Table 2. Effect of seed-priming practices on economics of winter (*rabi*) sorghum (pooled data of 2 years)

Treatment	Cost of cultivation ($\times 10^3$₹/ha)	Gross returns ($\times 10^3$₹/ha)	Net returns ($\times 10^3$₹/ha)	Bene fit: cost ratio	Incremental cost over RPP (₹/ha)	Incremental net returns over RPP (₹/ha)
Control	30.8	67.9	37.0	2.20	– 1,019	–5,222
Seed-priming with water	31.8	70.3	38.4	2.21	– 44	–3,777
Seed-priming with $ZnSO_4$ (0.5%)	33.3	72.4	39.1	2.18	1,420	–3,085
Seed-priming with KNO_3 (0.5%)	31.5	76.7	45.1	2.43	– 350	2,932
Seed-priming with KH_2PO_4 (0.5%)	31.8	69.2	37.4	2.17	– 32	–4,837
Seed-priming with $CaCl_2$ (2%)- RPP	31.8	74.1	42.2	2.33	–	–
SEm±	–	1.0	1.0	0.03	–	–
CD (P=0.05)	–	3.2	3.2	0.09	–	–

RPP, Recommended package of practice

in maize and sorghum. The results showed that the extra cost due to seed priming practice with KH_2PO_4 (0.5%) was highest (₹1420/ha) due to its higher price. While the lowest extra cost was in seed priming with KNO_3 (0.5%) due to its lower market price which reflected in lower cost of cultivation (₹31.5 × 10^3/ha) and maximum incremental net returns over seed-priming practice with $CaCl_2$ (2%)-RPP. These results are in conformity with the findings of Priya *et al*. (2011) in maize and sorghum who reported the higher net returns and benefit: cost ratio with KNO_3 (0.5%) seed-priming.

Based on the results, seed-priming with KNO_3 (0.5%) can be advocated in *rabi* sorghum owing to realization of higher grain and fodder yield besides net income over other practices under rainfed conditions.

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Research Paper

Impact of various sowing environment and nutrient sources on growth performance of Indian mustard (*Brassica juncea*)

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ABSTRACT

A field study was carried in 3 time replicated split-plot design at Varanasi, Uttar Pradesh, during the winter (*rabi*) seasons of 2015–16 and 2016–17, to find out the effect of sowing dates and nutrient sources on the performance of Indian mustard [*Brassica juncea* (L.) Czernj. J.]. The sowing dates (17 November, 27 November and 7 December) were assigned in main plots and 8 nutrient sources [Control (zero fertilizer), 100% recommended dose of fertilizers (RDF), 100% RDF + *Azotobacter,* 100% RDF + phosphorus solubilizing bacteria (PSB), 100% RDF + *Azotobacter* + PSB, 75% RDF + 25% N through pressmud + *Azotobacter,* 75% RDF + 25% N through pressmud + PSB, 75% RDF + 25% N through pressmud + *Azotobacter* + PSB] were allocated to subplots. Among the sowing dates, the maximum values of growth parameters, economic yield and economics were recorded when the crop raised 17 November in pooled analysis. Application of 75% RDF + 25% N through pressmud + *Azotobacter* + PSB significantly improved the plant height, number of primary branches/plant, number of secondary branches/plant, dry-matter accumulation, leaf-area index and chlorophyll content, economic yield and economics than the other nutrient sources in the pooled analysis. Thus, crop sowing on 17 November with 75% RDF + 25% N through pressmud + *Azotobacter* + PSB proved beneficial in improving the growth parameters in Indian mustard.

Key words : *Azotobacter*, Growth, Pressmud, PSB, Sowing

In rice–wheat cropping system crop productivity declining or stagnating mainly due to decline in resource-use efficiency and intensive land cultivation, lack of alternate cropping system, injudicious use of inputs, decline in soil organic carbon and application of organic manures and continuously avoidance of environmental quality (Meena *et al*., 2020a). In the winter (*rabi*) season wheat crop can be replaced with the suitable alternate crop like Indian mustard to sustain the crop and soil productivity and to maintain nutrient balance in the system. Diversification of the system with Indian mustard may prove a beneficial tool to maintain soil health, increase productivity, resource-use efficiency and farmers income by decreasing cost of cultivation (Singh *et al*., 2020).

