rates of fertilizers and the control. On average, this combination of organic manures recorded higher seed yield of Indian mustard (1822 kg/ha) and oil content (38.44%) compared to the recommended rates of fertilizers (1775 kg/ha) and the control (1064 kg/ha).

Bilalis et al. (2010) found no significant difference between the organic fertilization treatments (compost, vetch and faba bean as green manure) on leaf area index, dry weight and AM root colonization in linseed. Vetch and faba bean green manures had significant effect on oil content. A high correlation was observed between oil yield and oil content.

Laura and Stanislava (2010) found that the highest dry matter in white mustard, was obtained when it was either grown with buckwheat or as a mono crop and green manure and farmyard manure were incorporated.

Jat et al. (2013) found that with each successive increase in level of FYM and minerals nutrients individually and in combination there was significant increase in the seed and stover yield, content and uptake of nitrogen, sulphur, zinc, and iron in seed and straw compared to control in mustard at Jaipur.

In Egypt, Afifi et al. (2014) found that application of two types organic fertilizers alone or in combination with two types of bio-fertilizers had significant effects on yield and its components as well as on seed oil and mineral content as compared to recommended mineral fertilizer treatment in flax. The study therefore, recommended that application of sludge and inoculation with bio-fertilizers (*Azotobacter* or yeast) is the best treatment for better growth and high seeds and oil yield of flax plants grown in sandy soil.

Chaudhary (2016) found that the oil content (41.75%) was high under the treatment having application of 100% RDN from vermicompost in linseed at Navsari.

Shaikh and Gachande (2016) revealed that in organic inputs applied groundnut field there was significant increase in soil properties like organic carbon (0.11 % to

0.34 %), phosphorus (6.62 kg/ha to 15.16 kg/ha), water holding capacity (3.3 % to 8.5 %) over inorganic inputs applied field in Maharashtra.

Sharma et al. (2017) revealed that growth and yield attributes *viz.*, plant height (161.5 cm), number of branches per plant (5.2), length of siliqua (6.0 cm), number of siliqua per plant (235.6), number of seeds per siliqua (15.4) and test weight (5.1 gm) of mustard were significantly higher with poultry manure @ 1.7 t/ha + BD 500 + BD 50% over rest of the organic treatments in Uttar Pradesh. Application of poultry manure @ 1.7 t/ha + BD 500 + BD 501 gave highest net return (₹ 51204/ha) and BC ratio (2.9).

Hadiyal et al. (2017) at Junagarh found that among organic manures, application of FYM 5 t/ha enhanced growth parameters *viz*. plant height, number of primary and secondary branches per plant of groundnut. Among biofertilizers, seed inoculation with *azotobacter* + PSB also promoted said growth parameters.

Makkar et al. (2017) practiced organic nutrient management in two varieties of linseed using different proportions of vermin-compost and combination of vermin-wash as an environment friendly substitute to chemical fertilizers. They found that germination and yield were improved when foliar application of vermiwash was integrated with vermicompost application as compared to recommended chemical fertilizer treatment and control.

Beenish et al. (2018) found that among organic treatments, application of 75% N through vermicompost + *Azotobacter* resulted in significantly tallest plant, more number of primary branches, number of siliquae/plant, seeds per siliquae, seed and straw yield of Indian mustard at Allahabad.

Kumar et al. (2018) while studying the effect of organic management practices on growth, yield attributes and seed yield in mustard found that the organic treatments receiving 100% recommended N through FYM + neem cake + vermicompost (1/3 from each source) along with different management practices provided lower yields. The reduction in dose of nutrients (50% FYM along with bone meal, PSB and *Azotobacter*) provided significantly lower yield and nutrient (NPK) uptake. The regular application of 100% nutrients through organic sources (FYM +neem cake + vermicompost) showed appreciable increase in organic carbon and availability of nutrients (NPK) as compared to INM and fertilizer treatments. The availability of nutrients in 100% NPKS through chemical fertilizers and INM treatment was at par. The higher profit was obtained in INM treatment followed by 100% chemical fertilizer treatment. The conjunctive use of organic sources and fertilizer (INM) proved conducive in sustaining soil fertility and productivity of mustard in long run.

Makkar et al. (2018 a&b) found that treatments with vermicompost and vermiwash produced linseed with most suited ratio of omega-3 and omega-6 in its seeds.

Murali et al. (2018) at Allahabad studied the effect of different levels of organic manure on growth and yield of mustard (*Brassica juncea* L.) under Jatropha (*Jatropha circus L*) based agroforestry system. They reported that application of 50% farm yard manure (4 t/ha) + 50% VC (2 t/ha) had maximum plant height with more number of branches and dry weight, yield attributes (number of siliquae/plant, number of seeds/siliqua, test weight), seed yield, stalk yield and BC ratio. These parameters were significantly influenced by different sources and level of organic manure.

Beenish and Lal (2019) found significantly highest oil content and oil yield, protein content and protein yield in Indian mustard with the application of 75% N through vermicompost.

At Agra, Kumar and Singh (2019) found that application of FYM @ 5t/ha, significantly increased the seed and stover yield by 12.7 and 10.2%, respectively over control. They found that there was significant enhancement in seed and stover yields with dual inoculation of *Azotobacter* + PSB over no inoculation. Application of 5 t/ha FYM alone significantly increased the seed and stover yields by 12.7 and 10.2%, respectively over control. Addition of FYM to the soil also significantly increased the uptake of N, P, K and S by seed and stover of mustard over control. About 25% requirement of inorganic fertilizers can be supplemented through FYM. The crop quality in respect of oil and protein content was improved significantly with the use of chemical fertilizers, FYM and bio-fertilizers.

2.3 Effect of natural farming nutrient management

Among the several methods of eco friendly agriculture and farmer friendly alternative systems of farming, Natural Farming (NF) is increasingly becoming popular among the farming community. Natural Farming (NF) as the name implies, is a method of farming where the cost of cultivation of crops is reduced. This means farmers need not to purchase costly fertilizers and pesticides for obtaining higher yield. In this system, soil is supplemented with the microbial inoculums like *Beejamrit*, *Jeevamrit* etc. which enhances microbial activity in soil and ultimately ensure the availability and uptake of nutrients by the crops (Yadav and Mowade 2004).

Venkatakrishnan and Balasubramanian (1998) suggested that application of *jeevamrit* significantly increased the yield attributes *viz.*, test weight, seed yield and stalk yield of sunflower.

Yadav and Mowade (2004) reported that fermented liquid organics (*panchagavya*, *jeevamrit*, *beejamrit*, *sasyamrit* and *amrutpani* etc.) prepared from cow dung, urine and leguminous leaves or vermiwash are effective in rapid build-up of soil fertility through enhanced activity of soil micro-flora and fauna.

Palekar (2006) opined *jeevamrit* as a fermented liquid product which is prepared by mixing of cow dung (10 kg), cow urine (10 L), jaggary (2 kg), legume flour (2 kg) and a handful of soil brought from the bunds of the cultivated lands. *Jeevamrit* contains enough amount of beneficial microbes which on application enhance the microbial activity in soil and ultimately ensures the availability and uptake of nutrients by the crops. He also explained that *beejamrit* is not a source of nutrients. It is being used by the organic farmers for seed or seedling treatment which was found to increase seed germination and seedling growth as it contains growth hormones and beneficial microflora.

Vasanthkumar (2006) explained that *jeevamrit* is not a source of nutrients, but it is a fermented liquid product which contains large quantity of microbial activity that enhances soil bio-mass when applied to the soil even at very less rate as it acts as a tonic to the soil besides improving soil health.

Devakumar et al. (2008) reported that maximum microbial population was observed between 9^{th} and 12^{th} day of the preparation of *jeevamrit*, which might have enhanced the decomposition process in the soil and resulted in relatively quick release of nutrients from compost than without application of *jeevamrit*.

Shwetha (2008) reported significantly higher leaf area index, plant height, number of branches, dry matter accumulation, yield parameters like the number of pods per plant and seed yield with the application of organic manures in combination with liquid organic manures *viz*., *beejamrit*, *jeevamrit* and *panchagavya* as compared with the application of organics alone in soybean crop in soybean-wheat cropping system.

According to Gore and Sreenivasa (2011), *jeevamrit* will promote biological activity in soil and as a result the nutrient availability to the crop will be improved. They have also enumerated microbes present in *jeevamrit viz.* fungi (13.40×10^3 cfu per ml), bacteria (19.70×10^5 cfu per ml), actinomycetes (3.50×10^3 cfu per ml), nitrogen fixers (4.60×10^2 cfu per ml) and phosphate solubilisers (4.20×10^2 cfu per ml).

Sreenivasa et al. (2011) analyzed *jeevamrit* for the nutrient content and found that it contained major nutrients like nitrogen, phosphorous and potassium (770-1000, 166-175 and 126-194 ppm, respectively) and minor nutrients like zinc, copper, iron and manganese (1.27-4.29, 0.38-1.58, 29.7-282 and 1.8-10.7 ppm, respectively).

Ravikumar et al. (2011) reported that application of *Jeevamrit* along with biodigester improved the yield in groundnut and it could be due to the addition of calcium and presence of nitrogen fixing bacteria.

Chadha et al. (2012) studied the efficiency of vedic krishi inputs, which were *panchagavya*, vermiwash, compost tea, *beejamrit* and *jeevamrit* with the objective to work out their applicability for ecofriendly nutrient and disease management in organic farming. The nutritional and microbial analysis of these liquid organic manures showed the presence of different macro and micro nutrients and large population of essential microbes.

2.4 Effect of integrated nutrient management

Intensive cropping systems with fertilizer responsive crops that rely on high input of inorganic fertilizers often lead to non-sustainability in production and also pose a serious threat to soil health. Application of organic sources of nutrients with no or very little use of fossil fuel based inorganic fertilizers is rapidly gaining favour. However, considering economics and also physiological potential of varieties, entire dependence on organic sources of nutrients may not be adequate to attain the most productivity. Integrated nutrient management with both organic and inorganic fertilizers was found to be more effective, productive and ecological better than the two done separately. The basic concept underlying integrated plant nutrition system, is the maintenance and possible increase of soil fertility for sustaining enhanced crop productivity through optimal use of all sources of plant nutrients, particularly inorganic fertilizer, in an integrated manner and as appropriate to each specific ecological, social and economic situation.

Jat et al. (2000) revealed that application of 10 t FYM + 30 kg N and 20 kg P_2O_5/ha significantly increased plant height, dry matter accumulation, number of primary and secondary branches, number of siliquae per plant, number of seeds per siliqua and seed yield of mustard over the control. Under limited irrigations in Chhattisgarh plains, Choubey et al. (2002) found that a saving of 25% RDF *i.e.* 15 kg N and 7.5 kg P_2O_5 per ha was achieved with the application of 5 tonnes FYM per ha in integration with 75% RDF.

Shankar et al. (2002) revealed that application of 100% recommended NPK + 10 t/ha farmyard manure + *Azotobacter* in Indian mustard (*Brassica juncea*) resulted in higher seed yield. Physico-chemical properties of the soil also improved with the application of farmyard manure along with inorganic fertilizers.

Mandal and Sinha (2002) found significantly taller plants with more number of branches/plant, siliquae/plant, seeds/siliqua, 1000 seed weight, seed and oil yield of Indian mustard with the application of 100% recommended dose of NPK (80:17.2:33.2) + FYM @ 10 t/ha as compared to 100% NPK alone on sandy loam acidic soil in foothills of eastern India.

In Rajasthan, Premi et al. (2004) observed that application of vermicompost at 5t/ha + 75% RDF had maximum plant height, number of primary and secondary branches, number of siliqua per plant and number of seeds per siliqua which in turn resulted in higher seed yield in sarson. It was at par with FYM 10t/ha + 75% RDF application.

Bhovi (2005) reported that combined application of phosphorous (30 kg/ha), phosphate solubilizer (200 g/acre of seeds) and vermicompost (2.5 t/ha) resulted in significantly higher growth and yield components *viz*. number of capsules/plant (30.00), number of seeds/capsule (7.52), seed yield/plant (1.84 g), seed yield/ha (653 kg) and 1000 seed weight (7.9 g) of linseed at Dharwad.

