**Synergistic effects of FYM, vermicompost and dual biofertilizer inoculation on growth and yield of Linseed (*Linum usitatissimum* L.) in semi-arid regions**

**Abstract**

The average seed yield of linseed is very low mainly due to its cultivation on residual moisture and lack of package of practices for seed production. Hence there is a need to develope seed production technology for obtaining higher seed yield and quality in linseed. Use of organic manure alone or in combination with biofertilizers and chemical fertilizer, helps in improving physio-chemical properties of soil and improve availability of nutrients ultimately increase the linseed productivity. A field investigation is carried out in *Rabi* season 2020-21 at Agronomy Farm, College of Agriculture, Nagpur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, on “Effect of organic sources of nutrients and biofertilizers on growth and yield of linseed (*Linum usitatissimum* L)”. Experimental results observed that, combined application of 50% RDN through FYM + 50% RDN through Vermicompost recorded significantly highest Plant height (51.22), No. of branches (4.41), dry matter (7.48 g), No. of capsule plant-1 (78.78), No. of grains capsule-1 (8.50), grain yield plant-1 (4.45 g), straw yield (2555 kg ha-1) and grain yield (1302 kg ha-1). In Azotobacter treatments dual inoculation of *Azotobacter* and PSB recorded significantly highest Plant height (48.79), No. of branches (4.15), dry matter (6.74 g), No. of capsule plant-1 (74.36), No. of grains capsule-1 (7.99), grain yield plant-1 (4.14 g), straw yield (2410 kg ha-1) and grain yield (1233 kg ha-1). It might be due to balanced and continuous supply of macro and micro nutrients required to enhance the enzymatic activity and physiological process of plant which in turn reflected through the inflated stature of growth and yield attributes of linseed and also activity of N-fixing and phosphate solubilizing bacteria in supplying additional N and P2O5 to the crop resulting highest growth and yield attributes. Application of organic sources of nutrients 50% RDN through FYM + 50% RDN through Vermicompost and Dual seed inoculation with *Azotobacter* + PSB recorded higher growth; yields attributes and yield over control.

**Keywords:** Linseed, Organic manure, Azotobacter, PSB and Vermicompost

**1. Introduction**

“ Linseed (*Linum usitatissimum* L.) is a *rabi* season herbaceous plant belongs to family *linaceae* and genus Linum. India ranks 3rd in the world with respect to area and production of linseed. Madhya Pradesh, Karnataka, Chhattisgarh, Jharkhand, Bihar, Maharashtra, Odisha, Uttar Pradesh, West Bengal and Assam are the major linseed growing states in the country. The world, linseed is grown on an area of 3.06 million ha with a production of 2.2 million tonnes and productivity of 720 kg per ha. Presently the area under linseed in India is 1.799 lakh ha with a production of 1.206 lakh tonnes and the average yield is 671 kg ha-1 which is less than worlds average yield (720 kg ha-1). In Maharashtra, linseed occupies an area of 0.72 lakh ha with a production of 0.23 lakh tonnes ha-1. The average yield is 318 kg ha-1 which is less than the average yield of the country” (Anonymous, 2021).

“Due to continuous use of chemical fertilizers, the fertility of the soil and the number of beneficial microorganisms decreased to a great extent. Now we want to study how to increase production by using chemical plus organic nutrients source. FYM i.e. Farm Yard Manure and vermicompost plays an important role in increasing crop production. They contain macronutrients like N (nitrogen) P (phosphorous) and K (potassium) as well as various micronutrients. FYM and vermicompost Plays an important role in improves the physical properties of soil like water holding capacity, soil texture, soil structure, aggregation and permeability. They contain all the essential micro and macro elements which can fill the imbalance nutrient deficiency of the plant” (Ray et al. 2000).

“Due to the high nitrogen fixation capacity of Azotobacter, it plays a major role in atmospheric nitrogen fixation. Azotobacter secretes some growth promoting hormones such as gibberellins, IAA etc. PSB (Phosphorus Solubilizing Bacteria) is the main source of P for plants. PSB reduces the rate of fertilizer application by 50% without any reduction in production” (Jilani et al., 2007 and Yazdani et al., 2009). Phosphate solubilization increases organic acid production and helps in increasing phosphorus in the soil and its uptake (De and Singh, 2010), considering all the above points, the present experiment is planned to study the effect of organic source of nutrients and biofertilizer on growth and vidarbha region of Maharashtra.

