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Residual effect of integrated nutrient management on the growth, yield and profitability of linseed in black gram -linseed cropping system of plateau region of Jharkhand

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Abstract
A field experiment was conducted during Kharif 2020-21, 2021-22, Rabi 2022-21 and 2021-22 on sandy loam soil at Agronomy Research Farm of the Birsa Agricultural University, Kanke, Ranchi, Jharkhand to investigate the residual effect of integrated nutrient management imposed to preceding black gram on growth, yield and economics of linseed grown in black gram-linseed cropping system consecutively for two years. The experiment was laid out in factorial randomized block design, replicated thrice with four levels of fertilizer (inorganic source i.e., control, 75% RDF, 100% RDF and 125% RDF), two levels of FYM (organic source i.e., without FYM and FYM @5t/ha) and three biofertilizer levels (rhizobium, plant growth promoting rhizobium (PGPR), and rhizobium + PGPR) and their interaction. Linseed crop was given only 50% of RDF. The results revealed that maximum plant height of linseed at 40,60,80 DAS and at harvest i.e.,19.20,48.40,59.50 and 73.80 cm during 2020-21and 20.20 ,49.40.61.30 and 74.90 cm during 2021-22 were observed in 125% RDF while statistical at par to 100% RDF (18.30, 47.20, 58.30 and 73 cm in 2020-21 and 19.20,48.70,59.80 and 74.20 cm during 2021-22, respectively). FYM @5t ha-1 to preceding black gram recorded significantly maximum plant height of succeeding linseed of 17.60,49.10,56.50 and 67.60 cm at 40, 60, 80 DAS and at harvest during 2020-21 and of 18.20,49.80,57.50 and 68.20 cm at 40, 60, 80 DAS and at harvest during 2021-22, respectively. Residual effect of dual seed inoculation of preceding black gram with Rhizobium + PGPR showed maximum plant height of linseed at 40,60,80 DAS and at harvest i.e17.20,46.80,55.10 and 66.30 cm during 2020-21 and 17.70,47.70,56.30 and 66.90 cm during, 2021-22 respectively than Rhizobium and PGPR alone. Similar trend was observed w.r.t. dry matter, CGR and yield attributing characters of linseed in both the consecutive years. Maximum seed and stover yield of linseed i.e., 1090 and 2158 kg ha-1 and 1107 and 2183 kg ha-1 were registered with 125% RDF imposed to Kharif black gram, while statistical at par to 100% RDF imposed to black gram. The treatment receiving FYM @ 5t ha-1 to preceding black gram recorded significantly maximum seed and stover yield of linseed i.e., 1028 and 2061 kg ha-1 and 1038 and 2076 kg ha-1 during 2020-21 and 2021-22, respectively. Maximum seed and stover yields of linseed i.e., 988 and 1998 kg ha-1 and 997 and 2013 kg ha-1 were registered with dual seed inoculation with Rhizobium + PGPR of preceding Kharif black gram during both consecutive years. 125% RDF imposed to black gram recorded highest value of gross return of linseed (₹46331 ha-1and ₹48119 ha-1), net return (₹26902 ha-1and ₹28690 ha-1) and B:C ratio (1.38 and 1.48), respectively during both consecutive years of experimentation. This treatment was statistically at par to 100% RDF applied to black gram i.e., gross return (₹43503 ha-1and ₹45326 ha-1), net return (₹24074 ha-1and ₹25807 ha-1) and B:C ratio (1.24 and1.33). The treatment receiving FYM @5t ha-1 to preceding black gram recorded significantly maximum gross return, net return and B:C ratio of Rabi linseed i.e., ₹43680 ha-1, ₹45142 ha-1 and ₹24251 ha-1, ₹25713 ha-1 and 1.25 ,1.32 during 2020-21 and 2021-22, respectively, this return was higher due to higher seed and stover yield over no FYM applied to preceding Kharif black gram. Maximum gross return, net return and B:C ratio of Rabi linseed i.e., ₹42005 ha-1, ₹43401 ha-1and ₹22576 ha-1, ₹23972 ha-1 and 1.16 ,1.23 during 2020-21 and 2021-22, respectively, were registered with dual seed inoculation with Rhizobium + PGPR of preceding Kharif black gram during both consecutive years. Integrated nutrient management through application of 125% RDF along with FYM @ 5t ha-1and seed inoculation with biofertilizers, Rhizobium + PGPR of preceding Kharif black gram, save the 50% RDF of succeeding linseed and found profitable for linseed in black gram - linseed cropping system.

