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Research Paper

Evaluation of agro-chemicals for enhancing the productivity and profitability of late-sown Indian mustard (*Brassica juncea*) under acidic soils of Manipur

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ABSTRACT

A field experiment was conducted during the winter seasons of 2015–16 and 2017–18 at Imphal, Manipur to investigate the best combination of agro-chemicals for maximizing the productivity and profitability of late-sown Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] under moisture-stress conditions. The experiment was laid out with 9 treatment combinations of hydrogel and thiourea in randomized completely block design (RCBD) with 3 replications. The results indicated that productivity and economic efficiency increased by 68.9% and 39.7% and 88.3% and 45.1% with 5.0 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation over the control and water spray twice at 50% flowering and at siliquae formation respectively. The significant improvement in growth attributes like plant height (116.8 cm), dry-matter accumulation/plant (16.9 g/plant), number of primary and secondary branches (4.1 and 6.3/ plant), leaf-area index (LAI) at 45 days after sowing (DAS): 3.2) and 75 DAS (5.7) and yield attributes such as siliqua/plant (155) seed yield (1.56 t/ha), biological yield (1.56 t/ha), oil recovery (648 kg/ha), protein recovery (263 kg/ha). The economic benefit: in term of gross and net returns (64.58 and 30.99 10^3₹/ha) and benefit: cost ratio (0.92) reflected that feasibility of the treatment over the control and water spray at 50% flowering and at siliquae formation.

Keywords: Fertilizers, Hydrogel, Indian mustard, Moisture stress, Productivity, Profitability, Thiourea

In India, rapeseed–mustard group of crops are grown in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south under irrigated/ rainfed, timely/ late sown and mixed cropping. Of the 6.7 million ha area under rapeseed–mustard, Indian mustard accounts for about 75–80% (Chandrashekar *et al.,* 2013) in the country. In India, the total production of rapeseed–mustard was 7.9 million tones with average productivity of 1,088 kg/ha (AICRP-RM), 2016). In Manipur, Indian mustard is the most important winter oilseed crop being cultivated at lowlands (valley) and foothills under the rainfed situation with available residual soil moisture. The share of Indian mustard in area and production has rapidly increased in the recent past with the introduction of high-yielding varieties in the state.

The state experiences an acute shortage of irrigation water during the winter season and the farmers depend only on the winter shower for raising the crop. Hence, it is important to exploit the residual soil moisture by applying the soil conditioners like superabsorbent polymer (Hydrogel). The hydrogel is water-retaining, a cross-linked hydrophilic, biodegradable amorphous polymer that can absorb and retain water by 400 times than its original weight and at least 95% of its stored water make it available to plants for their further absorption and utilization (Johnson and Veltkamp, 1985). Incorporation of the hydrogel also helps to bind the residual soil moisture and release it slowly such that the moisture is supplied to the crop till flowering (Singh *et al.*, 2018). El-Hady *et al*. (2006) reported that, hydrogel could reduce the amount of irrigation from 65 to 80% of the total crop water requirements and increase crop yield by 16–25%.

Thiourea, a sulfhydryl compound, either is supplied to crop through seed treatment to enhance the germination and vigour or applied at flowering and siliquae formation for regulating the stomatal activity for overcoming the moisture deficit. It also plays an important role in the biosynthesis of metabolites such as chlorophyll and essential oils. Its application in rapeseed–mustard influences oil, protein and glucosinolate concentration (Haneklaus *et al*., 1999). In oilseed *Brassica*, for achieving higher productiv-

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ity with better quality oil, the application of sulphur is usually recommended higher than other crops (cereals and legumes). The foliar applications of thiourea at critical crop stages particularly at 50% flowering and 50% siliquae formation, supplement sulphur and improve the photosynthetic efficiency partitioning chlorophyll contents, shoot dry matter and 1,000-seed weight (Jagetiya and Kaur, 2006).

Keeping these facts in view, the present study was, therefore, conducted to enhance the productivity and profitability of late-sown Indian mustard using the different combinations of the hydrogel, thiourea, and recommended dose of fertilizers.

