Received: 11 Jun 2021 | Revised: 16 Dec 2021 | Accepted: 05 Jan 2022

Electronic Journal of Plant Breeding

Research Article

Yield stability under different agronomic situations in linseed (*Linum usitatissimum* L.)

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Abstract
The present investigation was carried out at Bihar Agricultural College, Sabour, Bhagalpur (Bihar) during the *rabi,* 2017-18 with eighteen genotypes including three checks, in order to identify the high yielding stable linseed genotypes in three agronomic situations *viz., Utera* (sowing of the seed before harvesting of standing paddy crop in order to utilize moisture efficiently under rainfed agro-ecosystem), Rainfed, and Irrigated conditions. The mean squares due to genotypes and environments (linear) were highly significant for all the characters studied. The mean squares due to genotype x environment interactions (linear) were significant for days to days to 50 per cent flowering, oil content and seed yield per plant. The mean squares due to pooled deviations were significant for all the characters *viz.,* flowering period, the number of primary branches per plant, the number of capsules per plant, the number of seeds per capsule, bud fly infestation, 1000-seeds weight, oil content and seed yield per plant. The highest yielding genotype, BRLS 111-3 and the lowest yielding genotype, BRLS 105-1 were found unstable. The genotype, BRLS 119 had reasonably high seed yield per plant (rank 2nd) and non-significant regression from deviation with regression coefficient at on par with one and identified as stable genotype having high seed yield. This genotype had also non- significant deviation from regression and regression coefficient at on par with one for the other characters *viz.,* days to 50 per cent flowering, days to 50 per cent maturity, plant height, the number of primary branches per plant, the number of capsules per plant, bud blight infestation and 1000-seed weight. Hence, BRLS 119 was identified as a promising stable genotype which may be commercially grown after critical evaluation over locations.

Keywords: Agronomic situations, Linseed and Stability

INTRODUCTION

Linseed (*Linum usitatissimum* L.) commonly known as flax, is a self-pollinated crop that belongs to the genus *Linum* of the family Linaceae and order *Geranial* having 14 genera and over 200 species. Linseed/flax is one of the oldest crop plants cultivated in around 47 countries for the purpose of seed oil and fibre (Dash *et al.,* 2017). In south-west Asia and Canada, it is primarily cultivated for oil, whereas, in Russia, Egypt and northwestern European countries, it is mainly cultivated for the production of high quality fibre for making linen fabrics and several other products in an area of 2.21 lakh ha with average fibre productivity of 1448 kg/ha. Linseed is one of the important *rabi* oilseed crops of India cultivated in about 2.94 lakh hectares with an annual production of 1.54 lakh tonnes and productivity of 525 kg/ha (Annual Report, AICRP on linseed, 2017-18). In Bihar, linseed is cultivated on about 0.17 lakh hectares with a production of 0.14 lakh tonnes and productivity of 857 kg/ha (Annual Report, AICRP on linseed, 2017-18).

Every part of the linseed plant is utilized commercially either directly or after processing. Linseed contains about 33 to 45 per cent oil (Gill, 1987) used as a drying oil and 20-30 per cent protein characterized by a high coefficient of digestibility (89,6%) and biological value (77,4%) (Martinchik *et al.,* 2012). About 20% of the total linseed oil produced in India is used by farmers and the rest about 80% goes to industries for the manufacture of paints, varnish, oilcloth, linoleum and printing ink etc.