Keywords: Integrated nutrient management, linseed, black gram, growth, profitability, PGPR

Introduction
Linseed (*Linum usitatissimum L.*) is one of the oldest crop plants cultivated in around 47 countries for the purpose of seed, oil and fiber. In South West Asia and Canada, it is primarily

cultivated for oil whereas, in Russia, Egypt and north western European countries it is mainly cultivated for the production of high-quality fiber for making linen fabrics and several other products. Linseed occupies an area of 3.27 million ha yielding 3.18 million tonnes with an average productivity of 975.10 kg/ha in the world (FAO Stat, 2020) [8]. India holds fifth position in area after Kazakhstan, Russian Federation, Canada and China but ranks sixth in production after Kazakhstan, Canada, Russian Federation, China and USA. India is the most prominent country in oilseed production from time immemorial. Oilseed crops contribute a significant proportion to the Indian agricultural economy. Linseed (*Linum usitatissimum L.*) is the second most important *rabi* oilseed crop next to rapeseed and mustard in India. It is mostly grown under upland condition due to its low nutrient and water requirement. Linseed has wide use, it is a source of food, feed, fiber, oil, medicine, industrial raw material and export commodity. Linseed possesses a very healthy fatty acids (linoleic-Omega 6 and alpha-linolenic acids or Omega 3). Linseed cake is rich in micro elements, vitamins, dietary cellulose, and proteins (up to 38%) (Altai, 2010) [1]. Seed contains a good percentage of oil which varies from 33 to 47 per cent in different varieties. India occupies area under linseed is 3.20 lakh ha with a production and productivity of about 1.74 lakh tonnes and 543.80 kg/ha, respectively (Anonymous, 2020) [2]. Madhya Pradesh is the leading state both in area and production followed by Jharkhand and Uttar Pradesh, accounting 97per cent of total area of the country. In Jharkhand linseed crop have potential of increasing the farmer's income and simultaneously effectively use of moisture and nutrients after harvesting of *Kharif* cops.

In Jharkhand it is cultivated in area 52.07 ('000) ha with production 29.68 ('000) tonnes and average yield is 570 kg ha^{-1} (Anonymous, 2020) [2]. The lower productivity of linseed is mainly due to inadequate nutrition management and crop is grown on marginal land without proper management. Doubling farmers income can be achieved by crop diversification, pulses as a candidate crop, growing double purpose linseed is a viable option through INM. The influence of nutrient applied to the preceding crops in a cropping system is constructively affecting the productivity of succeeding crop. Based on the applied source and level of nutrients, the residual outcome would vary along with nature of the crop followed by and INM practices applied to preceding crop. Application of organic sources like FYM and seed inoculation with bio fertilizers like *rhizobium* and plant growth promoting *rhizobium* (PGPR) compared to inorganic sources alone to the preceding crop, had more carry overcapacity (CoC) on the succeeding crop. Integration of different sources of nutrients also reduces the load of chemical fertilizers within reach of small and marginal farmers (Saikia *et al*. 2018) [25]. Black gram imposed integrated nutrient management being a leguminous crop grown as preceding crop in the system, through fixing atmospheric nitrogen biologically, exert great influence on the productivity of succeeding linseed crop. Uplands are mainly rainfed, monocropped dominated by rice with low and unstable yield. Among different rainfed rice ecosystems, productivity of rainfed upland rice area is low. Crop diversification and rice substitution in rainfed upland rice area through low water requiring deep- rooted crops like black gram was effective means for ensuring higher and stable productivity of rainfed upland rice ecosystem (Kar *et al*. 2005) [10]. Crop diversity in rainfed by black gram can increase productivity. Since, black gram is predominantly raised under upland rainfed conditions. Rice-fallow cropping system is predominant cropping system in upland rainfed condition and more extensive, while rice-wheat cropping system as it exploits more natural resources. Under upland rainfed condition short duration of black gram-linseed cropping system will be more remunerative with respect to productivity, profitability and eco-friendly.

Keeping above points in view, the present study was taken to assess the residual effect of integrated nutrient management practiced in black gram on the growth, yield and profitability of linseed in black gram -linseed cropping system.

Materials and Methods

The field experiment was conducted at the Agronomy Research Farm of Birsa Agricultural University, Kanke, Ranchi, Jharkhand, during *kharif* and *rabi* season in two consecutive years, 2020-2021 and 2021- 2022. The soil was sandy loam in texture (60.8% sand, 27.8% silt and 11.4% clay), acidic in reaction (pH 5.89), low in available nitrogen (247.13 kg/ha) and organic carbon (0.39 %), medium in available phosphorus (47.52 kg/ha), potassium (186.32 kg/ha) and in Sulphur (32.12 kg/ha). Experiment was laid out in Factorial RBD and replicated thrice. The treatments imposed to preceding black gram crop were 12 treatment combination, four fertilizer level viz. CF1= Control, CF2=75% RDF, CF3=100% RDF and CF4=125% RDF (RDF: 20:40:20:20 N: P2O5:K2O:S kg/ha), two level of organic manure viz. FYM1= control and FYM2=@5tha^{-1} and three biofertilizer level viz. BF1=*rhizobium*, BF2=PGPR and BF3= *rhizobium* + PGPR. Treatments were randomly assigned in three replicates. Well decomposed FYM was incorporated in soil 15 days before sowing of black gram as per treatment. Full dose of nitrogen, phosphorus, potassium and Sulphur were applied as per treatment through Urea, DAP, MOP and phosphogypsum as basal application just before sowing of black gram. A uniform dose of lime was applied @ 4q/ha on furrow at sowing of black gram. Black gram seed treatment with biofertilizers viz. *Rhizobium* and plant growth promoting *Rhizobium* (PGPR) LMn16 were applied by inoculating seeds with biofertilizers culture @25 g kg^{-1} of seed by slurry method. The seed inoculation was done as per the treatment. In linseed crop, 50 % RDF (RDF: 40:30:20:20 N: P2O5:K2O :S kg/ha) i.e., nitrogen, phosphorous, potassium and Sulphur were given through DAP, MOP and phosphogypsum as basal application. Without disturbing the experimental layout, succeeding linseed var. Divya with a seed rate of 20kg ha^{-1} was sown in line at spacing 30 X 10 cm. During both the season 2020-21 and 2021-22 crop was sown on November 13th and 11th and harvested on 9th April in 2021and 13th April in 2022, respectively. All observations related to crop growth on different growing stages and yield attributes were recorded from randomly selected 5 plants of each treatment. Seed yield from the net plot area leaving two boarder rows all around was recorded after drying bundles under sun to an optimum moisture level of 9% and converted into yield $kgha^{-1}$.The cost of inputs as well as price of linseed was accorded by using government regulated minimum support prices and profitability was calculated in terms of ₹ha^{-1}.Data on growth, yield and yield attributes and profitability were statistically analyzed by using the standard statistical procedures (Gomez and Gomez,1984) [9].

