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Effect of PGRs on Yield, Quality Parameters and Economics of Linseed (*Linum usitatissimum* L.) Cultivation under Rainfed Conditions of Nagaland

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ABSTRACT: The use of PGRs (plant growth regulators) has opened new opportunities for enhancing the productivity of several crops under stress conditions and is becoming an integral component for production technology of several agricultural crops. In India a number of research works on PGRs has been conducted on major oilseed crops *viz.*, Soybean, Indian mustard and Groundnut however, very little is known about the role of PGRs in improving yield and yield components of minor oilseed crops like linseed which needs to be addressed given the practical applicability of such technology for linseed cultivation under its current cultivation scenario and increasing global demand. A field experiment was conducted at the experimental farm of School of Agricultural Sciences, Nagaland University, Medziphema campus during the rabi season of 2018-2019. The experiment was laid out in a RBD with three replications with seven PGR treatments *viz.*, IAA @ 1 ppm, IAA @ 2 ppm, GA_3 @ 200 ppm, GA_3 @ 400 ppm, Salicyclic acid @ 75 ppm, 0.1 % Tebuconazole and IAA @ 1 ppm + GA_3 @ 200 ppm along with control (water spray) to study their effect on yield, quality parameters and economics of linseed cultivation under rainfed conditions of Nagaland. Among the PGR treatments IAA @ 2 ppm recorded significantly higher number of capsules plant^{-1} (53.33) and seed weight plant^{-1} (3.84 g) as well as significantly highest seed yield of 1244.42 kg ha^{-1} whereas, the lowest seed yield of 1013.47 kg ha^{-1}, excluding control, was recorded by 0.1 % Tebuconazole. Stover yield was also found to be significantly higher with application of IAA @ 2 ppm (2589.62 kg ha^{-1}) followed by GA_3 @ 200 ppm (2548.75 kg ha^{-1}). Application of 0.1 % Tebuconazole was found to record significantly highest oil content of 32% followed by Salicylic Acid @ 75 ppm (30.7 %). The highest oil yield of 352.17 kg ha^{-1} was recorded by IAA @ 2 ppm followed by GA_3 @ 200 ppm (348.04 kg ha^{-1}) and IAA @ 1 ppm (343.94 kg ha^{-1}). The highest cost of cultivation Rs. 29811 ha^{-1} was incurred with application of GA_3 @ 400 ppm whereas, application of IAA @ 2 ppm was found to record the highest gross returns, net returns and BCR of Rs. 49773 ha^{-1}, Rs. 30314 ha^{-1} and 2.6 respectively followed by application of IAA @ 1 ppm with net returns of Rs. 25970 ha^{-1} and BCR of 2.3.

Keywords: PGRs, linseed, rainfed, yield, quality parameters, cultivation economics.