MATERIALS AND METHODS

The field experiment was laid out at the research farm of Central Agricultural University Imphal, (94° 0.03463 E, 24° 0.45893 N and of 875.0 m above sea-level) Manipur during the 2015–16 and 2017–18. The experimental site was under Sub-Tropical Plane Zone (NEH4) of the Agro Climatic Zone. The soils was acidic (*p*H 5.6) and clay loam in texture, with 46.4% sand, 12.6% silt and 39.1% clay. The experimental soil was moderately fertile, being high in available organic carbon (0.93%), available potassium (304.0 kg/ha) and medium in available nitrogen (292.2 kg/ha), available phosphorus (18.0 kg/ha) and adequate in available sulphur (14.1 mg/kg). However, the topography of experimental unit was gently sloping, with the slope varying from 3% to 4.5%. The soils in Manipur belong to the Order Inceptisols showing not much horizonation. The bulk density of the surface layer was 1.38 Mg/m^3 and the water-holding capacity of the soil was 42.2%. The soybean–mustard cropping system has been followed at the experimental site since 2011–12.

The climate of the location is sub-tropical with average annual rainfall of 1,814 mm, 80–82% received during April–September. Weather data on SMW during the experimental seasons, 2015–16 and 2017–18, is presented in Fig. 1.

The weather data were collected from the 40th to 52nd and 1st to 13th standard weeks. All the crop husbandry practices from field preparation to harvest of the crop were carried out utilizing the moisture received from rains. The weather was congenial and, though the lesser amount of rainfall received was equally distributed during different growth stages to support the growth of the crop, during the winter seasons of 2015–16 and 2017–18, respectively. A total rainfall received during the cropping seasons at the site was lesser in 2015–16 (256.3 mm) than 2017–18 (455.0 mm). The lowest temperature was observed during 2nd fortnight of December to entire January (minimum ranged from < 4°C). The maximum and minimum temperature ranged from 11°C to 25°C, with the number of rainy days ranging from 22 to 24 over the years.

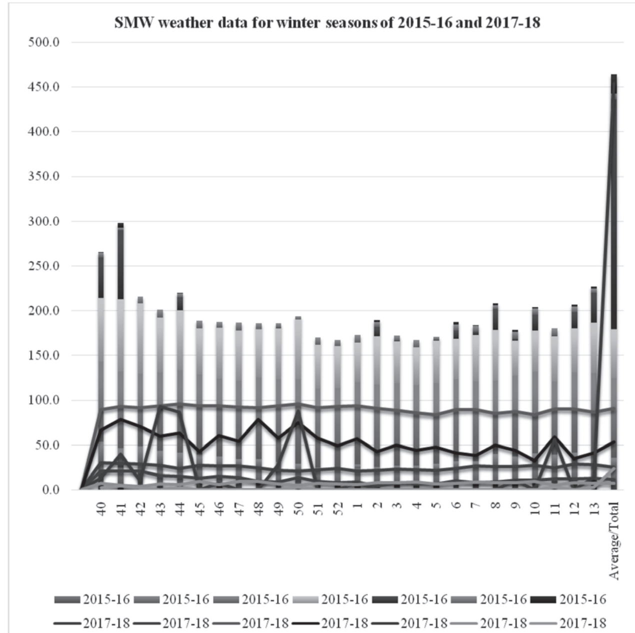

Fig. 1. Standard meterological week weather data for winter seasons, 2015–16 and 2017–18, at experimental site

Seedbed preparation, including ploughing, disk harrowing, and planking, was done as per the requirement of the crop. The variety used in the study was 'NRCHB 101' and was sown on 3rd of December 2015 and on 30th of November 2017 during the first and second years respectively. The experiment was laid out in randomized complete-block design with 9 treatments, replicated thrice. Various agrochemical treatments investigated were randomly arranged in each replication to reduce experimental error and enhance the precision of experimentation. The experiment comprising 9 treatments, viz. (i) absolute control, (ii) water spray at 50% flowering and at siliquae formation, (iii) 2.5 kg hydrogel + water spray at 50% flowering and at siliquae formation, (iv) 0.05% thiourea at 50% flowering and at siliquae formation, (v) 2.5 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation, (vi) 2.5 kg hydrogel, (vii) 5.0 kg hydrogel, (viii) 5.0 kg hydrogel + water spray at 50% flowering and at siliquae formation, and (ix) 5.0 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation, respectively, for the field study during both the years (2015–16 and 2017–18).

The recommended dose of fertilizers (RDF), i.e. 60-40-30-30 kg N-P-K-S/ha were uniformly supplied to Indian mustard crop through urea, single superphosphate and muriate of potash in all the treatments except absolute control. N (80%), P (100%), and K (100%) were applied in rows before sowing, and the remaining 20% N was given before flowering just after life-saving irrigation. Sowing was done @ 6 kg seed/ha at a row spacing of 30 cm and at a depth of 2–3 cm only. Thinning was done twice at 25 days after sowing (DAS) and 35 DAS of the crop and plant distance was maintained at 10–12 cm of interval. The crop didn't not experience any biotic stress during its growth period.