Linseed oil is a rich source of unsaturated fatty acids i. e. oleic acid (16-24 %), linoleic acid (18-24 %), and linolenic acid (36-50 %) (Flachowsky *et al.,* 1997) and has a relatively low glucosinolate content (Schuster and Friedt, 1998). It is also a good source of phosphorous (370 mg/100g), magnesium, calcium (170 mg/100g), and potassium. Linseed varieties are rich in omega-3 (alpha linolenic acid, 55-57%) fatty acids which have been functionally associated with numerous positive health claims. ALA (alpha linolenic acid) is an essential fatty acid that acts as a precursor for biologically active longer chain polyunsaturated fatty acids of omega-3 class, mainly the Eicosapentaeonic acid and Docosahexaeonic acid (Pali *et al.,* 2014). Improvement in the genetic architecture of crop depends upon the nature and extent of genetic variability which is a prerequisite for selection. Genotype x Environment Interaction is a prevalent issue among farmers, breeders, geneticists, and production agronomists. Genotype x environment interaction is a major concern in plant breeding for two main reasons; *first,* it reduces progress from selection, and *second,* it makes cultivar recommendation difficult because it is statistically impossible to interpret the main effects. The average response of varieties, thus depends largely upon the absence or presence of genotype x environment interaction, coupled with high yield indicate that the genotype is suitable for general adaptation in the range of environments considered. But this ideal situation is rarely found because the phenotypic stability of a genotype is universally proportional to the mean yield. The varieties with high stability are generally low yielders and vice versa. G x E interaction causes difficulty in demonstrating the significant superiority of any variety when varieties are compared over a series of environments. Hence, methods are in need to be investigated for reducing G x E interaction. One such method would be to select stable genotype that interact less with the environment in which they are grown. Hence, preliminary evaluation is to be done to identify the stable genotypes. However, selection for stability is not possible until a biometrical model with stable parameters is available to provide the criteria necessary to rank varieties for stability. Keeping the above points in consideration, the present investigation is to study genotype x environment interaction and stability parameters for yield and its related traits in linseed.

MATERIALS AND METHODS

The present investigation was carried out with eighteen linseed genotypes including four checks, namely, T-397 (National check), Shekhar (Zonal check), Sabour Tisi-1 (Local check) and Shubhra (Local check) to identify the stable genotype over different agronomic situations such as *utera*, rainfed and irrigated. The experiment was conducted at Experimental Farm, Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour in a randomized block design with three replications during *Rabi,* 2017-18. The date of sowing under *utera*, rainfed and irrigated conditions was 15th, 22nd and 25th November 2017, respectively. The net plot size was 6.00 m^2. The number of rows per plot was five in rainfed and irrigated conditions with spacing between row to row 30 cm and plant to plant 05 cm. The recommended cultural practices were followed. The observations were recorded on days to 50% flowering, days to maturity, plant height, the number of primary branches per plant, the number of secondary branches per plant, the number of capsules per plant, the number of seeds per capsule, plant weight, 1000 seed weight, harvest index and seed yield per plant. The observations on bud fly infestation, bud blight infestation, leaf blight infestation was taken under field conditions as follows

Bud blight infestation: Total number of capsules and bud blight infested buds were counted on ten randomly selected plants. Bud blight infestation was computed by the following formula in percentage.

$$\text{Bud blight infestation (\%)} = \frac{\text{Number of blight infested bud}}{\text{Total number of capsules including blight infested bud}} \text{ X } 100$$

Bud fly infestation: Total number of capsules and bud fly infested buds were counted on ten randomly selected plants. Bud fly infestation was computed by the following formula in percentage.

$$\text{Bud fly infestation (\%)} = \frac{\text{Number of infested bud}}{\text{Total capsules including infested bud}} \text{ X } 100$$

Leaf blight infestation: The disease severity was estimated from ten randomly selected plants in each genotype. On average sixty leaves were selected randomly from selected plants and disease severity was estimated on the basis of symptomology.

The analysis of variance was done based on the formula suggested by Panse and Sukhatme (1976). Stability analysis was performed using Windowstat software following Eberhart and Russell model (1966).

RESULTS AND DISCUSSION

The most important objective of a plant breeder is to develop varieties with high yield and stable performance. Multi-environment testing is required to obtain a reliable estimate of productivity of the genotypes under test

and to evaluate them for phenotypic stability over the environments. Stability analysis was done following Eberhart and Russell's model (1966) in the present investigation. Eberhart and Russell's model elaborated the regression approach, which was first suggested by Yates and Cochran (1938), and later used by Finely and Wilkinson (1963). In addition to regression coefficient (bi), they suggested deviation from regression (S^2d) as a parameter for stability performance. A stable variety, according to them should be characterised by an average linear response (bi = 1) and non-significant deviation from regression ($S^2d=0$). The results obtained in the present study with regard to phenotypic stability of the linseed genotype are discussed below.

