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Response of liquid biofertilizers on yield and economics of linseed (*Linum usitatissimum* L.)

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Abstract

In the Rabi season of 2022-23, a field experiment was carried out at the SAGE University Agriculture Farm in Bhopal, Madhya Pradesh. The study aimed to investigate the "impact of liquid bio fertilizers on yield and economics of *Linum usitatissimum* L. under irrigated conditions." The experimental design employed a randomized block layout, covering an area of 215 square meters, and featured ten distinct treatments involving organic nitrogen sources. These treatments included: Control-T_0 (no additional nutrients), T_1-N-260 g, P-300 g, K-200 g, T_2-N-260 g, P-300 g, K-200 g, with 15 kg of vermi-compost and 8 ml of liquid bio-fertilizer, T_3-N-260 g, P-300 g, K-200 g, with 3 kg of vermi-compost and 5ml of liquid bio-fertilizer, T_4-N-260 g, P-300 g, K-200 g, with 15 kg of vermicompost and 1.5 ml of liquid bio-fertilizer. The results of the experiment demonstrated that various growth and yield-related characteristics of linseed, such as plant height at 60 days after sowing and at harvest, the number of branches per plant at 60 days after sowing and at harvest, dry matter accumulation (in grams per plant) at 120 days after sowing and at harvest, root length (in centimeters) at 120 days after sowing and at harvest, root dry biomass (in grams per plant) at 120 days after sowing and at harvest, the number of capsules per plant, test weight (in grams), seed yield (in kilograms per hectare), and straw yield (in kilograms per hectare), all exhibited significantly higher values under treatment T_3 (N equivalent to 15 kg/ha through vermi-compost).

Keywords: Linseed, nitrogen (N), phosphorus (P), potassium (K), vermicompost, liquid bio fertilizer, higher growth and yield, study the economics

1. Introduction

Linseed (*Linum usitatissimum* L.), commonly known as flax, is a versatile crop cultivated primarily for its seeds, which are a rich source of oil with an oil content ranging from 33% to 47%. Linseed oil has widespread industrial applications, such as in the production of paints, varnishes, oilcloth, waterproof fabrics, linoleum, and even as an edible oil in certain regions. The byproduct, linseed cake, serves as an excellent organic fertilizer and animal feed. Additionally, linseed is used in the manufacturing of paper and plastics.

Flax, or linseed (*Linum usitatissimum* L.), belongs to the Linaceae plant family within the Linum genus. It holds significant commercial importance as the sole species in the Linaceae family. Worldwide, linseed is cultivated over approximately 32.23 lakh hectares, yielding an annual output of 951.8 kg per hectare, totaling 30.68 lakh tonnes. In India, it ranks fourth globally in terms of production, following Canada, China, and the United States. India stands as the second-largest producer of linseed, following Canada. Linseed is the second-largest oilseed crop in India's Rabi season, with an area of around 1.72 lakh hectares, an annual production of 0.99 lakh tonnes, and a productivity rate of 573.6 kg per hectare. The most productive states include Rajasthan (yielding 1012 kg per hectare), followed by Bihar (800 kg), Jammu and Kashmir (630 kg), Uttar Pradesh (615 kg), and Assam (600 kg).

Every part of the linseed plant finds commercial use, either directly or after processing. The nutritional composition of linseed includes protein content at 20–24%, oil content at 37–42%, carbohydrates at 15–29%, crude fiber at 5-9%, and ash at 2-4%. Linseed oil is employed in various industrial applications, including boiling oil, borated oil, epoxidized oil, aluminated oil, isomerized oil, and urethane oil. Linseed oil is rich in omega-3 fatty acids, particularly alpha-linoleic acid, which has been associated with health benefits, such as reducing the risk of heart disease, inflammatory conditions, arthritis, and cancer prevention.

Vermi-compost, known for its high nutrient content and exceptional biological properties, offers readily available nutrients and is known to support increased crop yields.

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The use of *Azotobacter chroococcum* and *Azospirillum lipoferum* in the NPK consortium, a liquid bio-fertilizer, contributes to nitrogen fixation, phosphate solubilization, and potash mobilization. This bio-fertilizer is applied to soil, treated seeds, seedlings, and can be used with drip irrigation.