Growth parameters, viz. plant height, dry-matter accumulation, primary and secondary branches, leaf-area index (LAI), no. of days taken to attain 50% flowering and 80% maturity, and yield attributes, viz. siliquae/plant, siliqua length, seeds/siliqua, test weight, seed yield, harvest index (HI), and qualitative traits, viz. oil recovery and protein recovery, along with a gross returns, net return and profit/rupee invested were estimated. All the data were statistically analysed by SAS version 9.

The productivity efficiency, economic efficiency and profit/rupee invested (Benefit: cost ratio) were computed as:

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Biological yield (kg/ha)}}{\text{Duration of the crop (days)}}$$

$$\text{Economic efficiency (₹/ha/day)} = \frac{\text{Gross returns (₹/ha)}}{\text{Duration of the crop (days)}}$$

$$\text{Profit/rupee invested (B : C ratio)} = \frac{\text{Net returns (₹/ha)}}{\text{Cost of production (₹/ha)}}$$

RESULTS AND DISCUSSION

Growth attributes

The data pooled over 2 years, 2015–16 and 2017–18, revealed that significantly higher dry-matter accumulation, and leaf-area index (LAI) were observed in the treatment having the highest inputs applied, i.e. 5.0 kg hydrogel + 0.05% thiourea at flowering and at 50% siliquae formation over the control and water spray at 50% flowering and at siliquae formation (Table 1). However, it remained statistically on a par with treatments having other combinations of hydrogel and thiourea. The application of agrochemicals (hydrogel and thiourea) increases the availability of soil moisture and nutrients. The adequate soil moisture increases the absorption of major nutrients (NPKS), resulting in a rapid expansion in foliage growth, better accumulation of photosynthates which eventually led to an increase in higher dry-matter production and LAI. The addition of agrochemicals (hydrogel and thiourea) enhances the turgor pressure inside the cells by providing a sufficient amount of water and thus increases the LAI and other related growth parameters.

Application of 2.5 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation and 5.0 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation though both produced significantly taller plants, higher dry-matter production and more number of branches over other treatment combinations, but remained comparable between each other (Table 1). The total dry-matter production is an indication of the overall utilization of available resources. Similarly, a significant increase in total dry-matter production due to hydrogel polymer was reported by Volkamar and Chang (1995) in Canola and Shashidhar *et al.* 2020 in lentil.

During both the years under field study, the 5.0 kg hydrogel/ha incorporated into soil and subsequently sprayed 0.05% thiourea at 50% flowering and at siliquae formation to the crop took 8 ± 1 more days to attain the physiologi-

Table 1. Effect of agro-chemicals on growth attributes of late-sown Indian mustard (pooled data of 2 years)

Treatment variables/ha basis	Plant population ($\times10^3$/ha)	Plant height (cm)	Dry-matter accumulation (g/plant)	Number of branches		Leaf-area index (LAI)	
				Primary	Secondary	45 DAS	75 DAS
Control (input not applied)	312.3	87.4	8.5	2.7	3.8	2.6	4.3
RDF + water spray (WS) at 50% FL and 50% SF	318.9	94.1	13.1	3.0	4.5	2.9	4.9
RDF + 2.5 kg hydrogel + WS at 50% FL and 50% SF	326.0	106.9	15.0	3.5	5.3	3.0	5.1
RDF + 0.05% thiourea (TU) at 50% FL and 50% SF	322.0	97.3	15.3	3.2	4.8	3.1	5.3
RDF + 2.5 kg hydrogel + 0.05% TU at 50% FL and 50% SF	324.9	112.6	15.9	3.8	5.7	3.0	5.4
RDF + 2.5 kg hydrogel	322.0	100.7	15.2	3.2	4.9	3.0	5.2
RDF + 5.0 kg hydrogel	326.2	103.8	16.5	3.4	5.3	3.1	5.4
RDF + 5.0 kg hydrogel + WS at 50% FL and 50% SF	328.1	109.2	16.2	3.7	5.6	3.1	5.4
RDF + 5.0 kg hydrogel + 0.05% TU at 50% FL and 50% SF	328.0	116.8	16.9	4.1	6.3	3.2	5.7
SEM±	4.9	1.6	0.9	0.2	0.1	0.1	0.2
CD (P=0.05) for T	NS	4.8	2.6	0.5	0.4	0.3	0.6
Years	NS	3.2	2.0	0.2	0.2	0.3	0.5
Y×T	64.0	12.5	3.0	0.7	1.2	0.8	1.1

RDF, Recommended dose of fertilizer; FL, flowering; SF, siliquae formation; DAS, days after sowing cal maturity than the absolute control (Table 2). However, the reverse trend was noted concerning the number of days taken to attain the 50% flowering. The higher availability of nutrients to the crop has stimulated early flowering, this could be ascribed to the greater supplies of hydrogel and thiourea in addition to the recommended dose of fertilizer to the crop.

