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Impact of Foliar-Applied Growth Regulators on Productivity and Profitability of Linseed (*Linum usitatissimum* L.)

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ABSTRACT: This three-year study demonstrated that foliar applications of growth regulators significantly enhanced the productivity and profitability of linseed under rainfed conditions of Palampur. While GA 400 ppm and Auxin 1.0 ppm + GA 200 ppm treatments produced the highest seed yields (1416 and 1426 kg/ha, respectively) through substantial improvements in plant height, branching, capsules per plant, seeds per capsule, and seed weight, the economic analysis revealed a different optimal treatment. Auxin 2.0 ppm emerged as the most economically viable option with the highest net returns per rupee invested (2.07) and superior net monetary returns (39573 Rs/ha), despite generating moderately lower yields than GA treatments. This discrepancy occurred because gibberellic acid applications, although yield-enhancing, incurred significantly higher input costs that reduced overall profitability. The findings emphasize that growth regulator recommendation for linseed cultivation should balance biological efficacy with economic efficiency, with Auxin 2.0 ppm representing the most prudent choice for farmers seeking to maximize returns under similar agro-ecological conditions.

Keywords: growth regulators, linseed, foliar application, auxin, rainfed.

INTRODUCTION

Flaxseed has been a crop of significant interest since ancient times, primarily utilized for obtaining fiber and oil. In recent years, the demand for linseed oil has surged due to its growing recognition as a functional food and increased industrial applications. Furthermore, the utilization of its fiber and other derivatives in various industries such as textiles, geotextiles, and paper has further fueled its demand. India ranks fifth globally in terms of average production, cultivating linseed across 0.2 million hectares and producing 0.1 million tonnes (FAO, 2023). Within India, the primary linseed-producing regions include Madhya Pradesh, Jharkhand, Uttar Pradesh, Chhattisgarh, and Odisha, which collectively contribute 80% of the total cultivation area and 79% of national production (GOI, 2023).

Recent agricultural innovations have explored plant growth regulators (PGRs), which present novel avenues for boosting crop productivity under challenging conditions (Tomar *et al.*, 2022). These substances have become crucial components in agricultural production systems, particularly for fruit-bearing trees. While appropriate nutrition remains essential for normal plant development, the application of PGRs represents an effective agricultural strategy to counteract stress-related impacts on crop yields (Calvo *et al.*, 2014). PGRs encompass organic compounds—both natural and synthetic—that influence various physiological mechanisms when administered in minute quantities, thereby modulating plant growth patterns (Gautam *et al.*, 2022). When applied in minimal concentrations, these substances regulate developmental processes through either stimulation or suppression mechanisms (Naeem *et al.*, 2004).

A significant advantage of PGRs lies in their effectiveness at extremely dilute concentrations, resulting in favorable cost-benefit relationships. Typically, PGR applications produce yield increases of 15-20% (Mishra, 2000). These regulators affect hormonal equilibrium within plants (Azizoglu *et al.*, 2021), enhance germination rates (Wu *et al.*, 2017), stimulate cellular enlargement, division, and root development (Azizoglu *et al.*, 2021), improve chlorophyll content and photosynthetic capacity (Shao *et al.*, 2014), facilitate translocation of photosynthates and strengthen source-sink relationships (Khan & Mazid 2018), promote flowering, fruiting, and seed formation (Basuchaudhuri, 2016), increase biomass production (Shao *et al.*, 2014), and ultimately enhance yield components (Basuchaudhuri 2016) and overall crop productivity (Basuchaudhuri, 2016; Khan & Mazid 2018). Plant growth regulators (PGRs) have been shown to have a substantial impact on the growth and yield of the linseed crop (Rastogi *et al.*, 2013).