In India among the oilseeds, Indian mustard has the second place with production of 8.32 million tonnes. Indian mustard mainly cultivated in Rajasthan with minimum resources as a rainfed crop. If it is grown in place of wheat in rice –wheat system with lot of resources, may double the yield as compared to present average productivity (13.97 q/ha) and can boost the oilseed economy of the country. Indian mustard if diversified in place of wheat crop in the rice–wheat cropping system, it helps in reducing the input requirement of NPKS, water etc. as compared to wheat crop (Singh *et al*., 2018).

About 8–10 million tonnes pressmud is produced every year in India (Kumar *et al*., 2018). The pressmud is the rich source of essential plant nutrients and carbon and being used as organic fertilizer in field after composting process. It has beneficial effects on soil physical, chemical and biological properties (Kumar *et al*., 2020). When pressmud compost applied with suitable dose of fertilizers and combined with bio-fertilizers to Indian mustard, it helps in achieving its full yield potential (Bokhtiar *et al.,* 2015). Biofertilizers helps increase microbial activity in soil to solubilize and mobilize the nutrients to reach the plant roots. The application of biofertilizers to enhances the nutrient levels of soil which support plant growth and productivity in agricultural field (Mittal *et al.,* 2018). Therefore,

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it is an important to evaluate the pressmud, recommended dose of fertilizer (RDF) and biofertilizers combination with different date of sowings in increasing the crop growth and productivity. Considering these facts in view, the present experiment was conducted under various sowing environments with nutrient sources on growth parameters of Indian mustard.

MATERIALS AND METHODS

The present investigation was conducted during the winter (*rabi*) seasons of 2015–16 and 2016–17 at Agricultural Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25˚18' N, 83˚ 30' E and 76.216 m from the mean sea-level)- Kumar *et al.,* (2017). The total rainfall of 61.3 and 52.1 mm was received during the experimentation crop growth periods of the both years respectively. Maximum weekly mean temperature was 31.29˚C and 31.15˚C and minimum 17.70˚C and 17.54˚C during experimentation in the first and second year respectively. Weekly mean average temperature was maximum of 31.29˚C and minimum at 17.7˚C during experimentation 2015–16, and 31.15˚C and 17.54˚C during 2016–17 were recorded, respectively. The soil was sandy clay loam, having pH (7.85 and 7.62), organic carbon (0.42% and 0.45%), available N (205.7 and 210.3 kg/ha), P (19.4 and 21.1 kg/ha), K (210.2 and 219.9 kg/ha) and S (20.8 and 22.6 mg/kg) during both the years, respectively. The experiment was laid out in split-plot design, replication thrice. Treatments comprised 3 sowing dates (17 November, 27 November, 7 December) and 8 nutrient sources, *viz.* N_0, control, 0 NPKS; N_1, 100% recommended dose of fertilizer (RDF), 100 kg N + 50 kg P_2O_5 + 50 kg K_2O + 40 S/ha); N_2, 100% RDF (NPKS) + *Azotobactor*; N_3, 100% RDF (NPKS) + PSB; N_4, 100% RDF (NPKS) + *Azotobactor* + PSB; N_5, 75% RDF + 25 % N through Pressmud+ *Azotobactor*; N_6, 75% RDF + 25% N through Pressmud + PSB; N_7, 75% RDF + 25 % N through pressmud +*Azotobactor* + PSB). The RDF was applied through diammonium phosphate (46% P_2O_5, 18% N), urea (46% N), muriate of potash (60% K_2O) and elemental sulphur (90% S). Pressmud compost was collected from KM Sugar Mills, Faizabad, Uttar Pradesh, and air-dried and grounded before application. The seed was treated with biofertilizers, *i.e*. *Azotobacter* and PSB, about 2 hours before sowing according to a routine procedure. 'Ashirwad' variety of Indian mustard was selected for this experiment owing to its yield potential of 1,450–2,358 kg/ha with oil content 31–41%. It is suitable for irrigated late-sown conditions. A general dose of herbicide (Pendimethalin 30 EC) was applied as pre-emergence for 2 hours after sowing to control weeds. Data were recorded on plant height, number of primary and secondary branches were recorded on 5 randomly tagged plants of Indian mustard. Dry-matter accumulation was recorded at by removing plants from 1 m row length from the sample rows in each plot. Chlorophyll content was measured at 30, 60 and 90 days after sowing (DAS) with the help of SPAD meter. Leaf-area index (LAI) was measured at 45 and 90 DAS with the help of leaf area meter. Statistical analysis was done for determining the significance between the treatment means and to draw valid conclusion. Data were to statistically analysed by adopting appropriate method of Analysis of Variance (Gomez and Gomez, 1976).