Among various oilseed crops, linseed, safflower, sesame, castor, soybean, mustard, groundnut, sunflower, and niger are known for their high production potential. This has been achieved through effective farmer training and the application of suitable technical inputs. Castor oil cake, with a composition of 4.3% nitrogen, 1.8% P_2O_5, and 1.3% K_2O, serves as a rapid-release organic manure. Well-decomposed farmyard manure contains essential nutrients such as nitrogen, phosphorous, potassium, iron, zinc, boron, and molybdenum, and contributes to improved crop yields by enhancing soil properties and releasing macro-and micronutrients.

While the use of fertilizers and pesticides contributed to agricultural advancements in the past, overuse in recent decades has led to concerns about declining crop growth, soil fertility, and increased environmental problems. Excessive use of these chemicals has resulted in soil degradation and reduced microbial activity, negatively affecting soil productivity. Attention is now focused on sustainable agricultural practices to address these challenges.

2. Materials and Methods

The study, titled "Effect of Liquid Bio-fertilizers On Linseed (*Linum usitatsimum*) Yield and Economics," took place in the 2023-24 Rabi season at the Instructional Farm of the Sanjeev Agrawal Global Educational University College of Agriculture and Research Station in Bhopal, Madhya Pradesh. The experimental site, soil characteristics, climate conditions, and weather data recorded during the crop season, as well as the materials and methods employed, are presented in detail.

2.1 Harvest index (%)

Harvest index indicated the crop yielding efficiency to produce grain yield per unit of total biological yield. The harvest index was drawn up in different treatments using the formula given by Donald (1962) [18]. It is computed as the ratio of the economic yield to biological yield from same area and expressed in percentage.

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

Economic yield = Seed yield (kg ha^{-1})

Biological yield = seed yield + stover yield (kg ha^{-1})

2.2 Economics of the treatment

Cost of cultivation (Rs ha^{-1})

The whole amount spent on cultivating the crop in a treatment is the overall cost of agriculture. Calculating the cost of materials, cultivation fees, manpower, and other expenses led to the cost of cultivation (in Rs ha^{-1}) for each treatment.

2.3 Gross return (Rs ha^{-1})

Gross returns, which are determined based on the pricing of the local markets, are the overall monetary worth of the economic goods and byproducts acquired from the crop cultivated in the various treatments.

2.4 Net returns (Rs ha^{-1})

Net return is obtained by subtracting cultivation costs from gross returns. It is good indicator of suitability of a treatment since it represents the actual income.

Net profit (Rs ha^{-1}) = Gross income (Rs ha^{-1})-Cost of cultivation (Rs ha^{-1})

2.5 Benefit: Cost ratio

Benefit: Cost ratio of each treatment was calculated with the help of the following
formula:

Gross return (Rs ha^{-1})
Benefit cost ratio = Cost of cultivation (Rs ha^{-1})

2.6 Experimental site

The field experiment was conducted at the Sanjeev Agrawal Global Educational University School of Agriculture and Research Station in Bhopal, Madhya Pradesh, under the purview of Barkatullah Vishwavidyalaya, Bhopal (Madhya Pradesh), during the 2023-24 Rabi season. The experimental site exhibited consistent topography and efficient drainage. Situated at 22.25° N latitude, 77° 24' E longitude, and at an altitude of 298 meters above mean sea level, the research farm is located within India's Eastern plateau and hill region, specifically in Agro-climatic zone-11. The state of Madhya Pradesh is categorized into three agro-climatic zones, with Bhopal belonging to the Madhya Pradesh plains zone. The experimental field maintained uniform topography and effective drainage.

Throughout the testing year, the other weather variables remained within the typical range. The weather conditions during the harvest season were generally favorable. The soil in the experimental area was characterized as Goradu soil, which is typical for the region. It possessed a loamy sand texture, had a light brown color, originated from alluvial deposits, exhibited good drainage, moderate moisture-retention capacity, low organic carbon content, and adequate nitrogen availability. The soil was medium in phosphorus content and had a high level of available potash. It responded positively to fertilization and was free from salinity and sodicity issues.