Results and Discussion

Effect on growth

Progressive data on growth and development of linseed in terms of plant height, dry matter accumulation and crop growth rate at 40,60,80 DAS and at harvest is presented in Table 1 and graphically illustrated in Fig1. Data revealed that the residual effect of integrated nutrient management practiced for black

gram were significantly influenced the growth and development of linseed crop. Plant height of linseed increased with increasing levels of fertilizer and the advancement of crop age. Maximum plant height at 40,60,80 DAS and at harvest i.e., 19.20, 48.40, 59.50 and 73.80 cm during 2020-21and 20.20,49.40.61.30 and 74.90 cm during 2021-22 were observed in 125% RDF while statistical at par to 100% RDF (18.30, 47.20, 58.30 and 73 cm in 2020-21 and 19.20,48.70,59.80 and 74.20 cm during 2021-22, respectively) and both were significantly superior over 75% RDF and control. Inorganic fertilizers with high nutrient content are very important sources and improves the availability of nutrients in significant growth stages that facilitate better crop growth, payoff greater transfer of nutrients as well as left their residual effects on soil. The results are with conformity with the observations by Sharma *et al*. (2011) [26].

FYM applied to preceding black gram significantly influenced the plant height of succeeding linseed. An appraisal of data in Table 1 indicated that during both years of experimentation the treatment receiving FYM @5t ha^{-1} to preceding black gram recorded significantly maximum plant height of succeeding linseed of 17.60,49.10,56.50 and 67.60 cm at 40, 60, 80 DAS and at harvest during 2020-21and of 18.20,49.80,57.50 and 68.20 cm at 40, 60, 80 DAS and at harvest during 2021-22, respectively as compared to treatment without FYM. This might be due to the improvement of soil condition through FYM as a source of organic matter. Application of organic manure improved the whole soil health by increasing soil organic carbon, soil microbes and soil nutrient availability and ensure better plant growth. The superiority of residual effect of FYM through efficient utilization of mineralized N and Zn from FYM would have increase the availability of N throughout the growth period of succeeding linseed crop resulted in better absorption, translocation and assimilation of nutrients as photosynthates. Better portioning of photosynthates between source and sink led to greater assimilation of dry matter in fruiting parts resulted in improvement of yield attributing characters.

Seed inoculation of preceding black gram seed with biofertilizers have no significantly residual effect on plant height of linseed. Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR showed maximum plant height of linseed at 40,60,80 DAS and at harvest i.e17.20,46.80,55.10 and 66.30 cm during 2020-21 and 17.70,47.70,56.30 and 66.90 cm during,2021-22 respectively than *Rhizobium* and PGPR alone. Increase in crop growth due to combined inoculation of *Rhizobium* + PGPR might be improvement of nutrient status of soil due to symbiotic nitrogen fixation of atmospheric nitrogen by microbes and PGPR have favorable effects on metabolic process and better vegetative growth by synergistic interactions with microorganisms within the rhizosphere, which indirectly boosts plant growth rate. The results are in agreement with the findings of Basim and Raghu (2015) [3].

Data presented in Table 2 revealed that maximum dry matter accumulation of linseed at 40,60,80 DAS and at harvest i.e.,53.97,120.08,172.52 and 211.31 gm m^{-2} during 2020-21 and 56.12,123.31,174.50 and 212.67 gm m^{-2} during 2021-22 were recorded with 125% RDF imposed to preceding black gram crop while statistical at par to 100% RDF i.e.52.22,115.36169.18 and 205.28 gm m^{-2} during 2020-21 and 54.29,117.98,170.17 and 206.91 gm m^{-2} during 2021-22, respectively and both were significantly superior over 75% RDF and control. Increasing in dry matter accumulation is the prerequisite for higher yields and is an index that representing the plant's growth and metabolic efficiency tends to crop yield. This might be due to the nitrogen as a major component of protoplasm helps in photosynthesis and enhances metabolic rate, cell division and cell elongation and phosphorus enhances leaf expansion, leads to more accumulation of net photosynthates and due to balanced and optimum nutrition of N, P, K and S. The results are in agreement with the findings of Patil *et al*. (2018) [22] and Sune *et al*. (2006) [29]. Increasing level of nutrients imposed to succeeding black gram and 50% RDF applied to preceding linseed resulted in better dry matter production which might be due to increased photosynthates and their translocation to different parts. which was also noticed by Bharat *et al*. (2013) [4], Singh *et al*. (2013) [28] and Meena *et al*. (2011) [16].

