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Effect of Agro-Chemicals on Growth, Yield and Economics of Indian Mustard (*Brassica juncea* L.) under Limited Irrigation

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ABSTRACT: A field experiment was conducted during *Rabi*, 2022-23 at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan) to study the "Effect of Agro- Chemicals on Growth, Yield and Economics of Indian Mustard (*Brassica juncea* L.) under Limited Irrigation". The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.36 %) and available N (171.48 kg ha^{-1}) and medium available P (15.2 kg ha^{-1}) and available K (232.5 kg ha^{-1}). The experiment was laid out in Randomized Block Design with nine treatments (T1: Control, T2: Cycocel @ 250 ppm, T3: Cycocel @ 500 ppm, T4: Hydrogel @ 2.5 kg ha^{-1}, T5: Hydrogel @ 5 kg ha^{-1}, T6: Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}, T7: Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}, T8: 4 Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}, T9: Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) each replicated thrice. The results showed that application of Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1} recorded significantly higher plant height, dry matter accumulation, No. of siliquae/plant, No. of seeds/siliqua and test weight. The above treatment proved superior to the remaining treatments with respect to seed yield, biological yield (5017.96 kg ha^{-1}) and nutrient uptake. Maximum net returns and benefit cost ratio (2.16) were also obtained with application of Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1} (T9).

Keywords: Mustard, Hydrogel, Cycocel, Growth, Yield, Economics.

INTRODUCTION

Rapeseed and Mustard belongs to the family Cruciferae (*Brassicaceae*) and genus *Brassica*. Brown mustard and Indian mustard are both naturally occurring amphidiploids with chromosome number (2n=36) and Chinese origin. Although it is a self-pollinated crop, there is some cross-pollination (2-15%) because of insects and other factors. Its seeds are known by various names depending on where they are found, such as sarson, rai or raya, toria or lahi. Rape seed is referred to as white sarson and toria, while mustard is referred to as rai, raya, or laha. India is one of the leading oilseeds producing country in the world. Oilseed crop is the succeeding largest agricultural commodity after cereals. Indian mustard is the second important edible oilseed crop after groundnut, meeting the fat requirement of about 50 per cent population in all the northern states of India (Shivran *et al.,* 2019).

India is the third largest rapeseed-mustard producer in the world after China and Canada with 11 per cent of world's total production. Indian mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat, Punjab and Bihar. This crop accounts for nearly one third of the oil produced in India, making it the country's key edible oilseed crop. Total area under mustard in India is 66.90 lakh hectares with annual production of about 101.10 lakh tonnes and an average productivity of about 1511 kg ha^{-1} (Anonymous, 2022). In Rajasthan, rapeseed and mustard occupies prime place amongst all the oilseed crops grown in the state, occupying 27.20 lakh hectares area with annual production of 45.10 lakh tonnes and an average productivity of 1659 kg ha^{-1} (Anonymous, 2022). Rajasthan ranks first both in area and production of rapeseed and mustard in the country. Although it is a major oilseed crop but its productivity in the state is much lower than its realizable yield potential of 2200 to 2400 kg ha^{-1}.

Cycocel (CCC or Chlormequat chloride) and PBZ both block the GA cycle in stages I and II, respectively. Instead of eliminating it or competing with it for the active site, cycocel prevents the production of gibberellins. This is based on the observation that *Fusarium moniliforme*, a fungus, does not make gibberellic acid when cycocel is present. Cell wall thickness and the quantity of vascular bundles were shown to increase after cycocel treatment. CCC is an anti-gibberellin growth retardant, that also plays a major role in drought tolerance (Pirasteh-Anosheh *et al.,* 2016).

The hydrogels are distinguished from other materials by their viscous modulus, which is significantly smaller than the elastic modulus in the plateau region, and by an elastic modulus that exhibits a pronounced

plateau extending to times at least of the order of seconds from the perspective of their mechanical properties (Almdal and Roy 1993). By enhancing soils' ability to retain water and controlling plants' access to water, particularly in arid environments, the hydrogel amendments may promote seedling growth and establishment (Moghadam *et al.,* 2009). Cross-linked materials that are hydrophilic gels, or hydrogels, can absorb a lot of water without dissolving. Hydrogels are distinctive materials because of their softness, intelligence, and water-storing ability (Shibayama and Tanaka 1993). Hydrophilic functional groups attached to the polymer backbone give hydrogels their capacity to absorb water, whereas cross-links between network chains give them their capacity to resist dissolution.