RESULTS AND DISCUSSION

Effect of sowing environments

Among the sowing dates, the maximum plant height at 45 days after sowing (DAS), at 90 DAS and at harvesting stage, number of primary branches/plant (at 45 and 90 DAS and at harvesting stage; secondary branches/plant at 90 DAS and 16.21 at harvesting stage; dry-matter accumulation (g/plant) at 45 and 90 DAS and at harvest stage; leaf-area index at 45 and 90 DAS; and chlorophyll content at 30, 60 and 90 DAS were recorded in 17 November-sown crop and the lowest plant height, primary branches/plant secondary branches/plant, dry-matter accumulation leaf-area index and chlorophyll content were observed on 7 December-sown crop in pooled analysis (Table 1, 2 and 3). Furthermore, the maximum seed yield (1.85 t/ha) net return (₹45,242/ha) and B: C ratio (1.31) were recorded on 17 November-sown crop followed by 27 November-sown crop and lowest seed yield (Table 4) was observed on 7 December-sown crop in pooled analysis. Different sowing dates could not bring variation in harvest index of Indian mustard up to the level of significance. The plant height (Table 1) increased with first sowing, may be due the fact that first sowing took maximum days to maturity, which enhances the growth period for maximum utilization of the available resources and provides suitable growing conditions for the timely sowing and sufficient growth of plants (Kumar *et al.,* 2004). However, the second sowing 27 November and last sowing 7 December of Indian mustard took less days to maturity. Hence the crop could not utilize the available resources and environmental condition properly. Similar evidences on height were observed by Rafiei *et al*. (2011). Further, the crop sown on 17 November produced significantly higher number of primary and secondary branches/plant (Tables 1 and 2) may be owing to prolonged vegetative growth period of crop in congenial environmental conditions which help increase the availability of nutrients and improve the better growth attributes. While the late-sown crop (27 November and 7 December) experienced sub-optimal weather regime, especially during the second fortnight of December and the first fortnight of

January, which retarded their growth compared to early-sown crop (17 November). Significant increase in dry-matter accumulation (Table 2) under the sowing on 17 November was owing to fact that the earlier sowing provide more days to maturity and more growing degree-days (GDD), which help in sufficient photosynthesis to accumulate higher dry-matter in the crop. Likewise, significantly higher leaf-area index (LAI) was recorded in 17 November-sown crop as compared to crops sown on 27 November and 7 December, may be owing to the better growth of the crop under favourable growing environment and high heat-use efficiency (HUE). Higher plant height (Table 1) also helps in bearing more leaves, which increases more leaf area per unit land area (Kumari *et al.*, 2012). Chlorophyll content (Table 3) was also produced significantly higher in crop sown on 17 November as compared to delayed sowing November 27 and December 7 may be because of the sufficient supply of major nutrients (NPKS) which are constituent of amino acids and of fatty acids as well as essential for the biosynthesis of chlorophyll. Due to this reason chlorophyll content (SPAD value) was higher in 17 November-sown crop in comparison to the other dates. The higher seed yield with first sown crop coupled with primarily owing to more dry-matter accumulation (Table 2), which led to enhanced sink capacity of yield attributes (Singh *et al.,* 2014). The favourable effect of early sowing (17 November) on sink component could be attributed to the better development of the plants and supplies the required photosynthetic material and increased bearing capacity due to optimum growth on account of constructive environmental conditions ultimately more seed weight. The reduction in seed yield (Table 4) under delayed sowing (7 December) could be due to less translocation of photosynthates towards reproductive parts, rapid initiation of inflorescence, maturity and less number of siliqua because of non-fulfilment of temperature demands under late sowings (Patel *et al.,* 2015). The maximum net returns and benefit: cost (B: C) ratio were recorded on 17 November-sown crop in pooled analysis (Table 4). Date of sowing is an important non-monetary input (Kumar *et al.,* 2013). This may be due to the early sowing date, day length and temperature can provide congenial conditions to have maximum growth and yield attributes, which ultimately had effect on yield of crop that decided the economic returns (Table 4) of the crop (Shivani and Kumar, 2002).