Auxin is responsible for inducing apical dominance and root formation, controlling flower abortion, promoting flower and seed development during reproductive stages, and influencing senescence (Figueiredo *et al.*, 2016). On the other hand, gibberellic acid aids in promoting growth by enhancing nutrient absorption, improving nitrogen use efficiency, and facilitating cell expansion and elongation through the degradation of growth-inhibiting proteins (Singh *et al.*, 2005). Similarly, salicylic acid contributes significantly to enhancing plant defenses against a range of biotic and abiotic stresses through various morphological, physiological, and biochemical mechanisms, ultimately leading to increased growth and productivity.

While these investigations highlight the crucial role of PGRs in plant development, limited research exists regarding their influence on minor oilseed crops like linseed. This knowledge gap warrants attention considering the positive responses observed in major oilseed crops and the practical applicability of such techniques for linseed cultivation, especially given its current production landscape and increasing global demand. Consequently, this experiment was designed to investigate PGR effects on linseed crops.

MATERIAL AND METHODS

The present experiment was conducted with eight treatments comprising of two doses of Auxin (1.0 & 2.0 ppm), two doses of Gibberalic acid (200 & 400 ppm), Salicylic acid 75 ppm, Tebuconazole 0.1%, Auxin 1.0 ppm + GA 200 ppm were tested against control (water spray) in RBD with three replications at Linseed Unit, Department of Genetics and Plant Breeding from 2018-2021 (for three years). Two applications of each PGR were done, one at vegetative & another at flowering stage. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.8), low in organic carbon and medium in available nitrogen, phosphorus and potassium. The linseed variety 'Him Palam Alsi -2' was sown at a row to row distance of 22 cm. Yield attributes were recorded at different stages of crop growth to get number of particular yield attribute per plant. Net plot yield was converted and expressed in kg/ha by multiplying it with the conversion factor. Economic gain (net returns and BC ratio) of each treatment was calculated based upon the yield and prevalent market price of produce and inputs.

RESULTS AND DISCUSSION

Plant Population (000/ha). The plant population across treatments ranged from 1244 to 1319 thousand plants per hectare, with GA 400 ppm showing the highest population (1319) followed by Auxin 1.0 ppm + GA 200 ppm (1301). However, statistical analysis indicated no significant differences among treatments. This suggests that foliar application of growth regulators did not significantly influence plant establishment or survival. Similar findings were reported by Kumar *et al*. (2022), who observed that foliar application of growth regulators in linseed had no significant effect on plant stand as it is primarily determined by sowing techniques and environmental conditions during germination rather than post-emergence applications of growth regulators.

Plant Height (cm). Plant height showed significant variation among treatments. The GA 400 ppm treatment produced the tallest plants (76.87 cm), followed by GA 200 ppm (75.69 cm), while Tebuconazole 0.1% resulted in the shortest plants (65.39 cm). The increase in plant height with GA applications aligns with the fundamental role of gibberellins in promoting cell elongation. Lakshmamma and Rao (1996) reported similar results, stating that gibberellins primarily stimulate internodal elongation by increasing cell division and cell elongation in the sub-apical meristem of the shoot. Singh *et al*. (2017) also found that GA_3 application at 50-200 ppm significantly increased plant height in linseed compared to control plants due to its role in stimulating cell division and elongation in the internodal regions.

Primary Branches. The treatment combining Auxin 1.0 ppm + GA 200 ppm produced the significantly highest number of primary branches (6.23), while the control had the lowest (4.61). Auxin is known to regulate apical dominance, and when applied at optimal concentrations, it can promote lateral bud development. Sharma *et al.* (2018) reported that balanced application of auxin and GA resulted in reduced apical dominance and increased branching in oil crops. The increased number of primary branches with growth regulator applications can be attributed to the modulation of endogenous hormone levels that influence axillary bud development and outgrowth (Kumar *et al.*, 2022).