2.7 Experimental details

The experimental design adopted for this study utilized a randomized block design, comprising six distinct treatments, each replicated three times. In line with the prescribed fertilizer recommendations, which included the application of 50 kg/ha of nitrogen (N), 30 kg/ha of phosphorus (P), and 20 kg/ha of potassium (K), these nutrients were administered based on the respective treatments. As organic nutrient sources, vermi-compost was applied to the soil, and liquid bio fertilizer was administered via foliar application.

To assess the height of the plants, five designated plants were selected, and measurements were taken from the base to the tip of each plant. The average plant height for each plot was then calculated.

In each experimental plot, five tagged plants were assessed for the number of major branches that sprouted from the main stem. The results were expressed per plant.

The boundary rows surrounding each experimental plot were randomly eliminated, leaving five plants for further analysis.

Following sun-drying, the roots were measured to determine their length. The dry weights of the plants and roots were recorded for each plot based on the experimental treatments.

For the total number of capsules at harvest, five tagged plants in each plot were counted, and the average number of capsules per plant was calculated. To evaluate the quantity of seeds, five tagged plants were selected, and ten capsules from each plant were randomly chosen. These capsules were opened, and the seeds were counted and averaged.

After winnowing, a representative seed sample was randomly chosen from the bulk production of each net plot. One thousand seeds were counted using a seed counter, and their weight was recorded as the test weight for each treatment.

The entire biomass collected from each net plot was washed, dried, and threshed. The seeds obtained were weighed in kilograms per plot and then scaled up by the appropriate factor to determine the seed yield in kilograms per hectare. The straw yield was estimated by subtracting the biological yield from the seed yield.

To calculate the harvest index for each treatment, the formula established by Donald and Hamblin in 1976 [19] was applied. The data underwent statistical analysis, following the methodology outlined by Cochran and Cox in 1967 [20].

2.8 Economic analysis

Economics of linseed production was calculated on the prevailing prices of different inputs used. The production was converted into gross return (₹ ha^{-1}) on the basis of prevailing prices of market. Net return was calculated by deducting the cost of cultivation from the gross return. Benefit: cost ratio was computed by dividing net return with cost of cultivation.

3. Results and Discussion

The plant height at 60 days after sowing (DAS) showed no significant differences among the treatments, as indicated in Table 1. However, treatment T_3, which involved the application of nitrogen equivalent to 60 kg/ha through vermi-compost, demonstrated a notable increase in plant height. At 60 DAS, the height reached 55.00 cm, and at harvest, it extended to 71.50 cm, surpassing the other treatments significantly. It is important to note that the plant height in treatment T_3 was comparable to that in treatments T_0, T_1, T_4, and T_5 at 120 DAS and at harvest.

In contrast, a marked reduction in plant height was observed in a particular treatment. The notable increase in plant height within treatment T_3, where vermi-compost was applied to the soil and through soil application, was likely attributed to the basal application of vermi-compost. This application supplied both macro and micro nutrients via an organic source, thereby enhancing soil physical and biological properties. Moreover, it led to improved nutrient availability and solubility. This favorable nutrient influence contributed to the development of larger cells with thinner cell walls, promoting cell division and elongation. Consequently, this positive impact on vegetative growth resulted in increased plant height.

3.1.1 Number of branches

The data presented in Table 1 reveals that treatment T_3, which involved the application of recommended dose fertilizer (RDF) and soil application of vermi-compost equivalent to 60 kg/ha through vermi-compost, resulted in a significantly higher number of branches per plant (11.91) at the time of harvest in the linseed crop. This finding was consistent with treatments T_0, T_1, T_3, T_4, and T_5, where the number of branches per plant was also notably high, and there were no significant differences among these treatments.

In contrast, the treatment not mentioned showed the lowest value in terms of the number of branches per plant. The observed increase in the number of branches per plant can be attributed to the presence of growth hormones in vermicompost. These growth hormones play a crucial role in activating cell division and cell elongation in axillary buds. These findings align with the results reported by Chobey *et al*. (2012) [17].

3.1.2 Dry matter accumulation g/plant)

In the case of plant dry matter accumulation, treatment T_3, which involved the application of recommended dose fertilizer (RDF) and soil application of vermi-compost equivalent to 60 kg/ha through vermi-compost, demonstrated significantly higher values. Specifically, it recorded 7.11 g/plant at 60 days after sowing (DAS) and 16.84.31 g/plant at the time of harvest, outperforming the other treatments. Nevertheless, it's important to note that at both 60 DAS and at harvest, treatment T_3 was on par with treatments T_0, T_1, T_3, T_4, and T_5, with no significant differences observed among them.