Sharma and Dayal (2005) found application of FYM 7.5 t + 37.5 kg N/ha as the best treatment for recording taller plants (at 45 days and at the time of harvest), higher number of tillers and capsules/plant, dry matter production, straw and grain yield of linseed. The maximum uptake of N (grain and straw), P and K by linseed straw was recorded with same treatment. Application of FYM 6 t + 30 kg N/ha also behaved statistically similar to FYM 7.5 t + 37.5 kg N/ha in recording higher uptake of P and K, during the first year and that of P and K by linseed grain with FYM 6 t + 30 kg N/ha during the second year. The physico-chemical properties of soil were also improved with application of FYM 7.5 t + 37.5 kg N/ha.

In acidic soils of Nagaland, Singh et al. (2009) revealed that all the growth and yield parameters increased with application of fertilizer with integrated approach over the control. Application of 50% NPK + vermicompost @ 2 t/ha produced significantly higher seed and stover yield of mustard.

Deshmukh et al. (2010) revealed that the application of RDF + FYM @ 5t/ha + vermicompost @ 5 t/ha + seed treatment of *Azospirillum* and Phosphorus solubilizing bacteria in summer sesamum (*Sesamum indicum* L.) at Maharashtra resulted in the higher seed yield and seed weight per plant. The highest gross and net monetary returns were recorded with the same treatment.

Husain et al. (2010) revealed that yield attributes, seed yield, net monetary return, BC ratio and oil yield were substantially higher when linseed crop was supplied with 75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur +

Azotobacter and Phosphorus solubilizing bacteria (PSB) and was at par with 75% RDF + 5t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur. The same treatments enriched the soil with regard to available N, P, K, Zn and S after the harvest of last crop of linseed. Though, 75% RDF + 5 kg/ha zinc + 25 kg/ha sulphur + bio-fertil1zer was at par with above module for net monetary return but it depleted the soil with regard to available K and S. They concluded that it would be advantageous to supply nutrients to linseed crop using the modules either 75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur + *Azotobacter* or 75% RDF + 5 t/ha FYM + 5 kg/ha zinc + 25 kg/ha sulphur depending upon the availability of the inputs at command.

Jerin (2010) from Dhaka reported that application of recommended dose of fertilizers and cow dung 8 t/ha + compost 8 t/ha + ½ RDF being at par with each other were superior with respect to all morphological, yield and yield contributing characters of mustard over individual or combined application of organic and inorganic treatments. Application of cow dung 4 t/ha + compost 4 t/ha + ½ RDF was also at par to these treatments in respect of yield contributing characters as well as seed yield. So, it is possible to reduce the use of chemical fertilizers by combined use of organic and chemical fertilizer without having any significant loss in the yield of mustard.

Kashved et al. (2010) observed that the growth parameters (*viz*. plant height, number of primary and secondary branches and dry matter), yield attributes (number of siliquae, length of siliqua per plant, number of seeds per siliqua, seed weight per plant, 1000 seed weight and seed yield (12.43 q/ha) of mustard (*Brassica juncea* L.) were increased significantly by integrated application of 75% RDN through urea + 25% N through FYM than rest of treatments. The highest yield was obtained with combined application of 75% RDN + 25%N through FYM.

Singh et al. (2010) reported that mean plant height, total dry matter accumulation, leaf area and seed yield of mustard (*Brassica juncea*) were higher when 100% recommended fertilizers (120:40:20:40-N:P_2O_5:K_2O:S kg/ha) were applied along with farmyard manure (FYM) @ 10 t/ha, $ZnSO_4$ @ 25 kg/ha and seed treatment with *Azotobacter*. Mean seed yield of mustard with this treatment increased by 41.2% over application of recommended fertilizers.

Tripathi et al. (2010) found that application of FYM @ 2t/ha + 40 kg/ha sulphur along with RDF or 75% RDF resulted in significant increase in mustard yield. With respect to net return, application of RDF + FYM + S + Zn + B + *Azotobacter* was more promising to rest of the treatments.

Singh and Pal (2011) found that the plant height, total dry matter accumulation, leaf area index, seed and stover yields of mustard increased significantly when recommended dose of fertilizers (RDF) *i.e.* 120:17.6:16.6:40, N:P:K:S kg/ha was applied along with FYM 10 t/ha, $ZnSO_4$ 25 kg/ha and seed treatment with *Azotobacter*.

Bhanwariya et al. (2013) obtained higher production of linseed with higher profit by fertilizing the crop with 100% RDF (100:50:0 NPK/ha) along with seed inoculation with *Azotobacter* + PSB or PSB alone in clayey soils under south Gujarat condition.

From Nagpur, Mahammad et al. (2013) reported that in linseed, various growth characters (*viz.* height of plant, number of branches/plant and dry matter accumulation/plant), yield contributing characters (*viz.* number of capsules/plant and grain weight/plant), seed yield, gross and net monetary return increased significantly and were the highest in treatment receiving 100% RDF + *Azotobactor* + PSB and it remained at par with 100% RDF + *Azotobactor*, 100% RDF and 75% RDF + *Azotobactor* + PSB applied treatments. Highest BC ratio was recorded with the application 100% RDF + *Azotobactor* + PSB. However, test weight and oil content remained unaffected. Application of 100% RDF + *Azotobactor* + PSB recorded significantly maximum oil yield which was at par with treatment receiving 100% RDF + *Azotobactor*. Application of 100% RDF + *Azotobacter* + PSB resulted in having significantly higher available nitrogen, phosphorus and potassium and it was at par with 100% RDF + *Azotobactor*, 100% RDF, 75% RDF+*Azotobactor* + PSB and 50% RDF + *Azotobactor* + PSB treatments.

In Vertisols of Maharashtra, Meena et al. (2013) found that application of 100% RDF (80,17.5 and 60 N,P and K kg/ha) + seed inoculation with *Azotobacter* + *PSB* significantly increased number of primary and secondary branches/plant, number of siliquae/plant, test weight, seed and stover yield, net return (₹ 37200/ha), BC ratio

(2.64), oil content and oil yield (1,034 kg/ha) of Indian mustard (*Brassica juncea*) over control.

In Central plain zone of Uttar Pradesh Dubey et al. (2015) found that application of 75% RDN + 25% N through farmyard manure (FYM) + *Azotobacter* + phosphate solubilizing bacteria (PSB) was significantly superior in terms of yield, protein and oil content as well as NPK uptake in both linseed and Indian mustard crops over the plots receiving 100% RDN and 50% RDN + 50% N through FYM + *Azotobacter* + PSB. Grain and straw yield was 10.7 and 19.8% higher under above said treatment over 100% RDN and 22.8 and 38.9% more over 50% RDN + 50% N through FYM + *Azotobacter* + PSB in linseed, respectively. The oil content was markedly reduced with increase in RDN through chemical fertilizer but reverse trend was observed in case of protein content. Nutrient uptake in terms of NPK in seed and straw of linseed was recorded significantly higher in plots receiving 75% RDN + 25% N through FYM + *Azotobacter* + PSB application over other treatments.

On a sandy loam soil at Agra (U.P.) Lawania et al. (2015) recorded significantly higher linseed plant height in plots receiving 75 kg N/ha + biofertilizer application, whereas, other growth parameters such as a number of primary (3.7) and secondary (17.3) branches/plant, dry matter accumulation (18.18 g/plant) increased significantly with application of 50 kg N/ha + biofertilizer as compared to other applied treatments. All yield attributes such as capsules/plant (41.3), seeds/capsule (7.9), 1000-seed weight (5.6 g) and seed yield (1322 kg/ha) were also increased significantly.

Chaudhary (2016) at Navsari found that all the growth [plant height, fresh weight per plant (24.32 g), dry weight per plant (15.97 g) and number of leaves per plant] and yield attributes [number of branches per plant, number of capsules per plant (71.49), number of seeds per capsule (9.24), seed yield per plant (7.62 g) seed yield (554.33 kg/ha) and straw yield (1452.41 kg/ha)] were found maximum in linseed with application of 50 % RDN from vermicompost + 50 % RDN through inorganic fertilizers.

Patel et al. (2016) at Raipur found that application of RDF + FYM placement in rows @ 5 t/ha had significantly higher growth parameters *viz.* plant height (88.44

cm), primary branches/plant (3.83), secondary branches/plant (23.39), dry matter accumulation (6.76 g/plant) and yield attributes [*viz*. capsules/plant (30.86), seeds/capsule (7.63), seeds/plant (235.32)], seed yield (2100 kg/ha) and stover yield (4885 kg/ha) of linseed.

Verma and Yadav (2017) found that the use of integrated nutrient management exhibited the significance over recommended dose of nitrogen at Kanpur. The application of 75% RDN through inorganic + 25% RDN through vermicompost + bio-fertilizer (seed coating) + PSB @ 2.5 kg/ha in soil exhibited significantly higher values of different growth and yield parameters.

Kumar et al. (2018) found that the availability of nutrients in 100% NPKS through chemical fertilizers and INM treatment was at par. The higher profit was obtained in INM treatment followed by 100% chemical fertilizer treatment. The conjunctive use of organic sources and fertilizer (INM) proved conducive in sustaining soil fertility and productivity of mustard in long run.

Kumar et al. (2018) reported increase in growth parameters (*i.e* plant height, branches per plant, dry matter accumulation and leaf area index) in mustard with the application of 50% RDF + FYM 6 t/ha + vermicompost 2 t/ha + biofertilizer at Merrut.

Makkar et al. (2018 a&b) found that INM proved to be nutritionally balanced strategy with enhanced yield leading to better soil health in linseed. Higher oil yield and oil content was obtained with Integrated Nutrient Management in tested varieties.

Tiwari et al. (2018) reported highest grain yield (17.0 q/ha) and stover yield (34.80 q/ha) with the application of 100% RDN + 30 kg S/ha + 5 kg Zn/ha, which was 98.8 and 85.0% higher, respectively than control in linseed at U.P. In integrated treatments substitution of 25% N through FYM along with 75% RDN produced 11.60 q/ha grain yield and 23.41 q/ha stover yield which was found at par to the yield of 100% RDN indicting the possibility to reduce N fertilizer need by 25% through the application of FYM along with chemical fertilizers.

Kumar and Singh (2019) found that about 25% requirement of inorganic fertilizers can be supplemented through FYM in Indian mustard. The crop quality in respect of oil and protein content was improved significantly with the use of chemical fertilizers, FYM and bio-fertilizers. Best results were obtained with the application of FYM @ 5t/ha along with dual inoculation of *Azotobacter* + PSB.

3. MATERIALS AND METHODS

The present study entitled, **"Performance of linseed (*Linum usitatissimum* L.) varieties under different nutrient management practices"** was carried out at experimental farm of Linseed unit, Department of Genetics and Plant Breeding, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *Rabi* 2018-19. The details of field experiment and methodology adopted have been described in this chapter.

3.1 General description of study area

3.1.1. Location

The experimental farm is located at 32°4´ N latitude, 76°3´ E longitude and 1224 metres altitude. Agro-climatically the site falls in the sub-temperate mid hill zone of Himachal Pradesh. The region is endowed with mild summers and cool winters.

3.1.2. Weather conditions

The mean weekly meteorological observations of the cropping season *i.e* 26th Oct., 2018 to 24th May, 2019 recorded at meteorological observatory of the Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur have been given in Appendix-1 and illustrated in Fig. 3.1. The data revealed that the total rainfall received during the crop period was 613 mm. The mean maximum temperature for the crop season varied from 10.7 to 33.7 ^{o}C and the mean minimum temperature ranged from 1.5 to 20.4 ^{o}C. The mean relative humidity remained between 30 to 70% during the crop season.