INTRODUCTION

Linseed (*Linum usitatissimum* L.) commonly known as flax is a dual purpose rabi oilseed crop which is grown for both its oil and fibre (Kumari *et al.*, 2021). Globally linseed is grown in an area of 4.1 mha in over 47 countries with a total production of 3.3 mt and average productivity of 806 kg ha^{-1}. Russian Federation holds first position in terms of area and production (1.5 mha and 1.3 mt lakh respectively) whereas, India, with an area of 0.2 mha and production of 0.1 mt, holds 5th position in terms of global average and production (Anonymous, 2023a). The leading linseed producing states in India are Madhya Pradesh, Jharkhand, Uttar Pradesh, Chhattisgarh and Odisha accounting for 80% of area and 79% of production (Anonymous, 2023b). In Nagaland, linseed is grown in an area of 5870 ha with a total production of 4770 mt (Anonymous, 2022). The average productivity of linseed in India has substantially increased from 533 kg ha^{-1} to 642 kg ha^{-1} during the last 5 years (Anonymous, 2023b) however; we are still far behind in productivity compared to other linseed growing countries like Canada, Russian Federation and China with average productivity ranging from 857-1308 kg ha^{-1}. In India linseed is usually grown under input starved conditions facing a number of constraints *viz.*, moisture stress, poor soil fertility, insufficient application of nutrients and traditional cultivation practices (Kumari *et al.*, 2021) and this coupled with the fact that majority of the crop being grown under rainfed and utera conditions (63% and 25% respectively, Dash *et al.*, 2017), usually associated with low yield, results in low productivity of the crop.60% of the net cultivated area under linseed is in poor condition and more than 30% of area receives insufficient rainfall (Yadav *et al.,* 2023). The present status of linseed production could be increased 2-3fold by adopting improved varieties along with recommended production technologies. In recent years, the use of plant growth regulators (PGRs) has opened new opportunities for enhancing the productivity of several crops under stress conditions (Tomar *et al.,* 2022) and is becoming an integral component for production technology of several agricultural crops and particularly in fruit trees. While nutrients are required for normal growth and development of crop, the agricultural practice that is successfully employed to eliminate the negative effects of stressful situation on crop productivity is the application of plant growth regulators (PGRs) (Calvo *et al.,* 2014). PGRs are organic substances, natural or artificial, that regulate various physiological processes in a plant when used in extremely low levels and modulate plant growth and development (Gautam *et al.,* 2022). The application of PGRs in low concentration regulates growth, differentiation and development, either by promotion or inhibition (Naeem *et al.,* 2004). One of the potentials of PGRs utility is their effectiveness at extremely low concentrations and the resultant high cost-to benefit ratios. Further, PGR-potentiated yield increments of 15-20 % are very common (Mishra, 2000). PGRs are known to influence hormone balance in plants (Azizoglu *et al.,* 2021) and promote germination (Wu *et al.,* 2017), plant cell enlargement and division and root extension (Azizoglu *et al.,* 2021), chlorophyll content and photosynthetic ability (Shao *et al.,* 2014), transportation of photosynthates and source–sink association (Khan & Mazid 2018), flower formation, fruit and seed development (Basuchaudhuri, 2016), biomass production (Shao *et al.,* 2014) and ultimately enhancing yield components and yield (Basuchaudhuri 2016) and productivity of the crop (Basuchaudhuri, 2016; Khan & Mazid 2018). PGRs can successfully enhance the yield of economically important oilseed crops (Rastogi *et al.,* 2013). In India a number of research works on PGRs such as Indole Acetic Acid, Giberellic Acid, Naphthalene Acetic Acid, Salicylic Acid, Jasmoic Acid, Cycocel, Abscisic Acid has been conducted on major oilseed crops *viz*., Soybean (Upadhyay and Ranjan 2015; Khatun *et al.,* 2016; Sun *et al.,* 2016; Giri *et al.,* 2018; Liu *et al.,* 2019), Indian mustard (Khaliq *et al.,* 2006; Akter *et al.,* 2007; Mishra and Kushwaha, 2016; Nehal *et al.,* 2018; Sumi *et al.,* 2021), Groundnut (Verma *et al.,* 2009; Vinothini *et al.,* 2018; Kiruthika *et al.,* 2018; Avinasha *et al.,* 2019; Subha and Mehera 2022). Findings from these research works indicate that the use of different PGRs have significant positive effect on different physiological processes of the crops which was ultimately reflected in terms of enhanced crop growth, yield and quality attributes *viz.*, plant height, plant dry weight, number of leaves, number of flowers, percent fruit set, number of pods/siliquae, number of seeds/kernels, test weight, seed yield, biological yield, harvest index, protein and moisture content in seed. It can be clearly seen from the above review that PGRs play a very important role in plant growth and development however, despite the huge plethora of research on major oilseed crops, very little is known about the role of PGRs in improving yield and yield components of minor oilseed crops like linseed which needs to be addressed given the response of major oilseed crops to PGRs and the practical applicability of such technology for linseed cultivation given its current cultivation scenario and growing global demand. Hence, the following experiment was conducted to study the effect of PGRs on yield and quality parameters of linseed as well as their cultivation economics under rainfed conditions of Nagaland.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of School of Agricultural Sciences, Nagaland University, Medziphema campus during the rabi season of 2018-2019. The soil of the experimental field was clayey loam in texture, which was found to be acidic in nature, high in organic carbon and available P and medium in available N and K. The experiment comprising of eight treatments was laid out in a Randomized Block Design with three replications. The treatments were Control-water spray, IAA @ 1ppm, IAA @ 2ppm, GA_3 @ 200 ppm, GA_3 @ 400ppm, Salicyclic Acid @ 75ppm, 0.10% Tebuconazole and IAA @ 1 ppm + GA_3@ 200 ppm. The linseed variety "Shekhar" was sown with a seed rate of 25 kg ha^{-1} and 25 × 5 cm^2 spacing. FYM @ 5 t/ha was incorporated during final land preparation and uniform NPK dose of 40:20:10 kg/ha was applied to all the experimental units all other cultural operations were kept uniform. Different PGR treatments were given as foliar sprays, first spray was given at vegetative stage followed by second spray at reproductive stage. To avoid possible degratation of PGRs, different concentrations of the PGRs required for spray treatments were freshly prepared 1-2 hours prior to application and stored in amber glass bottles in dark room under room temperature. Foliar spray of PGRs was given on wind free clear day during the early morning hours for better results. Separate low volume hand sprayers were used for each PGR treatment. To avoid any form of dilution in concentrations, lower concentrations of each PGR was first sprayed and the sprayer was rinsed with some quantity of next concentration to be used. For testing oil content of linseed nuclear magnetic resonance (NMR) method was applied. The seed and stover samples were analyzed for NPK content (%) and NPK uptake in kg ha^{-1} was worked out. Economics of cultivation was worked out as per prevailing market prices of inputs and outputs *viz*., IAA @ Rs. 97.2 g^{-1}, GA_3 @ Rs. 113 g^{-1}, Salicylic Acid @ Rs.1.2 g^{-1}, Tebuconazole @ Rs. 2 ml^{-1} and linseed seeds @ Rs. 40 kg^{-1}. Data recorded during the course of experiment were statistically analysed and computed by following the standard ANOVA procedure as outlined by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