Residual effect of FYM @ 5t ha^{-1} as organic manure applied to preceding black gram significantly increased the dry matter of linseed at 40,60,80 DAS and at harvest i.e., 51.86,115.75,165.83 and 201.81 gm m^{-2} during 2020-21 and 53.23,117.53,167.16 and 202.43 gm m^{-2} during 2021-22, respectively, over no FYM. This might be due to improvement of soil health by slow releasing of nutrients and having more carry over capacity (CoC) on succeeding crop. At subsequent growth stages of linseed, residual effect of FYM ensures the supply of micro and macro nutrients as well as plant growth promoting hormones which implies positive impact on plant growth and development leads to more dry matter. The results were in with the observations by Murali *et al.* (2018) [18] and Dubey *et al.* (2020) [6]. These results are in concurrence with the findings of Reddy and Singh (2018) [24], Sunil *et al.* (2018) [30], Kumar and Sood (2020) [12], Kaushal and Umrao (2020) [11], Meena *et al.* (2020) [16] and Nautiyal *et al.* (2021) [20].

Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR or alone did not influence the dry matter accumulation of linseed. Maximum dry matter (50.42,110.87,160.25 and194.49 gm m^{-2} during 2020-21 and 51.77,113.69,161.21 and 195.01 gm m^{-2} during 2021-22) were registered with dual seed inoculation of black gram with *Rhizobium* + PGPR in all respective growth stages and at harvest during both consecutive years.

Data on crop growth rate presented in Table 3 and graphically depicted in Fig 2 revealed that residual effect of fertilizer levels imposed to black gram significantly influenced the crop growth rate of linseed. Linseed crop grow with increasing growth rate up to 80 DAS and thereafter crop growth rate declines. Maximum CGR i.e., 1.52,3.31,2.62 and 1.29 gm m^{-2}day^{-1} during 2020-21 and 1.53,3.36,2.56 and 1.27 gm m^{-2}day^{-1} during 2021-22 at 20-40 DAS, 40-60 DAS,60-80 DAS and 80 DAS-at harvest were recorded from 125% RDF applied to black gram in *Kharif*. This treatment was statistically at par to 100% RDF applied to black gram and significantly superior to control and 75% RDF to imposed to black gram. It is probably due to the better availability of nutrients to linseed at critical growth stages during *Rabi* when applied to preceding black gram in *Kharif* season and active contribution of leaves in photosynthesis which directly influenced crop growth rate. These results are in concurrence with the findings of Ramesh and Ram Prasad (2013) [23] and Kumari *et al.* (2021) [13].

There was significant influence of residual effect of FYM applied to *Kharif black* gram on CGR of *Rabi* linseed at different growth stages. Maximum CGR i.e.,1.46,3.19,2.50 and 1.20 gm m^{-2}day^{-1} during 2020-21 and 1.46,3.21,2.48 and 1.18 gm m^{-2}day^{-1} during 2021-22, respectively of linseed were registered with FYM @ 5t ha^{-1}applied to black gram, which was found to be superior over without FYM. This might be due to additional supply of plant nutrients after decomposition and mineralization, FYM supplied available nutrients directly to

succeeding crop, which are responsible for activation of cell division and elongation in axillary buds and attributed to improved vegetative growth. These findings are in line with the observations by Singh *et al*. (2013) [28], Chaudhary (2016) [5] and Markar *et al*. (2018) [15]. FYM has favorable effect on chemical, physical and biological properties of soil lead to more CoC (carry over capacity) to preceding linseed crop.

Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR or alone did not influence the CGR of linseed. Maximum CGR (1.47,3.02,2.47 and 1.14 gm $m^{-2}day^{-1}$ during 2020-21 and 1.45,3.10,2.38 and 1.13 gm $m^{-2}day^{-1}$ during 2021-22) were registered with dual seed inoculation of black gram with *Rhizobium* + PGPR in all respective growth stages and at harvest during both consecutive years. Beneficial effect of dual seed inoculation of black gram with *Rhizobium* + PGPR on CGR of linseed might be due to increased nodulation and nitrogen fixation in preceding black gram, which indirectly improve nutrient status of soil and make available to linseed crop and substantially reduce the need for soil nitrogen supplement. On the other hand, PGPR enhances ability to resist biotic and abiotic stress of black gram by improving nutrient absorption, producing phytohormones and releasing antibiotics. (Lyu *et al*., 2020 and Sindhu *et al*., 2020) [14, 27] which improv soil health for succeeding linseed.

Interaction effects of residual effect of fertility levels, FYM levels and biofertilizers imposed to preceding black gram were non-significant to all respective growth parameters at all growth stages of linseed.