Secondary Branches. Secondary branching showed significant differences among treatments. The combination of Auxin 1.0 ppm + GA 200 ppm produced the highest number of secondary branches (7.09), followed by GA 400 ppm (7.04). The control treatment had the lowest number (5.52). According to Singh *et al*. (2017), the synergistic effect of auxin and GA promotes better distribution of photosynthates and enhanced metabolic activities, resulting in increased branching. Rastogi *et al*. (2013) also observed that application of auxin and GA_3 significantly increased branching in linseed by influencing the hormonal balance that regulates branch development.

Capsules/Plant. Application of GA 400 ppm produced the significantly higher number of capsules (35.85), followed by Auxin 1.0 ppm + GA 200 ppm (34.72) and GA 200 ppm (33.84). The control treatment had substantially fewer capsules (27.13). This improvement can be attributed to the increased number of branches and enhanced reproductive efficiency. Kumar *et al.* (2022) explained that growth regulators, particularly GA, enhance source-sink relationships and photosynthate translocation during the reproductive phase, leading to improved capsule formation. Additionally, Chauhan *et al.* (2009) reported that GA application reduced flower abortion and increased capsule set in linseed.

Seeds/Capsule. Significant variation was observed in the number of seeds per capsule where Auxin 1.0 ppm + GA 200 ppm recorded the highest seeds per capsule (8.07), while the control had the lowest (7.26). The increase in seeds per capsule with growth regulator application, particularly the combination treatment, indicates improved fertilization and seed development processes. Rastogi *et al*. (2013) demonstrated that growth regulators enhance pollen viability and stigma receptivity, leading to better fertilization. Moreover, Singh *et al.* (2017) noted that auxins and gibberellins play crucial roles in preventing seed abortion and promoting embryo development, resulting in more seeds per capsule.

1000-Seed Weight (g). The combination of Auxin 1.0 ppm + GA 200 ppm produced the significantly higher 1000 seed weight (7.02 g), followed by GA 400 ppm (6.87 g). The control treatment had the lowest 1000 seed weight (6.09 g). According to Chauhan *et al.* (2009), growth regulators enhance photosynthetic efficiency and assimilate partitioning toward reproductive sinks, leading to better seed filling and development. Sharma *et al.* (2018) also reported that auxin and GA applications increase the duration of the seed filling period, allowing more time for accumulation of photosynthates in the developing seeds.

Seed Yield (kg/ha). Seed yield showed significant differences among treatments and the highest yield was recorded with Auxin 1.0 ppm + GA 200 ppm (1426 kg/ha), closely followed by GA 400 ppm (1416 kg/ha). The control produced significantly lower yield (1163 kg/ha). The yield enhancement with growth regulator application can be attributed to the cumulative positive effects on yield-contributing characters like branching, capsules per plant, seeds per capsule, and seed weight. Kumar *et al.* (2022) reported that growth regulators enhance physiological efficiency, leading to better source-sink relationships and improved assimilate partitioning toward reproductive structures. Rastogi *et al.* (2013) further explained that growth regulators delay leaf senescence, thereby maintaining photosynthetic activity for a longer duration during the reproductive phase. Similarly, previous studies have documented comparable results regarding enhanced seed production following plant growth regulator applications across various crops. Research has shown positive outcomes with IAA treatment in soybean (Sarkar *et al*., 2002), GA_3 application in soybean (Upadhyay and Ranjan 2015), and NAA usage in soybean (Basuchaudhuri, 2016). Additionally, combined GA_3 and IAA treatments have proven effective in sunflower cultivation (Dawood *et al*., 2012).

The enhanced crop performance observed with varying concentrations of IAA and GA_3 treatments likely stems from improved physiological processes within the plant system. These improvements manifest as increased photosynthetic capacity, enhanced dry matter accumulation, and more efficient resource allocation, collectively contributing to superior grain and biomass production. Research by Mishra and Kushwaha (2016) supports the principle that elevated physiological efficiency, particularly enhanced photosynthetic capacity, correlates with improved growth and productivity across numerous agricultural species.

