

**Using hydrogel and salicylic acid to increase the yield, profitability, and water efficiency of Indian mustard (*Brassica juncea*)**

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**ABSTRACT**

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Due to water scarcity, increasing Indian mustard (*Brassica juncea* (L.) Czern.) production in Rajasthan's arid and semi-arid regions is a major challenge. The lack of water in certain areas of India results in reduced mustard production. A field experiment was conducted at the Sri Karan Narendra Agriculture University research farm in Jobner, Rajasthan, during the rabi (winter) seasons of 2018–19, 2019–20, and 2020–21 to evaluate the effects of hydrogel and foliar application of salicylic acid on the growth, yield, economic returns, and water use efficiency of Indian mustard. The results demonstrated a significant and very effective impact from foliar spraying hydrogel at a rate of 5.0 kg/ha together with salicylic acid at a concentration of 200 ppm during the blooming and siliqua production phases. This treatment increased growth characteristics, yield features, seed yield (1840 kg/ha), stover yield (3847 kg/ha), water usage efficiency (8.53 kg/ha-mm), protein content (18.6%), oil content (39.13%), net returns (₹51,710/ha), and benefit-cost ratio (2.03). Furthermore, similar results were obtained for treatments containing 2.5 kg/ha of hydrogel with 200 ppm of salicylic acid and 5.0 kg/ha of hydrogel with 100 ppm of salicylic acid. The combined findings of the experiment confirm that hydrogel and salicylic acid are a practical and effective way to increase the yield, profitability, and water-use efficiency of Indian mustard in the dry and semi-arid regions of Rajasthan.

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**Keywords:** hydrogel, mustard, salicylic acid, water efficiency, yield

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**Introduction**

*Brassica juncea* (L.) Czern., often known as Indian mustard, is a significant oilseed crop that is cultivated in India during the winter (rabi) season. In northern India, it yields edible oil, which is widely used as a cooking medium. Rajasthan is the Indian state that produces the highest rapeseed and mustard in terms of both production and planted area (Anonymous 2022). Although this significant oilseed crop is well-known in the state, its productivity is significantly below what it might provide. The way to achieve progress is via the use of state-of-the-art agricultural production technologies. The primary reasons of mustard's low yield are water stress and other biotic and abiotic conditions. On the sandy soils of Rajasthan's semi-arid regions, where crop water needs are not sufficiently satisfied, inadequate soil moisture conservation is a major issue. This deficit produces moisture stress during the active growth period, which seriously hinders the crop's development. In this case, the introduction: 1 Sri Karan Narendra Agriculture University, Jobner, Rajasthan; 2 CCS Haryana Agricultural University, Hisar, Haryana. \*Hydrogel is a unique solution (corresponding author email: pkumawat.agro@gmail.com). Hydrogel is a cross-linked, insoluble three-dimensional polymer that can absorb more than 400 times its own weight in water. It exhibits a gradual release of absorbed water in addition to the additional benefit of enhancing various hydro-physical properties of the soil. Anupama and Parmar (2012) showed that a number of crops' yield and water-use efficiency were greatly enhanced by the application of hydrogel.

Salicylic acid is a naturally occurring phenolic phytohormone that is vital to plant physiology. Among other aspects of plant development, it has an impact on growth, photosynthesis, transpiration, ion uptake, and transport (Nasrin et al. 2014). It aids in boosting resilience to osmotic stress, heat, cold, and drought. Its main role is to support osmotic adjustment, which helps regulate the water balance within cells and, therefore, reduces

water loss from these cells. Applying hydrogel and salicylic acid together is a possible management approach to boost mustard output in the face of water scarcity problems. In light of the above stated factors, the present study was carried out to evaluate the impacts of hydrogel and salicylic acid focuses on increasing the yield, profits, and water-use efficiency of Indian mustard.