Effect on yield and yield attributes

It is evident from Table 3 that different fertilizer and FYM levels applied to preceding black gram have significant residual effect on yield and yield attributes of preceding linseed, while seed inoculation of black gram with biofertilizers has no significant residual effect during both years of experimentation. Among yield attributes, maximum primary and secondary branches (8.02 and 22.03; 8.32 and 22.91Nos.) and capsules per plant (75.32 and 76.73Nos.), respectively were registered with residual effect of 125% RDF imposed to black gram and this was *fb* the treatment receiving residual effect of 100% RDF applied to black gram in two consecutive years i.e., 2020-21 and 2021-22 and superior over control and 75% RDF applied to black gram. Residual effect of fertilizer levels imposed to black gram not significantly influenced the seeds per capsule and 1000 seed wight of linseed. Maximum seeds per capsule (8.88 and 9 Nos.) and 1000 seed weight (7.441 and 7.448 gm) were recorded during 2020-21 and 2021-22 with residual effect of 125% RDF applied black gram which is *fb* 100% RDF applied to *Kharif* black gram.

Residual effect of FYM @ $5tha^{-1}$ practiced in black gram recorded highest number of primary and secondary branches per plant of linseed (i.e., 6.87 & 21.02 and 7.08 & 21.51Nos.) and capsules per plant (70.37 and 70.88 Nos.) during both years. Residual effect of FYM levels applied to preceding *Kharif* black gram not significantly influenced the number of seeds per capsule and 1000 seed weight of linseed. Maximum seeds per capsule (8.83 and 8.87 Nos.) and 1000 seed weight (7.446 and 7.449 gm) during 2020- 21 and 2021-22 were registered with residual effect of FYM @ $5tha^{-1}$ imposed to black gram over without FYM imposed to black gram.

Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR or alone did not influence the yield attributes of linseed. Maximum primary and secondary branches, capsules per plant, seeds per capsule and 1000 seed weight i.e., 6.61& 20.43, 67.72, 8.82 Nos. & 7.43 gm and 6.73& 21.01, 68.8, 8.83Nos. & 7.433 gm were registered with dual seed inoculation of black gram with *Rhizobium* + PGPR in all respective growth stages and at harvest during both consecutive years and this was *fb* seed inoculation with PGPR alone.

The residual effect of different fertilizer levels along with different FYM levels and seed inoculation with bio- fertilizers (Rhizobium, PGPR alone or combined (*Rhizobium* + PGPR), practiced for black gram were influenced the yield of linseed significantly during both the years of experimentation. The seed and stover yields of linseed were 19.52,30.48&39.03and 14.11,27.14 &30.16 per cent and 23.35,34.63 &43.58 and 17.70,30.92 &33.68 per cent higher during 2020-21 and 2021-22, respectively under 75%,100% and125% RDF to black gram. Maximum seed and stover yield of linseed i.e., 1090 & 2158 kg ha^{-1} and 1107 &2183 kg ha^{-1} were registered with 125% RDF imposed to *Kharif* black gram, while statistical at par to 100% RDF imposed to black gram. Both were significantly superior over control and 75% RDF to black gram. This might be due to better availability of nutrients to linseed during *Rabi* resulting in better growth. which resulted in adequate supply of photosynthates for development of sink under higher level of fertilizer. Positive response of inorganic fertilizers has also been reported by Patel (2012) [21] and Bharat *et al*. (2013) [4].

FYM applied to preceding black gram significantly influenced the seed and stover yield of succeeding linseed. The treatment receiving FYM @5t ha^{-1} to preceding black gram recorded significantly maximum seed and stover yield of linseed i.e.,1028 &2061 kg $ha^{-1}$and 1038 &2076 kg ha^{-1} during 2020- 21 and 2021-22, respectively, which was 15.51&11.59% and 15.85 & 11.49% higher than no FYM applied to preceding black gram. This might be due to better portioning of photosynthates between source and sink led to greater assimilation of dry matter in fruiting parts resulted in improvement of yield.

Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR or alone did not influence the seed and stover yield of linseed. Maximum seed and stover yields of linseed i.e., 988 & 1998 kg ha^{-1} and 997& 2013 kg ha^{-1} were registered with dual seed inoculation with *Rhizobium* + PGPR of preceding *Kharif* black gram during both consecutive years and this was *fb* seed inoculation with PGPR alone. Dual inoculation benefited both black gram and linseed crop by fixing atmospheric N and decomposition of leaf fall and roots of black gram increased the organic matter and thus enhances the availability of nutrients in the rhizosphere of itself as well as linseed while PGPR increases the accumulation and translocation of assimilates from source to sink.

Profitability

Economics of linseed was significantly affected by residual effect of different fertilizer and FYM levels applied to preceding black gram, while seed inoculation of black gram with biofertilizers has no significant residual effect on economics of linseed during both years of experimentation.

Results summarized in Table 4 revealed that 125% RDF imposed to black gram recorded highest value of gross return of linseed (₹46331 ha^{-1}& ₹48119 ha^{-1}), net return (₹26902 ha^{-1}& ₹28690 ha^{-1}) and B:C ratio (1.38 & 1.48), respectively during

both consecutive years of experimentation. This treatment was statistically at par to 100% RDF applied to black gram i.e., gross return (₹43503 ha^{-1}& ₹45326 ha^{-1}), net return (₹24074 ha^{-1}& ₹25807 ha^{-1}) and B:C ratio (1.24 & 1.33), respectively during both consecutive years. This is due to higher grain yield with low input cost. The results are in conformity with the findings of EI- Nagdy *et al*. (2010) [7] and Meena *et al*. (2011) [16].