Effect of nutrient sources

Application of 75% RDF + 25% N through pressmud + *Azotobacter* + PSB significantly improved the plant height, primary branches/plant, secondary branches/plant at 90 DAS at harvesting stage, dry-matter accumulation at 45 and 90 DAS at harvesting stage, leaf-area index and chlorophyll content than the other nutrient sources in the pooled analysis (Tables 1, 2 and 3). The treatments of 75% RDF + 25% N through pressmud + PSB and 75% RDF + 25% N through pressmud + *Azotobacter* were found at par to each other for growth parameters. However, plant height at 45 and 90 DAS at harvesting stage, primary branches/

Table 1. Effect of sowing dates and nutrient sources on growth parameters of Indian mustard (pooled data of 2015–16 and 2016–17)

Treatment	Plant height (cm)			Primary branches/plant		
	45 DAS	90 DAS	At harvesting	45 DAS	90 DAS	At harvesting
Sowing dates						
17 November	58.1	130.6	168.5	3.8	6.3	6.4
27 November	52.5	120.6	155.7	3.5	5.8	5.9
7 December	48.4	111.1	144.0	3.2	5.3	5.5
SEm±	0.72	1.66	2.17	0.05	0.08	0.08
CD (P=0.05)	2.35	5.41	7.07	0.16	0.26	0.27
Nutrients sources						
Control (Zero, NPKS)	30.6	62.7	91.2	1.8	3.0	3.1
100% RDF (NPKS)	45.7	105.0	134.5	3.1	5.0	5.2
100% RDF (NPKS) + *Azotobacter*	51.6	118.4	151.8	3.5	5.7	5.8
100% RDF (NPKS) + PSB	52.2	119.7	153.4	3.5	5.8	5.9
100% RDF (NPKS) + *Azotobacter* + PSB	55.6	127.5	163.4	3.7	6.1	6.7
75% RDF + 25% N through PM + *Azotobacter*	59.8	137.8	175.7	4.0	6.6	6.7
75% RDF + 25% N through PM + PSB	60.9	139.8	179.0	4.1	6.7	6.9
75% RDF + 25% N through PM + *Azotobacter* + PSB	67.8	155.7	199.5	4.5	7.5	7.6
SEm±	0.56	1.29	1.60	0.04	0.06	0.06
CD (P=0.05)	1.59	3.64	4.49	0.11	0.17	0.18

RDF, Recommended dose of fertilizers; NPKS, nitrogen, phosphorus, potassium and sulphur; PSB, phosphorus-solubilizing bacteria, PM, pressmud; DAS, days after sowing plant at 45 and 90 DAS at harvesting stage, secondary branches/plant, dry-matter accumulation (g/plant) at 45 and 90 DAS and at harvesting stage), leaf-area index at 45 and 90 DAS and chlorophyll content at 30, 60 and 90 DAS with application of 100% RDF + *Azotobactor* + PSB was higher than rest of the treatments.

Moreover, the 100% RDF + PSB and 100% RDF + *Azotobactor* in respect of all growth parameters were found at par with each other.