MATERIALS AND METHODS

This experiment was conducted during the *rabi* season of 2022-23 at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan), located at 75° 51′44″ E longitude and 26°48′35″ N latitude and an altitude of 431 m mean sea level. This area is located near Akshyapatra temple, about 19 km from Jaipur city. Organic carbon (0.87%), accessible nitrogen (225 kg/ha), phosphorus (41.8 kg/ha), and potassium (261.2 kg/ha) are the most abundant elements. The region has a subtropical climatic conditions. One hand weeding was performed after 17 days and second was after 17 days of first weeding following sowing to prevent crop-weed competition. Two irrigations were administered at 30-day intervals. The growth characteristics observations were recorded using conventional technique at 30-day intervals and displayed at harvest DAS. Yield metrics were measured on harvest day, February 3rd, 2023. All of the parameters were recorded and statistically analysed using appropriate analysis of variance techniques as described by Gomez and Gomez (1984).

RESULT AND DISSCUSSION

Growth parameters. Plant height (cm). The plant height varied from 173.68 to 194.03 cm among all the treatments. Highest plant height (194.03 cm) was reported with application of treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) which was significantly superior over other treatments. However, it was found that treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}) and T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) were statistically at par with treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}). The minimum plant height at harvest (173.68 cm) was observed in control (T1). Foliar application of cycocel reduced the plant height in greengram (Garai and Datta 2003).

Dry matter accumulation (g/plant). Highest dry matter accumulation in mustard plant (45.43 g $plant^{-1}$) was registered with application of the treatment T9 (Cycocel @ 500ppm + hydrogel @ 5 kg ha^{-1}) which was significantly superior over all treatments. However, it was found that treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}) and T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) were statistically at par with treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}). Singh and Choudhary (2017) reported that the important vegetative growth characters were significantly influenced by different plant growth regulators and variety treatments tried under this investigation. The application of GA3 300 ppm + CCC 1500 ppm recorded highest plant spread, stem diameter, number of primary and secondary branches $plant^{-1}$ and fresh and dry weight of plant.

Yield parameters

Number of Siliquae per plant. The highest number of siliquae $plant^{-1}$ (218.00) was observed with the application of treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) which was significantly superior over all treatments. However, it was found that treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}) and T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) were statistically at par with treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}). (Singh *et al.,* 2001) also reported the same results.

Number of Seeds per Siliquae. Number of seeds $siliqua^{-1}$ was found highest (23.53) in treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) which was significantly superior over all treatments. The number of seeds $siliqua^{-1}$ ranged from 19.22 to 23.53. However, it was found statistically at par with treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}) and T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}). Matysiak and Kaczmarek (2013) reported that increase of seeds/siliqua appeared only at the lower sowing density as a result of application of tebuconazole with CCC.

Grain yield (kg/ha). The maximum seed yield (1757.48 kg ha^{-1}) was observed under the treatment T9 (Cycocel @ 500ppm + hydrogel @ 5 kg ha^{-1}) which was significantly superior over all treatments. However, treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}), T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) and T6 (Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}) were statistically at par with treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}).

Stover yield (kg/ha). The data showed that stover yield varied from 2438.26 to 3260.48 kg ha^{-1} among all the treatments. The maximum stover yield (3260.48 kg ha^{-1}) was observed with T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}). However, treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg/ha), T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) and T6 (Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}) were statistically at par with treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}).

Quality Parameters

Oil Content (%). Oil content of mustard seed ranges from 34.55 to 42.53 per cent among the all treatments. The maximum oil content (42.53 %) was observed with application of treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) followed by treatment T8 (Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}) and T7

(Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}). The minimum oil content (34.55 %) was observed under treatment T1 (Control).

Oil yield (kg ha^{-1}). Oil yield of mustard seed was significantly influenced by different treatments. The maximum oil yield (657.85 kg ha^{-1}) was observed with T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) which excelled all other treatments. The minimum oil yield (378.45 kg ha^{-1}) was observed with treatment T1 (control).

Protein content (%). Treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) gave the highest result of protein content with value 16.65 per cent which was statistically at par with the treatments T8 (Cycocel @ 500ppm + hydrogel @ 2.5 kg ha^{-1}) and T7 (Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}) whose value were 15.87 and 15.56 per cent. The minimum protein content (13.55 %)was observed under treatment T1 (control).

Protein yield (kg ha^{-1}). Treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) recorded the highest protein yield with value 273.29 kg ha^{-1}, the next protein yield (255.76 kg ha^{-1}) was of treatment T8 (Cycocel @ 500ppm + hydrogel @ 2.5 kg ha^{-1}). The minimum protein yield (152.42 kg ha^{-1}) was observed under treatment T1 (control).

Economics: The result [Table 5] showed that the maximum gross returns (96580.00 INR/ha), net returns (66045.00 INR/ha) and B:C ratio (2.16) was recorded in T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) as compared to other treatments. Jain and Thangaraj (2017) found that increase in hydrogel treatment up to 5.0 kg ha^{-1} increased the net returns (₹ 58519 ha^{-1}) but was significant at par with 2.5 kg hydrogel ha^{-1} which was 1.10 fold higher over the control. With B:C Ratio (@ 5 kg 2.33, @ 2.5 kg 2.43).

