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Pre-sowing Seed Treatment and Foliar Application of Gibberellic Acid Improve Seed and Fibre Yield by Inducing Net Photosynthetic Rate and Carbonic Anhydrase Activity of Linseed Genotypes

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ABSTRACT

Linseed (*Linum usitatissimum* L.) is an important oilseed and fibre crop. However, the production of linseed crop is unable to keep pace with the increasing demand of linseed products. Under these circumstances, the best strategy for dual-purpose linseed would be to increase the height of the plant and to improve seed weight, a task which may prove simpler than achieving the synchronization of seed and fibre maturity. To achieve this, the present work was carried out with an aim to find out whether the application of gibberellic acid (GA_3) could improve the performance of linseed crop. The experiment consisted of three GA_3 treatments, viz. 0, 10^{-8} and 10^{-6} M, with each treatment consisting of a pre-sowing seed treatment followed by foliar spray on plants raised from the treated seeds of five newly released genotypes of linseed namely 'Laxmi 27', 'Parvati', 'Rashmi', 'Shekhar' and 'Shubhra'. Crop performance was assessed in terms of growth characteristics, physiological and biochemical parameters at 60 and 75 DAS and yield and quality characteristics at harvest. Pre-sowing seed and foliar treatment with GA_3 at 10^{-6} M proved best for most of the parameters studied. This treatment enhanced, for example, dry weight per plant by 40.5% and P_N by 12.2% at 75 DAS and seed yield per plant by 24.7%, oil yield per plant by 27.1% and fibre yield per plant by 55.9% at harvest as compared with 0 M GA_3 (i.e. the control). However, GA_3 treatments increased lodging, with 10^{-6} M GA_3 by 43.7% than the control. The data revealed that genotypes differed critically with regard to parameters studied. Among the genotypes tested 'Shubhra' performed best while 'Laxmi 27' worst.

Keywords: lodging, oilseed, growth performance, physio-biochemical attributes

INTRODUCTION

Oilseeds are not only a source of oil but also of proteins, sugars, minerals and even vitamins. Besides edible oils, non-edible oils also play a vital role in everyday life. As far as linseed (*Linum usitatissimum* L.) is concerned, it is used in various ways. Its seeds are used for the extraction of oil. About 80% of linseed oil goes for industrial use and the remaining 20% for edible purpose (Verma *et al*. 2005). Linseed oil is, therefore, primarily industrial oil used in the manufacture of paints, varnishes, linoleum, oil cloth, printing and lithographic ink and soft soap (Anonymous 2003). The fibre extracted from its stem is used in the manufacture of canvas, coating, durries, shirting and strong twines. Good quality fibre is used for the manufacture of linen. The woody matter, left after the removal of fibre, is used for the manufacture of paper (Samba Murty and Subrahmanyam 1989). Commercial cultivation of linseed for both seed and fibre is clearly not cost effective and attempts have been made to produce a dual-purpose linseed crop with good yield of both seed and fibre. However, little progress has been made in breeding dual-purpose varieties synchronized for both seed yield and fibre quality. Under these circumstances, the best strategy for dual-purpose linseed would be to increase the height of the plant and to improve seed weight.

To achieve this, plant growth regulators could be used as they are known to affect many facets of plant life, including growth, flowering, fruiting and ion transport (Khan and Samiullah 2003; Siddiqui *et al.* 2008). Gibberellins play a central role in the regulation of growth and development. It is well established that gibberellins promote growth through cell expansion by stimulating the destruction of growth-repressing proteins (Achard *et al.* 2009). They are also known to control a wide range of physiological functions in plants, they increase the N-use efficiency, nitrate reductase (NR) and carbonic anhydrase (CA) activities (Shah *et al.* 2007; Siddiqui *et al.* 2008). Therefore, the present author proposed to apply gibberellic acid (GA_3) to linseed to increase stem height for better harvesting of solar energy for maximum utilization of its potential for seed, oil and fibre production.