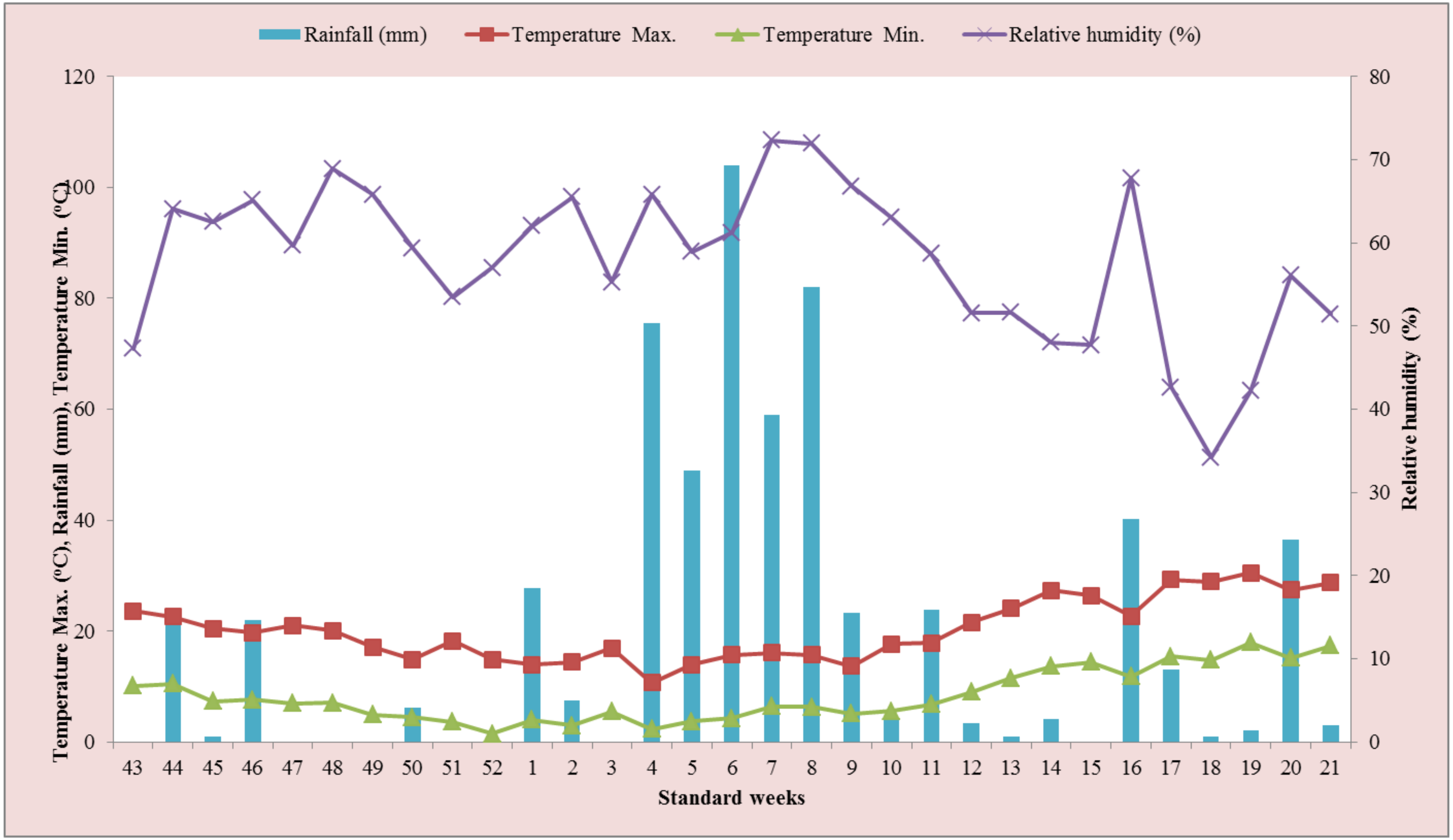


Fig. 3.1 Mean weekly weather data of Palampur station *w.e.f.* 26th Oct, 2018 to 24th May, 2019

3.1.3. Soil

Before the commencement of experiment, a composite soil sample from 0-15 cm depth was collected. The sample was analyzed for different physico-chemical properties and the results of the analysis have been given in Table 3.1. A perusal of data presented in Table 3.1 showed that the soil of the experimental field was silty clay loam in texture, acidic in reaction and medium in available nitrogen, phosphorus and potassium.

Table 3.1 Mechanical and chemical analysis of soil

Particulars	Content	Method employed
A. Mechanical analysis		
Sand (%)	35.38	International pipette method (Piper 1966)
Silt (%)	38.10	
Clay (%)	25.23	
Texture	Silty clay loam	
B. Chemical properties		
pH	5.9	1:2.5 soil water suspension, Digital pH meter
C. Available nutrient (kg/ha)		
N	243.3	Alkaline permagnate method (Subbiah and Asija 1956)
P	24.7	$NaHCO_3$ method (Olsen et al. 1954)
K	145.4	Ammonium acetate extraction method (AOAC 1970)

3.1.4. Cropping history

Prior to the commencement of the present experiment, after taking linseed crop during *rabi* 2017-18, green manure crop Dhaincha (*Sesbania aculeata*) was raised in the fields during *kharif* 2018.

3.2 Experimental details

The present investigation was carried out during *Rabi* 2018-19 at research farm of Linseed Unit, Department of Genetics and Plant Breeding, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Twelve treatments comprising of four nutrient management practices in main plots and three varieties in sub plots were tested in split plot design with three replications. The characterstics of different varieties are given in Appendix IV. The actual plan of layout has been shown in Fig. 3.2. The detail of the treatments applied in the experiment has been given in Table 3.2.

Table 3.2: Treatments detail of the experiment

Main Plot: Nutrient Management Practice (4)	
	N_1: Inorganic (RDF)
	N_2: Organic management {FYM10 t/ha + *Azotobacter* + PSB (seed inoculation) + *Vermiwash* (2 sprays at 30 and 45 DAS)}
	N_3: Natural Farming management {*Beejamrit* (seed treatment) + sieved FYM @ 2.5 q/ha with *Ghanjeevamrit* @ 2.5 q/ha (Basal)+ *Jeevamrit* (5 sprays) + Fermented Butter Milk (1 spray) and mulching}
	N_4: Integrated management {75% NPK + 25% N through FYM + *Azotobacter* + PSB (Seed inoculation)}
Sub Plot: Varieties (3)	
	V_1: Him Palam Alsi-2
	V_2: Himani
	V_3: Priyam

Design	:	Split Plot Design
Total number of treatments	:	12
Replications	:	Three
Total number of plots	:	36
Gross plot size	:	3.375 m × 3.75 m = 12.65 m^2
Net plot size	:	2.475 m × 3.25 m = 8.04 m^2
Row spacing	:	22.5 cm

3.2.1 Preparation of field

Proper land preparation and fine seed bed is essential to obtain good tilth for good germination and growth of plants. Physical properties particularly soil moisture and air circulation, evaporation and nutrient availability depend on optimum soil conditions. Keeping these points in view, initial ploughing was given by cultivator followed by discing with tractor. Each ploughing was followed by planking for proper levelling. However, in natural farming nutrient management treatment, slightly raised plots were made.

3.2.2 Layout

The layout of the experiment was carried out with the help of manual labours. The experimental area was divided into three equal parts to adjust three replications and each replication was divided into four main plots. The treatments in the main plot were randomized first in each replication. Nutrient management practices *viz.* RDF/inorganic, organic, natural and integrated nutrient management were then imposed in main plots. Each main plot was further subdivided into three equal sub plots (3.375 m × 3.75 m gross plot) to allocate different varieties *viz.* ‘Him Palam Alsi-2’, ‘Himani’ and ‘Priyam’ after randomization. The field arrangement of replications and plots has been shown in Fig. 3.2.

3.2.3 Seed treatment

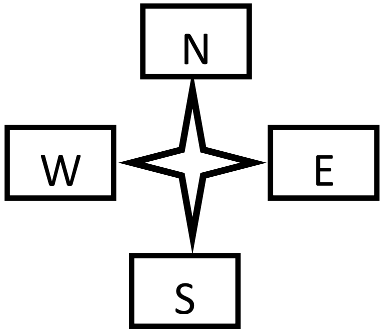
The method employed for seed treatment in respective nutrient management practices has been given as under:

3.2.3.1 Natural farming nutrient management

Prior to sowing, seeds of respective varieties as per treatments were treated directly with *beejamrit* @ 10 litres/100 kg of seeds. Coated seeds with *beejamrit* were spread on polythene sheet and allowed to dry for 2 to 3 hours in shade.

Beejamrit was prepared by using the ingredient *viz.* 5 kg cow dung, 5 litre cow urine, 250 gm lime and handful of soil for dissolution in 20 litre of water basis. All the ingredients were thoroughly mixed in plastic jar stirred two times with a wooden stick and kept overnight before use.

R_2		**R_1**				
N_1V_1	N_4V_2	N_3V_3	N_2V_2	N_4V_1	N_1V_2	PLOT=I
N_1V_2	N_4V_1	N_3V_2	N_2V_3	N_4V_2	N_1V_1	
N_1V_3	N_4V_3	N_3V_1	N_2V_1	N_4V_3	N_1V_3	



R_3				**R_2**		
N_4V_2	N_2V_3	N_1V_1	N_3V_3	N_2V_1	N_3V_3	PLOT=II
N_4V_3	N_2V_1	N_1V_2	N_3V_2	N_2V_3	N_3V_2	
N_4V_1	N_2V_2	N_1V_3	N_3V_1	N_2V_2	N_3V_1	

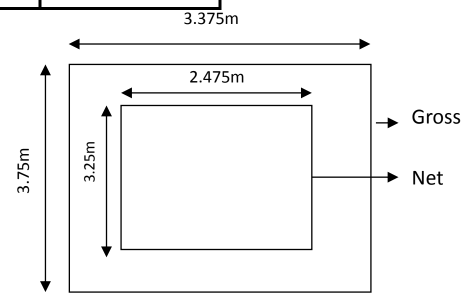


Fig. 3.2: Layout plan of Experimental site

3.2.3.2 Organic nutrient management and Integrated Nutrient Management

In organic and integrated nutrient managed practices, seeds of respective varieties were treated with *Azotobacter* + PSB culture @ 250 g/10 kg of seeds each. For this about half litre of water was taken to which bio-culture was added and mixed so as to form the slurry. The seeds were mixed with this slurry of culture with clean hands, taking care that all seeds were equally coated with the product. This coated seed material was spread on a polythene sheet in shady place and was allowed to dry for about 2 to 3 hours.

3.2.4 Manure application

3.2.4.1 Organic nutrient management

FYM was applied @ 10 t/ha on dry weight basis and mixed well before sowing.

3.2.4.2 Natural Farming nutrient management

In these plots, sieved FYM @ 2.5 q/ha along with finely ground *Ghanjeevamrit* @ 2.5 q/ha was applied in furrows opened with hand plough for placing seeds and mixed well before sowing.

Ghanjeevamrit was prepared by using 100 kg cow dung, 1 kg gram flour (Besan), 1 kg jaggery, 5 litre cow urine and handful of soil. After mixing it was allowed to dry in shade for 2-3 days by covering it. After drying it is ready for use in the fields.

3.2.4.3 Integrated nutrient management

25% N on dry weight basis was applied through FYM in these plots.

3.2.5 Fertilizer application

3.2.5.1 Inorganic nutrient management/RDF

The crop was fertilized with 50 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha. For this 110 kg/ha urea, 250 kg/ha Single Super Phosphate and 35 kg/ha Muriate of Potash were used to supplement the said nutrients. Half of the nitrogen and whole phosphorus and potassium were applied at the time of sowing. The remaining nitrogen was applied as top dressing after about one month of sowing.

3.2.5.2 Integrated nutrient management

The fertilizers were applied @ 75% NPK (*i.e.* 45 kg N, 30 kgP_2O_5 and 30kg K_2O/ha). Nitrogen, phosphorus and potassium were applied through Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O), respectively and the quantity used were 98 kg/ha urea, 187.5 kg/ha Single Super Phosphate and 50 kg/ha Muriate of Potash, respectively. Half of the nitrogen and whole phosphorus and potassium were applied at the time of sowing. The remaining nitrogen was applied as top dressing after about one month of sowing.

3.2.6 Sowing

The seeds of linseed varieties 'Him Palam Alsi-2', 'Himani' and 'Priyam' as per treatments were sown at a spacing of 22.5 cm with the seed rate of 40 kg/ha.

3.2.7 Mulching

In plots where nutrient management was done through natural farming practice, straw mulch @ 3t/ha was spread between crop rows after one month of their emergence.

3.2.8 Liquid inputs application

3.2.8.1 Natural farming nutrient management

Jeevamrit was sprayed as per the schedule mentioned in Table 3.3 in natural farming nutrient managed plots. Five sprays of the *jeevamrit* were done in the entire crop season.

Jeevamrit was prepared by mixing 10 kg cow dung, 2 kg gram flour (Besan), 2 kg jaggery, 10 litre cow urine and handful of soil for one acre land area basis and was allowed to ferment for 2-3 days by covering it with clock wise stirring in morning and evening hours. The fresh product was sprayed after dilution with water @ 1:10 ratio.

