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EFFECTS OF HYDROGEL AND SALICYLIC ACID ON THE GROWTH AND YIELD OF MUSTARD UNDER RAINFED CONDITION

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Abstract

A field experiment was conducted during winter (*rabi*) season of 2017-18 at Varanasi to evaluate the effects of hydrogel as Super Absorbent Polymer (SAP) and salicylic acid (SA) as stress-ameliorating agent, in growth and productivity of Indian mustard (*Brassica juncea* L.) at rainfed condition. The experiment comprised nine treatments such as Control (T1), Hydrogel (H) @ 2.5 kg/ha (T2), H @ 5 kg/ha (T3), SA 100 ppm (T4), Salicylic acid (SA) 200 ppm (T5), H @ 2.5 kg/ha+ SA 100 ppm (T6), H @ 2.5 kg/ha+ SA 200 ppm (T7), H @ 5 kg/ha+ SA 100 ppm (T8), and H @ 5 kg/ha+ SA 200 ppm (T9). Among the different treatments, soil application of H @ 5 kg/ha and foliar spray of SA@ 200 ppm registered the highest value (mean of two year) of plant height (177.66 cm), primary (7.37) and secondary branches (7.74), siliqua/plant (306.84) as well as maximum seed yield (18.02 q/ha) and straw yield (2344.09 kg/ha). Exogeneous spray of SA alone with higher dose performed better in all parameters than individual application of hydrogel, however, their combination also gave superior result in minimizing moisture stress in plant.

Introduction

Rapeseed-mustard is grown in many temperate and sub-tropical region particularly in arid and semi-arid regions of the world (Ashraf and McNeilly 2004). India is the fourth largest producer of rapeseed-mustard (8.5 MT) after Canada (19.49 MT), European Union (16.29 MT) and China (14 MT) (USDA, 2021). Also, India is the largest importer of edible oil ($10.5 billion) followed by China and USA which share nearly 15% in world vegetable import (FAO, 2019). Indian mustard (*Brassica juncea* Cosson and *Czern* L.) is a predominant oilseed crop and covers nearly 80% of total rapeseed mustard growing area and contribute nearly 31.3% in domestic edible oilseed production (Rathore *et al.* 2019).

Worldwide production of oilseed declined after 2018 and rape seed and mustard production grow by 1.4% p.a., only in the 2019-2020 which is projected to grow 3.4% p.a. There is a significant gap between global productivity (20.47 q/ha) and India's productivity (13.24 q/ha) and it can be can be attributed to the crop's susceptibility to various of abiotic and biotic stresses specially moisture stress. The water requirement of Indian mustard is low nearly 25-35 cm (Rathore *et al.* 2017) but its cultivation is mainly neglected due to untimely rainfall, shortage of moisture during sowing window and dependency on conserved soil moisture of previous kharif crop.

In recent year agricultural sector has begun to suffer a global water scarcity challenge which affect the mustard yield as heavy and scanty application both lower down the yield. Agriculture sector (85%) is the most water consuming area compared to industrial (10%) and domestic (5%).

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India ranks 41 among 181 countries with regard to water stress. More than 42% of net cultivated area comes under dry land and 30% area are facing insufficient rainfall (Soni *et al.* 2019). So, there is need to have some technology which can preserve soil moisture without compromising on crop yield and protect crop from stress.

Hydrogel also known as Super Absorbent Polymer (SAP), which is a synthetic hygroscopic macro molecule which swell in water and improves hydro-physical properties of soil. These covalent bonded cross-linked polymers can absorb water 500-600 times from their weight and build reservoir for the plant soil-system (Bouranis *et al.* 1995). These are used to enhance water holding capacity, boost water usage efficiency, minimise soil erosion and nutrient losses, and absorb nutrients to gradually release them. These are synthetic polymers which are biodegradable and can easily be degraded in high UV radiation. Salicylic acid (SA) is ortha hydroxyl benzoic acid ($C_7H_6O_3$) which is produced in cytoplasmic cell of plant. SA is a potent signalling molecule which provoke many biochemical and physiological function of plant when plant is under any biotic or abiotic stress (Gunes *et al.* 2007). Exogenous application of SA in plant regulates the redox balance and enhanced photosynthesis and stomatal conductance by inhibiting ethylene production in drought condition (Nazar and Sareer 2015)