A. Effect of PGRs on yield attributes

With respect to number of seeds capsule^{-1} (Table 1) no significant effect was recorded due to application of growth regulators. Significant differences were recorded in number of capsules plant^{-1} and seed weight plant^{-1} as influenced by various growth regulators (Table 1). Among the treatments IAA @ 2 ppm recorded numerically highest number of capsules plant^{-1} as well as seed weight plant^{-1} whereas, application of IAA @1ppm, GA_3 @ 200 ppm and 0.1 % Tebuconazole were also found to be at par with IAA @ 2 ppm and all four treatments were found to record significantly higher number of capsules plant^{-1} compared to Salicylic acid @ 75 ppm, IAA @ 1ppm + GA_3 @ 200 ppm and control. GA_3 @ 400 ppm was also found to record significantly higher capsules plant^{-1} as compared to control and seed weight plant^{-1} as compared to Salicylic Acid @ 75 ppm, IAA @ 1ppm + GA_3 @ 200 ppm and control. The effect of GA_3 and Auxin (IAA) in increasing the number of capsules plant^{-1} has also been reported by Katore *et al.* (2021); Kumar *et al.* (2021). Effect of different PGRs on enhancing the number of siliqua/pods/capsules plant^{-1} in different crops has also been reported in mustard with application NAA (Mishra and Kushwaha 2016) and GA_3 (Sumi *et al.,* 2021); in soybean with application of GA_3 and IAA (Sarkar *et al.,* 2002) and GA_3 and NAA (Dhakne *et al.,* 2015) and in groundnut with application of GA_3 (Patil, 2019) and NAA (Vinothini *et al.,* 2018). Application of IAA at both the concentrations resulted in an increase in the number of capsules plant^{-1} as well as seed weight plant^{-1}, which is the close conformity with work done by Ayala-Silva *et al*. (2005), who also reported that application of IAA was found to increase flowering and number of bolls in linseed whereas, significantly lower number of capsules recorded with higher concentration of GA_3 (400 ppm) as compared to lower dose of GA_3 @ 200 ppm may be due to inhibitory action of GA_3 of flowering and fruiting with increasing dose. Dybing and Lay (1981) also reported decrease in size and number of bolls of flax with application of GA_3. Ayala-Silva *et al.* (2005) also reported reduction of upto 53% and 50% in number of flowers and bolls with application of increased dose of GA_3 @ 250 mg/L in flax. The increase in number of capsules plant^{-1} recorded due to application of 0.1 % Tebuconazole might be due to inhibitory action of triazole in production of endogenous gibberellic acid. Triazole fungicides affect the isoprenoid pathway and alter the levels of certain plant hormones by inhibiting gibberellin synthesis (Graebe, 1987; Setia *et al.,* 1995). Significantly higher seed weight plant^{-1} as recorded with different doses of IAA and GA_3 as well as tebuconazole could be attributed to significantly higher number of capsules plant^{-1} recorded by those treatments.