One spray of *Fermented Butter milk* was done on the date mentioned in Table 3.3. ***Fermented butter milk*** was prepared by taking an empty earthern pot in which 5 litre of buttermilk and a piece of copper was added in the mixture and was allowed to ferment for 10-15 days by keeping it in a shade. The product was sprayed @ 1:10 ratio by diluting it with water.

3.2.8.2 Organic nutrient management

In organic nutrient management, two sprays of *vermiwash* were done @ 1:10 ratio with water at 30 and 45 DAS, respectively.

For preparing ***vermiwash,*** three earthern pitchers were taken. A hole was made in one of the pitcher and rubber pipe was fitted to it. At the bottom of this pitcher, few pebbles were placed and 2-3 inches layer of sand was spread. Above this, a layer (5-10 cm) of dry biomass and then 10 cm thick layer of cow dung (15-20 days old) were placed. As $2/3^{rd}$ pitcher was filled, 200-300 adult earthworms were added to it. A little biomass was added over it and some amount of water was sprinkled on it. This pitcher was hanged with the help of a jute rope on a tree. Another pitcher, filled with water and having small hole at the bottom was also hanged above this pitcher so that water may fall drop by drop down in the pitcher having earthworms. Third pitcher was placed below it to get the secretion coming out from second pitcher fitted with rubber pipe. This way the secretion in the form of the concentrated *vermiwash* was collected and used after diluting with water @ 1:10 ratio.

3.2.9 Inter culture and weed control

Two hand weedings were done at 30 and 50 DAS, irrespective of the treatments.

3.2.10 Harvesting and Threshing

To obtain the true treatments effect, four outer rows (two on each side) and 0.25 m on either side of each row were removed, leaving a net plot area of 2.475 m × 3.25 m. The crop was harvested manually with the help of sickles from the net plot area, dried and threshed manually with wooden sticks. The seeds and stalk were separated.

3.3 Dates of Agronomic operations

The crop was raised following all recommended package of practices for linseed except that of variable treatments. The dates of various operations followed in the conduct of the experiment have been given in Table 3.3.

Table 3.3: Schedule of cultural and other operations performed during *Rabi* 2018-19

Sr. No.	Operation	Date
1.	Field preparation	20 October, 2018
2.	Layout	24 October, 2018
3.	Sowing	26 October, 2018
(I)	**In Inorganic nutrient management/RDF plots**	
4.	Fertilizer application	
	a) Basal	26 October, 2018
	b) Top dressing	26 November, 2018
(II)	**In Organic nutrient management plots**	
4.0	FYM application	25 October, 2018
4.1	Seed treatment with biofertilizers	26 October, 2018
4.2	Vermiwash application	
	a) 1st spray	26 November, 2018
	b) 2nd spray	10 December, 2018
(III)	**In Natural farming nutrient management plots**	
4.0	Seed treatment with *beejamrit*	26 October, 2018
4.1	Sieved FYM and *Ghanjeevamrit*	26 October, 2018
4.2	Mulching	25 November, 2018
4.3	*Jeevamrit* application	
	a) 1st spray	26 November, 2018
	b) 2nd spray	17 December, 2018
	c) 3rd spray	29 January, 2019
	d) 4th spray	19 February, 2019
	e) 5th spray	31 March, 2019
(IV)	**In INM plots**	
4.0	FYM application	25 October, 2018
4.1	Fertilizer application	
	(i) Basal	26 October, 2018
	(ii) Top dressing	26 November, 2018
5.	Hand weedings	
	a) First hand weeding at 30 DAS	26 November, 2018
	b) Second hand weeding at 60 DAS	26 December, 2018
6.	Irrigation	12 January, 2019
7.	Harvesting	24 May, 2019
8.	Threshing	27 May, 2019

The following observations were recorded from experimental plots to assess the effect of treatments on growth, yield attributes and yield, soil properties, quality of the produce and their economics.

3.4.1 Growth studies

3.4.1.1 Plant height

Five plants were selected randomly from each plot and tagged. Height of these tagged plants was recorded from the ground level up to the tip of top branch in the main stalk. The observations were taken at 60, 90, 120, 150 DAS and at harvest. The average of five plants was worked out to get the mean plant height in cm.

3.4.1.2 Dry matter accumulation

For recording dry matter accumulation, the plants sample from one metre row length on either side in the sampling row next to border row were cut close to the ground surface at 60, 90, 120, 150 DAS and at harvest of the crop. These samples were dried in oven at 70 ^{o}C till constant weight. Dry matter thus recorded was converted into g/m^2**.**

3.4.2 Development Studies

The experimental plots were visited on every alternate day after 105 days of sowing for recording following observations.

3.4.2.1 Days taken to 50% flowering

The experimental plots were visited on every alternate day after the initiation of flowering. Eight plants were randomly selected and the dates on which 50% of these plants (*i.e.* 4) showed flowering were recorded and used for calculating number of days taken from sowing to 50% flowering.

3.4.2.2 Days taken to 50% capsule formation

When the flowering was complete, the plots were observed on alternate days to record the days taken to 50% capsule formation. The dates were recorded when 50% of the randomly selected plants attained capsule formation and were used for calculating number of days taken to 50% capsule formation from sowing.

3.4.2.3 Days taken to maturity

When stems of selected plants turned yellow, capsules got ripened and seed gave shinning brown appearance, the crop was considered to attain maturity. The days from sowing to maturity were counted and recorded as number of days taken to maturity.

3.4.3 Yield and yield attributes

3.4.3.1 Final plant stand

The total number of plants present in one meter row length were counted from two randomly selected places in each net plot, averaged and expressed in thousand plants/ha.

3.4.3.2 Number of primary branches per plant

The branching emerging out from the main shoot just above the ground level was considered as primary branches. Five plants randomly selected from the net plot area were taken for recording the observation. The total number of primary branches was calculated from these tagged plants at harvest and averaged to get number of primary branches/plant.

3.4.3.3 Number of secondary branches per plant

The further branching from the primary branch was taken as secondary branches. The total number of secondary branches from five plants which were tagged was counted at harvest. Number of secondary branches per plant was determined by dividing the total number of secondary branches by five.

3.4.3.4 Number of capsules per plant

Total number of capsules from five tagged plants was counted and average value was expressed as number of capsules per plant.

3.4.3.5 Number of seeds per capsule

Five capsules from each five tagged plants in the net plot area were plucked and seeds from these capsules were counted. The total number of seeds obtained was divided by total number of capsules and the mean number of seeds per capsule was obtained.

3.4.3.6 1000-seed weight

1000 seeds were counted from the seeds sample drawn at random from a net plot area. The seeds were dried in the sun and the weight of 1000 seeds was recorded in gram.

3.4.3.7 Seed yield

The harvested stalks from each net plot were threshed gently by beating with wooden rollers at maturity. The seed yield was obtained in kg/ha by multiplying the net plot yield by factor 1243.20.

3.4.3.8 Straw yield

After threshing, the stalks were sun dried and weighed. The recorded weight was expressed in kg/ha by multiplying the net plot yield by factor 1243.20.

3.4.3.9 Harvest Index

Harvest index was determined by working out the ratio of seed to biological yield of individual plot as per the formula given below.

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3.4.4 Chemical, microbiological and quality studies

3.4.4.1 Chemical studies

3.4.4.1.1 NPK uptake by crop (kg/ha) at harvest

Representative grain and straw samples were collected for each treatment at harvest. These samples were oven dried and ground into fine powder by using mixer grinder and straw grinding machine. Further it was used for estimation of nitrogen, phosphorus and potassium as per standard procedure mentioned below.

Nitrogen content in seed and straw was determined by digesting the sample with concentrated sulphuric acid with K_2SO_4 + $CuSO_4$ + Se mixture and distilling in alkaline medium (Jackson 1973).

Phosphorus content in grain and straw samples was determined by digesting the sample in tri-acid mixture and then using Vanado-molybdo-phosphoric acid method (Jackson 1973).

Potassium content in grain and straw samples was determined by digesting the sample in tri-acid mixture and then using wet digestion method (Black 1965).

The calculated nitrogen, phosphorus and potassium content in seed and straw samples of a treatment was multiplied with seed and straw yield of that particular treatment to obtain uptake of respective nutrient.

3.4.4.1.2 Available NPK (kg/ha) in soil after harvest of crop

The soil samples were collected from 0-15 cm depth from each net plot immediately after harvesting of crop. These samples were dried, processed and analyzed for available nitrogen, phosphorous and potassium by following the same procedure as mentioned in Table 3.1.

3.4.4.2 Soil microbiological studies

3.4.4.2.1 Bacteria, fungi and actinomycetes count

Soil samples were collected from the rhizosphere of the soil profile for counting microbial load present in the soil at harvest (*i.e*. for population of soil bacteria, fungi and actinomycetes) by the standard serial dilution plate count method using Nutrient agar for bacteria, Krustose agar for actinomycetes and Rose Bengal agar for fungi (Wollum 1982). Plates were incubated at 28 ± 2^{0}C in an incubator and colony counts were recorded after six days of incubation. The population was expressed as number of colony forming units per gram (cfu/g) dry weight of soil.

3.4.4.2.2 Microbial biomass carbon

Microbial biomass carbon was determined by fumigation – extraction method (Vance et al. 1987).

For the determination, 20 g soil of each sample was taken in a 50 ml capacity beaker. The soil was then fumigated with 50 ml of ethanol free chloroform in desiccator. The desiccator was evacuated with a vacuum pump. After incubating for 24 hours at room temperature, chloroform was removed and desiccator was evacuated 5 to 6 times. The soil was extracted with 80 ml potassium sulphate (0.5 M) for 30 minutes on a rotary shaker at 160 rpm and contents were filtered through Whatman No. 1 filter paper. Thereafter, 8 ml of filtrate was refluxed with 2 ml $K_2Cr_2O_7$ and 15 ml of acid mixture for half an hour on a hot plate at 150 ^{o}C. It was then titrated with ferrous ammonium sulphate solution using about 3-4 drops of indicator. During titration first brown colour appeared followed by green and then brown again.

A cold blank was prepared by taking 2 ml of $K_2Cr_2O_7$, 8 ml of potassium sulphate (0.5M) and 15 ml of diacid mixture. It was thereafter, titrated with ferrous ammonium sulphate. A hot blank was prepared by taking 2 ml of$K_2Cr_2O_7$, 8 ml of potassium sulphate (0.5 M) and 15ml of diacid mixture, refluxed at 150 ^oC, cooled and titrated with ferrous ammonium sulphate.

Calculations

Normality of ferrous ammonium sulphate was determined by titrating it with cold blank.

$$\text{Exact normality of ferrous ammonium sulphate} = \frac{0.04 \text{ X } 2}{\text{Y}}$$

Where,

0.04 - Expected normality of ferrous ammonium sulphate

2 - Millilitre of potassium dichromate

Y - Millilitre of ferrous ammonium sulphate used for cold blank

Extractable C (µg/g) = (volume of ferrous ammonium sulphate for hot blank - Volume of ferrous ammonium sulphate for sample) x Normality of ferrous ammonium sulphate x 12 x1000 x (80 + Water content)/4 x 8 x dry weight of soil

Biomass C = 2.64 x (Extractable C in fumigated soil – Extractable C in unfumigated soil)

3.4.4.3 Seed quality

3.4.4.3.1 Oil content

The oil content in seeds was determined by the method given in A.O.A.C. (1970) using ether as solvent. The oil content was expressed in percentage on the basis of oven-dried seed basis as:

$$\text{Oil (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of sample (g)}} \times 100$$

3.4.4.3.2 Oil yield

Total oil yield on hectare basis was worked out by multiplying seed yield (kg/ha) with oil percent present in seeds of respective treatment.

3.4.5 Economic Studies

In order to work out the most profitable treatment, the economics of each treatment was worked out.

3.4.5.1 Cost of Cultivation

Cost of cultivation was calculated by adding all the costs involved in each operation or input. For nutrients supplying sources except inorganic fertilizers, the computed cost of cultivation based on the price of inputs made from farmer's own resources have been appended in Appendix II (A, B, C and D).

3.4.5.2 Gross return

To obtain the gross return, yield of the produce *i.e.* seed yield for respective treatment was multiplied with university price for linseed mixture and given in Table 4.14.

3.4.5.3 Net return

The treatment-wise net return were obtained by subtracting the cost of cultivation from gross return.