The highest seed yield (2.21 kg/ha), net returns (₹57,888/ha) and benefit: cost (B: C) ratio (1.62) were observed with 75% RDF + 25% N through pressmud + *Azotobactor* + PSB as compared to the other nutrient sources. Application of 75% RDF+ 25% N through pressmud + PSB and 75% RDF + 25 % N through a pressmud+ *Azotobactor* were at par for seed yield, net return and B: C ratio (Table 4). The minimum seed yield, net returns and B: C ratio were observed with 100% RDF in the pooled analysis (Table 4), respectively. The nutrient sources could not bring variation in harvest index of Indian mustard up to the level of significance. The highest plant height, primary branches/plant, secondary branches/plant, dry-matter accumulation, leaf-area index, chlorophyll content, seed yield, net returns and B: C ratio were observed in 75% RDF + 25% N through pressmud + *Azotobactor* + PSB may be owing to availability of NPKS to the plant initially through fertilizers and then through pressmud compost during the cropping season. Pressmud compost plays an important role in the better development of roots and increased microbial activity because of the balanced food to the biofertilizers in soil rhizosphere (Datta *et al.,* 2009). The availability of N and utilization by plant from pressmud compost which also contains micro-nutrients were available to plants within short period with RDF. Nutrients promote the plant growth and its contribution to improvement of the vegetative growth and ultimately increased number of primary and secondary branches/plant. Dry-matter accumulation was significantly influenced due to all the supplementary ingredients available to plants with combined application of nutrient sources. Adequate supply of readily available N and other essential nutrients produced taller plants. Organic manures may enhance the supply of the plant nutrients, improvement in biological properties and increased availability of nutrients (Kumar, 2015). The plant system and *Azotobacter* and PSB have ability to fix the atmospheric N and solubilizing of native P, produce plant growth-promoting antifungal and antibacterial substances, which influence nutrient availability to the plant. Thus, the higher LAI of Indian mustard was observed (Meena *et al.*, 2013).

The data on the chlorophyll content (SPAD value) (Table 3) showed that maximum accumulation of chlorophyll was recorded from 75% RDF + 25% N through pressmud + *Azotobactor* + PSB. This may be due to the maximum N content and uptake and increased the uptake of nutrient from the soil under the influence of pressmud application and also the beneficial effects of bacterial inoculation which help in chlorophyll synthesis. Significant

Table 2. Effect of sowing dates and nutrient sources on growth parameters of Indian mustard (pooled data of 2015–16 and 2016–17)

Treatment	Secondary branches/plant		Dry-matter accumulation (g/plant)		
	90 DAS	At harvesting	45 DAS	90 DAS	At harvesting
Sowing dates					
17 November	15.6	16.2	10.9	38.3	41.7
27 November	14.4	15.0	10.0	32.9	35.9
7 December	13.3	13.8	9.2	30.5	33.3
SEm±	0.20	0.21	0.14	0.43	0.47
CD (P=0.05)	0.65	0.67	0.45	1.40	1.53
Nutrients sources					
Control (Zero, NPKS)	7.5	7.8	5.2	17.2	18.8
100% RDF (NPKS)	12.6	13.0	8.7	29.5	32.2
100% RDF (NPKS) + *Azotobactor*	14.2	14.7	9.8	33.7	36.8
100% RDF (NPKS) + PSB	14.3	14.9	9.9	34.0	37.1
100% RDF (NPKS) + *Azotobactor* + PSB	15.3	15.8	10.6	35.9	39.2
75% RDF + 25% N through PM + *Azotobactor*	16.4	17.0	11.4	38.4	42.0
75% RDF + 25% N through PM + PSB	16.7	17.4	11.6	39.1	42.7
75% RDF + 25% N through PM + *Azotobactor* + PSB	18.6	19.3	12.9	43.3	48.2
SEm±	0.15	0.16	0.11	0.32	0.36
CD (P=0.05)	0.44	0.45	0.30	0.91	1.00

RDF, Recommended dose of fertilizers; NPKS, nitrogen, phosphorus, potassium and sulphur; PSB, phosphorus-solubilizing bacteria, PM, pressmud; DAS, days after sowing