Yield and yield attributes

The 5.0 kg hydrogel incorporated into the root zone prior to sowing of Indian mustard crop and later 2 foliar applications of 0.05% thiourea was given at 50% flowering and at siliqua formation significantly enhanced the yield attributes, i.e. siliquae/plant, seeds/siliqua, test weight. These improvements further manifested higher biological yield, better production efficiency and harvest index (Table 3). As Indian mustard has a determinate growth habit and the competition for getting adequate light, nutrients, water, and metabolites is very common at the vegetative and reproductive stages of the plant. The increase in biological yield and yield attributes under treatment with 5.0 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation might have minimized the competition for photosynthates and improved the vegetative and reproductive crop growth stages by influencing carbon reduction cycle, thereby increasing net CO_2 fixation in source and conse-

Table 2. Effect of agro-chemcials on 50% flowering, physiological maturity and yield attributes of late-sown Indian mustard (pooled data of 2 years)

Treatment variables/hectare basis	Days taken to attain the 50% flowering	Days taken to attain the 80% maturity	Siliquae/ plant	Siliqua length (cm)	Seeds/ siliqua	Test weight (g)
Control (input not applied)	62.4	110.7	85	5.43	13.3	4.77
RDF + water spray (WS) at 50% FL and 50% SF	61.9	113.8	94	5.64	13.6	4.78
RDF + 2.5 kg hydrogel + WS at 50% FL and 50% SF	58.2	114.3	128	6.07	13.6	4.83
RDF + 0.05% thiourea (TU) at 50% FL and 50% SF	60.0	114.3	119	5.78	14.1	4.83
RDF + 2.5 kg hydrogel + 0.05% TU at 50% FL and 50% SF	57.8	115.8	143	6.14	14.0	4.82
RDF + 2.5 kg hydrogel	59.5	112.5	120	5.76	14.8	4.80
RDF + 5.0 kg hydrogel	58.3	114.8	128	5.85	13.3	4.80
RDF + 5.0 kg hydrogel + WS at 50% FL and 50% SF	57.2	114.4	133	6.07	14.9	4.82
RDF + 5.0 kghydrogel + 0.05% TU at 50% FL and 50% SF	56.6	117.3	155	6.27	14.8	4.82
SEM±	0.3	1.1	4.0	0.08	1.2	0.02
CD (P=0.05) for T	0.8	3.1	11.9	0.24	3.4	0.10
Years	0.8	3.0	9.8	0.34	2.0	0.09
Y×T	3.1	6.7	38.9	0.78	3.0	0.27

RDF, Recommended dose of fertilizer; FL, flowering; SF, siliquae formation

Table 3. Effect of agro-chemicals on yield, biological yields, productivity efficiency and oil and protein recovery of Indian mustard (pooled data of 2 years)

Treatment variables/ha basis	Seed yield (t/ha)	Biological yield (t/ha)	Productivity efficiency (kg/ha/day)	Harvest index (%)	Oil recovery (kg/ha)	Protein recovery (kg/ha)
Control (input not applied)	0.76	3.91	34.10	19.3	263.6	107.2
RDF + water spray (WS) at 50% FL and 50% SF	1.02	4.85	41.26	21.1	385.4	153.2
RDF + 2.5 kg hydrogel + WS at 50% FL and 50% SF	1.14	5.25	44.53	21.7	451.9	180.4
RDF + 0.05% thiourea (TU) at 50% FL and 50% SF	1.07	5.33	45.34	20.1	413.5	173.7
RDF + 2.5 kg hydrogel + 0.05% TU at 50% FL and 50% SF	1.41	6.23	52.58	22.6	589.9	233.5
RDF + 2.5 kghydrogel	1.00	4.85	41.76	20.7	376.6	156.2
RDF + 5.0 kghydrogel	1.18	5.69	48.25	20.8	438.8	187.9
RDF + 5.0 kg hydrogel + WS at 50% FL & 50% SF	1.35	6.29	53.06	21.4	524.8	220.1
RDF + 5.0 kghydrogel + 0.05% TU at 50% FL and 50% SF	1.56	6.88	57.62	22.7	648.0	262.7
SEM±	0.07	0.25	2.19	0.9	32.8	14.8
CD (P=0.05) for T	0.21	0.76	6.45	2.6	100.9	43.5
Years	0.13	0.38	3.27	1.0	51.1	21.5
Y×T	0.23	0.86	7.34	2.9	96.1	43.7