**2. Materials and Methods**

The present experiment was conducted in rabi season 2020-21 at Agronomy Farm, College of Agriculture, Nagpur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, in split plot design with three replications. The soil of experimental plot was vertisol, with pH 7.7, organic carbon 0.52%, low in available nitrogen (205.18 kg ha-1), low in available phosphorus (17.16 kg P2O5 ha-1) and available potassium (420.45 kg K2O ha-1) content. In main plot treatments comprised of different organic sources of nutrients viz., N1 - 100 % RDN through FYM, N2 - 100 % RDN through vermicompost and N3 - 50 % RDN through FYM + 50 % RDN through vermicompost; and in sub plot four treatments of biofertilizer *viz.*, B0 - No Biofertilizer (control), B1 - *Azotobacter*, B2 - PSB and B3 - *Azotobacter* + PSB. The biometrical observations on crop growth attributes, yield attributes and yield were recorded.

**3. Results and Discussion**

**3.1 Plant height (cm)**

Plant height was significantly highest with the application of 50% RDN through FYM + 50% RDN through Vermicompost (51.22 cm) over 100% RDN through FYM (41.83 cm) but was on par with 100% RDN through Vermicompost (46.62 cm). It might be due to optimum supply of nutrients during the crop growth period, resulting into better vegetative growth with tallest plants. The results are in close agreement with the findings of Choudhary *et al*. (2017), Kulkarni *et al*. (2018) and Parewa *et al*. (2018).

Dual inoculation of *Azotobacter* and PSB recorded significantly highest plant height (48.79 cm) over control treatments (43.68 cm) but was on par with inoculation with *Azotobacter* (46.67 cm) and PSB alone (47.09 cm). This might be due to positive effect of dual inoculation to the plants by way of extra N by providing atmospheric nitrogen and rendering the insoluble phosphorous into available form. The enhanced availability of phosphorus favored nitrogen fixation and rate of photosynthesis and consequently led to better plant height. The result is in agreement with those reported by Patra *et al*. (2013), Acharya and Nirala (2015) and Kumar *et al.* (2016).

**3.2 Number of branches plant-1**

Combined application of 50% RDN through FYM + 50% RDN through Vermicompost recorded significantly highest number of branches plant-1 (4.41) over 100% RDN through FYM (3.42), which was at par with 100% RDN through Vermicompost (3.92). The increase in number of branches might be due to better uptake and translocation of nutrients by growing plants which boosted the plant for producing better number of branches plant-1 in linseed. Results obtained are in accordance with the findings of Kulkarni *et al*. (2018) and Parewa *et al*. (2018).

Dual inoculation of *Azotobacter* and PSB recorded significantly highest number of branches plant-1 (4.15) over control treatment (3.61); however, it remained at par with biofertilizer inoculation of *Azotobacter* (3.93) and PSB alone (3.97). This might be due to positive effect of dual inoculation to the plants by way of extra N by providing atmospheric nitrogen and rendering the insoluble phosphorous into available form. The enhanced availability of phosphorus favored nitrogen fixation and rate of photosynthesis and consequently led to higher number of branches plant-1. The results obtained during investigation are in close conformity with the findings of Acharya and Nirala (2015) and Kumar *et al.* (2016).

**3.3 Dry matter accumulation plant-1 (g)**

Significantly highest dry matter accumulation plant-1 was recorded with the application of 50% RDN through FYM + 50% RDN through Vermicompost (7.48 g) over 100% RDN through FYM (4.60 g) but it was at par with 100% RDN through Vermicompost (6.07 g). Higher dry matter accumulation plant-1 might be due to adequate amount of nutrients in combined application of FYM and Vermicompost which resulted in vigorous crop growth with effective interception of light coupled with higher rate of photosynthesis. Results obtained during course of investigation are similar to the findings of Lambade (2013).

Dual inoculation of *Azotobacter* and PSB recorded significantly highest dry matter accumulation plant-1 (6.74 g) over control (5.17); however, it remained at par with biofertilizer inoculation of *Azotobacter* (6.08 g) and PSB alone (6.21 g). The significant increase in mean dry matter accumulation plant-1 in dual inoculation of *Azotobacter* and PSB treatment might be due to the increase in foliage which in turn might have accelerated the photosynthetic activity in plants producing more plant food material leading there by to healthy growth and higher dry matter accumulation. Similar results were reported by Gudadhe *et al*. (2005), Mahammad *et al*. (2013) and Kumar *et al*. (2016).

**3.4 Number of capsules plant-1**

Significantly highest number of capsules plant-1 was recorded with the application of 50% RDN through FYM + 50% RDN through Vermicompost (78.78) over 100% RDN through FYM (61.69) but was at par with 100% RDN through Vermicompost (70.40). The supremacy of FYM and vermicompost might be due to balanced and continuous supply of macro and micro nutrients required to enhance the enzymatic activity and physiological processes of plant. The results are in consonance with Lambade (2013) and Choudhary *et al*. (2017).