The analysis of variance for the experiment on 18 linseed genotypes including checks conducted in three environments (*utera*, rainfed and irrigated) (**Table 1**). The mean squares due to genotypes and environments (linear) were highly significant for all the characters. Thus, the result indicated existence of significant differences among genotypes and environments. These results are in accordance with Vishnuvardhan and Rao (2014). Kumar and Kumar (2021) also reported highly significant mean squares due to genotype for the trait days to 50 per cent flowering, 1000-seed weight, and seed yield, mean squares due to G x E interaction and environment linear for the trait 50 per cent maturity and 1000-seed weight.

The mean squares due to genotype x environment interactions (linear) were significant for days to 50 per cent flowering, oil content and seed yield per plant thus, indicated significant linear response for these characters. The mean squares due to pooled deviations were significant for all the characters studied except days to 50 per cent flowering, days to 50 per cent maturity, plant height and leaf blight infestation. Therefore, the results revealed that non-linear component of genotype x environment interactions was important for the characters, namely, flowering period, the number of primary branches per plant, the number of capsules per plant, the number of seeds per capsule, bud fly infestation, 1000-seeds weight, oil content and seed yield per plant (**Table 2**). Statistically significant genotype by environment interaction for days to flowering, days to maturity and seed per capsule was reported by Alem and Dessalegn (2014) in linseed. Similarly, significant G x E interaction for days to flowering and days to maturity was reported by Adugna and Labuschagne (2003) in linseed; for seed yield by Mekonnen and Mohamme (2009 and 2010) in sesame; for seed yield by Temesgen *et al*. (2014) in linseed; for days to 50% flowering, days to maturity, plant height, the number of primary branches per plant, the number of secondary branches per plant, the number of capsules per plant, the number of seeds per capsule, thousand seed weight by Vishnuvardhan and Rao (2014) in linseed; for seed yield per plant, oil content, number of capsules per plant by Aher *et al*. (2016) in castor. Thus, deviation from regression should be given more importance than regression in the final characterization of genotypes for phenotypic stability. Linear regression could simply be regarded as a measure of the response of a particular genotype to environments (Eberhart and Russell, 1966).

Out of eighteen genotypes including checks, 13 genotypes had non-significant deviation from regression for seed yield per plant except BRLS 104, BRLS 107, BRLS 110-1, BRLS 111-1 and BRLS 111-3. These eighteen genotypes had also a regression coefficient on par with one except

Table 1. Analysis of variances for stability of thirteen characters in linseed

S.No.	Character	Mean squares					
		Genotype (d.f.=17)	Env+(G x E) (d.f. =36)	Env.(linear) (d.f. =1)	G x E (linear) (d.f. =17)	Pooled deviation (d.f. =18)	Pooled error (d.f. =102)
1	Days to 50% flowering	42.75**	19.94**	602.23**	6.14**	0.62	1.39
2	Flowering period	4.12	35.64**	1064.91**	7.49	5.04**	0.47
3	Days to 50% maturity	23.74**	47.92**	1280.25**	16.06	9.56	7.71
4	Plant height	77.71**	15.17	281.33**	6.52	8.56	5.57
5	Number of primary branches per plant	0.93*	0.50	4.50**	0.37	0.41**	0.06
6	Number of capsules per plant	77.08**	163.45**	4705.85**	36.03	31.43**	4.62
7	Number of seeds per capsule	1.20	1.17	5.96*	1.13	0.94**	0.07
8	Bud fly infestation	26.06**	8.14	56.78**	6.90	6.61**	0.16
9	Bud blight infestation	47.29	39.74	620.01**	22.47	23.81**	0.32
10	Leaf blight infestation	18.24	14.13	81.04	14.48	10.08	0.14
11	1000- seed weight	4.53**	0.11	0.43	0.10	0.11**	0.02
12	Oil content	66.34**	7.88**	231.49**	2.40**	0.64**	0.03
13	Seed yield per plant	0.19**	0.96**	31.67**	0.12**	0.06**	0.01

*: Significant at 5% level; **: Significant at 1% level, E: Environment, G: Genotype, G x E: Genotype by Environment Interaction

Table 2. Estimation of mean, regression coefficient and deviation from regression for various yield and yield component traits in linseed