Application of FYM to preceding black gram significantly influenced the economics of succeeding linseed. The treatment receiving FYM @5t ha^{-1} to preceding black gram recorded significantly maximum gross return, net return and B:C ratio of *Rabi* linseed i.e., ₹43680 ha^{-1}& ₹45142 ha^{-1}and ₹24251 ha^{-1}& ₹25713 ha^{-1} and 1.25 &1.32 during 2020-21 and 2021-22, respectively, this return was higher due to higher seed and stover yield over no FYM applied to preceding *Kharif* black gram. Though cost of cultivation with FYM was more, but overall productivity increases with FYM @5t ha^{-1} than no FYM, which tends to fetched maximum returns.

Residual effect of dual seed inoculation of preceding black gram with *Rhizobium* + PGPR or alone did not influence the economics of linseed. Maximum gross return, net return and B:C ratio of *Rabi* linseed i.e., ₹42005 ha^{-1}& ₹43401ha^{-1}and ₹22576 ha^{-1}& ₹23972 ha^{-1} and 1.16 &1.23 during 2020-21 and 2021-22, respectively, were registered with dual seed inoculation with *Rhizobium* + PGPR of preceding *Kharif* black gram during both consecutive years and this was *fb* seed inoculation of *Kharif* black gram with PGPR alone. This might be due to maximum recovery of nutrients with dual seed inoculation with *Rhizobium* + PGPR, with less expenditure.

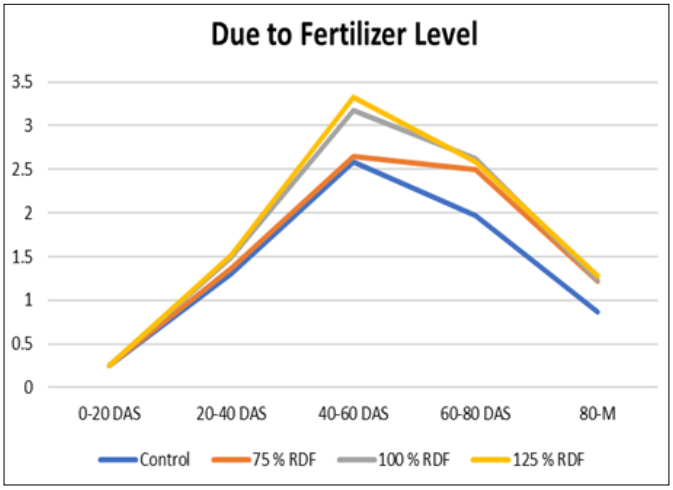
Proper integration of inorganics, organics and bio-fertilizers in preceding *Kharif* black gram has beneficial residual effect on *Rabi* linseed crop. It increases the availability of nutrients to both black gram as well as succeeding linseed crop, resulted in better absorption, translocation and assimilation of nutrients with better portioning of photosynthates between source and sink.

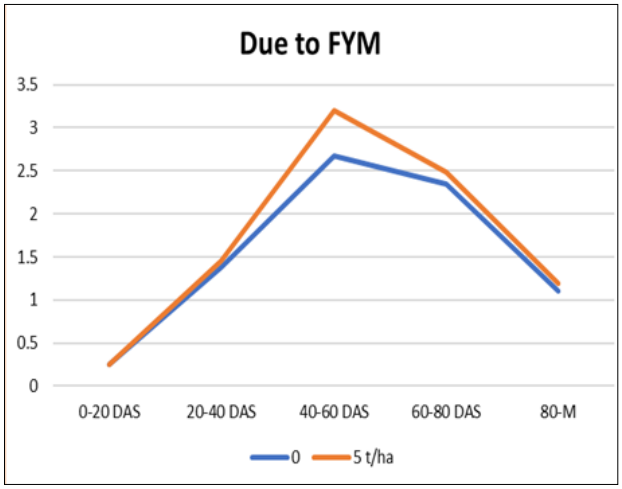
Table 1: Plant height (cm) of Linseed as influenced by residual effect of Integrated Nutrient Management in preceding black gram during 2020-21 and 2021-22.

Treatments	20DAS		40 DAS		60 DAS		80 DAS		At harvest	
	2020-21	21-22	20-21	21-22	20-21	21-22	20-21	21-22	20-21	21-22
Fertility levels										
Control	5.60	5.40	12.60	12.10	42.20	41.80	44.80	44.10	53.60	52.40
75 % RDF	6.90	7.50	16.50	17.50	44.50	45.40	53.20	54.90	58.40	59.80
100 % RDF	7.40	7.70	18.30	19.20	47.20	48.70	58.30	59.80	73.00	74.20
125 % RDF	7.60	7.80	19.20	20.20	48.40	49.40	59.50	61.30	73.80	74.90
SEm±	0.18	0.16	0.37	0.36	0.93	0.91	1.18	1.21	1.79	1.77
CD (P=0.05)	0.52	0.47	1.06	1.02	2.64	2.61	3.35	3.45	5.08	5.03
FYM levels (t ha^{-1})										
0	6.50	6.80	15.70	16.30	42.00	42.80	51.40	52.60	61.80	62.50
5	7.20	7.40	17.60	18.20	49.10	49.80	56.50	57.50	67.60	68.20
SEm±	0.13	0.12	0.26	0.25	0.66	0.65	0.83	0.86	1.26	1.25
CD (P=0.05)	0.37	0.33	0.75	0.72	1.87	1.84	2.37	2.44	3.60	3.55
Biofertilizers (PGPR /BF)										
Rhizobium	6.70	6.90	16.20	16.80	44.60	45.10	52.90	53.70	63.30	63.90
LMn16	6.90	7.10	16.50	17.20	45.30	46.20	54.00	55.10	64.60	65.30
Rhizobium + LMn16	7.00	7.30	17.20	17.70	46.80	47.70	55.10	56.30	66.30	66.90
SEm±	0.16	0.14	0.32	0.31	0.80	0.79	1.02	1.05	1.55	1.53
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interactions	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	11.26	9.79	9.51	8.86	8.64	8.38	9.24	9.34	11.71	11.47