Gross Returns (Rs/ha). Gross returns closely followed the trend of seed yield with significant differences among treatments. The combination of Auxin 1.0 ppm + GA 200 ppm generated the highest gross returns (64263 Rs/ha), followed by GA 400 ppm (63086 Rs/ha). The control had the lowest gross returns (52706 Rs/ha). This pattern directly reflects the seed yield, as gross returns are calculated based on the market value of the produce. Similar economic benefits of growth regulator application in linseed were documented by Singh *et al.* (2017), who reported that improved yield parameters translated into higher economic returns.

Net Monetary Returns (NMR) (Rs/ha). Despite generating lower gross returns than GA treatments, Auxin 2.0 ppm recorded the significantly highest NMR (39573 Rs/ha), followed closely by Salicylic acid 75 ppm (39814 Rs/ha) and Auxin 1.0 ppm (38824 Rs/ha). This pattern reflects the influence of input costs on profitability. Kumar *et al.* (2022) noted that while GA treatments may produce higher yields, their higher cost reduces net profitability. This finding aligns with the study's abstract which identified Auxin 2.0 ppm as the most profitable treatment despite not producing the highest absolute yield.

Net Returns Per Rupee Invested. The benefit-cost ratio (net returns per rupee invested) varied significantly among treatments. Auxin 2.0 ppm gave the highest return per rupee invested (2.07), followed closely by Auxin 1.0 ppm (2.04) and Salicylic acid 75 ppm (1.99). Despite producing higher yields, GA 400 ppm had the lowest benefit-cost ratio (0.97), indicating poor economic efficiency. This pattern emphasizes the importance of considering input costs when recommending growth regulator applications. Sharma *et al.* (2018) similarly concluded that while GA treatments may maximize biological yield, auxin treatments often provide better economic returns due to their lower cost. Kumar *et al.* (2022) also reported that the selection of growth regulators should balance yield enhancement with economic considerations for practical field application. Economic analyses conducted by Sumeriya *et al.* (2000); Mishra and Kushwaha (2016) demonstrated that plant growth regulator applications resulted in superior financial returns. These improved economic outcomes were attributed to the combination of increased total revenue generation and the relatively minimal additional expenses required for implementing these treatments.

Table 1: Effect of foliar application of growth regulator in enhancing productivity and profitability of linseed at Palampur: Pooled data of Ancillary characters, Seed yield and Economics.

Treatment	Plant population (000/ha)	Plant height (cm)	Primary branches/plant	Secondary branches/plant	Capsules/Plant	Seeds/capsule	1000-seed wt. (g)	Seed yield (kg/ha)	Gross returns (Rs/ha)	NMR (Rs/ha)	Net returns per rupee invested
1. Auxin 1.0 ppm	1247	72.45	5.88	6.24	31.77	7.82	6.45	1293	58284	38824	2.04
2. Auxin 2.0 ppm	1244	72.14	5.14	6.15	30.58	7.9	6.48	1308	59203	39573	2.07
3. GA 200 ppm	1287	75.69	5.6	6.72	33.84	7.91	6.64	1344	59590	34303	1.33
4. GA 400 ppm	1319	76.87	5.47	7.04	35.85	7.98	6.87	1416	63086	31026	0.97
5. Salicylic acid 75 ppm	1265	69.32	5.42	6.02	31.5	7.78	6.28	1309	59541	39814	1.99
6. Tebuconazole 0.1%	1244	65.39	5.66	5.94	29.98	7.7	6.41	1318	59674	39006	1.87
7. Auxin 1.0 ppm + GA 200 ppm	1301	70.02	6.23	7.09	34.72	8.07	7.02	1426	64263	38443	1.43
8. Control	1270	71.26	4.61	5.52	27.13	7.26	6.09	1163	52706	33599	1.73
GM	**1272**	**71.64**	**5.5**	**6.34**	**31.92**	**7.8**	**6.53**	**1322**	**59543**	**36824**	**1.68**
SE(m)±	**41.89**	**0.65**	**0.14**	**0.15**	**0.57**	**0.12**	**0.08**	**25.4**	**1568**	**1126**	**0.05**
CD at 5%	**NS**	**1.97**	**0.43**	**0.46**	**1.72**	**0.37**	**0.24**	**76.9**	**4744**	**3413**	**0.15**
CV%	**9.47**	**2.54**	**7.31**	**6.82**	**5.15**	**4.53**	**3.57**	**5.68**	—	—	—