## **MATERIALS AND METHODS**

A field experiment was conducted at the Sri Karan Narendra Agriculture University research farm in Jobner [26°05' N; 75°28' E; altitude of 427 meters amsl], Rajasthan, throughout the winter (rabi) seasons of 2018–19, 2019–20, and 2020–21. This region is situated in agroclimatic zone III A, which is the semi-arid eastern plain zone of Rajasthan. There are noticeable year-round temperature fluctuations in this region, which is obviously semi-arid. Summers enjoy high temperatures, sometimes reaching 48°C, while winters witness a sharp drop in temperature, with lows as low as -1.0°C. Frost occurrences are common throughout the winter. The soil in the experimental field is classified as loamy sand and has a low organic carbon content (0.23%). The soil samples were taken from the top 15 cm of soil depth. It contains medium levels of available phosphorus (P) at 16.5 kg/ha, available nitrogen (N) at 135.8 kg/ha, and available potassium (K) at 149.6 kg/ha. T1, Control; T2, Hydrogel application at 2.5 kg/ha; T3, 5.0 kg/ha; T4, Salicylic acid application at 100 ppm during the siliqua formation and flowering stages; T5, Salicylic acid application at 200 ppm during the same stages; T6, Hydrogel at 2.5 kg/ha combined with Salicylic acid at 100 ppm; T7, Hydrogel at 2.5 kg/ha combined with Salicylic acid at 200 ppm; T8, Hydrogel at 5.0 kg/ha; and T9, Hydrogel at 5.0 kg/ha. These treatments were assessed using a randomized block design (RBD) with three replications, each encompassing a gross plot size of 5.0 × 3.6 m<sup>2</sup>. The mustard variety NRCHB 101 received a baseline dose of 60 kg of nitrogen (N) and 40 kg of phosphorus (P<sub>2</sub>O<sub>5</sub>) per hectare via urea and diammonium phosphate (DAP) before to planting. In order to enhance soil conditions and water retention, plants from a 1 m row were randomly plucked after hydrogel was thoroughly mixed with the harvest. After the roots were removed, the samples were left to air dry for a few days before being dried in an electric oven at 70°C until their weight remained consistent. Based on the given weight, the average dry matter accumulation per meter of the row (in grams) was subsequently shown. When the main plots reached maturity, they were harvested, and the material was then completely sun-dried. The weight of the sun-dried food from each plot was recorded independently before to the threshing procedure. This weight is known as the biological yield. The threshing, washing, and drying procedures were meticulously carried out in order to get the seed yield. For a thorough assessment, the economic elements of the various treatments were examined, taking into consideration the input costs and the revenue from the product at the current market pricing. Water-use efficiency (WUE) was calculated and expressed as kg/ha-mm using the method provided by Viets (1966):

$$WUE = \frac{\text{Seed yield (kg/ha)}}{\text{Actual Evapo-transpiration (mm)}}$$

The amount of protein in the seed was calculated by multiplying its nitrogen content by the

6.25. Using a Soxhlet apparatus and petroleum ether (60–80°C) as an extractant, the oil content of mustard seed was determined using the procedure described in the A.O.A.C. (1960). Standard methods of analysis of variance (ANOVA) were used to statistically analyze the experimental data. Following the methods described by Gomez and Gomez (1984), pooled analysis of the data was carried out. Additionally, important differences at the 5% probability level were used for mean comparison.

## **OUTCOMES AND TALK**

Growth parameters: According to the three-year pooled results (Table 1), every treatment demonstrated notable Table 1: Hydrogel and salicylic acid's effects on Indian mustard growth metrics at harvest (three-year pooled data)

| Treatment            | Plant height (cm) | Branches/plant |           | Dry matter (g/m row length) |
|----------------------|-------------------|----------------|-----------|-----------------------------|
|                      |                   | Primary        | Secondary |                             |
| T <sub>1</sub>       | 155.3             | 5.18           | 9.52      | 190.0                       |
| T <sub>2</sub>       | 172.8             | 6.20           | 10.4      | 208.7                       |
| T <sub>3</sub>       | 177.4             | 6.32           | 10.8      | 216.3                       |
| T <sub>4</sub>       | 171.1             | 6.22           | 10.3      | 205.7                       |
| T <sub>5</sub>       | 175.7             | 6.37           | 10.7      | 211.7                       |
| T <sub>6</sub>       | 185.3             | 6.84           | 12.9      | 228.3                       |
| T <sub>7</sub>       | 187.2             | 6.94           | 13.2      | 230.7                       |
| T <sub>8</sub>       | 193.1             | 7.17           | 13.5      | 240.0                       |
| T <sub>9</sub>       | 196.0             | 7.60           | 13.7      | 244.0                       |
| SEm±                 | 3.59              | 0.14           | 0.23      | 5.01                        |
| CD ( <i>P</i> =0.05) | 10.78             | 0.42           | 0.71      | 15.02                       |