MATERIALS AND METHODS

A factorial randomized pot experiment was conducted to select the best GA_3 treatment for five newly released genotypes of linseed (*Linum usitatissimum* L.), namely 'Laxmi 27', 'Parvati', 'Rashmi', 'Shekhar' and 'Shubhra'. Authentic seeds of linseed genotypes were obtained from the Division of Oilseed Crops of the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh). After selecting healthy seeds of uniform size, their viability was tested. There were three GA_3 treatments, each consisting of pre-sowing seed treatment (S) followed by foliar spray (F) on plants raised from treated seeds. Before sowing, seeds of each of the five genotypes were soaked for 8 h in three concentrations of GA_3, viz. (i) 0 M (double distilled water, i.e. DDW), (ii) 10^{-8} and (iii) 10^{-6} M GA_3. For each treatment, 20 seeds were sown 2 cm deep in pots containing a uniform dose of fertilizer. Finally, 15 plants in each pot were maintained. Forty days after sowing (DAS), plants raised from seeds treated with 0, 10^{-8} and 10^{-6} M GA_3 were sprayed with 0, 10^{-8} and 10^{-6} M GA_3, respectively. Thus,

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GA_3 treatments were designated as (i) S 0 M GA_3 + F 0 M GA_3 (control), (ii) S 10^{-8} M GA_3 + F 10^{-8} M GA_3 and (iii) S 10^{-6} M GA_3 + F 10^{-6} M GA_3. GA_3 was purchased from Sigma-Aldrich (India). By dissolving 0.346 g GA_3 in 10 ml ethyl alcohol a 10^{-2} M stock solution of GA_3 was prepared by diluting with DDW. From this stock solution 10^{-8} and 10^{-6} M GA_3 was made using DDW. A uniform recommended dose of 40.2 mg N, 13.4 mg P and 13.4 mg K/kg soil, equivalent to 90 kg N, 30 kg P and 30 kg K/ha was applied to each pot. Half of the dose of N together with full dose of P and K was applied at the time of sowing and the remaining half dose of N was added as top-dressing at 30 DAS. The sources of N, P and K were urea, diammonium phosphate and muriate of potash, respectively. While calculating urea, N of diammonium phosphate was kept in mind. Each treatment was replicated four times.

The performance of the crop was assessed in terms of height per plant, leaf area (LA) per plant, leaf area index (LAI), fresh weight (FW) per plant and dry weight (DW) per plant, net photosynthetic rate (P_N), carbonic anhydrase (CA) activity, leaf chlorophyll content and leaf-nitrogen (N), phosphorus (P) and potassium (K) content at 60 and 75 DAS and capsules per plant, seeds per capsule, 1000-seed weight, seed yield, biological yield, harvest index, oil content, oil yield, iodine value, fibre yield and lodging at harvest.

LA was determined according to a gravimetric method and leaf area index, by using the formula proposed by Watson (1958). Net photosynthetic rate was determined with the help of a portable photosynthesis system (LiCOR, 6200 Lincoln, USA). CA activity was measured by adopting the method of Dwivedi and Randhawa (1974). The method of Arnon (1949) was used for the estimation of leaf chlorophyll content. Leaf -N and -P content was estimated according to Lindner (1944) and Fiske and Subba Row (1925) respectively. Leaf K content was estimated with the help of a flame photometer. Oil of the seeds was extracted by taking 25 g meal of ground seeds and transferring into a Soxhlet apparatus to which 100 mL pure petroleum ether was added. The apparatus was kept on a water bath at 60°C for ~6 h. At the end of each extraction process, the petroleum extract of seeds was left in air to evaporate the petroleum ether. The oil left after the evaporation of petroleum ether was weighed and expressed as percentage of the mass of the seed. Oil yield was computed on the basis of seed yield and oil percentage. Data were analyzed statistically with SPSS-11 statistical software (SPSS Inc., Chicago, IL, USA). In applying the F test, the error due to replicates was also determined. When 'F' value was found to be significant at 5% level of probability, critical difference (CD) was calculated.

RESULTS AND DISCUSSION

Effect of GA_3 on growth characteristics

Pre-sowing seed and foliar treatment of GA_3 affected plant height, LA, LAI, FW and DW of plants significantly at both sampling stages (60 and 75 DAS), with 10^{-6} M GA_3 being optimum (**Table 1**). The ameliorative effect of seed and foliar treatment of GA_3, particularly at 10^{-6} M GA_3 on the growth parameters can be traced to its various roles in cell division (Huttly and Phillips 1995) and cell enlargement and differentiation (Buchanan *et al*. 2000; Marschner 2002) at apical, lateral and intercalary regions which culminated into the enhanced constituents of the infrastructure of the plants that might have lead the plants to improved height, LA and LAI. **Table 1** revealed that 10^{-6} M GA_3-treated plants enhanced plant height by 14.9 and 16.3% at 60 and 75 DAS, respectively, it may be the role of GA_3 in cell enlargement and differentiation. The improved plant height lead the plants to bear more number and better orientation of leaves for harvesting the solar energy as well as for facilitating leaf expansion leading to larger LA and LAI (Siddiqui *et al.* 2008). Moreover, increased LAI due to GA_3 treatment might have enabled the plants to harvest more solar energy. These responses are expectedly reflected in the enhanced FW and DW of treated plants. Thus, we may postulate that the effect of 10^{-6} M GA_3 was found more effective in the improvement of plant growth characteristics.