Net Return (₹ /ha) = Gross Return (₹ /ha) - Cost of cultivation (₹ /ha)

3.4.5.3 BC ratio

Benefit cost ratio was obtained by dividing net return with the treatment wise cost of cultivation as follow:

$$\text{Benefit cost ratio} = \frac{\text{Net returns (₹ /ha)}}{\text{Cost of cultivation (₹ /ha)}}$$

3.5 Statistical analysis

The data obtained were subjected to statistical analysis as per Gomez and Gomez (1984) and were tested at 5 per cent level of significance to interpret the treatment differences. The layout of ANOVA table has been given in Appendix V.

4. RESULTS AND DISCUSSION

The results emanated from the present investigation have been presented in this chapter through Tables and Graphs. An attempt has been made to establish cause and effect relationship of experimental findings, justifying by giving possible scientific explanation and supportive evidences based on the available literature. The results have been discussed under following headings:

4.1 Crop studies

4.2 Chemical, microbiological and quality studies

4.3 Economic studies

4.1 Crop studies

Data with regard to different growth parameters, yield attributes and yield of linseed have been presented in this section.

4.1.1 Growth studies

Data on effect of different treatments on plant height and dry matter accumulation have been given in this section. Data pertaining to these characters were recorded at monthly interval commencing from 60 days after sowing (DAS) till 150 DAS and at harvest.

4.1.1.1 Plant height

The data on the progressive plant height of linseed as influenced of nutrient management practices and varieties have been embodied in Table 4.1. A critical perusal at the data revealed that plant height of linseed increased at increasing rate upto120 DAS and thereafter increase was at decreasing rate upto harvest.

Nutrient management practices influenced the plant height significantly at all stages of observation. The plants in integrated nutrient managed plots were significantly taller which were at par to inorganic nutrient managed plots with recommended dose of fertilizers at all the stages of observation. However at 60 DAS, nutrient management through organics also behaved statistically similar to above said two nutrient management practices. This is due to better availability of nutrients by both organic and inorganic sources in integrated nutrient management practice. The greater uptake of nutrients might have increased the photosynthetic and carbohydrate synthesis and then translocation to different parts for promoting meristematic development in potential apical buds and intercalary meristem which ultimately increased root and shoot development in terms of all the growth parameters. Similar results were found by Badiyala and Kumar (2003) in linseed. Plants were shortest in height where nutrients were supplied through natural farming practices.

The plant height of linseed was significantly influenced by varieties also. Among varieties, 'Him Palam Alsi-2' had produced plants with significantly taller height at all stages of observation. However at 60 and 90 DAS variety 'Priyam' and at 120 and 150 DAS, variety 'Himani' was also at par to 'Him Palam Alsi-2'. At harvest 'Him Palam Alsi-2' was statistically tallest over rest of the varieties.

Table 4.1 Effect of nutrient management practices and varieties on plant height (cm) of linseed

Treatment	Plant height				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
Nutrient management practices					
Inorganic (RDF)	12.6	23.3	47.3	53.7	56.1
Organic management	11.7	20.5	43.7	49.5	50.5
Natural farming management	10.4	19.1	41.7	49.0	49.2
Integrated management	13.9	24.4	51.3	56.1	57.9
SE (m±)	0.51	0.74	1.30	1.47	1.82
CD (P=0.05)	1.79	2.56	4.50	5.08	6.31
Varieties					
Him Palam Alsi-2	12.7	23.9	49.5	54.7	57.0
Himani	11.5	18.9	46.1	51.6	53.9
Priyam	12.3	22.6	42.4	50.0	49.4
SE (m±)	0.31	0.58	1.23	1.05	1.00
CD (P=0.05)	0.94	1.75	3.68	3.16	3.01

Interaction data presented in Table 4.2 revealed that while comparing varieties at same level of nutrient management practice that variety ‘Priyam’ and ‘Him Palam Alsi-2’ under integrated and natural farming nutrient management, respectively had significantly more plant height. While, under inorganic and organic nutrient management plants of variety ‘Him Palam Alsi-2’ were at par to ‘Priyam’ for recording significantly maximum plant height at 90 DAS.

While comparing nutrient management practices with same or different varieties, it was found that plants of variety ‘Priyam’ grown under integrated nutrient management being at par with plants of ‘Him Palam Alsi-2’ grown under inorganic practice with RDF had significantly maximum plant height of linseed at 90 DAS.

Table 4.2 Interaction effect of nutrient management practices and varieties on plant height at 90 DAS of linseed

Nutrient management practice / **Varieties**	**Him Palam Alsi-2**	**Himani**	**Priyam**
Inorganic (RDF)	25.6	20.7	23.5
Organic management	21.3	18.1	21.9
Natural farming management	24.5	15.1	17.6
Integrated management	24.4	21.5	27.1
	SE (m±)	CD (P=0.05)	
CD for two varieties at the same nutrient management practice	0.74	2.56	
CD for nutrient management practice with same or different varieties	0.58	1.75	

4.1.1.2 Dry matter accumulation

The data on progressive dry matter accumulation by linseed crop under different treatments have been presented in Table 4.3. Similar to plant height, crop dry matter accumulation was significantly influenced by different nutrient management practices and varieties at all the stages of observation except at 60 DAS. The plant dry weight increased consistently with advancement in crop.

Among different nutrient management practices, integrated nutrient management behaving statistically similar to inorganic practice with RDF recorded significantly more dry matter accumulation from 90 DAS, upto harvest. It may be due to better crop growth due to better availability of nutrients which might increase photosynthates and thereby significantly higher dry matter accumulation. These results are in conformity with those reported by Lawania et al. (2015). However, at 120 DAS, organic nutrient management being at par with these said nutrient management practices was other best practice in this regard.

Table 4.3 Effect of nutrient management practices and varieties on dry matter accumulation (g/m^2) of linseed

Treatment	**Dry matter accumulation**				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
Nutrient management practices					
Inorganic (RDF)	25.4	55.0	81.0	287.0	305.1
Organic management	23.5	50.2	76.5	283.0	296.0
Natural farming management	22.1	49.3	72.4	279.6	288.9
Integrated management	24.3	51.8	78.6	296.1	312.5
SE (m±)	0.86	1.15	1.65	3.27	4.72
CD (P=0.05)	NS	3.98	5.73	11.32	16.35
Varieties					
Him Palam Alsi-2	25.3	54.2	81.4	296.5	316.2
Himani	22.6	50.0	76.6	286.4	302.5
Priyam	23.6	50.6	73.3	276.5	283.2
SE (m±)	0.55	1.12	1.51	2.82	2.56
CD (P=0.05)	1.67	3.36	4.54	8.46	13.80

Among varieties, except at 60 DAS, ‘Him Palam Alsi–2’ had significantly highest dry matter accumulation and was followed by variety ‘Himani’ at all the stages of observation. However, at 60 DAS variety ‘Him Palam Alsi–2’ followed ‘Priyam’ which was significantly superior among all. While, at 90 and 120 DAS, variety ‘Priyam’ also behaved statistically similar to ‘Himani’, at 150 DAS and harvest it had significantly lowest dry matter accumulation.

4.1.2 Development studies

4.1.2 Days to 50% flowering, 50% capsule formation and 100% maturity

Data on number of days taken for attainment of different development stages *viz.* 50% flowering, 50% capsule formation and 100% maturity have been presented in Table 4.4.

Different nutrient management practices failed to influence different phenophases significantly *viz.* 50% flowering, 50% capsule formation and 100% maturity. However numerically, maximum number of days for attaining 50% flowering, 50% capsule formation and 100% maturity were took in integrated nutrient management plots, followed by inorganic (RDF) and organic nutrient managed plots.

Table 4.4 Effect of nutrient management practices and varieties on number of days taken to 50% flowering, 50% capsule formation and maturity of linseed

Treatment	Days taken to		
	50% Flowering	50 % Capsule formation	Maturity
Nutrient management practices			
Inorganic (RDF)	134	162	205
Organic management	133	161	206
Natural farming management	131	158	204
Integrated management	136	163	208
SE (m±)	1.35	1.30	1.21
CD (P=0.05)	NS	NS	NS
Varieties			
Him Palam Alsi-2	139	168	216
Himani	141	170	214
Priyam	129	145	186
SE (m±)	0.97	1.15	0.84
CD (P=0.05)	2.92	3.47	2.52

The plants grown under natural farming practices took minimum number of days for attaining above said phenophases. As compared to natural farming practice, plants grown under integrated nutrient managed plots delayed 50% flowering and 50% capsule formation by 5 days each and maturity by 4 days.

Among varieties, ‘Him Palam Alsi-2’ and ‘Himani’ behaved statistically similar to each other and significantly delayed different phenophases over ‘Priyam’. Variety ‘Himani’ took 12, 25 and 28 days more for attaining 50% flowering, 50% capsule formation and 100% maturity, respectively as compared to ‘Priyam, while the corresponding delay was 10 , 23 and 30 days with ‘Him Palam Alsi-2’.

4.1.3 Yield attributes and yield

The data on effect of different treatments on yield attributes and yield of linseed crop have been presented in Table 4.5 to 4.9.

4.1.3.1 Final plant stand

It is evident from the data presented in Table 4.5 that different nutrient management practices failed to influence plant stand significantly. However, numerically maximum plant stand was achieved in plots managed by integrated nutrients and followed closely by inorganic and organic practice of nutrient management. Similar results were obtained by Chopra and Badiyala (2016) who reported more plant stand/ha of linseed in the plots receiving integrated nutrient management application.

Among varieties, ‘Him Palam Alsi-2’ and ‘Himani’ being at par with each other proved significantly superior over ‘Priyam’ in recording significantly higher plant stand.

4.1.3.2 Primary branches/plant

It is evident from the data presented in Table 4.5 that different nutrient management practices and varieties significantly influenced the number of primary branches per plant. From the data it was found that all the nutrient management practices except natural farming being at par among themselves had recorded significantly higher number of primary branches per plant. This might be owing to better availability of nutrients which helped in better and vigorous vegetative growth. These results are in close conformity with Patel et al. (2016) who proved the superiority of integrated nutrient management in linseed for this character.

Among varieties 'Him Palam Alsi-2' and 'Priyam' which were at par to each other had significantly higher number of primary branches per plant. Significantly lowest number of primary branches per plant was recorded by 'Himani' variety of linseed.

4.1.3.3 Secondary branches/plant

Secondary branches per plant were significantly influenced by different nutrient management practices and varieties. Among different nutrient management practices, plants supplied with integrated nutrients had significantly higher number of secondary branches per plant. However, plants fertilized only with inorganic (RDF) were also at par to it. Organic nutrient management being at par with inorganic (RDF) one followed these nutrient management practices in having significantly more number of secondary branches per plants. Similar results were found by Patel et. al (2016) for this character.

Among varieties, 'Priyam' and 'Him Palam Alsi-2' which were at par to each other had recorded significantly higher number of secondary branches per plant. Significantly lowest number of secondary branches per plant was recorded by 'Himani' variety of linseed.

4.1.3.4 Capsules/plant

Among different yield attributes, capsules per plant were also significantly influenced by different nutrient management practices and varieties. Among different nutrient management practices, significantly highest number of capsules per plant was recorded in integrated nutrient managed plots. The plants receiving inorganic nutrients (RDF) were the next one in recording significantly higher capsules per plant and followed by organically managed. Significantly lowest number of capsules per plant was recorded in naturally managed plots.

Among varieties, 'Him Palam Alsi-2' was found to be significantly superior over rest of varieties for recording highest number of capsules per plant. While, the other two varieties *viz.* ‘Himani’ and ‘Priyam’ remained at par with each other in influencing number of capsules per plant.

As evident from the interaction data presented in Table 4.6 that while comparing varieties at same level of nutrient management practices, variety ‘Priyam’ and ‘Him Palam Alsi-2’ being at par with each other recorded significantly higher number of capsules/plant when sown under integrated nutrient management practice.

While comparing nutrient management practices with same or different varieties, significantly higher number of capsules per plant was recorded by all the varieties, which performed statistically similar among themselves when sown under integrated nutrient management practices. However variety ‘Him Palam Alsi-2’ grown under inorganic nutrient management with RDF was also at par to these said combinations.

