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Assessing the Influence of Hydrogel and Salicylic Acid on Indian Mustard (*Brassica juncea* L.) Yield and Quality under restricted irrigation conditions

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ABSTRACT

An experiment was conducted at Dholi farm of RPCAU, Pusa, 2017 to 2020 to evaluate the effectiveness of hydrogel and salicylic acid in increasing the growth and productivity of Indian mustard in restricted irrigation conditions. Twelve treatment combinations were formulated, including control, soil application of hydrogel at 2.5 and 5 kg/ha,foliar spray of salicylic acid @ 100 and 200 ppm at flowering and siliqua formation, and combinations of hydrogel and salicylic acid. The results showed that using hydrogel at 5 kg/ha with two sprays of salicylic acid at 200 ppm at flowering and siliqua formation significantly increased plant height, dry matter, siliquae plant^{-1}, seed yield and oil yield. The highest grain and oil yield were recorded under irrigation treatment applied at pre-flowering and siliqua formation. The experiment findings after three years suggest that the application of hydrogel at 2.5 or 5 kg/ha with two sprays of salicylic acid at 200 ppm at flowering and siliqua formation are beneficial for obtaining high seed and oil yield.

Key words: *Mustard, Hydrogel, Salicylic acid, Restricted irrigation*

Introduction

Indian mustard (*Brassica juncea*) is an important oilseed crop that is widely cultivated for its oil-rich seeds. Approximately 37% of the total area used for growing rapeseed-mustard is dependent on rainfall, making it particularly susceptible to drought (Nazar *et al*., 2015). Drought stress is a major problem for Indian mustard (*Brassica juncea*) cultivation in Bihar, India, where water resources are limited and the crop is often grown under restricted irrigation conditions which can negatively impact yield and seed quality. One potential solution to this problem is the use of hydrogel and salicylic acid has shown promise as a means of improving crop yield and seed quality under drought stress (Khan *et al*., 2019; Liu *et al*., 2011).

Hydrogel is a water-absorbing polymer that can be applied to the soil to improve water retention and reduce the amount of water required for crop growth (Goyal *et al.,* 2018). This can help to improve plant growth and crop yields in conditions where water is limited, such as in rainfed agriculture. Studies have shown that the application of hydrogel in

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soil can increase crop yields, improve water use efficiency, and reduce water loss through evaporation. It can be used to improve crop productivity under various stress conditions such as drought, salinity, and heat.

Salicylic acid is a plant hormone that can promote stress tolerance and improve crop yield under adverse conditions (Zhou *et al*., 2020). Foliar application of salicylic acid (SA) is a well-established method to enhance growth, yield and antioxidant activity of Indian mustard (*Brassica juncea*) under environmental stress conditions like drought and high temperature. Studies have shown that SA can be an effective tool to improve crop growth and yield under water-stress conditions. Salicylic acid improves growth, yield and quality of various oil seed crops like soyabean, sunflower, flax and sesamum (Bakry *et al*., 2012; Reza, 2014; Nayyef and Hammad, 2021; Kuchlan and Kuchlan 2021). These studies suggest that foliar application of SA can be an effective method for improving growth and yield of Indian mustard under environmental stress conditions.

The purpose of this study is to evaluate the effect of hydrogel and salicylic acid application on Indian mustard yield and seed quality under restricted irrigation conditions in Bihar. The study will investigate the influence of these treatments on various parameters such as growth & yielding attributes, seed yield, oil content and protein content. The results of this study will provide valuable information for farmers and researchers in Bihar seeking to improve Indian mustard production under drought stress.

Materials and Method

A field experiment was conducted at Tirhut College of Agriculture Farm, Dholi of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar (India), during the rabi seasons of 2017 to 2020 for 3 years to evaluate the effective dose of hydrogel and salicylic acid for increasing the productivity and improving quality of Indian mustard (Variety-Rajendra Suflam) in restricted irrigation conditions. The study was conducted in Eastern Plain hot sub humid (Moist.) Agro-eco-region having sandy loam soil type with alkaline soil reaction (pH -8.23). The treatments consisted of different rates of hydrogel application to the soil and foliar spray of salicylic acid @ 100 & 200 ppm at flowering and siliqua formation either alone or in combination with control. The total of 12 treatment combinations were laid out in a randomized block design with three replications. The hydrogel used in the study was developed by the Indian Agricultural Research Institute, New Delhi and was applied by mixing it with phosphate fertilizer and drilling it in the planting furrows at the time of sowing. The mustard seed variety used was Rajendra Suflam', planted at a crop geometry of 30 x10 cm. The recommended doses of N, P_2O_5 and K_2O (40:20:20 kg/ha) were applied as basal. For the preparation of an aqueous solution of salicylic acid, a small amount of ethanol was used to dissolve it and then it was added to water. Foliar spray of salicylic acid was done at the flowering and siliqua formation stage with the help of a knapsack sprayer fitted with holocone nozzle with a spray volume of 600 liters/ha. Growth, yield attributes, seed yield, and quality parameters were calculated using standard statistical procedures. The data were analyzed statistically and the results of the pooled analysis are presented.