Just before to planting, the soil was mixed with the soil and placed to the chosen experimental plots within furrows. As per the treatment strategy, salicylic acid was sprayed on the leaves throughout the phases of blooming and siliqua production. Using a seed rate of 4 kg/ha, the crop was sown with a row-to-row spacing of 30 cm and a plant-to-plant distance of 10 cm. To guaranty a suitable plant stand, thinning operations were carried out 20 days after sowing (DAS). To improve aeration and get rid of weeds, hand hoeing and weeding were then done at 35 DAS. The growing methods adhered to the zone's suggested agronomic criteria.

Five plants were carefully chosen from each assigned plot during the harvest period. For further measurements, these plants were meticulously marked with important details including plant height, number of branches/plant, siliqua/plant, and

seeds or siliqua. Details of the treatment are provided under Materials and Methods in order to evaluate dry matter buildup at the time.

impact in improving Indian mustard growth characteristics relative to control. Among all the treatments, the one that applied 5.0 kg/ha of hydrogel and 200 ppm of salicylic acid during the flowering and siliqua formation stages produced the highest dry matter production (244.0 g/m of row length), the tallest plant height (196.0 cm), and the greatest number of primary branches (7.60) and secondary branches per plant (13.7). It's important to note that the treatments that applied 5.0 kg/ha of hydrogel and 100 ppm of salicylic acid during the stages of siliqua formation and flowering, as well as the treatments that applied 2.5 kg/ha of hydrogel and 200 ppm of salicylic acid during the same stages, performed similarly in these areas. These treatments were statistically identical in enhancing plant height, dry matter accumulation, and the growth of main and secondary plants, according to the observed similarities in the aforementioned criteria. Furthermore, a single application of hydrogel at 5.0 kg/ha and 2.5 kg/ha, together with salicylic acid at 200 ppm and 100 ppm, showed a significant increase in mustard plant height, main and secondary branches/plant, and dry matter accumulation compared to the control. Hydrogel's ability to retain moisture allows it to maintain ideal soil moisture levels in the rhizosphere for a longer period of time, which promotes nutrient availability and, in turn, vital physiological processes that propel plant growth (Anupama et al. 2005). Salicylic acid foliar spray was essential for boosting plant height, branching, and crop growth. The results of the current experiment also closely match those of Sharma et al. (2017), who found that applying salicylic acid to mustard crops greatly improved growth indices. Additionally, prior research by Jat et al. (2018) supports the current study's conclusions. Water usage efficiency (WUE), yield, and yield attributes:

The largest number of siliqua per plant (223.0), seeds per siliqua (14.2), and maximum test weight (4.42) were obtained when hydrogel (5.0 kg/ha) and salicylic acid (200 ppm) were applied throughout the flowering and siliqua formation phases. This result was much better than the control, hydrogel treatments at 2.5 kg/ha and 5.0 kg/ha, and salicylic acid treatments at 200 ppm and 100 ppm. Additionally, it was statistically comparable to the treatments hydrogel at 5.0 kg/ha + salicylic acid at 100 ppm and hydrogel at 2.5 kg/ha + salicylic acid at 200

ppm (Table 2). This specific treatment also had the greatest stover output (3847 kg/ha) and seed yield (1840 kg/ha). In this regard, it was statistically comparable to the treatment hydrogel at 5.0 kg/ha + salicylic acid at 100 ppm throughout the blooming and siliqua production phases, as well as to the treatment hydrogel at 2.5 kg/ha + salicylic acid at 200 ppm during the same stages. Together, these three treatments significantly increased the seed output above the control by 46.14%, 43.84%, and 36.13%, respectively. Increased water availability and, indirectly, better nutrient delivery made possible by the application of hydrogel under water stress conditions are responsible for the higher yields and other yield-related characteristics shown in these treatments. This finally led to increased production by improving the transfer of water, nutrients, and photosynthates (El Hady et al. 2006). The highest number of siliqua/plant and 1000-seed weight of Indian mustard were reported when hydrogel was applied at a rate of 5.0 kg/ha, according to Singh et al. (2017). Additionally, salicylic acid's involvement in cell division and stress reduction may be responsible for the improved mustard production in the current research brought about by foliar spraying. The foliar spraying of salicylic acid, which enhanced photosynthates' translocation into reproductive organs, may have contributed to the experiment's increased seed output. The higher mustard seed output is indicative of this improvement. The yield characteristics and mustard yield were further improved by using hydrogel and salicylic acid together. Additionally, Kumawat et al. (2021) noted a significant increase in the quantity of seeds and siliqua per plant.