Effect of GA_3 on physiological and biochemical parameters

Table 2 shows that the application of GA_3 improved significantly most of physiological and biochemical parameters except leaf -N, -P and -K content (**Table 3**) which showed a non-significant effect at 60 and 75 DAS. The plants treated with 10^{-6} M GA_3 exhibited increased values for P_N and CA activity (**Table 2**). The enhanced activity of CA may have led to increased P_N conceivably through a rapid reversible hydration of carbon dioxide maintaining its constant supply to Rubisco, a key enzyme responsible for the fixation of CO_2. Application of 10^{-6} M GA_3 to linseed plants ameliorated the primary growth potential, activity of carbonic anhydrase, and N-use efficiency, thereby the available nutrients in the growth medium might have been absorbed more rapidly due to maximum utilization in developing

Table 1 Effect of pre-sowing seed treatment and foliar application of gibberellic acid on growth parameters of linseed cultivars at two stages of growth.

Treatments (T) (M GA_3)		Cultivars (Cv)	Height per plant (cm)		Leaf area per plant (cm^2)		Leaf area index		Fresh weight per plant (g)		Dry weight per plant (g)	
Seed	Spray		60	75	60	75	60	75	60	75	60	75
0	0	Laxmi 27	46.5	58.8	159.9	260.8	4.88	7.97	10.2	15.9	2.20	3.00
		Parvati	55.0	65.5	176.7	304.6	5.40	9.31	11.9	17.2	2.98	4.16
		Rashmi	49.2	61.4	148.5	253.9	4.54	7.76	10.6	14.8	2.61	3.46
		Shekhar	51.7	64.7	168.1	276.4	5.14	8.44	12.3	19.9	2.70	4.98
		Shubhra	59.3	68.4	179.9	318.6	5.50	9.73	12.1	20.3	3.32	5.25
		Mean	52.3	63.7	166.6	282.9	5.09	8.64	11.4	17.6	2.76	4.17
10^{-8}	10^{-8}	Laxmi 27	51.8	64.7	169.9	271.2	5.19	8.28	12.4	18.2	2.68	3.67
		Parvati	61.2	72.5	189.2	323.0	5.78	9.87	15.0	20.9	4.02	5.29
		Rashmi	54.3	67.5	156.5	264.1	4.78	8.06	12.9	17.6	3.22	4.42
		Shekhar	56.9	71.2	179.5	291.0	5.48	8.89	15.7	24.8	3.36	6.32
		Shubhra	63.3	77.1	198.6	343.9	6.07	10.50	16.5	26.6	4.50	6.98
		Mean	57.5	70.6	178.7	298.6	5.46	9.12	14.5	21.6	3.56	5.34
10^{-6}	10^{-6}	Laxmi 27	52.9	67.0	178.6	280.8	5.46	8.58	14.1	20.0	3.11	4.69
		Parvati	64.7	77.0	202.7	341.8	6.19	10.44	17.1	23.8	4.62	6.61
		Rashmi	56.8	70.8	169.2	276.5	5.17	8.44	15.1	19.8	3.79	5.50
		Shekhar	59.9	74.9	189.0	303.6	5.77	9.27	19.6	29.9	4.21	8.44
		Shubhra	66.1	81.1	212.7	368.3	6.50	11.25	20.6	32.1	5.13	9.42
		Mean	60.1	74.2	190.4	314.2	5.81	9.60	17.3	25.1	4.17	6.93
CD at 5%		T	1.99	3.99	3.75	5.35	0.10	0.21	1.09	1.11	0.22	0.34
		Cv	2.57	5.16	4.84	6.91	0.13	0.27	1.40	1.44	0.28	0.43
		T x Cv	4.46	8.93	8.39	11.97	0.23	0.47	2.43	2.49	0.49	0.75

Each value is the mean of four replicates

Table 2 Effect of pre-sowing seed treatment and foliar application of gibberellic acid on physiological and biochemical parameters of linseed cultivars at two stages of growth.