Mean number of capsules plant-1 was influenced significantly by biofertilizer inoculation at harvest. Dual inoculation of *Azotobacter* and PSB recorded significantly highest number of capsules plant-1 (74.36) over control (65.05); however, it remained at par with biofertilizer inoculation of *Azotobacter* (70.50) and PSB alone (71.26). This might be due to the activity of N- fixers playing a major role in improving soil fertility and yield contributing characters as reported by Khoshkhooi *et al*. (2013), Mahammad *et al*. (2013) & Acharya and Nirala (2015).

**3.5 Number of grains capsule-1**

Different organic sources of nutrients produced significant variation in number of grains capsule-1. Significantly highest number of grains capsule-1 was recorded with the application of 50% RDN through FYM + 50% RDN through Vermicompost (8.50) over 100% RDN through FYM (6.53) but was at par with 100% RDN through Vermicompost (7.53). This might be due to the use of organic manure helps in improving the nutritional environment in the soil, which in turn results in the growth and development of the plant and also increases the number of grains per capsule. The results obtained during this investigation are in agreement with the findings of Choudhary *et al*. (2017) and Lambade (2013).

Significant difference in number of grains capsule-1 was observed due to different biofertilizer inoculation. Dual inoculation of *Azotobacter* and PSB recorded significantly highest number of grains capsule-1 (7.99) over control treatment (6.91); however, it remained at par with biofertilizer inoculation of *Azotobacter* (7.54) and PSB alone (7.63). This might be due to significant improvement in overall growth of the plant by virtue of increased photosynthetic rate. Thus, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased number of grain capsules-1 with the dual inoculation of *Azotobacter* and PSB. The results are in consonance with the finding of Khoshkhooi *et al*. (2013) and Mahammad *et al*. (2013).

**3.6 Grain yield plant-1 (g)**

Grain yield plant-1 differed significantly due to different organic sources of nutrients. Significantly highest grain yield plant-1 was recorded with the application of 50% RDN through FYM + 50% RDN through Vermicompost (4.45 g) over 100% RDN through FYM (3.24 g) but was at par with 100% RDN through Vermicompost (3.86 g). Among the various organic sources tried, combined application of 50% RDN through FYM + 50% RDN through Vermicompost resulted in more grain yield plant-1. The supremacy of FYM and Vermicompost might be due to balanced and continuous supply of macro and micro nutrients required to enhance the enzymatic activity and physiological process of plant which in turn reflected through the inflated stature of yield attribute seed yield plant-1. This finding is similar to those reported by Lambade (2013) and Nagrare *et al.* (2018).

Significant difference in grain yield plant-1 was observed due to different biofertilizer inoculation at harvest. Dual inoculation of *Azotobacter* and PSB recorded significantly highest grain yield plant-1 (4.14 g) over control (3.48 g); however, it remained at par with biofertilizer inoculation of *Azotobacter* (3.86 g) and PSB alone (3.92 g). This might be due to positive effect of dual inoculation to the plants by way of extra N by providing atmospheric nitrogen and rendering the insoluble phosphorous into available form. The enhanced availability of phosphorus favored nitrogen fixation and rate of photosynthesis and consequently led to better grain yield plant-1. Similar results were also observed by Khoshkhooi *et al*. (2013) and Mahammad *et al*. (2013).

**3.7 Grain yield (kg ha-1)**

Various organic sources of nutrients influenced the grain yield of linseed. Significantly highest grain yield of 1302 kg ha-1 was recorded with the application of 50% RDN through FYM + 50% RDN through Vermicompost over 100% RDN through FYM (1037 kg ha-1) but was at par with 100% RDN through Vermicompost (1172 kg ha-1) at harvest. Higher grain yield obtained with combined application of nutrients through FYM and Vermicompost might have stimulated the activities of microorganisms that made the plant nutrients readily available to the crops which augmented seed yield of linseed. The results are in accordance with the results of Khoshkhooi *et al*. (2013) and Lambade (2013).

Significant difference in grain yield plant-1 was observed due to different biofertilizer inoculation. Dual inoculation of *Azotobacter* and PSB recorded significantly highest grain yield (1233 kg ha-1) over control (1089 kg ha-1); however, it remained at par with biofertilizer inoculation of *Azotobacter* (1173 kg ha-1) and PSB (1185 kg ha-1) alone at harvest. This might be due to the activity of N-fixing and phosphate solubilizing bacteria in supplying additional N and P2O5 to the crop resulting highest grain yield plant-1. Similar findings were reported by Gudadhe *et al*. (2005), Patra *et al*. (2013), Kumar *et al*. (2016) and Gabhane *et al*. (2019).