RDF = 30:40:20:20 kg N:P_2O_5:K_2O:S ha^{-1}

Var. = Divya





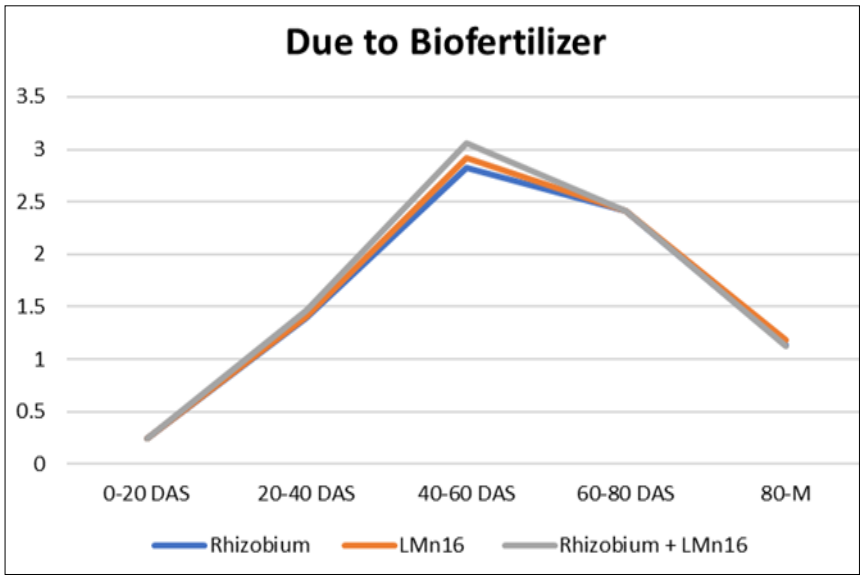


Fig 1: Crop growth rate (gm m-2 day-1) of linseed

Table 2: Dry matter (gm m^{-2}) of Linseed as influenced by residual effect of Integrated Nutrient Management in preceding black gram during 2020-21 and 2021-22.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		At Harvest	
	2020-21	21-22	20-21	21-22	20-21	21-22	20-21	21-22	20-21	21-22
Fertility levels										
Control	13.77	13.41	40.06	39.27	92.19	90.73	132.09	129.61	158.01	155.99
75 % RDF	20.69	23.16	48.50	50.11	101.15	103.47	151.31	153.28	188.38	189.40
100 % RDF	22.35	24.62	52.22	54.29	115.36	117.98	168.18	170.16	205.28	206.91
125 % RDF	23.63	25.60	53.97	56.12	120.08	123.31	172.52	174.50	211.31	212.67
SEm±	0.73	0.75	1.18	1.25	3.28	3.29	3.08	2.81	2.97	2.75
CD (P=0.05)	2.06	2.14	3.35	3.56	9.35	9.37	8.78	8.00	8.47	7.81
FYM levels (t ha^{-1})										
0	17.61	19.26	45.51	46.66	98.64	100.23	146.22	146.62	179.68	180.05
5	22.61	24.14	51.86	53.23	115.75	117.53	165.83	167.16	201.81	202.43
SEm±	0.51	0.53	0.83	0.88	2.32	2.33	2.18	1.99	2.10	1.94
CD (P=0.05)	1.46	1.51	2.37	2.52	6.61	6.63	6.21	5.66	5.99	5.53
Biofertilizers (PGPR /BF)										
Rhizobium	19.29	20.68	47.20	48.43	103.80	104.93	152.36	153.31	186.81	187.25
LMn16	19.94	21.60	48.45	49.64	106.91	108.01	155.47	156.14	190.94	191.46
Rhizobium + LMn16	21.10	22.81	50.42	51.77	110.87	113.69	160.25	161.21	194.49	195.01
SEm±	0.63	0.65	1.02	1.08	2.84	2.85	2.67	2.43	2.58	2.38
CD (P=0.05)	**NS**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions										
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	NS	NS	NS	NS
CV (%)	15.29	14.71	10.26	10.61	12.01	12.83	8.38	7.60	6.62	6.09

RDF = 30:40:20:20 kg $N:P_2O_5:K_2O:S$ ha^{-1}

Table 3: Crop Growth Rate (gm m-2 day-1) of Linseed as influenced by residual effect of Integrated Nutrient Management in preceding black gram during 2020-21 and 2021-22