Treatments (T) (M GA_3)		Cultivars (Cv)	P_N [µmol (CO_2) m^2/s]		CA [µmol (CO_2)/kg (f.m.)/s]		Leaf Chlorophyll content (mg/g)	
Seed	**Spray**		**60**	**75**	**60**	**75**	**60**	**75**
0	0	Laxmi 27	12.40	13.81	307.69	356.83	1.259	1.348
		Parvati	13.76	15.18	328.09	396.40	1.329	1.450
		Rashmi	12.49	14.76	311.47	381.27	1.276	1.362
		Shekhar	13.47	15.02	320.17	397.02	1.341	1.481
		Shubhra	13.81	15.60	331.52	407.31	1.351	1.564
		Mean	13.19	14.87	319.79	387.77	1.311	1.441
10^{-8}	10^{-8}	Laxmi 27	12.91	14.40	310.85	392.80	1.324	1.411
		Parvati	14.62	16.03	354.89	446.23	1.401	1.553
		Rashmi	13.07	15.39	335.33	422.90	1.316	1.402
		Shekhar	14.35	15.77	347.00	445.17	1.450	1.592
		Shubhra	14.74	16.42	359.67	461.36	1.482	1.676
		Mean	13.94	15.60	341.55	433.69	1.395	1.527
10^{-6}	10^{-6}	Laxmi 27	13.78	15.38	333.81	395.94	1.437	1.502
		Parvati	15.59	17.10	356.01	460.10	1.525	1.643
		Rashmi	14.11	16.50	337.04	426.22	1.400	1.471
		Shekhar	15.21	16.88	349.43	453.71	1.572	1.716
		Shubhra	15.80	17.56	367.09	474.07	1.590	1.794
		Mean	14.90	16.68	348.68	442.01	1.505	1.625
CD at 5%		T	0.43	0.51	3.19	5.37	0.034	0.051
		Cv	0.55	0.65	4.13	6.93	0.044	0.065
		T x Cv	0.96	1.13	7.15	12.01	0.076	0.113

Each value is the mean of four replicates

Table 3 Effect of pre-sowing seed treatment and foliar application of gibberellic acid on leaf N, P and K content of linseed cultivars at two stages of growth.

Treatments (T) (M GA_3)		Cultivars (Cv)	Leaf N content (%)		Leaf P content (%)		Leaf K content (%)	
Seed	**Spray**		**60**	**75**	**60**	**75**	**60**	**75**
0	0	Laxmi 27	1.61	2.21	0.218	0.235	2.34	2.52
		Parvati	1.81	2.48	0.221	0.241	2.49	2.63
		Rashmi	1.63	2.36	0.216	0.238	2.38	2.55
		Shekhar	1.70	2.51	0.226	0.251	2.41	2.76
		Shubhra	1.82	2.59	0.219	0.247	2.52	2.59
		Mean	1.71	2.43	0.220	0.242	2.43	2.61
10^{-8}	10^{-8}	Laxmi 27	1.71	2.25	0.233	0.239	2.46	2.59
		Parvati	1.98	2.78	0.237	0.255	2.52	2.68
		Rashmi	1.76	2.62	0.229	0.250	2.43	2.61
		Shekhar	1.84	2.63	0.247	0.269	2.48	2.74
		Shubhra	2.05	2.77	0.234	0.262	2.61	2.64
		Mean	1.87	2.61	0.236	0.255	2.50	2.65
10^{-6}	10^{-6}	Laxmi 27	1.78	2.57	0.240	0.243	2.49	2.67
		Parvati	2.10	2.67	0.246	0.265	2.62	2.72
		Rashmi	1.81	2.11	0.235	0.255	2.51	2.68
		Shekhar	1.93	2.90	0.257	0.276	2.53	2.79
		Shubhra	2.14	3.15	0.247	0.271	2.69	2.70
		Mean	1.95	2.68	0.245	0.262	2.57	2.71
CD at 5%		T	NS	NS	NS	NS	NS	NS
		Cv	NS	0.37	NS	NS	NS	0.06
		T x Cv	NS	0.64	NS	NS	NS	NS