B. Effect of PGRs on seed and stover yield

With respect to seed yield whereas, all PGR treatments were found to record significantly higher seed yield (Table 1) compared to control, application of IAA @2 ppm was found to record significantly highest seed yield of 1244.42 kg ha^{-1} compared to the rest of the treatments whereas, GA_3 @ 400 ppm, GA_3 @ 200 ppm and IAA @ 1 ppm were found to be at par with respect to seed yield and all three treatments were found to record significantly higher seed yield compared to Salicylic Acid @ 75 ppm, 0.1 % Tebuconazole, IAA @ 1ppm + GA_3 @ 200 ppm and control. Similar findings on increments in seed yield with application of PGRs *viz*., IAA (Sarkar *et al*., 2002), GA_3 (Upadhyay and Ranjan 2015) and NAA (Basuchaudhuri, 2016) in soybean; GA_3 and IAA in sunflower (Dawood *et al.*, 2012) and GA_3 in mustard (Sumi *et al.,* 2021) has been reported in previous research works. Application of different doses of IAA and GA_3 may have enhanced the physiological efficiency of the crop resulting in higher photosynthetic efficiency, dry matter production and partitioning ultimately resulting in higher grain and straw yields. Higher physiological efficiency including photosynthetic ability of plants leads to better growth and yield of several agronomic crops (Mishra and Kushwaha 2016). Assimilate availability and allocation to reproductive structures is an essential factor, which decides yield of any crop (Barimavandi *et al.,* 2010). Significantly higher seed yield recorded by different doses of IAA and GA_3 can also be be attributed to enhanced expression of yield attributes *viz*., capsules plant^{-1} and seed weight plant^{-1} by those treatments. Sumi *et al.* (2021) also reported a positive correlation of yield with number of siliqua plant^{-1} in mustard whereas, Subha and Mehera (2022) also reported cumulative effect of yield attributing characters *viz.*, pods plant-^{1}, kernels pod^{-1} on yield of groundnut. Rahimi *et al.* (2011) also reported that seed yield was strongly influenced by various growth components i.e., plant height, branches plant^{-1}, capsules plant^{-1} and seeds capsule^{-1}. Data on stover yield (Table 1) also shows maximum yield with application of different doses of IAA and GA_3. The highest stover yield of 2589.62 kg ha^{-1} was recorded with IAA @ 2 ppm followed by GA_3 @ 200 ppm, GA_3 @ 400 ppm, IAA @ 1 ppm + GA_3 @ 200 ppm and IAA @ 1 ppm all treatments being at par and recording significantly higher stover yield as compared to control whereas, IAA @ 2 ppm was also found to record significantly higher stover yield compared to Salicylic Acid @ 75 ppm, 0.1 % Tebuconazole. Increased stover yield in mustard was also reported with application of PGRs like GA_3 and Auxin (NAA) by Sumi *et al.* (2021); Mishra and Kushwaha (2016) respectively. Sarkar *et al.* (2002) also reported in soybean crop that application of GA_3 enhanced plant height, number of branches, number of leaves and leaf area plant^{-1} whereas, application of IAA produced the highest plant height. This might due to enhanced vegetative growth of crop plant under the influence of exogenous GA_3 and IAA application as they are known to involve in the formation of new cells (Emongor, 2007), and is involved in mitotic activity in sub-apical tissues, resulting in increased plant growth (Abel and Theologis 2010). Harvest index data presented in Table. 1 indicates no significant variations among the different PGRs tested however the highest harvest index of 32.57 % was recorded with application of 0.1 % Teboconazole. This may be due to due significantly lower stover yield recorded with application of tebuconazole among all the growth regulators and relatively higher seed yield as compared to stover yield obtained under the treatment. Tebuconazole has been reported to make plants more compact by reducing LAI and plant height (Ijaz and Honermeier 2011).