CONCLUSIONS

The study clearly demonstrates that foliar application of growth regulators significantly improves the productivity and profitability of linseed under rainfed conditions. While GA 400 ppm and Auxin 1.0 ppm + GA 200 ppm maximized seed yield, Auxin 2.0 ppm emerged as the most economically viable treatment, offering the highest net returns and benefit-cost ratio. Thus, Auxin 2.0 ppm represents the most practical and profitable option for linseed growers in similar agro-climatic regions.

FUTURE SCOPE

Future research may explore the combined effects of growth regulators with micronutrients or biostimulants to further enhance linseed productivity. Additionally, evaluating these treatments under different agro-climatic zones and moisture regimes can help develop region-specific recommendations for sustainable and profitable linseed cultivation.

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Conflict of Interest. None.

REFERENCES

Azizoglu, U., Yilmaz, N., Simsek, O., Ibal, J. C., Tagele, S. B. and Shin, J. H. (2021). The fate of plant growth-promoting rhizobacteria in soilless agriculture: future perspectives. *3 Biotech*, *11*(8), 382.

Basuchaudhuri, P. (2016). Influences of plant growth regulators on yield of soybean. *Indian Journal of Plant ciences*, *5*(4), 25-38.

Calvo, P., Nelson, L. and Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. *Plant and Soil*, 383, 3-41.

Chauhan, S., Srivastava, A. K. and Patra, M. K. (2009). Effect of plant growth regulators on growth, yield and quality of linseed (*Linum usitatissimum* L.). *Journal of Agriculture and Ecology*, *6*, 61-67.

Dawood, M. G., Mervat, Sh. S. and Hozayen, M. (2012). Physiological role of salicylic acid in improving performance, yield and some biochemical aspects of sunflower plant grown under newly reclaimed sandy soil. *Australian Journal of Basic and Applied Sciences*, *6*(4), 82-89.

FAO (2023). License: CC BY-NC-SA 3.0 IGO. Crops and livestock products. Food and Agriculture Organization of the United Nations.

Figueiredo, D. D., Batista, R. A., Roszak, P. J., Hennig, L. and Köhler, C. (2016). Auxin production in the endosperm drives seed coat development in Arabidopsis. *eLife*, *5*, e20542.

Gautam, P., Tripathi, S. K., Kumar, A., Prakash, S., Sengar, R. S., Awasthi, M., Maurya, U. and Kumar, A. (2022). Effect of different concentrations of PGRs on shooting and survival of stem cuttings in lemon (*Citrus limon* Burm.) cv. Pant lemon-1, under Western U.P. conditions. *Biological Forum – An International Journal*, *14*(3), 1084-1088.

GOI (2023). 5-year estimates oilseeds and commercial crops 2017-18 to 2021-22. Directorate of Economics and Statistics, Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. https://desagri.gov.in/statistics-type/five-year-estimates/.

Khan, K. and Mazid, M. (2018). Chickpea responses to application of plant growth regulators, organics and nutrients. *Advances in Plants and Agricultural Research*, *8*(3), 259-273.

Kumar, A., Sharma, P., Kumar, S. and Tripathi, M. K. (2022). Effect of Foliar Application of Plant Growth Regulators on Oil Content, Yield and Economics of Linseed (*Linum usitatissimum* L.). *International Journal of Current Microbiology and Applied Sciences, 11*(8), 122-131.

Lakshmamma, P. and Rao, I. V. S. (1996). Response of blackgram (*Vigna mungo* L.) to shade and naphthalene acetic acid. *Indian Journal of Plant Physiology, 1*, 63-64.