By considering the effect of hydrogel and SA in plant at water stress condition, it was hypothesized that combined use of hydrogel and salicylic acid enhances plant development because hydrogel reduces water stress by increasing water efficiency, and SA minimises environmental stress. Therefore, the present work conducted at Varanasi area of Uttar Pradesh to examine whether or not salicylic acid had capacity to mitigate ill effect of water stress and its combined effect of hydrogel on growth and productivity of Indian mustard under rainfed conditions.

Materials and Methods

A field experiment was carried out at Agricultural Research Farm (25°20′ N, 83°03′ E; 76.216 m) of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the *Rabi* season in the two consecutive year of 207-18 and 2018-19. The soil of the experiment site was sandy clay loam in texture and slightly alkaline in nature. Soils are low in organic carbon (0.35%), available nitrogen (135.2 kg/ha) and available phosphorus (14.2 kg/ha) and medium in exchangeable potash (205.3 kg/ha).

The experiment was laid out in a Randomized Block Design (RBD) with three replications for the nine treatments. Treatments comprised of different hydrogel application rate in soil and foliar spray of salicylic acid either alone or their combination. The total of 9 treatment combinations, viz. T1: control, T2: hydrogel (H) 2.5 kg/ha, T3: H 5 kg/ha, T4: salicylic acid (SA) 100 ppm at flowering and siliqua formation, T5: SA 200 ppm at flowering and siliqua formation,T6: H 2.5 kg/ha + SA 100 ppm at flowering and siliqua formation, T7: H 2.5 kg/ha + SA 200 ppm at flowering and siliqua formation, T8: H 5 kg/ha + SA 100 ppm at flowering and siliqua formation, T9: H 5 kg/ha + SA 200 ppm at flowering and siliqua formation. The mustard crop cv. Giriraj was sown in the first fortnight of October during both the study years. The seed rate was 5 kg/ha at 45 X 15 cm spacing. A thinning operation was done at 15- 20 DAS to maintain plant population. Uniform application of NPK fertilizers of 120:60:40 kg/ha was applied in the form of urea, diammonium phosphate and muriate of potash. Whole amount of phosphorus with potash and half dose of nitrogen were applied in the field as basal at the time sowing. Rest amount of nitrogen was top-dressed through urea at 35-40 days of sowing. All the inter-cultivation operation are kept uniform through the entire plot.

For this experiment, Hydrogel prepared by IARI, New Delhi was used. Hydrogel are superabsorbent cellulose grafted polymer belongs to polyacrylate family, having capacity to absorb more than 350–500 g of water/gram than the xerogel (IARI 2012). The swelling ratio of these anionic hydrogel increase as temperature rises without disturbing their polymer matrix upto 50°C. The hydrogel crystal are powdered then mixed with fine sand (<0.25 mm) in 1:10 ratio and drilled in planting furrows/root zone at the time of sowing with seed. Small amount of ethanol was mixed with salicylic acid to dissolve it and then this aqueous mixture is added in water. Foliar spray of this solution was done as per treatment at flowering and siliqua forming stage by knapsack sprayer fitted with a holocone nozzle. At harvesting, data were taken on plant height (cm), primary and secondary branches, yield parameters (per plant) and yield as per standard statistical procedure.

Data were statistically analyzed and the results of pooled analysis are presented. The mean significant differences were compared by Duncan's Multiple Range Test (DMRT) test at $p < 0.05$ and trait correlation analysis by using R-square (R Version 4.0.4.).