C. Effect of PGRs on oil content % and oil yield

The data obtained on oil content (Table. 1) shows significant variations in oil content of linseed due to application of various PGRs. All PGRs tested were found to record significantly higher oil % as compared to control. Application of 0.1 % Tebuconazole was found to record significantly highest oil content of 32% followed by Salicylic Acid @75ppm, IAA @1ppm and GA_3 @ 200 ppm with an oil content of 30.7 %, 30.3 % and 30.0 % respectively, the later three treatments being at par whereas, it was also recorded that lower doses of both IAA @ 1 ppm and GA_3 @ 200 ppm were found to record significantly higher oil % compared to corresponding higher doses of IAA @ 2 ppm and GA_3 @ 400 ppm. Similar findings have also been reported in other studies. Mert Türk *et al.* (2008), who worked with triazole fungicide Folicur, also reported significant increase in oil content of rapeseed after triazole application in comparison with the control. Dawood *et al.* (2012) reported that application of Salicylic Acid caused significant increases in sunflower oil content relative to those of the control. Jamshidi Jam *et al.* (2023) reported that application of Salicylic Acid increased oil content, oil yield, linoleic acid content, palmitic and linoleic acid yield in safflower. Ganesh *et al.* (2017) also reported that application of 75 ppm Salicylic Acid in mustard, when compared with the control, was found superior for oil content. Baydar (2000) reported that oil synthesis increases with increasing dose of GA in safflower. Like gibberellins, auxins are effective in increasing oil yield. Farooqui *et al.* (2005) reported that Indole Acetic Acid (IAA) application increases oil yield enormously in *Cymbopogon martinii* and *Cymbopogon winterianus*. All PGRs tested were found to record significantly higher oil yield (Table 1) ranging from 309.47 to 352.17 kgs ha^{-1} as compared to control. The highest oil yield of 352.17 kg ha^{-1} was recorded by IAA @ 2 ppm followed by GA_3 @ 200 ppm (348.04 kg ha^{-1}) and IAA @ 1 ppm (343.94 kg ha^{-1}) wherein, all three treatments were at par with each other and recorded significantly higher oil yield compared to 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm and IAA @ 1ppm + GA_3 @ 200 ppm. Significantly higher oil yield recorded by IAA @ 2 ppm, GA_3 @ 200 ppm and IAA @ 1 ppm could be attributed to significantly higher seed yield and oil % recorded by these treatments. Göre *et al.*, (2023) also reported that the strong and positive correlation between grain and oil yield of summer and winter camelina was due to calculation of oil yield by multiplying grain yield by oil content. Giri *et al.* (2018) also reported in soybean that the increase in oil yield was correlated directly with grain yield. Application of0.1 % Tebuconazole and Salicylic Acid @ 75 ppm despite recording significantly higher oil % registered lower oil yield due to lower seed yields.