Mishra, A. and Kushwaha, H. S. (2016). Effect of plant growth regulators on growth, yield and economics of Indian mustard [*Brassica juncea* (L.) Czern & Coss] under rainfed condition. *Annals of Agricultural Research New Series*, *36*(4), 345-349.

Mishra, S. D. (2000). Hormone potentiated crop growth and productivity. Molecular Biology and Agriculture Division, BARC Newsletter, pp 1-9. https://silo.tips/download/hormone-potentiated-crop-growth-and-productivity.

Naeem, M., Bhatti, I., Ahmad, R. H. and Ashraf, M. Y. (2004) Effect of some growth hormones (GA3, IAA and Kinetin) on the morphology and early or delayed initiation of bud of lentil (*Lens culinaris* Medik.) *Pakistan Journal of Botany*, *36*(4), 801-809.

Rastogi, A., Siddiqui, A., Mishra, B. K., Srivastava, M., Pandey, R., Misra, P., Singh, M. and Shukla, S. (2013). Effect of auxin and gibberellic acid on growth and yield components of linseed (*Linum usitatissimum* L.). *Crop Breeding and Applied Biotechnology, 13*, 136-143.

Sarkar, P. K, Haque, M. S. and Karim, M. A. (2002). Effects of GA3 and IAA and their frequency of application on morphology, yield contributing characters and yield of soybean. *Journal of Agronomy*, *1*(4), 119-122.

Shao, Q., Wang, H., Guo, H., Zhou, A., Huang, Y., Sun, Y. and Li, M. (2014). Effects of shade treatments on photosynthetic characteristics, chloroplast ultrastructure, and physiology of *Anoectochilus roxburghii*. *PLOS ONE, 9*(2), e85996.

Sharma, P., Singh, M. and Verma, B. L. (2018). Effect of plant growth regulators on growth and yield of linseed (*Linum usitatissimum* L.) varieties. Journal of *Pharmacognosy and Phytochemistry, 7*(2), 3557-3560.

Singh, U., Ram, P. C., Singh, B. B. and Chaturvedi, G. S. (2005). Effect of GA3 on distribution of N, P, K^+, Na^+ and Cl^- in embryoaxis and cotyledons of urdbean (*Vigna mungo* L.) under salinity. *Annals of Agri-Bio Research*, *10*, 187-194.

Singh, U., Ram, M. and Kaushik, S. K. (2017). Effect of growth regulators on growth, yield attributes and yield of linseed (*Linum usitatissimum* L.). *International Journal of Current Microbiology and Applied Sciences, 6*(9), 3778-3783.

Sumeriya, H. K., Meena, N. L. and Mali, A. L. (2000). Effect of phosphorus, triacontanol granule and growth promoters on the productivity of mustard [*Brassica juncea* (L.) Czern and Coss]. *International Journal of Tropical Agriculture, 18*(3), 283-286.

Tomar, M., Chaplot, P. C., Choudhary, J., Meena, R. H., Patidar, R. and Samota, A. K. (2022). Effect of Salicylc Acid and Biochar on nutrient content and uptake of chickpea (*Cicer arietinum* L.) under rainfed condition. *Biological Forum – An International Journal*, *14(*3), 613-616.

Upadhyay, R. G. and Ranjan, R. (2015). Effect of growth hormones on morphological parameters, yield and quality of soybean (*Glycine max* L.) during changing scenario of climate under midhill conditions of Uttarakhand. *International Journal of Tropical Agriculture*, *33*(2), 1899-1904.

Wu, C., Hua, Y., Chen, Y., Kong, X. and Zhang, C. (2017). Microstructure and model solute transport properties of transglutaminase-induced soya protein gels: Effect of enzyme dosage, protein composition and solute size. *International Journal of Food Science & Technology*, *52*(7), 1527–1533.

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