Table 2: Hydrogel and salicylic acid's effects on Indian mustard yield characteristics, yield, and WUE (three-year pooled data)

| Treatment   | Siliquea/ plant | Seeds/ siliqua | Test weight (g) | Seed yield (kg/ha) | Stover yield (kg/ha) | WUE (kg/ha-mm) |
|-------------|-----------------|----------------|-----------------|--------------------|----------------------|----------------|
| T1          | 171.5           | 10.1           | 3.38            | 1259               | 2753                 | 6.37           |
| T2          | 188.7           | 11.5           | 3.86            | 1448               | 2967                 | 7.47           |
| T3          | 193.6           | 11.8           | 4.08            | 1498               | 3141                 | 8.23           |
| T4          | 184.8           | 11.4           | 3.84            | 1441               | 2694                 | 6.73           |
| T5          | 189.6           | 11.6           | 3.93            | 1455               | 2743                 | 6.77           |
| T6          | 208.6           | 13.1           | 4.17            | 1700               | 3568                 | 7.87           |
| T7          | 211.4           | 13.4           | 4.24            | 1714               | 3605                 | 7.90           |
| T8          | 216.8           | 13.9           | 4.34            | 1811               | 3822                 | 8.43           |
| T9          | 223.0           | 14.1           | 4.42            | 1840               | 3847                 | 8.53           |
| SEm±        | 3.81            | 0.22           | 0.06            | 27.3               | 90.8                 | 0.16           |
| CD (P=0.05) | 11.4            | 0.66           | 0.20            | 81.9               | 272.4                | 0.47           |

Treatment details are given under Materials and Methods.

siliqua and test weight of taramira as a result of applying 5.0 kg hydrogel/ha together with 100 ppm salicylic acid. These outcomes also support Meena et al. (2020)'s findings.

The application of 5.0 kg/ha of hydrogel and 200 ppm of salicylic acid during the flowering and siliqua formation stages proved to be the most effective, showing the highest water use efficiency (8.53 kg/ha-mm) for Indian mustard, according to the combined data from the three years of the study. This performance was statistically comparable to the treatment that produced a water consumption efficiency of 8.43 kg/ha-mm by combining 5.0 kg/ha of hydrogel with 100 ppm of salicylic acid. Interestingly, both of these therapy combinations performed noticeably better than the other therapies used (Table 2). When 5.0 kg/ha of hydrogel and 200 ppm of salicylic acid were applied to the soil, the WUE of Indian mustard showed a significant increase of 33.9% in comparison to the control. Additionally, as compared to the control, the water usage efficiency of mustard was significantly improved by the single treatments of hydrogel at 5.0 kg/ha and 2.5 kg/ha, as well as salicylic acid at 200 ppm and 100 ppm. The mustard crop's increased water consumption may be explained by hydrogel's slow water release, strengthened soil structure, encouraged root development, and decreased watering frequency. Crop yield increased overall as a result of these combined impacts. Rathore et al. (2020) also showed similar results with mustard. The idea that using hydrogel might be a useful and sustainable method for optimizing crop and water productivity is further supported by Bharat et al. (2019), who also noted the increased seed production and WUE of Indian mustard.