Each value is the mean of four replicates; NS= non-significant

fruits. It is well documented that a higher portion of leaf-N is found in the chloroplast, most of it is invested in rubisco alone. In the present work, increased CA activity in leaves, as a result of GA_3 application, might have served in enhancing chlorophyll concentration (**Table 2**) and their cumulative effect ultimately contributed to increased P_N (**Table 2**). Thus, applied GA_3 might have provided an environment to perform photosynthesis normally which is further confirmed by enhanced dry matter accumulation (**Table 1**). The improvement in chlorophyll content in GA_3-treated plants (**Table 2**) can be attributed to its roles in various metabolic processes related to chlorophyll synthesis. Khan *et al.* (1998), Hayat *et al*. (2001), Khan and Samiullah (2003) and Afroz *et al*. (2005) who reported enhanced P_N and CA activity in GA_3 treated mustard plants. **Table 3** reveals that differences of treatment effect and cultivars, alone as well as in combination were non-significant for leaf -N, -P and -K content at 60 DAS. However, the non-significant effect of treatments on leaf -N, -P and -K content, cultivar differences for leaf-P content and interaction effect on leaf-K content at 75 DAS were observed (**Table 3**). Data recorded in **Table 3** are statistically non-significant but increasing levels of GA_3 increased nutrients content in leaves up to 10^{-6} M GA_3. N, P and K content in the leaves revealed that available nutrients in the soil were utilized for the growth of plants. It is well documented that the application of GA_3 triggers the inherent genetic potential of the crop for maximum performance (Taiz and Zeiger 1998) which possibly led to maximum utilization of absorbed nutrients because of enhanced vegetative growth and development of more capsules (Khan *et al.* 1998; Siddiqui *et al.* 2008).

Effect of GA_3 on yield attributes

It is evident from **Tables 4** and **5** that the effect of pre-sowing seed and foliar treatment of GA_3 was significant on all yield characteristics, except seeds per capsule, 1000-seed weight, harvest index, oil content and iodine value. Applica-

Table 4 Effect of pre-sowing seed treatment and foliar application of gibberellic acid on yield attributes of linseed cultivars at harvest.

Treatments (T) (M GA_3)		Cultivars (Cv)	Capsules per plant	Seeds per capsule	1000-seed weight (g)	Seed yield per plant (g)	Biological yield per plant (g)
Seed	Spray						
0	0	Laxmi 27	51.33	8.00	7.56	2.21	8.15
		Parvati	55.67	9.11	7.91	2.38	9.39
		Rashmi	48.00	8.28	7.69	2.31	8.07
		Shekhar	58.33	8.57	7.80	2.32	8.85
		Shubhra	62.67	8.93	8.18	2.49	9.90
		Mean	55.20	8.58	7.83	2.31	8.87
10^{-8}	10^{-8}	Laxmi 27	55.67	7.98	7.62	2.51	9.26
		Parvati	62.00	8.76	7.85	2.77	10.94
		Rashmi	52.37	8.39	7.66	2.40	9.01
		Shekhar	66.67	8.46	7.73	2.81	10.57
		Shubhra	70.33	9.15	8.22	2.89	11.32
		Mean	61.41	8.55	7.82	2.68	10.22
10^{-6}	10^{-6}	Laxmi 27	64.67	8.15	7.86	2.68	9.68
		Parvati	70.00	9.28	8.30	2.99	11.36
		Rashmi	61.00	8.37	8.02	2.58	9.28
		Shekhar	75.67	8.98	8.12	2.94	10.84
		Shubhra	86.00	9.30	8.54	3.20	12.27
		Mean	71.47	8.82	8.17	2.86	10.69
CD at 5%		T	2.75	NS	NS	0.08	0.43
		Cv	3.55	NS	NS	0.11	0.55
		T x Cv	6.15	NS	NS	0.19	0.96

Each value is the mean of four replicates; NS= non-significant

Table 5 Effect of pre-sowing seed treatment and foliar application of gibberellic acid on yield attributes of linseed cultivars at harvest.