Results

Plant Height

The table 1 shows the results of a plant height study in which different treatments were applied to the plants. The data shows that the difference between the treatments with the highest plant height and the control group (T_1) is statistically significant at all measurement points, with the exception of the plant height at 30 DAS.

The data suggests that the use of hydrogel and hydrogel in combination with salicylic acid can have a positive impact on plant height. The treatments include a control group (T_1), hydrogel applied at 2.5 kg/ha (T_2) and 5.0 kg/ha (T_3), salicylic acid applied at 100ppm (T_4) and 200ppm (T_5) at flowering and siliqua formation, and a combination of hydrogel and salicylic acid applied at different concentrations (T_6-T_9). The plant height was measured at 30, 60, 90 days after sowing (DAS) and at harvest. The data shows that the use of hydrogel alone (T_2 and T_3) had a significant positive impact on plant height, with the highest plant height observed in the treatment with hydrogel at 2.5 kg/ha (T_2) at 60 DAS and in the treatment with hydrogel at 5.0 kg/ha (T_3) at 90 DAS. The addition of salicylic acid to the hydrogel treatment (T_6, T_7, T_8, T_9) also had a positive impact on

Table 1. Plant height at different stages of Indian mustard under different treatments (Pooled data of 3 years)

Treatment	Plant height (cm)			
	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1: Control	13.74	60.47	151.44	152.79
T_2: Hydrogel @ 2.5Kg/ha	14.54	65.04	158.25	159.56
T_3: Hydrogel @ 5.0Kg/ha	15.23	66.60	163.81	164.08
T_4: Salicylic acid 100 ppm at flowering and siliqua formation	12.85	61.74	155.21	156.72
T_5: Salicylic acid 200ppm at flowering and siliqua formation	13.21	62.44	156.27	157.94
T_6: Hydrogel @ 2.5 Kg/ha + salicylic acid 100 ppm at flowering and siliqua formation	15.03	67.91	165.09	166.76
T_7: Hydrogel @ 2.5Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	15.31	69.97	167.91	169.51
T_8: Hydrogel @ 5.0Kg/ha +salicyclic acid 100 ppm at flowering and siliqua formation	15.57	71.97	169.87	171.44
T_9: Hydrogel @ 5.0Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	15.31	73.00	172.01	173.66
Sem±	0.84	2.20	4.12	4.23
CD (p=0.05)	2.51	6.58	12.37	12.68

plant height, with the highest plant height observed in the treatment with hydrogel at 2.5 kg/ha and 200ppm salicylic acid at flowering and siliqua formation (T_7) at 90 DAS, and in the treatment with hydrogel at 5.0 kg/ha and 200ppm salicylic acid at flowering and siliqua formation (T_9) at harvest.

Plant Dry matter per plant

This table 2 shows the results of a study that measured the dry matter (g plant^{-1}) of different treatments at different growth stages. The treatments include a control group (T_1), hydrogel applied at 2.5 kg/ha (T_2) and 5.0 kg/ha (T_3), salicylic acid applied at 100ppm (T_4) and 200ppm (T_5) at flowering and siliqua formation, and a combination of hydrogel and salicylic acid applied at different concentrations (T_6-T_9). The dry matter was measured at 30, 60, 90 days after sowing (DAS) and at harvest. The data shows that the difference between the treatments with the highest dry matter and the control group (T_1) is statistically significant at all measurement points, with the exception of the dry matter at 30 DAS. The results indicate that the use of hydrogel alone (T_2, T_3) and in combination with salicylic acid (T_6-T_9) had a positive impact on dry matter production, with the highest dry matter observed in the treatments with hydrogel at 2.5 kg/ha and 5.0 kg/ha (T_2, T_3) at harvest and in the treatment with hy-

Table 2. Dry matters per plant at different stages of Indian mustard under different treatments (Pooled data of 3 years)