D. Effect of PGRs on uptake by plant

The data on effect of PGRs on NPK uptake by plant (Table 1) did not show any significant variations however, NPK uptake in the range of 38.50 to 41.61 kg/ha, 18.83 to 19.21 kg/ha and 22.54 to 24.53 kg/ha respectively was recorded during course of the investigation. Numerically highest value for N uptake was recorded by IAA @1ppm followed by IAA @ 2 ppm recording N uptake of 41.61 and 40.96 kg ha^{-1} respectively whereas, in case of P and K uptake application of IAA @2ppm was found to record the highest uptake of 19.21 and 24.53 kg ha^{-1} respectively for P and K.

E. Effect of PGRs on cultivation economics

Data on economic parameters are presented in Table 2. All PGR treatments were found to record significantly higher gross returns, net returns and BCR ranging compared to control. The highest cost of cultivation Rs. 29811ha^{-1} was incurred with application of GA_3@ 400 ppm concentration followed by combined application of IAA @ 1 ppm and GA_3 @ 200 ppm and sole application of GA_3 @ 200 ppm. Whereas, among the PGR treatments the lowest cost of cultivation was registered by Salicylic Acid @ 75 ppm followed by IAA @ 1ppm. Higher cultivation costs associated with treatments involving single as well as combined application of GA_3 was due to high cost of the chemical as well as relatively higher doses of GA_3 as compared to rest of the PGR doses. Katore *et al.* (2021) also reported the lowest net monetary return and BC ratio with application of higher dose of GA@ 400 ppm which was attributed to the high market cost of GA. The highest gross returns, net returns and BCR of Rs. 49773 ha^{-1}, Rs. 30314 ha^{-1} and 2.6 respectively was obtained by IAA @ 2 ppm. Application of IAA @ 1 ppm, GA_3@ 200 ppm and GA_3 @ 400 ppm were also found to be at par with each other and recorded significantly higher gross returns compared to 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm and IAA @ 1 ppm + GA_3 @ 200 ppm. Significantly higher net returns of Rs. 25970 ha^{-1} and BCR of 2.3 was also recorded with application of IAA @ 1 ppm compared to rest of PGR treatments except for IAA @ 2 ppm whereas, GA_3 @ 200 ppm, 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm were also found to be at par with each other and recorded significantly higher net returns compared to combined application of IAA @ 1ppm + GA_3 200 ppm. Application of 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm were also found to record significantly higher BCR compared to all PGR treatments involving GA_3. The high gross returns and net returns as well as BCR recorded with IAA @ 1 ppm and 2 ppm can be attributed to significantly higher seed and stover yields as recorded under both the treatments. Kumar *et al.* (2017) also reported higher values of economic parameters with higher seed and stover yields of linseed. Whereas, higher net returns and BCR associated with both treatments can also be attributed to significantly higher gross returns and lower cultivation cost associated with both the treatments due to lower chemical dose as well as cost. Mishra and Kushwaha (2016); Sumeriya *et al.* (2000) also reported that the higher net return under PGR treatments were associated with higher values of gross returns and lower cultivation cost associated with the treatments. It may be noted that application of GA_3 @ 200 ppm and 400 ppm despite recording comparatively higher gross returns as compared to 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm could not outperform the later two treatments in terms of BCR and this can be attributed to the fact that due to lower cultivation costs both 0.1 % Tebuconazole, Salicylic Acid @ 75 ppm recorded relatively good yield performance in relation to cost of cultivation involved with the treatments whereas, in case of GA_3 economics of treatments were not viable due to high cost of treatments.

Table 1: Effect of different PGRs on yield attributes, yield and quality parameters of linseed.