Table 4.5 Effect of nutrient management practices and varieties on plant stand and yield contributing characters of linseed

Treatment	Plant stand (000’/ ha)	Primary branches/ plant	Secondary branches/ plant	Capsules/ plant	Seeds/ capsule	1000 seed weight (g)
Nutrient management practices						
Inorganic (RDF)	1295	5.1	4.8	30.3	8.0	7.0
Organic management	1267	4.8	4.2	28.5	7.8	6.5
Natural farming management	1212	4.3	3.8	26.2	7.7	6.2
Integrated management	1317	5.0	5.1	32.6	8.0	6.9
SE (m±)	47.05	0.12	0.19	0.48	0.15	0.23
CD (P=0.05)	NS	0.42	0.65	1.68	NS	NS
Varieties						
Him Palam Alsi-2	1357	5.1	4.5	30.6	8.1	7.0
Himani	1327	4.2	4.1	28.5	7.6	5.6
Priyam	1133	5.2	4.8	29.1	7.9	7.5
SE (m±)	17.77	0.20	0.12	0.28	0.14	0.22
CD (P=0.05)	53.28	0.62	0.37	0.88	NS	0.68

Table 4.6 Interaction effect of nutrient management practices and varieties on number of capsules/plant of linseed

Nutrient management practice \ Varieties	Him Palam Alsi-2	Himani	Priyam
Inorganic (RDF)	31.0	29.8	30.0
Organic management	29.4	26.4	29.7
Natural farming management	28.8	26.3	23.4
Integrated management	33.0	31.6	33.2
	SE (m±)	CD (P=0.05)	
CD for two varieties at the same nutrient management practice	0.48	1.68	
CD for nutrient management practice with same or different varieties	0.28	0.88	

4.1.3.5 Seeds/capsule

Both nutrient management practices and varieties were failed to influence number of seeds per capsule significantly.

4.1.3.6 1000-seed weight

As evident from the data presented in Table 4.5 that different nutrient management practices had no significant influence on 1000-seed weight.

While among varieties, 'Priyam' and 'Him Palam Alsi-2' behaved statistically similar to each other in recording significantly higher 1000-seed weight. Variety 'Himani' had significantly lowest 1000-seed weight as the seeds of this variety were comparatively smaller than the other two varieties.

4.1.3.7 Seed yield

It was evident from the data presented in Table 4.7 that seed yield of linseed was significantly influenced by different nutrient management practices and varieties. Among nutrient management practices, significantly higher seed yield was recorded in integrated nutrient managed plots. However, nutrient management through inorganic sources (RDF) was also statistically at par to it. Nutrient management through organics being at par with inorganic management was found to be significantly superior over natural farming nutrient management. Significantly lowest yield was recorded in natural farming nutrient management practice. Although both the nutrient management practices *i.e.* integrated and inorganic were at par to each other but the percent increase in the seed yield with integrated nutrient management was 7.53 per cent over inorganic practice. The corresponding increase in the yield with this particular nutrient management practice was 18.17 and 34.98 per cent, over organic and natural farming practice. The highest seed yield under this treatment seems to be due to more number of yield attributing characters like primary & secondary branches per plant and capsules per plant, which contributed in getting significantly higher seed yield of linseed. Results explained above are in close conformity with the finding of Husain et al (2010); Sharma and Dayal (2005) in linseed.

Among varieties ‘Him Palam Alsi-2’ surpassed all other varieties for recording significantly highest seed yield and was followed by ‘Himani’. The variety ‘Priyam’ had significantly lowest seed yield. ‘Him Palam Alsi-2’ had 10.64 and 30.09 per cent higher seed yield over ‘Himani’ and ‘Priyam’ respectively.

Interaction data presented in Table 4.8 revealed that while comparing varieties at same level of nutrient management practice, ‘Him Palam Alsi-2’ being at par with ‘Himani’ recorded significantly higher seed yield when sown under integrated nutrient management practice.

Sowing of ‘Him Palam Alsi-2’ or ‘Himani’ under integrated management practice being at par with sowing of ‘Him Palam Alsi-2’ under inorganic with RDF and organic management practices resulted in significantly higher seed yield of linseed.

4.1.3.8 Straw yield

The data presented in Table 4.7 revealed that the straw yield of linseed was significantly influenced with different nutrient management practices and varieties. Among nutrient management practices, integrated nutrient management being at par with inorganic (RDF) had significantly higher straw yield over others. However numerically, with INM practice there was an yield advantage of about 193.2 kg/ha which was 8.32 per cent higher over inorganic practice. Organic and natural farming nutrient management behaved statistically similar to each other in influencing straw yield of linseed.

Among varieties, 'Him Palam Alsi-2' was proved to be significantly superior for recording highest straw yield. 'Himani' was found to be next best variety for recording significantly higher straw yield. The significantly lowest straw yield was recorded with variety 'Priyam' , 'Him Palam Alsi-2' had registered 12.72 and 23.77 per cent higher straw yield over 'Himani' and 'Priyam', respectively.

Table 4.7 Effect of nutrient management practices and varieties on seed, straw, biological yield (kg/ha) and harvest index of linseed

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
Nutrient management practices				
Inorganic (RDF)	1101.5	2320.9	3665.3	30.2
Organic management	1002.3	2022.3	3233.2	31.0
Natural farming management	877.5	1872.5	2942.2	29.9
Integrated management	1184.5	2514.1	3848.6	30.8
SE (m±)	30.91	81.75	100.30	1.38
CD (P=0.05)	106.98	282.88	347.05	NS
Varieties				
Him Palam Alsi-2	1169	2429.5	3728.7	30.4
Himani	1056.5	2155.2	3395.0	31.4
Priyam	898.6	1962.8	3143.4	28.6
SE (m±)	15.92	46.66	65.48	0.88
CD (P=0.05)	47.75	139.89	196.30	NS

Interaction data presented in Table 4.9 revealed that while comparing varieties at same level of nutrient management practice 'Him Palam Alsi-2' and 'Himani' performed statistically similar to each other in recording higher straw yield when sown under integrated nutrient management practice.

While comparing nutrient management practices with same or different varieties, it was found that variety 'Himani' when sown under integrated nutrient management practice was at par to variety 'Him Palam Alsi-2' when sown under integrated nutrient management practice and inorganic nutrient management with RDF for recording significantly higher straw yield of linseed.

Table 4.8 Interaction effect of nutrient management practices and varieties on seed yield (kg/ha) of linseed

Nutrient management practice \ Variety	Him Palam Alsi-2	Himani	Priyam
Inorganic (RDF)	1197.9	1113.3	992.7
Organic management	1196.5	1001.9	808.5
Natural farming management	984.8	946.3	701.5
Integrated management	1296.8	1165	1091.7
	SE (m±)	CD (P=0.05)	
CD for two varieties at the same nutrient management practice	30.91	106.98	
CD for nutrient management practice with same or different varieties	15.92	47.75	

Table 4.9 Interaction effect of nutrient management practices and varieties on straw yield (kg/ha) of linseed

Nutrient management practice \ Variety	Him Palam Alsi-2	Himani	Priyam
Inorganic (RDF)	2682.1	2072.6	2208.1
Organic management	2367.5	1960.7	1738.7
Natural farming management	2013.4	1892.6	1711.6
Integrated management	2655.0	2694.6	2192.8
	SE (m±)	CD (P=0.05)	
CD for two varieties at the same nutrient management practice	81.75	282.88	
CD for nutrient management practice with same or different varieties	46.66	139.89	

4.1.3.9 Biological yield

Different nutrient management practices and varieties significantly influenced the biological yield of linseed. Significantly higher biological yield was recorded with integrated nutrient management which was statistically at par to inorganic (RDF) practice. However, numerically there was an increase of 5.00 percent in biological yield through INM over inorganic practice. Organic management which behaved statistically similar to inorganic practice followed the above said practices for recording significantly higher biological yield. Lowest biological yield was recorded in natural farming practice of nutrient management.

Among varieties, same trend of seed and straw yield was followed, where 'Him Palam Alsi-2' recorded significantly highest biological yield. It was followed by variety 'Himani' while, significantly lowest biological yield was recorded with 'Priyam'. There was an increase of 9.82 and 18.61 percent in biological yield through 'Him Palam Alsi-2' over 'Himani' and 'Priyam', respectively.

4.1.3.10 Harvest Index

It is evident from the data presented in Table 4.7 that both nutrient management practices and varieties were failed to influence the Harvest Index significantly.

Numerically 'Himani' had highest harvest index which was followed by 'Him Palam Alsi-2', while, lowest harvest index was recorded for 'Priyam'.

4.2 Chemical, microbiological and quality studies

4.2.1. Chemical studies

The data on uptake of nitrogen, phosphorus and potassium by crop (seed and straw of linseed) and available major nutrients *viz*. nitrogen, phosphorus and potassium (kg/ha) in soil as influenced by the treatments have been presented in Table 4.10 and 4.11, respectively.

4.2.1.1 Nutrient uptake by crop

Nutrient management practices and varieties have significant influence on nutrient uptake by seed and straw of linseed (Table 4.10).

Among nutrient management practices, integrated nutrient management behaving statistically similar to inorganic management through RDF had significantly higher N, P and K uptake by both seed and straw of linseed. Better availability of nutrients in integrated nutrient management led to increase growth and higher dry matter accumulation of the crop and thereby increased nutrient uptake by increasing the seed and straw yield of linseed, as the nutrient uptake in the function of nutrient content and dry matter (seed+straw) yield of the crop. These practices were followed by organic management for all the nutrients in seed and straw, except potassium in straw where natural farming nutrient management practice was also at par to it. Natural farming nutrient management practice was found to be significantly inferior for rest of nutrients in straw and seed.

Table 4.10 Effect of treatments on N, P and K uptake (kg/ha) by linseed crop at harvest

Treatment	Nutrient uptake (kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Seed	Straw	Seed	Straw	Seed	Straw
Nutrient management practices						
Inorganic (RDF)	66.9	43.4	7.1	10.9	21.0	40.2
Organic management	61.1	37.8	5.2	7.9	18.8	31.0
Natural farming management	54.1	32.3	4.8	5.9	13.3	27.3
Integrated management	69.2	46.8	6.4	11.5	22.8	37.7
SE (m±)	1.15	1.48	0.26	0.50	0.62	1.18
CD (P=0.05)	4.01	5.13	0.94	1.74	2.19	4.09
Varieties						
Him Palam Alsi-2	66.5	42.3	6.1	9.6	21.1	38.0
Himani	62.7	39.9	6.2	9.4	17.8	34.1
Priyam	59.3	38.0	5.4	8.2	18.0	30.1
SE (m±)	0.94	0.80	0.20	0.38	0.50	1.78
CD (P=0.05)	2.81	2.42	0.61	1.16	1.50	5.35

Among varieties, significantly higher uptake of all recorded nutrients in seed and straw was done by ‘Him Palam Alsi-2’. However, variety ‘Himani’ was also at par to it for recording significantly higher uptake of phosphorus in seed and uptake of N, P and K in straw.

4.2.1.2 Available NPK in soil at harvest

The data on the influence of nutrient management practices and varieties of linseed on available nitrogen, phosphorus and potassium after crop harvest have been presented in Table 4.11.

4.2.1.2.1 Available nitrogen

As evident from the data presented in Table 4.11 that all nutrient management practices except natural farming were statistically at par among themselves in recording higher available nitrogen in soil at harvest of the crop. Significantly lower available nitrogen was recorded in plots where nutrient management was done through natural farming practice, however, it was statistically at par to organically managed plots.

Available nitrogen in soil at crop harvest was not influenced statistically by different varieties.

4.2.1.1.2 Available phosphorus

Significantly higher available phosphorus in soil at harvest of crop was recorded in inorganically and integrated nutrient managed plots, which were statistically similar to each other. Nutrient management through organics, which was at par to integrated nutrient, followed these practices for recording higher available phosphorus in soil. Lowest value of available phosphorus was recorded in plots where nutrient management was done through natural farming practice.

Available phosphorus in soil after harvest of linseed crop was not influenced significantly by different varieties (Table 4.11).

4.2.1.1.3 Available Potassium

Integrated nutrient management practice resulted in significantly highest available potassium in soil at crop harvest. Nutrient management through inorganic (RDF) being at par with organic followed it for recording significantly high available potassium in soil. Lowest available potassium was recorded in plots where nutrient management was done through natural farming.

However in context to varieties, there was no significant influence on available potassium in soil at harvest of the crop (Table 4.11).