Treatment	Drymatter (g plant^{-1})			
	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
T_1: Control	0.25	3.67	13.29	18.37
T_2: Hydrogel @ 2.5Kg/ha	0.40	3.84	15.04	22.36
T_3: Hydrogel @ 5.0Kg/ha	0.38	4.76	15.31	22.21
T_4: Salicylic acid 100ppm at flowering and siliqua formation	0.35	5.25	15.97	25.04
T_5: Salicylic acid 200 ppm at flowering and siliqua formation	0.37	5.49	16.47	26.50
T_6: Hydrogel @ 2.5 Kg/ha + salicylic acid 100 ppm at flowering and siliqua formation	0.34	5.56	16.50	27.75
T_7: Hydrogel @ 2.5Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	0.38	5.64	16.64	27.27
T_8: Hydrogel @ 5.0Kg/ha +salicyclic acid 100 ppm at flowering and siliqua formation	0.56	5.64	18.24	28.29
T_9: Hydrogel @ 5.0Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	0.46	6.16	19.15	32.06
Sem±	0.03	0.40	1.06	1.73
CD (p=0.05)	0.10	1.20	3.17	5.19

drogel at 5.0 kg/ha and 200ppm salicylic acid at flowering and siliqua formation (T_9) at harvest. The addition of salicylic acid (T_4-T_5) alone also had a positive impact on dry matter production, with the highest dry matter observed in the treatment with 200ppm salicylic acid at flowering and siliqua formation (T_5) at harvest.

Yield Attributes

This Table 3 shows the results of a study that measured the number of siliquae per plant, number of seeds per siliqua, 1000-seed weight, and siliquae per plant for different treatments. The treatments include a control group (T_1), hydrogel applied at 2.5 kg/ha (T_2) and 5.0 kg/ha (T_3), salicylic acid applied at 100ppm (T_4) and 200ppm (T_5) at flowering and siliqua formation, and a combination of hydrogel and salicylic acid applied at different concentrations (T_6-T_9). The data indicates that the use of hydrogel alone (T_2, T_3) and in combination with salicylic acid (T_6-T_9) had a positive impact on the number of siliquae per plant and the number of seeds per siliqua. The highest number of siliquae per plant was observed in the treatment with hydrogel at 5.0 kg/ha and salicylic acid 200ppm at flowering and siliqua formation (T_9) with 4.28 siliquae per plant, and the highest number of seeds per siliqua was observed in the same treatment with 12.46 seeds per siliqua. The 1000-seed weight was slightly higher in the treatments T_8 and T_9 with 4.87g and 4.92g respectively.

Yield and oil content

The table 4 shows the results of a study that measured the seed yield, straw yield, harvest index, oil content, and oil yield of different treatments. The treatments include a control group (T_1), hydrogel applied at 2.5 kg/ha (T_2) and 5.0 kg/ha (T_3), salicylic acid applied at 100ppm (T_4) and 200ppm (T_5) at flowering and siliqua formation, and a combination of hydrogel and salicylic acid applied at different concentrations (T_6-T_9). The data indicates that the use of hydrogel alone (T_2, T_3) and in combination with salicylic acid (T_6-T_9) had a positive impact on seed yield, straw yield, and oil yield. The highest seed yield was observed in the treatment with hydrogel at 5.0 kg/ha (T_3) with 1225.37 kg ha^{-1}, the highest straw yield was observed in the treatment with hydrogel at 5.0 kg/ha and salicylic acid 200ppm at flowering and siliqua formation (T_9) with 5096.34 kg ha^{-1}, and the highest oil yield was observed in the same treatment with 577.84 kg ha^{-1}. The harvest index, which is the proportion of seed yield to total biomass, was slightly higher in the treatments T_8 and T_9 with 22.09% and 22.43% respectively. The oil content, which is the percentage of oil in the seed, was higher in the treatments T_7 and T_9 with 38% and 39.21% respectively. The data shows that the difference between the treatments with the highest seed yield, straw yield, and oil yield and the control group (T_1) is statistically significant.

Discussion

Salicylic acid is a plant hormone that plays an im-

Table 3. Yield attributes of Indian mustard under different treatments (Pooled data of 3 years)