S.No.	Genotype	Days to 50% flowering			Flowering period			Days to 50% maturity			Plant height		
		$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d
1	BRLS 103	86.22	1.86	-1.21	17.95	0.40	3.83*	124.88	0.92	6.01	68.33	0.71	-5.95
2	BRLS104	83.88	1.29	-0.69	20.02	0.43	18.79**	120.88	0.88	-6.01	59.22	-0.14	-4.77
3	BRLS105-1	76.11	0.68	-0.96	19.99	1.10	2.60	119.22	0.48	17.37	55.66	0.42	-2.60
4	BRLS106	77.22	1.02	1.05	20.77	0.98	-0.66	117.55	0.02	9.49	57.88	1.34	-0.19
5	BRLS 107	76.22	1.01	0.24	18.85	1.28	0.97	116.55	1.19	-3.90	47.97	0.65	-5.50
6	BRLS 107-2	76.11	0.75	-0.35	20.34	1.12	20.01**	116.44	1.20	-4.80	49.28	0.29	-6.11
7	BRLS 108-1	73.44	1.18	-1.24	21.74	1.24	4.55**	115.11	0.57	9.41	56.13	0.50	-5.64
8	BRLS 109-1	77.11	1.24	-0.70	19.21	1.25	-0.57	117.22	1.07	-7.02	47.77	0.69	-5.08
9	BRLS 110-1	76.33	1.41	-1.36	21.16	0.78	-0.55	117.55	1.58	-7.25	54.62	1.56	13.45
10	BRLS 110-3	72.22	0.73	-1.28	21.56	1.35	-0.03	112.55	0.97	-5.61	51.28	0.62*	-6.37
11	BRLS 110-4	76.77	1.39	-0.27	20.46	1.25	-0.21	121.55	1.38	50.15**	51.46	0.90	-4.91
12	BRLS 111-1	73.66	0.35	-0.83	20.83	1.14	1.87	115.66	1.21	1.28	54.80	1.28	3.38
13	BRLS 111-3	74.11	0.05	-1.15	20.40	1.41	-0.18	114.88	0.70	-0.77	57.75	0.81	-0.73
14	BRLS 119	75.88	0.52	-1.10	19.84	0.92	9.29**	119.44	1.45	-6.96	56.46	0.75	13.44
15	Sabour Tisi-1(LC)	83.33	1.13	-0.67	18.26	0.44	11.04**	118.00	1.67*	-7.33	53.26	2.14	7.50
16	Subhra(LC)	78.667	1.20	-1.02	19.31	1.45	-0.21	118.11	1.67	8.06	61.60	1.96	52.10**
17	Shekhar(ZC)	79.88	1.01	-1.26	19.87	1.01	1.92	119.11	0.79	-6.70	58.11	2.10	-4.51
18	T-397(NC)	79.44	1.18	-0.68	22.36	0.45	4.78**	116.22	0.25*	-7.27	58.78	1.44	1.99
19	Mean	77.59			20.16			117.83			55.58		
	SE m(±)	0.68			0.39			1.60			1.42		
	CD at 5%	1.91			1.11			4.49			3.99		