RDF, Recommended dose of fertilizer; FL, flowering; SF, siliquae formation quently the photosynthetic rate of the plant. Thus, the positive influence of its interaction resulted in higher seed yield, biological yield, and better production efficiency. These results are in close conformity with the findings of Singh *et al.* (2016) and Singh *et al.* (2017).

Significantly higher seed yield was recorded with 5.0 kg hydrogel + 0.05% thiourea at 50% flowering and at siliquae formation over other agro-chemicals either alone or in combinations. However, both the higher input treatments failed to statistically differ with each other in terms of seed yield and biological yield. Adequate crop nutrition improves vegetative and reproductive growth, as evident by taller and vigorous plants having wider leaf area, accumulated more dry matter and attained more number of siliquae/plant, seeds/siliquae, and other yield-contributing parameters (Mondal *et al.*, 2018).

Oil and protein content and their recoveries

The maximum oil and protein recovery was observed with the basal application of 5.0 kg hydrogel followed by 2 foliar applications of thiourea 0.05% at 50% flowering and at siliqua formation. The oil and protein recovery is directly dependent on seed yield and their contents. Moisture stress at flowering and pod formation reduces seed yield (Singh *et al.,* 2017), which resulted in poor oil and protein recovery in the present study. Haneklaus *et al.* (1999) reported that, sulfhydryl thiourea is involved in the synthesis of fatty acids and sulphur containing amino acids. Higher harvest index was observed in the present study with the combined application of sulfhydryl compounds like thiourea and polymer like hydrogel owing to significant improvement in seed yield.

Economics

The minimum and maximum cost of production were noticed in treatment which received the lowest and highest input, i.e. control and 5.0 kg hydrogel followed by 2 foliar sprays of 0.05% thiourea at 50% flowering and at siliquae formation respectively (Table 4). Similarly, the maximum gross returns and net returns, economic efficiency and benefit: cost ratio were recorded with treatment that incorporated hydrogel @ 5.0 kg followed by 2 foliar spray of 0.05% thiourea at 50% flowering and at siliquae formation; and these were found statistically comparable with the 2.5 kg hydrogel along with 0.05% thiourea at 50% flowering and at siliquae formation. Both the treatments significantly resulted in higher returns, benefit: cost ratio and economic efficiency over the rest of the treatments. Our results confirm the findings of Premi *et al*. (2004), Singh *et al.* (2016) and Shashidhar *et al.* (2020). In the present study, the combined application of hydrogel at sowing, and foliar nutrition of thiourea at flowering and at siliqua formationis augmented the growth, yield, and quality of Indian mustard under water-deficit conditions. Hence it has the direct influence in improving economic efficiency and benefit: cost ratio. This technique can be popularized among the farmers in improving the economic efficiency of the Indian mustard cultivation in the region through large-scale demonstrations.

Based on the field study, it is to conclude that the basal application of recommended dose of fertilizer (60-40-30-30 kg N-P-K-S) accompanied with 5.0 kg hydrogel followed by 2 foliar applications of 0.05% thiourea at 50% flowering and at siliqua formation is a viable management practice for profitable production of late-sown Indian mustard under acidic soils and water-deficit (stress) condition

Table 4. Effect of agro-chemicals on economics of late-sown Indian mustard (pooled data of 2 years)

Treatment variables/ha basis	Cost of production (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Economic efficiency (₹/ha/day)	Benefit: cost ratio
Control (input not applied)	19.60	32.17	12.57	278.6	0.64
RDF + water spray (WS) at 50% FL and 50% SF	26.49	42.85	16.36	361.7	0.62
RDF + 2.5 kg hydrogel + WS at 50% FL and 50% SF	29.79	47.49	17.70	396.0	0.59
RDF + 0.05% thiourea (TU) at 50% FL and 50% SF	26.99	45.12	18.13	380.3	0.67
RDF + 2.5 kg hydrogel + 0.05% TU at 50% FL and 50% SF	30.29	58.11	27.82	479.1	0.92
RDF + 2.5 kg hydrogel	28.97	42.22	13.25	358.7	0.46
RDF + 5.0 kg hydrogel	32.27	49.72	17.45	395.3	0.54
RDF + 5.0 kg hydrogel + WS at 50% FL and 50% SF	33.09	56.48	23.39	466.0	0.71
RDF + 5.0 kg hydrogel + 0.05% TU at 50% FL and 50% SF	33.59	64.58	30.99	524.7	0.92
SEM±	–	2.65	2.68	27.1	0.08
CD (P=0.05) for T	–	7.80	7.80	81.7	0.25
Years	–	5.32	5.32	44.8	0.19
Y×T	–	8.94	8.94	74.5	0.32