Table 4.11 Effect of treatments on available N, P and K uptake (kg/ha) in soil at harvest

Treatment	Available Nutrient		
	Nitrogen	**Phosphorus**	**Potassium**
Nutrient management practices			
Inorganic (RDF)	234.7	24.7	133.9
Organic management	239.7	22.7	126.8
Natural farming management	229.1	21.8	123.8
Integrated management	243.3	23.5	145.4
SE (m±)	2.59	0.55	2.58
CD (P=0.05)	8.98	1.92	8.97
Varieties			
Him Palam Alsi-2	233.6	22.5	130.6
Himani	237.2	23.2	132.4
Priyam	239.2	23.8	134.4
SE (m±)	6.54	0.42	1.72
CD (P=0.05)	NS	NS	NS

4.2.2 Microbial population

The data on population of bacteria, fungi, actinomycetes and total microbial biomass carbon in the soil recorded after the harvest of crop have been presented in Table 4.12.

Significantly higher microbial count *i.e.* of bacterial, fungal, actinomycetes count and total microbial biomass carbon was recorded in organic nutrient management practice. However integrated nutrient management practice was at par to it for all these microbiological parameter. This might be due to the fact that application of organic manures helped in increasing organic carbon content of soil which acted as carbon and energy sources for microbes in organic and integrated nutrient management practices and resulted in quick build-up of microflora and fauna.

With respect to count of fungal population, nutrient management practice through natural farming was also at par to these two said practices. Significantly lowest count of bacteria and actinomycetes were recorded in inorganic nutrient management with RDF.

Microbial count and total microbiological biomass carbon was not influenced by varieties.

Table 4.12 Effect of different nutrient management and varieties on microbial count and microbial biomass carbon (MBC)

Treatments	Bacterial population (× 10^4CFU g^{-1} soil)	Fungal population (× 10^4CFU g^{-1} soil)	Actinomycetes population (× 10^4CFU g^{-1} soil)	MBC (µg g^{-1})
Nutrient management practices				
Inorganic (RDF)	14.6	60.8	54.6	121.6
Organic management	16.7	68.1	60.4	131.1
Natural farming management	15.8	65.3	62.6	125.7
Integrated management	16.4	67.7	58.8	128.6
SE (m±)	0.23	1.08	0.70	1.82
CD (P=0.05)	0.80	3.73	2.45	7.28
Varieties				
Him Palam Alsi-2	16.1	64.3	57.9	125.7
Himani	16.3	65.7	58.7	125.0
Priyam	15.2	66.5	60.7	130.4
SE (m±)	0.29	1.23	1.38	1.73
CD (P=0.05)	NS	NS	NS	NS

4.2.3 Seed Quality

The data on quality studies of seed in terms of oil content and oil yield as influenced by different treatments in linseed have been presented in Table 4.13 and described in this section.

4.2.3.1 Oil content

It was evident from the data presented in Table 4.13 that different nutrient management practices and varieties were failed to influence the oil content of linseed significantly. However in general, nutrient management through organic sources resulted in highest oil content (34.3%) followed by integrated and natural farming practice with corresponding value of 33.7 and 32.6%, respectively.

Table 4.13 Effect of treatments on oil content and oil yield of linseed

Treatment	Oil content (%)	Oil yield (kg/ha)
Nutrient management practices		
Inorganic (RDF)	32.6	350.0
Organic management	34.3	319.2
Natural farming management	33.1	270.3
Integrated management	33.7	379.6
SE (m±)	0.63	9.79
CD (P=0.05)	NS	33.88
Varieties		
Him Palam Alsi-2	33.1	378.3
Himani	34.2	320.6
Priyam	33.0	290.5
SE (m±)	0.57	11.12
CD (P=0.05)	NS	33.36

Although different varieties did not significantly influence the oil content, but numerically due to varietal characteristic ‘Himani’ had advantage in term of higher oil content (34.2%) in seed.

4.2.2.2 Oil yield

Different nutrient management practices and varieties had significant influence on oil yield (Table 4.13).

Among different nutrient management practices, integrated nutrient being at par with inorganic (RDF) resulted in significantly higher oil yield. This was followed by organic which was statistically comparable to inorganic (RDF). Significantly lowest oil yield was recorded in natural farming nutrient management practice. The integrated nutrient management has recorded 8.45, 18.92 and 40.43% higher oil yield over inorganic, organic and natural farming practice of nutrient management, respectively. Hussain et al. (2010) also reported high oil yield in linseed with integrated nutrient management practice.

Among varieties, ‘Him Palam Alsi-2’ had the significantly highest oil yield and followed by ‘Himani’. As oil yield is the multiple of oil content and seed yield so the effects were reflected in the same way as that of seed yield due to particular treatment. Variety ‘Him Palam Alsi-2’ had 17.99 and 30.22 percent more oil yield as compared to ‘Himani’ and ‘Priyam’ varieties of linseed, respectively.

4.3 Economic studies

Data on economics of linseed as influenced by different nutrient management practices and varieties have been given in Table 4.14 and Appendix-III.

Cost of cultivation was calculated by adding all the costs involved in each operation or input. For nutrients supplying sources except inorganic fertilizers, the cost of cultivation was calculated based on the price of inputs made by the farmers from their own farm resources and based on this other economic parameters *viz.* gross return, net return and BC ratio were calculated.

4.3.1 Cost of cultivation

Among nutrient management practices, lowest cost of cultivation was incurred in inorganic practice with RDF (₹ 24653/ha) followed by integrated nutrient management (₹ 25444/ha), while the maximum cost of cultivation was incurred in organic farming (₹ 27890/ha). This is because of the use of synthetic fertilizers to supply nutrients in inorganically managed plots, whereas in integrated nutrient management, nutrients supply was supplemented with the use of FYM which added to the cost of production. Use of higher quantity of organic compost in the form of FYM added to the total cost of cultivation and thereby increased total cultivation cost of linseed crop in organic nutrient management. Also in natural farming nutrient management practice, repeated application of different natural farming inputs (*viz. Jeevamrit* and fermented butter milk) along with *ghanjeevamrit* and sieved farm yard manure increased the cost of cultivation.

Total cost of cultivation for raising different varieties was ₹ 26194/ha.

4.3.2 Gross return

Maximum gross return of ₹ 47380/ha were obtained through integrated nutrient management practice and followed by inorganic practice with RDF (₹ 44052/ha). Lowest gross return of ₹ 35102/ha were obtained with natural farming practice. There was an additional gain of ₹ 3328, 7288 and 12278/ha through integrated nutrient management as compared to inorganic, organic and natural farming practices, respectively.

Among varieties, 'Him Palam Alsi-2' has fetched highest gross return of ₹ 4676/ha which were ₹ 4496 and 10818/ha more as compared to 'Himani' and 'Priyam' respectively.

The higher gross returns were due to higher seed yield under integrated nutrient management practice and with 'Him Palam Alsi-2' variety of linseed.

4.3.3 Net Return

Integrated nutrient management practice resulted in maximum net return of ₹ 21936/ha and followed by inorganic practice having net return of ₹ 19400/ha. Natural farming practice of nutrient management has resulted in lowest net return of ₹ 8312/ha, while it was ₹ 12202/ha with organic nutrient management. Additional net return obtained with integrated nutrient management practice were ₹ 2536, 9734 and 13624/ha as compared to inorganic, organic and natural farming nutrient management practice, respectively. Lower cost of cultivation and higher gross returns resulted in obtaining higher net return under integrated nutrient management practice.

While among different varieties of linseed, highest net return of ₹ 20567/ha were obtained with 'Him Palam Alsi-2' and followed by 'Himani' (₹ 16071/ha). Sowing of 'Him Palam Alsi-2' has resulted in getting additional net return of ₹ 4496 and 10818/ha over 'Himani' and 'Priyam' respectively.

4.3.4 BC ratio

Among different nutrient management practices and varieties same trend as that of gross and net return was followed for BC ratio.

There was an advantage of 0.07, 0.42 and 0.55 in BC ratio through integrated nutrient management practice as compared to inorganic, organic and natural farming, respectively. Due to involvement of less cost of cultivation and highest net return, the higher value for BC ratio was obtained under integrated nutrient management practice.

Among varieties, 'Him Palam Alsi-2' had highest BC ratio of 0.79 due to higher net returns and similar cost of cultivation and followed by 'Himani' with a value of 0.62. Lowest BC ratio of 0.38 was obtained with sowing of 'Priyam' variety of linseed.

Table 4.14 Effect of nutrient management practices and varieties on cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha) and BC ratio

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Nutrient management practices				
Inorganic (RDF)	24653	44052	19400	0.79
Organic management	27890	40092	12202	0.44
Natural farming management	26790	35102	8312	0.31
Integrated management	25444	47380	21935	0.86
Varieties				
Him Palam Alsi-2	26194	46761	20567	0.79
Himani	26194	42265	16071	0.62
Priyam	26194	35943	9749	0.38

5. SUMMARY AND CONCLUSIONS

The field experiment entitled "**Performance of linseed (*Linum usitatissimum* L.) varieties under different nutrient management practices**" was carried out during *Rabi* 2018-19 at Linseed Unit, Department of Genetics and Plant Breeding, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur with the following objectives:

i. To find out the suitable variety for achieving higher productivity and profitability under different nutrient management practices, and

ii. to find out the effect of treatments on soil properties.

Twelve treatments comprising of four nutrient management practice (*viz.* Inorganic (RDF), Organic, Natural and Integrated) in main plots and three varieties (*viz*. 'Him Palam Alsi-2', 'Himani' and 'Priyam') in subplots were evaluated in split plot design with three replications. The results emanated from present study are summarized here as below:

5.1 Crop growth

5.1.1 Effect of nutrient management practices

Integrated nutrient management practice being at par with inorganic supplied through RDF has produced plants with significantly more height and dry matter during all the stages of observation except at 60 DAS for dry matter accumulation.

5.1.2 Effect of varieties

'Him Palam Alsi-2' has significantly taller plants at all the stages of observations. However, 'Priyam' and 'Himani' were also at par to it at 60-90 and 120-150 DAS, respectively.

Plants of ‘Him Palam Alsi-2’ had significantly highest dry matter accumulation at all the stages of observation. However, ‘Priyam’ behaved statistically similar to it at 60 DAS.

5.2 Development studies

5.2.1 Effect of nutrient management practices

Different nutrient management practices were failed to influence different development stages of plant (50% flowering, 50% capsule formation and maturity).

5.2.2 Effect of varieties

‘Him Palam Alsi-2’ and ‘Himani’ being at par to each other took more number of days to attain 50% flowering, 50% capsule formation and maturing over ‘Priyam’.

5.3 Yield and yield attributes

5.3.1 Effect of nutrient management practices

Plant stand was not influenced significantly by different nutrient management practices.

Application of nutrients through integrated management resulted in significantly higher number of primary and secondary branches per plant, which was equivalent to inorganic management. However organic nutrient management was also at par to said practices for higher primary branches per plants.

Significantly highest capsules per plant were recorded with integrated nutrient management practice.

There was no significant influence on number of seeds per capsules and 1000-seed weight of linseed by different nutrient management practices.

Integrated nutrient management practice behaving statistically similar to inorganic nutrient management through RDF has resulted in significantly higher seed, straw and biological yield of linseed.

Harvest index was not significantly influenced by different nutrient management practices.

5.3.2 Effect of varieties

'Him Palam Alsi-2' behaving statistically similar to 'Himani' had significantly more plant stand, number of primary & secondary branches per plant and 1000-seed weight than 'Priyam'.

Variety 'Him Palam Alsi-2' was proved to be significantly superior for recording highest number of capsules per plant.

Varieties failed to significantly influence seeds per capsule.

'Him Palam Alsi-2' over yielded all other varieties for recording significantly highest seed, straw and biological yield.

Harvest index was not significantly influenced by different varieties of linseed.

5.3.3 Effect of nutrient management practices and varieties in combination

All linseed varieties sown under integrated nutrient management practice and 'Him Palam Alsi-2' sown under inorganic nutrient practice behaved statistically similar among themselves for recording significantly higher number of capsules per plant.

Significantly higher seed yield of linseed was recorded with 'Him Palam Alsi-2' sown in any of the nutrient management practice except natural farming, which were at par to variety 'Himani' of linseed sown under integrated nutrient management practice.

Variety 'Himani' sown under integrated management practice behaved statistically with 'Him Palam Alsi-2' sown under integrated or inorganic nutrient management conditions for recording significantly higher straw yield of linseed.