Table 2. Continued

S.No.	Genotype	Number of primary branches per plant			Number of capsules per plant			Number of seeds per capsule			Bud fly infestation		
		$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d	$\bar{X}_i$	b_i	S^2d
1	BRLS 103	2.68	-0.60	0.49**	41.88	0.62*	-5.12	8.25	1.28	0.20	12.55	0.53	1.03**
2	BRLS104	2.61	-1.89	1.54**	35.31	0.87	81.39**	7.37	-2.29*	-0.07	7.94	3.59	15.08**
3	BRLS105-1	1.96	2.35	0.84**	32.28	0.95	22.13*	7.28	1.27	0.41*	3.55	0.74	1.75**
4	BRLS106	3.26	1.75	0.35**	42.27	0.71	60.65**	7.62	1.51	0.25*	3.44	0.40	2.97**
5	BRLS 107	3.18	1.40	1.40**	43.81	0.72	30.93*	8.60	0.78	2.16**	2.77	1.17	0.45
6	BRLS 107-2	3.60	2.18	0.36**	36.93	0.34	52.85**	7.61	-0.87	0.79**	2.88	1.16	3.70**
7	BRLS 108-1	3.32	1.08	-0.06	43.14	1.46*	-5.09	7.52	4.40	1.86**	3.44	0.40	2.97**
8	BRLS 109-1	2.65	1.54	0.05	37.02	1.21	-3.38	6.43	1.10	-0.01	3.22	1.55*	-0.16
9	BRLS 110-1	3.46	-0.03	0.91**	44.82	1.66	85.48**	8.11	-1.26	3.91**	3.33	1.29	1.49**
10	BRLS 110-3	2.95	-0.07	0.24**	39.84	0.80	16.08*	8.18	-0.09	-0.06	4.00	1.12	0.12
11	BRLS 110-4	3.12	0.77	0.44**	38.68	0.48*	-5.11	7.34	0.14	-0.08	4.66	2.18	1.06**
12	BRLS 111-1	2.93	-0.11	-0.06	39.24	0.93	76.57**	7.47	-1.11	0.37*	3.55	1.72	0.30
13	BRLS 111-3	3.35	2.48	-0.05	47.31	1.68	29.27*	8.34	0.19	0.37*	3.88	1.02	0.39
14	BRLS 119	3.42	-0.06	-0.04	46.15	1.05	-3.60	7.01	3.45	1.68**	4.77	1.78	0.78*
15	Sabour Tisi-1(LC)	3.58	2.41*	-0.06	41.41	1.09	-0.90	8.50	1.13	0.54**	3.88	-0.46	3.03**
16	Subhra(LC)	1.97	1.84	-0.06	36.02	0.96	15.33	7.34	2.14	-0.04	9.77	-2.33	21.46**
17	Shekhar(ZC)	2.17	1.90	0.10	31.84	1.22	17.78*	6.46	1.84	-0.07	10.44	-1.51	37.13**
18	T-397(NC)	2.13	1.05	-0.06	29.46	1.23	4.89	7.22	4.40	3.25**	6.67	3.64	22.65**
19	Mean	2.91			39.31			7.59			5.26		
	SE m(±)	0.13			1.24			0.15			0.23		
	CD at 5%	0.38			3.48			0.44			0.65		

*: Significant at 5% level; **: Significant at 1% level

Table 2. Continued

S.No.	Genotype	Bud blight infestation			Leaf blight infestation			1000- seed weight			Oil content			Seed yield per plant		
		$\bar{X}i$	Bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d	$\bar{X}i$	bi	S^2d
1	BRLS 103	7.88	-0.05	5.23**	6.11	0.04	4.81**	8.32	0.58	0.01	41.05	0.53*	-0.03	2.16	0.82	0.00
2	BRLS104	8.00	-0.27	4.04**	5.22	-0.36	2.90**	6.54	3.40	0.15**	38.20	1.02	2.60**	1.99	0.93	0.23**
3	BRLS105-1	15.11	2.52	23.57**	10.33	3.44	3.47**	6.67	1.67	-0.02	47.47	0.70*	-0.03	1.83	1.06**	-0.01
4	BRLS106	7.66	0.87	23.56**	6.33	0.78	2.67**	6.65	2.39	-0.01	44.48	0.82	0.00	2.08	0.92	0.00
5	BRLS 107	5.33	0.73	4.12**	4.33	-0.74	0.04	7.85	-0.69	0.03	47.52	0.85	-0.02	2.29	0.65	0.05*
6	BRLS 107-2	6.88	0.55	72.84**	8.56	-1.80	51.15**	7.51	0.14	0.02	45.20	0.77	0.11*	2.06	0.72	0.01
7	BRLS 108-1	5.11	0.69	4.40**	5.44	0.96	1.53**	8.59	2.83	0.18**	35.88	1.03	0.03	2.10	1.13	-0.01
8	BRLS 109-1	9.22	1.21	68.22**	10.33	1.72	31.15**	7.48	0.39	0.05	45.49	1.00	1.02**	2.00	0.85	-0.01
9	BRLS 110-1	7.44	1.15	40.18**	6.44	2.39	6.70**	8.19	-0.13*	-0.02	40.95	0.64	-0.02	2.31	1.32	0.05*
10	BRLS 110-3	8.66	1.01	45.64**	5.89	1.09	1.73**	7.63	1.69	0.07*	41.11	1.62	1.12**	2.14	0.84	-0.01
11	BRLS 110-4	6.75	0.82	3.44**	5.97	0.05	5.98**	8.27	0.10	-0.01	40.23	0.73	0.43**	2.08	0.82	0.00
12	BRLS 111-1	8.80	1.71	89.68**	8.44	3.99	6.48**	9.25	0.77	-0.01	38.77	0.52*	-0.02	2.09	1.14	0.19**
13	BRLS 111-3	5.68	0.72*	-0.31	5.44	0.87	0.11	9.62	0.57	-0.02	36.86	1.37	0.54**	2.86	1.83	0.43**
14	BRLS 119	5.33	-0.19	-0.04	5.56	-0.63	5.23**	9.53	-0.10	0.03	40.7	0.89	0.56**	2.41	1.04	-0.01
15	Sabour Tisi-1(LC)	7.66	0.89	0.14	4.88	0.97	5.04**	5.55	-0.14	0.09*	32.92	1.09	0.68**	2.18	0.93	-0.01
16	Subhra(LC)	12.88	1.21	23.49**	11.33	-1.73	43.88**	7.58	1.89	0.06	47.62	0.92	0.93**	1.77	0.86	-0.01
17	Shekhar(ZC)	19.88	1.72	5.39**	10.33	3.12	4.13**	5.21	2.65	-0.01	43.30	1.18	2.97**	1.82	1.06	-0.01
18	T-397(NC)	14.11	2.73	9.46**	11.88	3.84	1.88**	7.38	1.06*	-0.02	32.59	2.32	0.12*	1.82	1.09	0.00
19	Mean	9.02			7.38			7.66			41.13			2.11		
	SE m(±)	0.32			0.21			0.08			0.10			0.06		
	CD at 5%	0.91			0.60			0.23			0.29			0.17		