**3.8 Straw yield (kg ha-1)**

Data pertaining to straw yield (kg ha-1) of linseed as influenced by various treatments are presented. Mean straw yield obtained was (2275 kg ha-1). Significantly highest straw yield of (2555 kg ha-1)was recorded with the combined application of 50% RDN through FYM + 50% RDN through Vermicompost over 100 % RDN through FYM (1991 kg ha-1). but was at par with the application of 100% RDN through Vermicompost (2279 kg ha-1) alone. The increase in straw yield due to application of 50% RDN through FYM + 50% RDN through Vermicompost might be due to the fact that application of combined use of organic manure favorably improved the nutritional environment thereby resulting in better growth and development leading to higher straw yield. Results are in accordance with the results recorded by Khoshkhooi *et al*. (2013), Lambade (2013) and Nagrare *et al.* (2018).

Straw yield of linseed influenced significantly due to different biofertilizer inoculation. Significantly highest straw yield of (2410 kg ha-1)was obtained in seed inoculation with *Azotobacter* + PSB (2102 kg ha-1) over control but was at par in seed inoculation with *Azotobacter* (2282 kg ha-1) and PSB alone (2307 kg ha-1). Straw yield was significantly higher where combined application of *Azotobacter* and PSB seed inoculation this might be due to increased growth and yield attributing characters where both the biofertilizers were inoculated. Similar findings were reported by Hadiyal *et al*. (2017) and Gabhane *et al*. (2019).

**Interaction**

Interaction effect of different organic sources of nutrients and biofertilizers inoculation were found to be non-significant in respect of all the growth characters, yield attributes, yields of linseed.

**Conclusion:**

Application of organic sources of nutrients 50% RDN through FYM + 50% RDN through Vermicompost recorded higher growth; yield attributes and yield kg ha-1 over 100% RDN through FYM but was at par with 100% RDN through Vermicompost. Dual seed inoculation with *Azotobacter* + PSB recorded higher growth; yields attributes and yield over control but was at par with *Azotobacter* and PSB alone. Among the organic sources of nutrients, application of 50% RDN through FYM + 50% RDN through Vermicompost recorded highest GMR and NMR over 100% RDN through FYM but was at par with 100% RDN through Vermicompost. Highest B: C ratio was also recorded by application of 50% RDN through FYM + 50% RDN through Vermicompost. Among the biofertilizers, dual seed inoculation with *Azotobacter* + PSB recorded higher GMR and NMR over control but was at par with *Azotobacter* and PSB alone. Highest B: C ratio was also recorded by dual seed inoculation with *Azotobacter* + PSB.

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| **Treatments** | **Plant height (cm)** | **No. of branches plant-1** | **Dry matter plant-1 (g)** | **No. of capsule plant-1** | **No. of grains capsule-1** | **Grain yield plant-1 (g)** | **Grain yield ha-1 (kg)** | **Straw yield ha-1 (kg)** |
| **Organic sources of nutrients** |
| N1 - 100 % RDN through FYM | 41.83 | 3.42 | 4.60 | 61.69 | 6.53 | 3.24 | 1037 | 1991 |
| N2 - 100% RDN through Vermicompost | 46.62 | 3.92 | 6.07 | 70.40 | 7.53 | 3.86 | 1172 | 2279 |
| N3 - 50% RDN through FYM+50% RDN through Vermicompost | 51.22 | 4.41 | 7.48 | 78.78 | 8.50 | 4.45 | 1302 | 2555 |
| SE (m) ± | 1.18 | 0.12 | 0.39 | 2.15 | 0.25 | 0.15 | 33 | 71 |
| CD at 5% | 4.64 | 0.49 | 1.52 | 8.44 | 0.98 | 0.60 | 131 | 279 |
| **Biofertilizers** |
| B0- Control | 43.68 | 3.61 | 5.17 | 65.05 | 6.91 | 3.48 | 1089 | 2102 |
| B1- *Azotobacter* | 46.67 | 3.93 | 6.08 | 70.50 | 7.54 | 3.86 | 1173 | 2282 |
| B2- PSB | 47.09 | 3.97 | 6.21 | 71.26 | 7.63 | 3.92 | 1185 | 2307 |
| B3- *Azotobacter* + PSB | 48.79 | 4.15 | 6.74 | 74.36 | 7.99 | 4.14 | 1233 | 2410 |
| SE (m) ± | 0.89 | 0.09 | 0.28 | 1.62 | 0.19 | 0.11 | 25 | 54 |
| CD at 5% | 2.65 | 0.28 | 0.84 | 4.83 | 0.56 | 0.34 | 75 | 159 |
| **Interaction** |
| SE (m) ± | 1.55 | 0.16 | 0.49 | 2.81 | 0.32 | 0.20 | 93 | 93 |
| CD at 5% | NS | NS | NS | NS | NS | NS | NS | NS |
| **GM** | **46.56** | **3.92** | **6.05** | **70.29** | **7.52** | **3.85** | **1170** | **2275** |

**Table 1. Effect of organic sources of nutrients and biofertilizers on growth attributes and yield attributes of Linseed**

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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