Results and Discussion

Growth and yield attributes: The data of agronomic traits showed a significant difference among treatments variables during the course of the investigation. Among different combination of hydrogel and salicylic acid, a significant height (177.33 and 178.00 cm) was obtained with treatments H @ 5 kg/ha + SA 200 ppm spray at flowering and siliqua formation which was significantly higher than other treatments during both the years. This may be ascribed that soil application of hydrogel improving the soil moisture availability and foliar spray of SA mitigate the drought stress and induces more auxin production which improves the cell elongation and cell development of plant even in unfavourable climatic condition (Meena 2020).

A significant response of hydrogel and salicylic acid was recorded on the number of branches in mustard (Table 1). An increase of 30.36 and 41.29%, respectively of primary branches was observed with treatment hydrogel 5 kg/ha + SA 200 ppm spray at flowering and siliqua formation stage over control in both the years. Similarly combined application of hydrogel (5 kg/ha) with SA (200 ppm) gave maximum number of secondary branches (7.67 and 7.80) which was significantly higher than other treatments during both years. The probable reason that application of hydrogel to soil may increase water-holding capacities, reduces the water loss, and improve the nutrient utilization efficiency (Dar and Hariram, 2016). Similar finding reported by Mady (2007) in tomato.

Both hydrogel and SA had favourable effect on number of siliqua per plant. The treatment hydrogel 5 kg/ha + SA 200 ppm spray at flowering and siliqua formation stage produced significantly higher number of siliqua per plant (305.00 and 308.67) compared with other treatments in both the years. The positive effect of hydrogel and SA on number of siliquae per plant in *Brassica* crop also was reported by Meena *et al.* (2020). Pusa hydrogel have the capacity to retain water 300-400 times of its weight and its gradual release helps to maintain soil moisture till the maturity which provide enough time for siliqua formation and seed filling under less frequent irrigation (Shim *et al.* 2008).

Both hydrogel and SA acid showed no significant effect on the number of seeds per siliqua during both years and it varied from 15.00 to 16.33 and 15.3 to16.80 in year 2017-18 and 2018-19 respectively. Likewise, among all treatments, maximum siliqua length (7.07 cm and 7.3 cm) was documented in hydrogel (5 kg/ha) with SA (200 ppm) and lowest length (5.0 and 5.8 cm) in control during both years of trials. The shortage of water at critical stage lower brought down the crown diameter which have negative influence on siliqua lengths.

Table 1. **Effects of Hydrogel and SA application on growth and yield attributes of Indian mustard.**

Treatment	Average plant height (cm)		No. of primary branches		No. of secondary branches		No of siliqua/plant		Siliqua length (cm)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Control	125.15^{e}	126.67^{g}	5.27^{g}	5.57^{e}	5.00^{d}	5.55^{d}	229.47^{e}	245.3^{g}	5.00^{d}	5.80^{f}
H@2.5 kg/ha	129.90^{de}	130.33^{g}	5.50^{f}	5.60^{e}	5.47^{d}	5.58^{d}	232.57^{e}	250.0^{fg}	5.47^{d}	5.87^{f}
H@ 5 kg/ha	146.00^{c}	135.00^{ef}	5.40^{fg}	5.63^{e}	5.60^{d}	5.80^{d}	229.23^{e}	255.0^{ef}	5.60^{d}	5.93^{f}
SA @ 100 ppm at flowering and Siliqua formation	136.25^{cd}	139.33^{ef}	5.60^{ef}	5.67^{e}	5.80^{cd}	5.92^{d}	235.33^{e}	260.0^{e}	5.80^{cd}	5.87^{ef}
SA@ 200 ppm at flowering and Siliqua formation	143.00^{c}	148.33^{e}	5.87^{e}	6.27^{d}	5.80^{cd}	5.94^{d}	243.77^{de}	263.33^{e}	5.80^{cd}	6.07^{e}
H @2.5 kg/ha+ SA 100 ppm at flowering and siliqua formation	139.00^{cd}	143.33^{de}	6.10^{d}	5.83^{e}	6.63^{bc}	6.22^{c}	256.67^{d}	275.0^{d}	6.63^{bc}	6.27^{d}
H @2.5 kg/ha+ SA 200 ppm at flowering and siliqua formation	158.47^{b}	162.33^{c}	6.33^{c}	6.77^{c}	6.70^{bc}	6.92^{b}	275.00^{c}	286.67^{c}	6.70^{bc}	6.50^{c}
H @ 5 kg/ha+ SA 100 ppm at flowering and siliqua formation	165.13^{b}	170.67^{b}	6.57^{b}	7.30^{b}	6.77^{b}	7.06^{b}	290.00^{b}	298.33^{b}	6.77^{b}	6.70^{b}
H @ 5 kg/ha+ SA 200 ppm at flowering and Siliqua formation	177.33^{a}	178.00^{a}	6.87^{a}	7.87^{a}	7.67^{a}	7.80^{a}	305.00^{a}	308.67a	7.07^{a}	7.3^{a}
CD	*	*	*	*	*	*	*	*	*	*