Table 3. Effect of sowing dates and nutrient sources on growth parameters of Indian mustard (pooled data of 2015–16 and 2016–17)

Treatment	Leaf-area index		Chlorophyll content (SPAD value*)		
	45 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Sowing dates					
17 November	1.94	3.03	37.8	45.1	48.1
27 November	1.66	2.61	36.5	43.6	46.4
7 December	1.54	2.42	34.9	41.6	44.4
SEm±	0.02	0.03	0.17	0.20	0.21
CD (P=0.05)	0.07	0.11	0.54	0.65	0.69
Nutrients sources					
Control (Zero, NPKS)	0.87	1.36	33.6	40.1	42.7
100% RDF (NPKS)	1.49	2.34	34.9	41.6	44.3
100% RDF (NPKS) + *Azotobactor*	1.70	2.67	35.6	42.4	45.2
100% RDF (NPKS) + PSB	1.72	2.69	35.7	42.5	45.3
100% RDF (NPKS) + *Azotobactor* + PSB	1.81	2.84	36.6	43.6	46.5
75% RDF + 25% N through PM + *Azotobactor*	1.94	3.05	37.7	45.0	47.9
75% RDF + 25% N through PM + PSB	1.98	3.10	38.0	45.3	48.2
75% RDF + 25% N through PM + *Azotobactor* + PSB	2.2	3.43	39.4	47.0	50.1
SEm±	0.02	0.03	0.11	0.13	0.14
CD (P=0.05)	0.05	1.00	2,048	0.06	

enhancement in total chlorophyll content in leaves with combination of pressmud compost, biofertilizer and chemical fertilizer was observed. It may be owing to higher availability of N to the growing tissue and organs supplied by N-fixing *Azotobacter* species. The highest seed yield (2.21 t/ha) was observed in 75% RDF + 25% N through pressmud + *Azotobactor* + PSB than other nutrient sources. The probable reason may be that the increasing nutrient sources through inorganic, organic and microbial inoculation resulted in greater accumulation and translocation of dry-matter to the productive organs, which in turn, improved all growth and yield-attributing characters resulting the more seed yield (Kausale *et al*., 2009; Kumar, 2015). The data pertaining to economics indicated that the highest net returns (Table 4) was observed in 75% RDF + 25% N through pressmud + *Azotobactor* + PSB in pooled analysis, mainly owing to increase in seed and straw yield. There was not only remarkable increase in net returns owing to application of 75% RDF + 25% N through pressmud + *Azotobactor* + PSB but also application of pressmud replaced the 25% chemical fertilizers need, and certainly decreased the cost of fertilizer on price basis, which is ul-

Table 4. Effect of sowing dates and nutrient sources on yields and economics of Indian mustard (pooled data of 2015–16 and 2016–17)

Treatment	Seed yield (t/ha)	Harvest index (%)	Net returns (₹/ha)	Benefit: cost ratio
Sowing dates				
17 November	1.85	27.1	45,242	1.31
27 November	1.71	29.9	38,534	1.11
7 December	1.58	29.6	32,906	0.95
SEm±	0.02	0.13	982	0.03
CD (P=0.05)	0.08	0.44	3,204	0.09
Nutrients sources				
Control (Zero, NPKS)	0.89	29.7	12,214	0.48
100% RDF (NPKS)	1.49	28.7	28,776	0.83
100% RDF (NPKS) + *Azotobactor*	1.68	28.3	36,951	1.07
100% RDF (NPKS) + PSB	1.70	28.4	37,701	1.09
100% RDF (NPKS) + *Azotobactor* + PSB	1.81	28.7	42,308	1.22
75% RDF + 25% N through PM+ *Azotobactor*	1.95	28.7	46,883	1.31
75% RDF + 25% N through PM + PSB	1.98	28.9	48,429	1.35
75% RDF + 25% N through PM + *Azotobactor* + PSB	2.21	29.2	57,888	1.62
SEm±	0.02	0.35	728	0.02
CD (P=0.05)	0.05	1.00	2,048	0.06