Treatments	Capsules Plant^{-1}	Seeds Capsule^{-1}	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index %	Oil content (%)	Oil yield (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
Control (water spray)	31.8	8.71	2.14	814.47	1869.23	30.31	26.26	213.94	38.498	19.023	22.540
IAA @ 1 ppm	51.89	9.07	3.55	1135.10	2416.70	32.11	30.30	343.94	41.626	18.887	22.867
IAA @ 2 ppm	53.33	8.94	3.84	1244.42	2589.62	32.46	28.30	352.17	40.959	19.210	24.533
GA_3 @ 200 ppm	50.00	8.92	3.75	1160.12	2548.75	31.29	30.00	348.04	39.606	19.067	22.600
GA_3 @ 400 ppm	37.13	8.86	3.19	1161.66	2515.55	31.60	28.06	326.04	38.503	18.867	23.000
Salicylic acid @ 75 ppm	41.4.00	8.77	2.29	1018.86	2302.25	30.68	30.70	312.79	38.812	18.967	23.700
0.1 % Tebuconazole	50.00	8.82	3.83	1013.47	2102.62	32.57	32.00	324.31	38.809	18.833	24.400
IAA @ 1 ppm + GA_3 @ 200 ppm	35.93	8.87	2.82	1056.20	2483.33	30.04	29.30	309.47	39.082	18.893	23.933
Sem ±	1.68	0.17	0.12	23.58	81.45	0.61	0.36	9.51	1.598	0.252	0.621
CD (P=0.05)	5.11	NS	0.37	71.52	247.09	NS	1.10	20.40	NS	NS	NS

Table 2: Effect of PGRs on cultivation economics of linseed.

Treatments	Cost of Cultivation (Rs./ha^{-1})	Gross Return (Rs./ha^{-1})	Net Returns (Rs./ha^{-1})	BC Ratio
Control (water spray)	18961	32587	13626	1.7
IAA @ 1 ppm	19430	45400	25970	2.3
IAA @ 2 ppm	19459	49773	30314	2.6
GA_3 @ 200 ppm	24606	46400	21794	1.9
GA_3 @ 400 ppm	29811	46467	16656	1.6
Salicylic acid @ 75 ppm	19428	40760	21332	2.1
0.1 % Tebuconazole	19641	40533	20892	2.1
IAA @ 1 ppm + GA_3 @ 200 ppm	24635	42240	17605	1.7
Sem ±	-	943.69	943.69	0.05
CD (P=0.05)	-	2862.58	2862.67	0.15

CONCLUSIONS

The present investigation, in line with research work conducted on other oilseed crops, clearly shows that the use of PGRs can have a significant effect on yield attributes, seed and stover yield, oil % and oil yield of linseed under rainfed conditions and can be adopted as a viable low cost technology specially under rainfed conditions. From the findings of the present investigation it can be concluded that application of IAA @ 1ppm and 2 ppm and GA_3 at lower dose of 200 ppm were found to enhance both yield attributes and seed, stover and oil yield of linseed whereas, application of 0.1 % Tebuconazole and Salicylic Acid @ 75 ppm was found to enhance the seed oil content %.However, keeping in view economic feasibility of treatments, it is recommended to use IAA @ 2 ppm or 1 ppm for obtaining maximum yield performance as well as BCR from linseed cultivation under rainfed conditions.

FUSTURE SCOPE

A major shift in demand for linseed and its by products has been observed in the last decade, however due to non-availability of superior cultivars and preference for traditional cultivation practices of the crop under input starved conditions the productivity of this crop is very low specially under rainfed conditions. To overcome the production constraints, there is scope for chemical manipulation, through the use of PGRs, to enhance the performance and quality of the crop as the present investigation suggests. Also since linseed being a minor oilseed crop, which is usually grown with minimum inputs, successful use of PGRs could serve as a low cost and viable technology for linseed cultivation especially under rainfed conditions. There is more scope for further research and refinement of the applicability of PGRs in conjunction with other low cost precision production technology on yield and quality parameters of minor oilseed crops like linseed specially under rainfed and utera conditions.

Author contributions. L. Tongpang Longkumer, Noyingthung Kikon and Lanunola Tzudir designed the study. Noyingthung Kikon, Imlilemla Amlari and Tana Yagum prepared the material and conducted the field experiments. Tana Yagum collected the field datas and conducted analysis works. Noyingthung Kikon contributed analysis tools. Tana Yagum performed the analysis of datas. All authors contributed to interpretation of data. Noyingthung Kikon wrote the manuscript. L. Tongpang Longkumer supervised the entire investigation.

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