Conversely, the treatment not mentioned in the paragraph showed a significantly lower dry matter accumulation. The increase in dry matter accumulation in treatment T_3, which received nitrogen equivalent to 60 kg/ha through vermicompost, can be attributed to the application of vermicompost. Vermicompost provides essential nutrients, growth hormones, and enzymes to the plant, which, in turn, promotes rapid cell division and elongation. This ultimately results in enhanced plant development and higher dry matter accumulation. These findings are consistent with those reported by Chaudhary.

3.1.3 Root length (cm)

The treatment T_3, which involved the application of recommended dose fertilizer (RDF) equivalent to 60 kg/ha through vermicompost, exhibited significantly longer root length. Specifically, it recorded 12.17 cm at 60 days after sowing (DAS) and 17.80 cm at the time of harvest, outperforming the other treatments. Notably, at both 60 DAS and at harvest, treatment T_3 was on par with treatments T_2, T_4, and T_5, showing no significant differences among them.

In contrast, treatments T_5 and T_6 resulted in significantly lower root lengths. The greater root length observed in treatment T_3 could be attributed to a substantial increase in organic matter content in the soil due to the application of organic manure and liquid biofertilizer. This increase in organic matter had a positive impact on the physical properties of the soil, enhancing its capacity to retain more water and nutrients. Additionally, it improved aeration and stimulated microbial activities, ultimately leading to greater root length. These findings align with the results reported by Makkar *et al*. in their research.

3.1.4 Dry root biomass (g/plant)

The appraisal of result (Table1) revealed that treatment T_3 (Nequivalent to 60 kg/ha through vermicompost) registered significantly higher dry root biomass of 0.76 and 2.08 g/plant at 120 DAS and at harvest, respectively. However, it was remained at par with treatment T_2, and T_6. While lower values of dry root biomass were obtained with treatment T 5. The probable reason behind that application of vermicompost was cytokine synthesis and rapid conversion of synthesized carbohydrates into protein, consequent to increase in the number and size of growing cells. It improved the favourable effect on modifying the soil environment to hold more water and nutrients, better aeration and enhanced microbial activities resulting into more number of root and higher dry root biomass.

3.2 Yield parameters

3.2.1 Number of capsules/plant

The results summarized in Table 2 revealed that treatment T 3(N equivalent to 60 kg/ha through vermicompost and liquid bio fertilizer apply) obtained significantly higher number of capsules/plant (54.76). It was also remained at par with treatment T_1, T_2, T_4 and T_5, T_6 in linseed. While minimum value was secured with treatment T_5.

3.2.2 Number of seeds/capsule

The statistically analyzed data presented in Table indicated that application of various treatments had no any significant influence on number of seeds/capsules recorded at harvest in linseed. It might be due to genetic characters responsible for number of seeds/capsule.

3.2.3 Test weight (g)

The data presented in Table 2 indicates that treatment T_3, which involved the application of nitrogen equivalent to 60 kg/ha through vermicompost, exhibited a significantly higher test weight of 7.79 grams in comparison to the other treatments. Notably, at both 60 DAS and at harvest, treatment T_3 was on par with treatments T_2 and T_6, showing no significant differences among them. Conversely, treatment T_5 resulted in a significantly lower test weight. The increase in test weight observed in treatment T_3, which involved nitrogen equivalent to 60 kg/ha through vermicompost, could be attributed to the application of vermicompost. Vermicompost has been known to delay leaf senescence, and this delay might be the contributing factor to the increased seed weight.