Means with same letters are not statistically significant by DMRT ($p \leq 0.05$), H- Hydrogel, NS-Non Significant, SA-Salicylic acid.

Table 2. Effects of Hydrogel and SA application on yield parameter, seed and straw yield of Indian mustard.

Treatment	Seeds/siliqua		Seed yield (kg/ha)		Straw yield (kg/ha)		Production efficiency (kg/ha/day)		Economic efficiency (Rs/ha/day)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Control	15.00	15.30	1496.67^{f}	1553.33^{e}	2016.73^{d}	2033.41^{de}	11.00^{f}	11.42^{e}	102.97^{d}	106.31^{d}
H@2.5 kg/ha	15.17	15.67	1506.67^{f}	1556.67^{e}	2020.0^{cd}	2036.67^{d}	11.08^{f}	11.45^{e}	121.74^{d}	124.51^{cd}
H@ 5 kg/ha	15.30	15.43	1513.3^{ef}	1563.41^{e}	2031.4^{cd}	2040.17^{c}	11.13^{ef}	11.50^{e}	185.85^{cd}	189.13^{c}
SA @ 100 ppm at flowering and Siliqua formation	15.47	15.88	1516.7^{ef}	1593.47^{e}	2030.1^{cd}	2045.1^{c}	11.15^{ef}	11.72^{e}	293.16^{bc}	297.79^{bc}
SA@ 200 ppm at flowering and Siliqua formation	15.67	16.03	1556.67^{e}	1643.73^{e}	2050.4^{cd}	2060.2^{c}	11.45^{e}	12.09^{d}	294.86^{b}	299.59^{b}
H @2.5 kg/ha+ SA 100 ppm at flowering and siliqua formation	15.83	16.23	1603.33^{d}	1693.47^{d}	2116.7^{cd}	2123.49^{c}	11.79^{d}	12.45^{c}	326.48^{b}	333.61^{b}
H @2.5 kg/ha+ SA 200 ppm at flowering and siliqua formation	16.00	16.37	1648.33^{c}	1736.78^{c}	2145^{bcd}	2154.8^{bc}	12.12^{c}	12.77^{bc}	347.51^{ab}	355.03^{ab}
H @ 5 kg/ha+ SA 100 ppm at flowering and siliqua formation	16.00	16.57	1695.76^{b}	1782.17^{b}	2193.62^{b}	2216.80^{b}	12.47^{b}	13.10^{b}	332.94^{b}	339.34^{b}
H @ 5 kg/ha+ SA 200 ppm at flowering and Siliqua formation	16.33	16.80	1740.28^{a}	1833.29^{a}	2331.50^{a}	2356.67^{a}	12.80^{a}	13.48^{a}	394.10^{a}	404.48^{a}
CD	NS	NS	*	*	*	*	*	*		

Means with same letters are not statistically significant by DMRT ($P \leq 0.05$), H- Hydrogel, NS-Non Significant, SA-Salicylic acid.