5.4 N, P and K uptake by crop

5.4.1 Effect of nutrient management practices

Significantly higher uptake of nitrogen, phosphorus and potassium both by seed and straw was recorded in statistically alike nutrient management practices through integrated and inorganic sources.

5.4.2 Effect of varieties

Significantly highest uptake of nitrogen and potassium in seed was recorded by ‘Him Palam Alsi-2’.

However, significantly higher uptake of nitrogen and phosphorous in seed, phosphorus and potassium in straw was recorded in statistically alike varieties of ‘Him Palam Alsi-2’ and ‘Himani’.

5.5 Available nutrient (N, P and K) in soil

5.5.1 Effect of nutrient management practices

After harvest of the crop, significantly higher available nitrogen and phosphorus in soil was recorded with statistically alike nutrient management practices through integration and alone application of inorganic sources. However, nutrient management through organic sources was also at par to these two said nutrient management practices for higher available nitrogen.

Significantly highest available potassium in soil after harvest of crop was recorded in integrated nutrient management practice.

5.5.2 Effect of varieties

Varieties had no significant influence on available N, P and K in soil after harvest of the crop.

5.6 Microbial count and microbial biomass carbon

5.6.1 Effect of nutrient management practices

Organic practice of nutrient management resulted in significantly higher count of bacteria, fungi, actinomycetes and microbial biomass carbon, which was at par to integrated nutrient management practice for all these parameters. However, for higher fungal count, natural farming practice was at par to these above practices.

5.6.2 Effect of varieties

None of the microbial parameter (*i.e* bacterial, fungal, actinomycetes count and microbial biomass carbon) was significantly affected by varieties.

5.7 Seed Quality

5.7.1 Effect of nutrient management practices

Oil content was not varied with different nutrient management practices. Integrated and inorganic nutrient management practices were statistically at par to each other in recording significantly higher oil yield.

5.7.2 Effect of varieties

No significant influence of the varieties was found on oil content. However, significantly highest oil yield was obtained with 'Him Palam Alsi-2'.

5.8 Economics

5.8.1 Effect of nutrient management practices

Lowest cost of cultivation was incurred in inorganic through RDF followed by integrated nutrient management practice.

Highest gross return (₹ 47380/ha), net return (₹ 21936/ha) and BC ratio of 0.86 were obtained by following integrated nutrient management practice, which was followed by inorganic practice of nutrient management through RDF, for all these said economic parameters.

5.8.2 Effect of varieties

For cultivating all varieties, similar cost of cultivation was incurred. Highest gross, net return and BC ratio of ₹ 46761, 20567/ha and 0.79, respectively were obtained with 'Him Palam Alsi-2' followed by 'Himani'.

Conclusion

Variety 'Him Palam Alsi-2' sown under integrated nutrient management practice resulted in significantly higher seed yield (1297 kg/ha) and fetched highest net return of ₹ 26429/ha.

Among different nutrient management practices, integrated being comparable to organic farming was found to be significantly superior for recording higher microbial count and Microbial Biomass Carbon. Integrated Nutrient Management being at par with inorganic practice of nutrient management had significantly higher available major nutrient (NP&K) in soil after crop harvest. While, varieties had no significant influence on soil properties.

Thus, sowing of ‘Him Palam Alsi-2’ with integrated nutrient management was found to be the best module for recording higher yield with better sustainability.

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APPENDICES

Appendix-I: Mean weekly meteorological data at Palampur (26th Oct, 2018 to 24th May, 2019)

Standard week No.	Max. Temp. (°C)	Min. Temp. (°C)	Mean Relative humidity (%)	Rainfall (mm)
43	23.6	10.1	47	0.0
44	22.6	10.5	64	23.8
45	20.4	7.3	63	1.0
46	19.7	7.6	65	22.0
47	21.0	7.0	60	0.0
48	20.1	7.1	69	0.0
49	17.1	4.9	66	0.0
50	14.9	4.5	59	6.2
51	18.2	3.6	53	0.0
52	14.9	1.5	57	0.0
1	13.9	4.0	62	27.8
2	14.4	3.0	66	7.4
3	16.9	5.5	55	0.0
4	10.7	2.3	66	75.6
5	13.9	3.7	59	49.0
6	15.7	4.3	61	104.0
7	16.1	6.4	72	59.0
8	15.7	6.3	72	82.0
9	13.7	5.1	67	23.2
10	17.7	5.6	63	4.0
11	17.8	6.8	59	23.8
12	21.6	9.0	52	3.4
13	24.1	11.5	52	1.0
14	27.3	13.7	48	4.2
15	26.4	14.4	48	0.0
16	22.7	11.8	68	40.2
17	29.3	15.4	43	13.0
18	28.9	14.8	34	1.0
19	30.5	17.9	42	2.0
20	27.4	15.1	56	36.4
21	28.7	17.4	51	3.0

Appendix-II(A): Components of cost of cultivation in case of RDF/inorganic nutrient management practice

	Particulars	Quantity	Rate (₹)	Amount (₹ /ha)
A.	**Land Preparation**			
i)	Ploughing	8 hrs	700/hr	5600.00
ii)	Labour	5 man days	250/man day	1250.00
B.	**Cost of fertilizers**			
i)	50 kg N through urea (46 % N)	109 kg	5.33/kg	580.97
ii)	40 kg P through SSP (16 % P)	250 kg	11.14/kg	2785.00
iii)	20 kg K through MOP (60 %K)	33 kg	18.09/kg	596.97
iv)	Labour (Top dressing)	4 man days	250 / man day	1000.00
C.	**Cost of seed and sowing**			
i)	Cost of seed	40 kg	79/kg	3160.00
ii)	Labour	15 man days	250/man day	3750.00
D.	**Cost of irrigation**			
i)	1 Irrigation	2 man days	250/man day	500.00
ii)	Water charges	14 hrs	120/hr	1680.00
E	**Harvesting and Threshing**	15 man days	250/man day	3750.00
	Total			**24652.94**

Appendix-II(B): Components of cost of cultivation of natural farming nutrient management practice

	Particulars	Quantity	Rate (₹)	Amount (₹ /ha)
A.	**Land Preparation**			
i)	Ploughing	8 hrs	700/hr	5600.00
ii)	Labour	5 man days	250/man day	1250.00
B.	**Cost of fertilizers**			
i)	Bijamrit (seed treatment)	50L	2/L	100.00
ii)	Sieved FYM 2.5Q/ha	250 kg	1/kg	250.00
iii)	Ghanjivamrit 2.5Q/ha	250 kg	7.5/kg	1875.00
iv)	Jivamrit (5 sprays)	250 L	1.5/ L	375.00
v)	Fermented butter milk (1 spray)	50 L	10/L	500.00
vi)	Labour	16 man days	250/man day	4000.00
C.	**Cost of seed and sowing**			
i)	Cost of seed	40 kg	79/kg	3160.00
ii)	Labour	15 man days	250/man day	3750.00
D.	**Cost of irrigation**			
i)	Irrigation	2 man days	250/man day	500.00
ii)	Water charges	14 hrs	120/hr	1680.00
E	**Harvesting and Threshing**	15 man days	250/man day	3750.00
	Total			**26790.00**

Appendix-II(C): Components of cost of cultivation for organic farming nutrient management practice

Particulars	Quantity	Rate (₹)	Amount (₹ /ha)
Land Preparation			
Ploughing	8 hrs	700/hr	5600.00
Labour	5 man days	250/man day	1250.00
Cost of fertilizers			
FYM 10t/ha	11000 kg	0.5/kg	5500.00
Vermiwash (2 sprays)	100 L	3/L	300.00
Azotobacter(seed treatment)	200gm	1/gm	200.00
PSB(seed treatment)	200gm	1/gm	200.00
Labour	8 man days	250 / man day	2000.00
Cost of seed and sowing			
Cost of seed	40 kg	79/kg	3160.00
Labour	15 man days	250/man day	3750.00
Cost of irrigation			
Irrigation(1)	2 man days	250/man day	500.00
Water charges	14 hrs	120/hr	1680.00
Harvesting and Threshing	15 man days	250/man day	3750.00
Total			**27890.00**

Appendix-II(D): Components of cost of cultivation for integrated nutrient management practice

	Particulars	Quantity	Rate (₹)	Amount (₹ /ha)
A.	**Land Preparation**			
i)	Ploughing	8 hrs	700/hr	5600.00
ii)	Labour	5 man days	250/man day	1250.00
B.	**Cost of fertilizers**			
i)	75% N through urea	82.5 kg	5.33/kg	439.72
ii)	75% N through SSP	187.5 kg	11.14/kg	2088.75
iii)	75% N through MOP	24.9 kg	18.09/kg	450.44
iii)	25% N through FYM	2750kg	0.5/kg	1375.00
iv)	Azotobacter (seed treatment)	200gm	1/gm	200.00
v)	PSB (seed treatment)	200gm	1/gm	200.00
iv)	Labour	4 man days	250 / man day	1000.00
C.	**Cost of seed and sowing**			
i)	Cost of seed	40 kg	79/kg	3160.00
ii)	Labour	15 man days	250/man day	3750.00
D.	**Cost of irrigation**			
i)	Irrigation	2 man days	250/man day	500.00
ii)	Water charges	14 hrs	120/hr	1680.00
E	**Harvesting and Threshing**	15 man days	250/man day	3750.00
	Total			**25443.91**

Appendix-(III): Effect of nutrient management practices and varieties on cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha) and BC ratio

Treatments	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
N1V1	24653	47916	23263	0.94
N1V2	24653	44533	19880	0.81
N1V3	24653	39708	15055	0.61
N2V1	27890	47861	19971	0.72
N2V2	27890	40077	12187	0.44
N2V3	27890	32339	4449	0.16
N3V1	26790	39393	12603	0.47
N3V2	26790	37852	11062	0.41
N3V3	26790	28060	1270	0.05
N4V1	25444	51873	26429	1.04
N4V2	25444	46599	21155	0.83
N4V3	25444	43667	18223	0.72

Appendix-(IV): Detailed characteristics of different varieties

Him Palam Alsi-2: It is a seed type variety suitable for cultivation in Zone-1 of India (H.P, Uttrakhand, Punjab, Jammu and Haryana). It has an erect growth habit, disc shaped blue flowers, pointed tip capsules and brown seeds. It is resistant to powdery mildew and bud fly and has an average yield of 16.8 q/ha with 35.3% oil content.

Himani: It is a seed type variety suitable for cultivation in Zone-1 of India (H.P, Uttrakhand, Punjab, Jammu and Haryana). It has blue flowers, small brown seeds and is resistant to powdery mildew and rust. It has an average yield of 11.00 q/ha under cultivated conditions and 5.83 q/ha under utera conditions. Average oil content is about 36.4%.

Priyam: It is a seed type variety suitable for cultivation in Zone-1 of India (H.P, Uttrakhand, Punjab, Jammu and Haryana). It has white colour flowers, brown coloured seeds and is resistant to rust, wilt, alternaria blight and powdery mildew. It has average yield of 12.53q/ha with oil content of 37.5%.

Appendix-(V): Layout of ANOVA table

Source of Variation	**Degree of freedom**
Replication (R)	(R-1)=2
Nutrient management practices (N)	(N-1)=3
Error (a)	(R-1)(N-1) = 4
Varieties (V)	(V-1)=2
Interaction (NxV)	(N-1)(V-1)=6
Error (b)	N(R-1)(V-1)=16
Total	(RNV-1)=35

Brief Biodata of student

Name	**:**	Nitin Sood
Father's Name	:	Sh. Sudesh Kumar Sood
Mother's Name	:	Smt. Anita Sood
Date of Birth	:	24th November, 1993
Permanent Address	:	V.P.O Rajpur, Teh.- Palampur, District-Kangra

Academic Qualifications:

Qualification	Month	Year	School/Board/ University	Marks (%)	Division
10th	April	2010	Indian Certificate of Secondary Education, New Delhi	73.00	Ist
10+2	April	2013	Himachal Pradesh Board of Secondary Education, Dharamshala	81.00	Ist
B.Sc. (Agriculture)	June	2017	CSKHPKV, Palampur	70.60	Ist

Fellow/Scholarship/Gold Medals/Awards/Any Other Distinction: -Nil-

Publications:

Total: Nil
Research papers (in peered journals): - Nil
Scientific Popular Articles: - Nil
Others: Nil