Table 1: Influence of apply foliar spray soil treatment liquid bio fertilizer through various organic sources on plant population, plant height (cm), branches/plant, DMA/plant, root length and dry root biomass g/plant

Tr	Treat.	Plant population		Plant height (cm)			Branches/ plant	DMA/plant (g)		Root length (cm)		Dry root biomass (g/plant)	
		25 DAS	At Harvest	30 DAS	60 DAS	At harvest		60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
T_1	T_1	23.80	20.23	15.63	39.41	64.83	11.12	7.14	15.73	10.12	13.81	0.61	1.39
T_2	T_2	22.05	20.75	15.95	52.51	68.62	10.67	7.11	16.31	12.01	14.36	0.69	1.69
T_3	T_3	26.40	21.99	17.70	56.00	71.49	11.91	7.36	16.84	12.16	17.80	0.76	2.08
T_4	T_4	24.70	20.80	16.80	54.66	67.41	11.26	6.66	15.21	11.46	16.21	0.64	1.81
T_5	T_5	23.80	20.40	15.60	45.34	49.11	10.21	6.28	14.88	10.52	15.21	0.61	1.87
T_6	T_6	22.55	20.53	15.12	49.71	61.46	10.51	7.04	15.57	11.60	18.66	0.69	1.98
SE	S.E(m)	0.45	0.52	0.61	2.29	3.51	0.45	0.39	0.61	0.53	0.79	0.02	0.09
CD at	CD at 5%	NS	NS	NS	7.86	10.11	1.42	1.02	1.81	1.48	2.19	0.01	0.19
CV	CV%	4.29	5.03	8.39	10.50	11.11	9.52	11.05	8.35	9.34	9.42	8.45	7.85

Table 2: Influence of apply foliar spray soil treatment liquid bio fertilizer through various organic sources on no. of capsules/plant, no. of Seeds/capsule, test weight, seed yield (kg/ha), straw yield and harvest index (%) of linseed

Treat.	No. of capsules/plant	No. of seeds/capsule	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
T_1	48.49	6.53	5.61	1319	3038	30.00
T_2	44.56	6.18	6.30	1590	3683	30.16
T_3	54.76	6.88	7.79	1766	4132	29.94
T_4	38.97	6.67	6.53	1696	3997	29.79
T_5	40.03	6.62	6.23	1625	3796	29.98
T_6	40.02	6.70	6.13	1442	3356	30.06
S.Em ±	2.41	0.11	0.22	82.20	229.6	1.26
CD at 5%	9.09	NS	0.58	239	666	NS
CV%	10.05	3.1	6.81	11.67	11.03	1.95

4. Conclusion

The results of this study demonstrated that the application of nitrogen equivalent to 60 kg/ha through vermicompost (Treatment T_3) had a significant and positive impact on various growth and yield parameters of linseed (*Linum usitatissimum*).

In terms of plant height, Treatment T_3 exhibited a remarkable increase, with plant heights of 55.00 cm at 60 days after sowing (DAS) and 71.50 cm at harvest. This significant growth enhancement was attributed to the application of vermicompost, which provided essential nutrients and growth hormones, resulting in more extensive cell division and elongation, thus increasing plant height. Treatment T_3 also excelled in terms of the number of branches per plant, recording a high value of 11.91 at harvest. The presence of growth hormones in vermicompost contributed to the activation of cell division and cell elongation in axillary buds, leading to the increased number of branches.

Dry matter accumulation was notably higher in Treatment T_3, with 7.11 g/plant at 60 DAS and 16.84.31 g/plant at harvest. This increased dry matter accumulation was attributed to the application of vermicompost, which supplied essential nutrients, growth hormones, and enzymes, promoting rapid cell division and elongation.

Root length was significantly longer in Treatment T_3, with 12.17 cm at 60 DAS and 17.80 cm at harvest. The enhanced root length was linked to the higher organic matter content in the soil due to organic manure and liquid bio-fertilizer application, which improved soil physical properties and nutrient availability.

In terms of yield parameters, Treatment T_3 produced a higher number of capsules per plant (54.76), indicating a positive impact on reproductive growth.

The number of seeds per capsule remained unaffected by the treatments, suggesting a genetic influence on this parameter.

Treatment T_3 exhibited significantly higher test weight (7.79 g) due to the delay in leaf senescence attributed to vermicompost application.

The application of nitrogen equivalent to 60 kg/ha through vermicompost (Treatment T_3) proved to be highly effective in enhancing the growth and yield of linseed, positively influencing various parameters, from plant height to test weight. These findings emphasize the importance of organic nutrient sources, specifically vermicompost, in sustainable and productive linseed cultivation practices.

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