Application of hydrogel with SA marked a significant difference on yield of mustard over without SA (Table 2). A significant increase in seed yield was recorded with treatment hydrogel 5 kg/ha + SA 200 ppm spray followed by treatment of hydrogel 5 kg/ha + SA 100 ppm spray which was 16 and 18% higher than the control in 2017-18 and 2018-19, respectively. Similar trend was observed in stover yield during both years and combined application of hydrogel (5 kg/ha) with SA (200 ppm) at flowering and siliqua formation stage gave the highest stover yield which was statically superior over the entire treatment. The increase in yield might be due to better amendment of soil with hydrogel which modify the cation exchange capacity of soil which delays the fertilizer dissolution and improves the nutrient absorption capacity, subsequently more translocation of nutrient-cum-photosynthates in the sink and finally yield will increase (Rathore *et al*. 2019). While spray of SA reduced stress and oxygen radical formation resulted better growth even in unfavourable climatic conditions (Tirani *et al.* 2013).

The production efficiency (PE) and economic efficiency of mustard were significantly higher in hydrogel 5 kg/ha + SA 200 ppm spray as compared to the rest of treatments (Table 2). The increase in PE due to hydrogel (5 kg/ha) and SA (200 ppm) which was 13.4 and 17.2% more over hydrogel (5 kg/ha) without SA in 2017-18 and 2018-19 respectively.

The highest net return was recorded with hydrogel 5 kg/ha + SA 200 ppm spray at flowering and siliqua formation stage (Fig. 1). In close analysis of both year hydrogel 5 kg/ha + SA 200 ppm earned maximum net profit Rs. 53597.22 and Rs. 55008.28 in 2017-18 and 2018-19 which was found 18.2 and 19.1% higher than the net return of values of hydrogel 5 kg/ha + SA 100 ppm during first and second year, respectively. Since hydrogel 5 kg/ha + SA 200 ppm showed mark improvement in seed yields and thus gaining more profit in terms of net returns and benefit: cost ratio over rest of treatments.

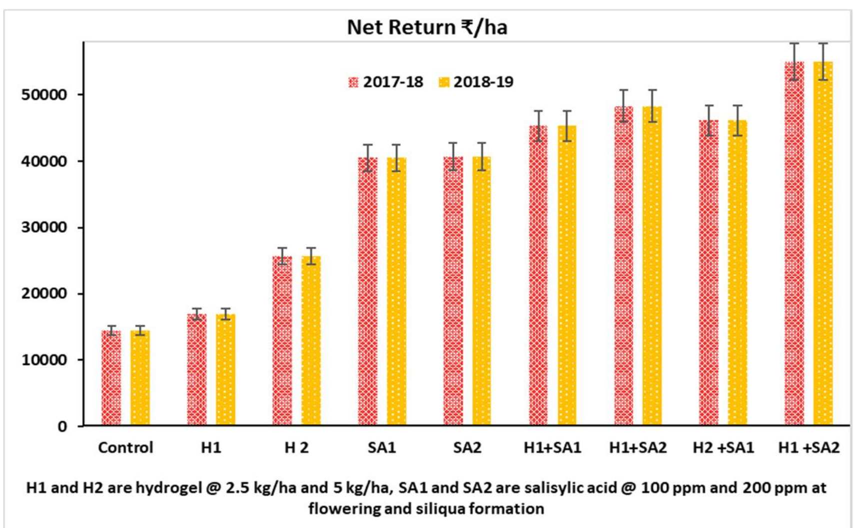

Fig. 1. Effects of hydrogel and salicylic acid on net return (Rs/ha) of Indian mustard yearwise.