Quality and economics: Over the course of all three years, the experimental findings consistently showed that

the combination of 5.0 kg/ha of hydrogel and 200 ppm of salicylic acid produced the greatest protein content (18.6%) and seed oil content (39.3%). This result was statistically comparable to the treatments that included 5.0 kg/ha of hydrogel containing 100 ppm of salicylic acid, 2.5 kg/ha of hydrogel containing 200 ppm of salicylic acid, and 2.5 kg/ha of hydrogel containing 100 ppm of salicylic acid. The protein and lipid contents of these treatments were much higher than those of the control (Table 3). Additionally, when hydrogel and salicylic acid were applied separately at different doses, the seeds' protein and oil content improved in comparison to the control treatment. In this work, the application of salicylic acid and hydrogel together created a more favorable nutritional environment in the soil and plant system. In this study, the application of hydrogel and salicylic acid together produced a more favorable nutritional environment for the soil and plant system. As a result, the mustard crop's seed oil and protein content significantly increased. A research on Indian mustard by Meena et al. (2020) revealed similar findings.

Table 3: The impact of hydrogel and salicylic acid on the economics and quality of Indian mustard (three-year pooled data)

| Treatment   | Protein content (%) | Oil content (%) | Gross returns (₹/ha) | Net returns (₹/ha) | B:C ratio |
|-------------|---------------------|-----------------|----------------------|--------------------|-----------|
| T1          | 17.1                | 37.39           | 54622                | 38134              | 2.30      |
| T2          | 17.7                | 38.10           | 62358                | 42710              | 2.19      |
| T3          | 17.8                | 38.20           | 64421                | 41346              | 1.81      |
| T4          | 17.5                | 38.17           | 62023                | 44535              | 2.55      |
| T5          | 17.8                | 38.33           | 62833                | 44345              | 2.40      |
| T6          | 18.0                | 38.57           | 71216                | 50301              | 2.44      |
| T7          | 18.2                | 38.67           | 72024                | 50276              | 2.35      |
| T8          | 18.5                | 38.93           | 76073                | 51331              | 2.09      |
| T9          | 18.6                | 39.13           | 77418                | 51710              | 2.03      |
| SEm±        | 0.30                | 0.49            | 1885                 | 1052               | 0.06      |
| CD (P=0.05) | 0.88                | 1.47            | 5652                 | 3153               | 0.17      |

Treatment details are given under Materials and Methods.

The economic feasibility of treatments is the most important consideration when making suggestions to farmers. Following a comparative economic analysis of the different treatments, it became clear that applying 5.0 kg/ha of hydrogel along with 200 ppm of salicylic acid during the flowering and siliqua formation stages produced the highest gross returns (₹77,418/ha) and net returns (₹51,710/ha). Following this, the treatment with 5.0 kg/ha of hydrogel and 100 ppm of salicylic acid produced gross returns of ₹76,073/ha and net returns of ₹51,331/ha, whereas the treatment with 2.5 kg/ha of hydrogel and 100 ppm of salicylic acid produced net returns of ₹50,276/ha and gross returns of ₹72,024/ha. Compared to the control, these three treatments boosted net returns by ₹13,576, ₹13,197, and ₹12,142/ha, respectively. Additionally, throughout the blooming and siliqua formation phases, the administration of hydrogel at rates of 2.5 kg/ha and 5.0 kg/ha, as well as salicylic acid at concentrations of 100 ppm and 200 ppm, produced higher gross returns and net returns than the control. However, throughout the blooming and siliqua production phases, the foliar spray of salicylic acid at 100 ppm showed the highest benefit-cost (B:C) ratio (2.55). Because this therapy is less expensive, the B:C ratio is greater. The improved crop yield is probably the main cause of the greater net returns obtained with the combination application of hydrogel and salicylic acid when compared to other treatments. Economic benefits also resulted from increased nutrient availability, decreased input prices, and optimised water usage efficiency. According to research by Rehman et al. (2011) and Meena et al. (2020), there is a link between higher yield and better economic returns.

A thorough three-year study's findings led to a definitive suggestion for Indian mustard in Rajasthan's semi-arid areas. The best strategy

entails using hydrogel at rates of 5.0 kg/ha or 2.5 kg/ha in conjunction with salicylic acid at 200 ppm or 100 ppm throughout the phases of siliqua development and flowering to increase Indian mustard production, net returns, and water usage efficiency. These findings have important ramifications for sustainable farming methods in water-constrained settings and provide insightful information for maximising mustard production.

Despite difficult weather circumstances, farmers in Rajasthan's semi-arid and dry areas may maximise their mustard yield by using hydrogel and salicylic acid during certain times of crop development.

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