Treatments (T) (M GA_3)		Cultivars (Cv)	Harvest index (%)	Oil content (%)	Oil yield per plant (g)	Iodine value	Fibre yield per plant (g)	Lodging (%)
Seed	Spray							
0	0	Laxmi 27	27.12	37.86	0.837	201.14	0.791	18.7
		Parvati	25.35	38.47	0.916	188.27	0.975	20.0
		Rashmi	26.41	37.10	0.790	198.20	0.820	21.7
		Shekhar	26.21	38.35	0.894	191.37	0.868	19.3
		Shubhra	25.14	38.31	0.954	182.59	0.969	20.0
		Mean	26.05	38.06	0.878	192.31	0.885	19.9
10^{-8}	10^{-8}	Laxmi 27	27.11	37.79	0.949	198.00	1.014	23.3
		Parvati	25.32	38.69	1.072	186.40	1.256	20.7
		Rashmi	26.64	37.27	0.894	195.57	1.057	22.3
		Shekhar	26.58	38.79	1.090	190.33	1.132	23.0
		Shubhra	25.54	38.52	1.113	179.32	1.369	23.7
		Mean	26.24	38.21	1.024	189.92	1.166	22.6
10^{-6}	10^{-6}	Laxmi 27	27.69	38.42	1.030	198.76	1.123	28.7
		Parvati	26.32	39.06	1.168	183.28	1.567	27.3
		Rashmi	27.80	37.68	0.972	191.61	1.262	27.7
		Shekhar	27.12	39.33	1.156	186.28	1.321	28.0
		Shubhra	26.07	39.15	1.253	179.11	1.628	31.3
		Mean	27.00	38.73	1.116	187.81	1.380	28.6
CD at 5%		T	NS	NS	0.024	NS	0.072	2.15
		Cv	NS	NS	0.031	NS	0.094	NS
		T x Cv	NS	NS	0.054	NS	0.162	4.81

Each value is the mean of four replicates; NS= non-significant

tion of 10^{-6} M GA_3 gave 29.5% more capsules than the water treatment. It revealed that increased seed yield was mainly due to increased capsules per plant but not due to seeds per capsule or 1000-seed weight (**Tables 4, 5**). Increasing levels of GA_3 also increased fibre yield and lodging linearly. Application of 10^{-6} M GA_3 increased fibre yield and lodging by 55.9 and 43.7%, respectively over the water treatment. The increase in fibre yield may be due to the influence of GA_3 on plant height and thus plants with increased height ultimately lodged maximally as compared to water treated plants. The increase in capsule number due to GA_3 treatment (**Table 4**) may be traced to its various roles, particularly in differentiation (Huttly and Phillips 1995; Afroz *et al*. 2005) leading to enhanced number of flowers which develop into fruits; cell division and cell enlargement (Liu and Loy 1976; Moore 1989; Huttly and Phillips 1995; Arteca 1996; Marschner 2002) resulting in desired development of under-developed capsules especially at the terminal end of branches; promotion of P_N (Afroz *et al*. 2005) providing sufficient C skeleton; and membrane permeability (Wood and Paleg 1972; Crozier and Turnbull 1984) facilitating partitioning. The effect of application of GA_3 on vegetative growth resulted in higher demand for absorption of nutrients and water which might have accelerated the yield of the crop in terms of enhanced number of capsules and subsequently seed yield and oil yield. Moreover, sufficient availability of nutrients re-directed mobilization of metabolites at the critical growing phase induced by the hormone treatment, (Davies 1995; Naidu and Swami 1995), associated with the inhibition of abortion of capsules. These results corroborate the findings of Khan *et al.* (1998).

Among the genotypes tested, 'Shubhra' gave the maximum value for most of the growth physiological and biochemical parameters, including P_N, CA activity and chlorophyll content at one or other stage of growth. On the other hand, 'Laxmi 27' (also 'Rashmi' for several parameters) showed the minimum value for most of these parameters (**Tables 1, 2**). For most of the yield parameters 'Shubhra' gave the maximum value. On the other hand, 'Rashmi' (also 'Laxmi 27' for several parameters) registered the minimum value for these parameters. However, genotypes did not vary for lodging. These variations in genotypes in the vari-

ous parameters can be attributed to the variation in the genetic makeup of the genotypes.

CONCLUSION

On the basis of the above mentioned results it may be concluded that pre-sowing seed treatment and foliar application of 10^{-6} M GA_3 proved best for most of the parameters particularly seed and fibre yield. Among the five cultivars, 'Shubhra', followed by 'Parvati' and 'Shekhar' in respect of seed and oil yield, gave the maximum value for most parameters. However, 'Laxmi 27' and 'Rashmi' registered the minimum value. Pre-sowing seed plus foliar spray treatment with 10^{-6} M GA_3 gave the maximum value for most parameters particularly with 'Shubhra'. However, 0 M GA_3 x 'Laxmi 27' exhibited the lowest value.

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