Table 1: Effect of agro-chemicals on growth attributes of Indian mustard.

Treatments		Growth parameters	
		Plant height (CM)	Accumulation (g/plant)
T1	Control	173.68	36.63
T2	Cycocel @ 250 ppm	175.37	37.59
T3	Cycocel @ 500 ppm	177.01	38.58
T4	Hydrogel @ 2.5 kg ha^{-1}	180.40	39.34
T5	Hydrogel @ 5 kg ha^{-1}	182.44	39.86
T6	Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}	190.74	40.60
T7	Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}	190.94	42.58
T8	Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}	191.49	43.55
T9	Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}	194.03	45.43
	SEm±	1.11	1.29
	CD (p=0.05)	3.29	3.84

Table 2: Effect of agro-chemicals on yield attributes of Indian mustard.

	Treatments	No. of Siliquae plant^{-1}	No. of Seeds siliqua^{-1}
T1	Control	161.54	19.22
T2	Cycocel @ 250 ppm	166.65	19.76
T3	Cycocel @ 500 ppm	169.39	20.27
T4	Hydrogel @ 2.5 kg ha^{-1}	176.56	20.72
T5	Hydrogel @ 5 kg ha^{-1}	181.54	21.26
T6	Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}	188.45	21.63
T7	Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}	202.62	22.33
T8	Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}	209.62	22.85
T9	Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}	218.00	23.53
	SEm(±)	6.73	0.63
	CD (p=0.05)	19.98	1.87

Table 3. Effect of agro-chemicals on yield and harvest index of Indian mustard.

Treatments		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T1	Control	1165.40	2438.26
T2	Cycocel @ 250 ppm	1219.62	2569.63
T3	Cycocel @ 500 ppm	1291.41	2658.37
T4	Hydrogel @ 2.5 kg ha^{-1}	1325.55	2769.32
T5	Hydrogel @ 5 kg ha^{-1}	1380.57	2849.53
T6	Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}	1676.21	3016.76
T7	Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}	1681.21	3082.59
T8	Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}	1690.21	3157.66
T9	Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}	1757.48	3260.48
	SEm(±)	44.18	83.38
	CD (p=0.05)	131.27	247.72

Table 4: Effect of agro-chemicals on oil content and oil yield and protein content and protein yield of Indian mustard.

	Treatments	Oil content (%)	Oil content (kg/ha^{-1})	Oil content (%)	Protein yield (kg/ha)
T_1	Control	34.55	378.45	13.55	152.42
T_2	Cycocel @ 250 ppm	35.53	419.93	13.71	165.33
T_3	Cycocel @ 500 ppm	36.40	445.63	13.89	172.58
T_4	Hydrogel @ 2.5 kg ha^{-1}	37.29	488.28	14.05	189.47
T_5	Hydrogel @ 5 kg ha^{-1}	38.67	508.59	14.57	199.85
T_6	Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}	39.01	541.39	15.16	207.61
T_7	Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}	40.63	576.44	15.56	237.42
T_8	Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}	41.59	592.48	15.87	255.76
T_9	Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}	42.53	657.85	16.65	273.29
	SEm(±)	1.15	18.14	0.43	5.99
	CD (p=0.05)	3.40	53.91	1.27	17.79

Table 5: Effect of agro-chemicals on economics of Indian mustard.

Treatments		Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	Control	60213.00	31493.00	1.09
T_2	Cycocel @ 250 ppm	60500.00	32080.00	1.13
T_3	Cycocel @ 500 ppm	63030.00	34910.00	1.24
T_4	Hydrogel @ 2.5 kg ha^{-1}	67650.00	37715.00	1.26
T_5	Hydrogel @ 5 kg ha^{-1}	71830.00	42195.00	1.42
T_6	Cycocel @ 250 ppm + hydrogel @ 2.5 kg ha^{-1}	75680.00	46345.00	1.58
T_7	Cycocel @ 250 ppm + hydrogel @ 5 kg ha^{-1}	89400.00	60660.00	2.00
T_8	Cycocel @ 500 ppm + hydrogel @ 2.5 kg ha^{-1}	92180.00	61345.00	2.07
T_9	Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}	96580.00	66045.00	2.16
	SEm(±)	2540.21	1814.44	0.05
	CD (p=0.05)	7547.36	5390.97	0.13

CONCLUSIONS

It is concluded that treatment T9 (Cycocel @ 500 ppm + hydrogel @ 5 kg ha^{-1}) was found to be best for obtaining maximum grain yield. It also fetched the maximum gross return, net returns and B:C ratio.

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