*: Significant at 5% level; **: Significant at 1% level

BRLS 105-1. Among the genotypes, BRLS 111-3 and BRLS119 significantly out yielded the best check, Sabour Tisi -1. The genotype, BRLS 119 had reasonably high seed yield per plant (rank 2nd) and non-significant regression from deviation with regression coefficient at on par with one. Thus, BRLS 119 was found to be a stable genotype having high seed yield per plant. The highest yielding genotype, BRLS 111-3 and the lowest yielding genotype, BRLS 105-1 were found be unstable, this indicated that there was no association between the mean performance of the genotype and stability parameters. Similar results were also reported by Alem and Dessalegn (2014), Yadav *et al.* (2014), Ashraf *et al.* (2016), Hosary *et al.* (2016), Tadesse *et al.* (2017).

The genotype, BRLS 119 had also a non-significant deviation from regression and regression coefficient on par with one for the other characters *viz.,* days to 50 per cent flowering, days to 50 per cent maturity, plant height, the number of primary branches per plant, the number of capsules per plant, bud blight infestation and 1000-seed weight. The biotic factors such as bud fly, bud blight and leaf blight are major constrains for the cultivation of linseed genotypes over environments. Hence, isolation of linseed genotypes which have a minimum infestation of these biotic factors over environments is necessary.

In the present investigation, genotypes namely, BRLS 107, BRLS 107-2 and BRLS 109-1 were found to have significantly minimum bud fly infestation over the best check, Sabour Tisi-1. The genotypes, namely, BRLS 107, BRLS 108-1, BRLS 111-3 and BRLS 119 had significantly minimum bud blight infestation over the best check, Sabour Tisi-1. None of the genotypes was found to have significantly lower leaf blight infestation over this check. The genotype namely, BRLS 107 and BRLS 111-3 had unit regression coefficient and non-significant value of deviation from regression lines for both the biotic factors *viz.,* bud fly and leaf blight infestation; while, the genotype BRLS 119 had unit regression coefficient and non-significant value of deviation from regression lines for the biotic factors such as bud blight infestation over the test environments. Therefore, the genotype mainly, BRLS 119 may be identified as the stable genotype with high seed yield per plant and stability for other desirable characters over three agronomic situations, *utera*, rainfed and irrigated conditions.

ACKNOWLEDGEMENT

The authors acknowledge the help received from AICRP Scheme on Oilseed Crops, BAU centre, Sabour, Bihar with thanks for providing necessary facilities during the course of the investigation.

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