Note: As per MSP in 2015–16 abd 2017–18, the price used for mustard seed was ₹34,500 and ₹39,000/tonne and however, for mustard stover was ₹1,250 and ₹1,500/tonne during 2015–16 and 2017–18, respectively

RDF, Recommended dose of fertilizer; FL, flowering; SF, siliquae formation of foothills and shallow valleys of Manipur.

REFERENCES

AICRP (Rapeseed–Mustard). 2016. *Annual Progress Report*. Directorate of Rapeseed–Mustard Research, Sewar, Bharatpur, Rajasthan.

Chandrashekar, U.S., Dadlani, M., Vishwanath, K., Chakrabarty, S.K. and Manjunath, C.T. 2013. Study of morpho-physiological, phenological and reproductive behaviour in protogynous lines of Indian mustard [*Brassica juncea* (L.)]. *Euphytica* **193**: 277–291

El-Hady, O.A., and Camilia, Y. El-Dewiny. 2006. The conditioning effect of composts (natural) and acrylamide hydrogels (synthesized) on sandy calcareous soil. I. Growth response, nutrients uptake and water and fertilizer-use efficiency by tomato plants. *Journal of Applied Sciences Research* **2**(11): 890–898.

Haneklaus, S., Paulsen, H.M., Gupta, A.K., Bloem, E. and Schnug, E. 1999. Influence of sulfur fertilization on yield and quality of oilseed rape and mustard. (In) *Proceedings of the 10th International Rapeseed Congress on New Horizons for an Old Crop*, 26–29 September, 1999, Canberra, Australia, pp. 1–5.

Jagetiya, B.L. and Kaur, M.J. 2006. Role of thiourea in improving productivity of soybean. *International Journal of Plant Sciences* **1**: 308–310.

Johnson, M.S. and Veltkamp, C.J. 1985. Structure and functioning of water storage agricultural polyacrylamides. *Journal of Science Food and Agriculture* **36**: 789–793.

Mondal, M.M.A., Malek, M.A. and Bhuiyan, M.S.H. 2018. The role of morpho-physiological attributes on the seed yield of *Brassica juncea Acta Scientific Agriculture* **2**(5): 22–26.

Premi, O.P., Kumar, A., Sinsinwar, B.S. and Kumar, M. 2004. Productivity and economics of Indian mustard (*Brassica juncea* L.) as influenced by foliar spray of agro-chemicals. *Journal of Oilseeds Research* **21**(2): 299–300.

Shashidhar, K.S., Samuel J.M., Ajay B.C., Singh, A.K., Premaradhya, N., Bhuvaneshwari, S., Elansary, D.O., Wani,S.H. and Elansary, H.O. 2020. Standardizing the hydrogel application rates and foliar nutrition for enhancing yield of lentil (*Lens culinaris*). *Processes* **8**: 420–432.

Singh, A., Singh, A.K. and Kumar, S. 2016. Impact of hydrogel and thiourea on yield and economics of Indian mustard (*Brassica juncea* L.) under moisture stress condition. *Advances in Life Sciences* **5**(19): 8,867–8,869.

Singh, A., Singh, A.K. and Ashwin, C. 2017. Effect of hydrogel and thiourea on yield, quality and nutrient uptake of Indian mustard under moisture stress condition. *Research on Crops* **18**(1): 42–48.

Singh, S.M., Shukla, A., Chaudhary, S., Bhushan, C., Negi, M.S. and Mahapatra. B.S. 2018. Influence of irrigation scheduling and hydrogel application on growth and yield of Indian mustard (*Brassica juncea*). *Indian Journal of Agronomy* **63**(2): 246–249.

Volkamar, K.M. and Chang, C. 1995. Influence of hydrophilic gel polymers on water relations, growth and yield of barley and canola. *Canadian Journal of Plant Sci*ence **75**(3): 605–611.