The sum of principal components PC1 and PC2 (Fig. 3) explained 97.2.8% and 96.4% of the variations among various growth and yield component of *Brassica* spp. in 2017-18 and 2018-19, respectively. PCA dimension showed the strong correlation among the plant height, number of

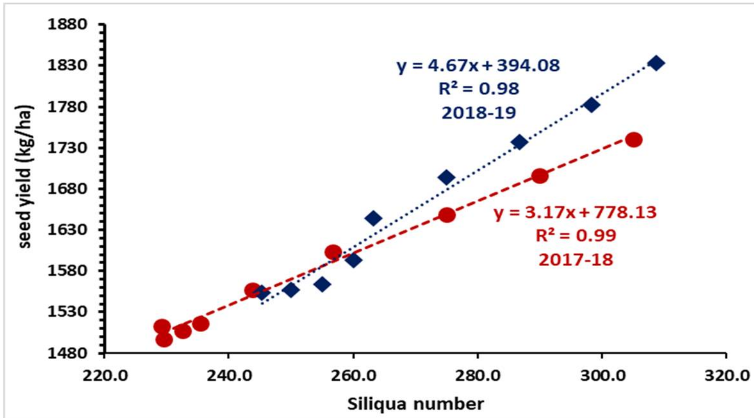

Fig. 2. Functional relationship between seed yield (kg/ha) and siliqua number**.**

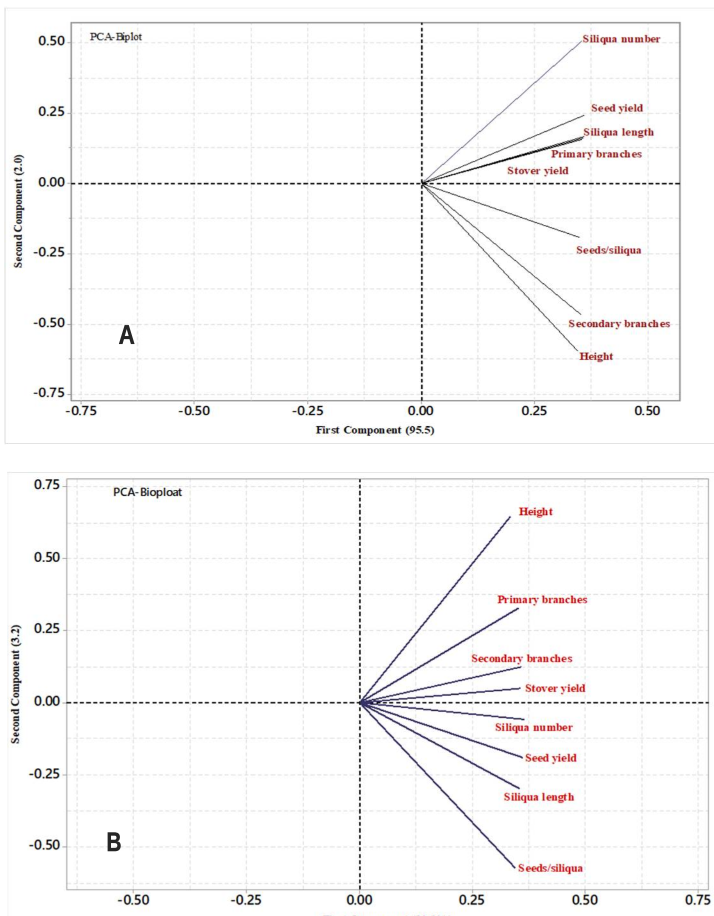

Fig. 3. PCA graphs of 9 treatment combinations for yield components, yield and agronomic traits of the years 2017-18 (A) and 2018-19 (B).

primary branches and secondary branches, number of siliquae/plants, number of seeds/siliquae, siliqua length, seed and stover yield. On superimposition of traits of all treatment in scattered plot matrix disclose the superiority of hydrogel 5 kg/ha + SA 200 ppm spray at flowering and siliqua formation stage in all growth and yield parameter and showed a substantial correlation among them.

From the present experimentation it may suggested that application of Hydrogel @ 5 kg/ha with salicylic acid @ 200 ppm spray at flowering and siliqua formation protect the plant from moisture stress and improve the growth parameter, yield attributes, yield and quality parameter of Indian mustard under the middle Gangetic plain of eastern Uttar Pradesh. Exogeneous spray of SA alone with higher dose performed better in all parameter than sole application of hydrogel. However, their combination also gave superior result in minimising the moisture stress.

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