Treatment	No. of siliqua $plant^{-1}$	Siliquae/ plant	Seeds/ siliqua	1000-seed weight (g)
T_1: Control	148.43	3.17	10.49	4.40
T_2: Hydrogel @ 2.5Kg/ha	165.54	3.25	11.26	4.61
T_3: Hydrogel @ 5.0Kg/ha	166.50	3.52	11.39	4.68
T_4: Salicylic acid 100ppm at flowering and siliqua formation	153.50	3.02	10.97	4.49
T_5: Salicylic acid 200ppm at flowering and siliqua formation	159.02	3.05	11.11	4.52
T_6: Hydrogel @ 2.5 Kg/ha + salicylic acid 100 ppm at flowering and siliqua formation	169.02	3.71	11.40	4.75
T_7: Hydrogel @ 2.5Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	170.79	3.81	11.58	4.82
T_8: Hydrogel @ 5.0Kg/ha +salicyclic acid 100 ppm at flowering and siliqua formation	174.69	4.18	12.19	4.87
T_9: Hydrogel @ 5.0Kg/ha +salicyclic acid 200 ppm at flowering and siliqua formation	174.93	4.28	12.46	4.92
Sem±	5.67	0.22	0.50	0.16
CD (p=0.05)	17.0	0.65	NS	NS

portant role in various physiological processes, including growth, development, and stress tolerance. Research studies have shown that the use of hydrogel in conjunction with salicylic acid can have a synergistic effect on plant growth and development. One study found that the application of hydrogel and salicylic acid to *Brassica juncea* (mustard) plants improved growth parameters such as plant height, leaf area, and dry weight. The study also found that the combination of hydrogel and salicylic acid increased the photosynthetic rate and reduced water loss through transpiration.

Hydrogel retain water as well as nutrients and make them readily available to plants as needed. which can encourage root growth. Meanwhile, Salicylic acid enhance various physiological processes, including growth, development, and stress tolerance which helps the uptake of nutrients, such as nitrates and phosphates, by roots. Additionally, Salicylic acid increase the activity of enzymes involved in photosynthesis, which can lead to improved crop yields by increasing the rate at which the plant converts sunlight into energy (Gunes *et al*., 2007). This can lead to improved crop yields by making sure the plant has access to the nutrients it needs to grow cause to increase the number of fruits set by the plant and to increase the size of the fruits. This can lead to improved crop yields by increasing the amount of produce the plant produces. Also, reported that the combination of hydrogel and salicylic acid improved the tolerance of *Brassica juncea* plants to drought stress by increasing the activity of antioxidant enzymes and reducing the level of oxidative damage. It also improves the quality of the yield like increased oil content.

Hydrogel used to retain water and nutrients in the soil, making them readily available to the plant's roots. This can improve the plant's overall growth and health. Salicylic acid, on the other hand, is a plant hormone that can trigger the plant's defense mechanisms against stressors such as disease and pests. This can also lead to improved growth and health. Additionally, salicylic acid has been found to enhance the uptake of nutrients and water by roots, which helps the plant to grow better. In turns crop yielding attributes. The authors reported that the treatment increased the oil content, protein content and improved the quality of the yield. The use of hydrogel and salicylic acid improved crop yield and water use efficiency in mustard plants under water-limited conditions. Similar results of yield advantage have been reported by (Rathore *at al*., 2020; Singh *et al*., 2017) in mustard, (Rathore *at al*., 2019) in pearl millet, and by (Dai *et al*., 2017) in sorghum.

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Table 4. Yield, Harvest Index, oil content and oil yield of Indian mustard under different treatments (Pooled data of 3 years)

Treatment	Seed Yield ($Kgha^{-1}$)	Straw Yield ($Kgha^{-1}$)	Harvest Index (%)	Oil content (%)	Oil yield ($kg\ ha^{-1}$)
T_1: Control	839	3149	20.98	36.33	303.96
T_2: Hydrogel @ 2.5Kg/ha	1167	4261	21.44	37.43	439.76
T_3: Hydrogel @ 5.0Kg/ha	1225	4528	21.32	37.50	459.54
T_4: Salicylic acid 100ppm at flowering and siliqua formation	1039	3835	21.34	37.12	385.26
T_5: Salicylic acid 200ppm at flowering & siliqua formation	1115	4072	21.49	37.35	415.50
T_6: Hydrogel @ 2.5 Kg/ha + salicylic acid 100ppm at flowering and siliqua formation	1292	4716	21.54	37.47	486.36
T_7: Hydrogel @ 2.5Kg/ha +salicyclic acid 200ppm at flowering and siliqua formation	1342	4939	21.36	38.00	510.74
T_8: Hydrogel @ 5.0Kg/ha +salicyclic acid 100ppm at flowering and siliqua formation	1413	4979	22.09	38.45	542.63
T_9: Hydrogel @ 5.0Kg/ha +salicyclic acid 200ppm at flowering and siliqua formation	1473	5096	22.43	39.21	577.84
Sem±	53.53	148.9	0.70	1.71	33.41
CD (p=0.05)	160.45	446.4	2.11	NS	100

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