Treatments	20-40 DAS		40- 60 DAS		60- 80 DAS		80 DAS- at harvest	
	2020-21	21-22	20-21	21-22	20-21	21-22	20-21	21-22
Fertility levels								
Control	1.31	1.29	2.61	2.57	2	1.94	0.86	0.88
75 % RDF	1.39	1.35	2.63	2.67	2.51	2.49	1.24	1.2
100 % RDF	1.49	1.48	3.16	3.18	2.64	2.61	1.24	1.22
125 % RDF	1.52	1.53	3.31	3.36	2.62	2.56	1.29	1.27
SEm±	0.03	0.034	0.113	0.112	0.094	0.088	0.05	0.052
CD (P=0.05)	0.085	0.097	0.321	0.318	0.269	0.251	0.143	0.147
FYM levels (t ha^{-1})								
0	1.4	1.37	2.66	2.68	2.38	2.32	1.12	1.11
5	1.46	1.46	3.19	3.21	2.5	2.48	1.2	1.18
SEm±	0.021	0.024	0.08	0.079	0.067	0.062	0.036	0.037
CD (P=0.05)	0.06	0.068	0.227	0.225	0.19 NS	0.177 NS	0.101 NS	0.104 NS

Biofertilizers (PGPR /BF)								
Rhizobium	1.4	1.39	2.83	2.82	2.43	2.42	1.15	1.13
LMn16	1.43	1.4	2.92	2.92	2.43	2.41	1.18	1.18
Rhizobium + LMn16	1.47	1.45	3.02	3.1	2.47	2.38	1.14	1.13
SEm±	0.026	0.029	0.098	0.097	0.082	0.076	0.044	0.045
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Other Interactions								
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.89	10.19	16.35	16.07	16.41	15.57	18.46	19.13

RDF = 30:40:20:20 kg N:P_2O_5:K_2O:S ha^{-1}
NS = Non-significant

Table 4: Economics of linseed var. Divya as influenced by residual effect of integrated nutrient management in preceding black gram during 2020-21 and 2021-22

Treatments	**Seed Yield (kg ha-1)**		**Stover Yield (kg ha-1)**		**Cost of cultivation (₹ha^{-1})**	**Gross Return (₹.ha-1)**		**Net Return (₹. ha^{-1})**			**B:C**
	2020-21	**2021-22**	**2020-21**	**2021-22**		**2020-21**	**2021-22**	**2020-21**	**2021-22**	**2020-21**	**2021-22**
Fertility levels											
Control	784	771	1658	1633	19429	33359	33640	13930	14211	0.72	0.73
75 % RDF	937	951	1892	1922	19429	39847	41399	20418	21970	1.05	1.13
100 % RDF	1023	1038	2108	2138	19429	43503	45236	24074	25807	1.24	1.33
125 % RDF	1090	1107	2158	2183	19429	46331	48119	26902	28690	1.38	1.48
SEm±	29.84	30.83	61.45	54.43	---	1255	1324	1255	1324	0.065	0.068
CD (P=0.05)	84.94	87.77	174.94	154.93	---	3573	3769	3573	3769	0.184	0.194
FYM levels (t ha^{-1})											
0	890	896	1847	1862	19429	37840	39055	18411	19626	0.95	1.01
5	1028	1038	2061	2076	19429	43680	45142	24251	25713	1.25	1.32
SEm±	21.10	21.80	43.45	38.49	---	888	936	888	936	0.046	0.048
CD (P=0.05)	60.06	62.06	123.7	109.55	---	2526	2665	2526	2665	0.13	0.137
Biofertilizers (PGPR /BF)											
Rhizobium	929	935	1912	1925	19429	39501	40739	20072	21310	1.03	1.1
LMn16	959	968	1953	1970	19429	40774	42155	21345	22726	1.1	1.17
Rhizobium + LMn16	988	997	1998	2013	19429	42005	43401	22576	23972	1.16	1.23
SEm±	25.84	26.7	53.22	47.14	---	1087	1147	1087	1146	0.056	0.059
CD (P=0.05)	NS	NS	NS	NS	---	NS	NS	NS	NS	NS	NS
Other Interactions	NS	NS	NS	NS	---	NS	NS	NS	NS	NS	NS
CV (%)	13.21	13.52	13.34	11.73	---	13.06	13.34	24.96	24.78	24.96	24.78

Selling Price Linseed seed 41.50 Rs. /kg
Linseed stover 0.50 Rs. /kg

Conclusion

It may be concluded that residual effect of integrated application of NPK and S @ 125%RDF (RDF: 20:40:20:20 N: P2O5:K2O :S kg/ha) + FYM @5t ha^{-1} and dual seed inoculation with *Rhizobium* + PGPR applied to preceding *Kharif* black gram and application of NPK and S@ 50% RDF (RDF: 40:30:20:20 N: P2O5:K2O :S kg/ha) to succeeding *Rabi* linseed gave maximum growth attributes, yield and economic returns of linseed, but statistically at par to 100 % RDF along with FYM @5t ha^{-1} and dual seed inoculation with *Rhizobium* + PGPR applied to preceding *Kharif* black gram and application of NPK and S@ 50% RDF (RDF: 40:30:20:20 N: P2O5:K2O :S kg/ha) to succeeding *Rabi* linseed and thus cut down the 50% RDF of linseed. Residual effect of integrated nutrient management practiced in black gram is profitable for linseed in black gram - linseed cropping system of Plateau region of Jharkhand.

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