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Effect of Super Absorbent Polymers on Grain Yield and Soil Microbial Counts in Mustard under Limited Irrigation

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ABSTRACT: A field experiment was conducted in *rabi* season 2019-20 and 2020-21 at Research farm of Bihar Agricultural College, Sabour with the aim to assess the effect of super absorbent polymers and irrigation on grain yield of mustard and soil microbial counts. The experiment comprised of 3 irrigation levels (control, one irrigation at pre flowering stage and two irrigations at pre flowering and siliqua formation stage) put in main plot whereas 10 super absorbent polymers (P_1- Control, P_2- Magic hydrogel 5.0 kg acre^{-1}, P_3- Alsta hydrogel 6.0 kg acre^{-1}, P_4- Vedic hydrogel 3.0 kg acre^{-1}, P_5- Eco sarovar hydrogel 3.0 kg acre^{-1}, P_6- Stockosorb hydrogel 8.0 kg acre^{-1}, P_7- Vaaridhar hydrogel 1.0 kg acre^{-1}, P_8- Nano hydrogel 8.0 kg acre^{-1}, P_9- Solid rain hydrogel 6.0 kg acre^{-1} and P_{10}- Zeba hydrogel 5.0 kg acre^{-1}) were put in sub plots, laid out in split plot design. Results revealed that solid rain hydrogel 6.0 kg acre^{-1} with two irrigations recorded highest grain yield (17.53 and 17.62 q ha^{-1}) of mustard in 2020 and 2021, respectively being at par with stockosorb hydrogel 8.0 kg acre^{-1} and nano hydrogel 8.0 kg acre^{-1} at same irrigation level. So far as microbial count was concerned, their population was enhanced with increasing irrigation levels in 2020; however, in 2021, their population was enhanced with increasing irrigation levels upto one irrigation, thereafter declined. Among superabsorbent polymers, fungi, bacteria and actinomycetes counts were maximum under stockosorb hydrogel 8.0 kg acre^{-1}, nano hydrogel 8.0 kg acre^{-1} and solid rain hydrogel 6.0 kg acre^{-1}, respectively in 2020; whereas in 2021, their respective count was maximum under nano hydrogel 8.0 kg acre^{-1}, solid rain hydrogel 6.0 kg acre^{-1} and stockosorb hydrogel 8.0 kg acre^{-1}, respectively. In 2021, interaction effect of superabsorbent polymers and irrigation on soil microbial counts revealed that fungi, bacteria and actinomycetes count were significantly maximum under alsta hydrogel 6.0 kg acre^{-1}, solid rain hydrogel 6.0 kg acre^{-1} and solid rain hydrogel 6.0 kg acre^{-1} with two irrigations.

Keywords: Irrigation, Microbial counts, Super absorbent polymer, Wheat, Yield.

I. INTRODUCTION

Indian mustard (*Brassica juncea* L.) is major winter oilseed crop of India. During 2018-19 in India, rapeseed and mustard recorded the highest production 9.3 m tonne from 6.1 m ha acreage with highest productivity 1511 kg ha^{-1}. It contributes more than 33% of vegetable oil production and plays crucial role to meet edible oil demand. Irrigation will play vital role in increasing the crop yield under changing climate [15]. Insufficient soil moisture either due to less or no rains during growth period and owing to frequent moisture stress during vegetative as well as reproductive phase, thereby resulting drastic reduction in yield of mustard [6].

Mustard is grown either under rainfed or limited irrigation. The crop recurrently faces drought during critical crop growth period [17]. This leads to poor seed yield. Use of chemicals for in-situ conservation and efficient utilization of available soil moisture in root zone will help in increasing crop productivity under limited water supply [4]. Super absorbent polymers are promising option to exploit existing water use in soil for field crops [22]. Hydrogel is semi-synthetic, cross linked super absorbent polymer [9]. It absorbs 350 times of its dry weight in pure water and gradually releases it. Use of hydrogel could be helpful in conserving soil moisture and improving productivity significantly [4].

Super absorbent polymers (SAPs) are not only used for water saving in irrigation, but they also have tremendous potential to improve biological properties of the soil [12]. The higher water storage capacity, irrigation water productivity and yield were recorded with SAPs [12]. Hydrogel @ 5.0 kg ha^{-1} improved the mustard yield [11]. In drought stress, application of super absorbent affects the seed yield [14]. Under adequate irrigation facilities, hydrogel could prove beneficial as the number of irrigations could be cut down.

Application of hydrogel remained significantly superior over no application [20]. Significant increase in seed yield of mustard with application of hydrogel over control [16]. The activity of microorganisms (e.g., by microbe-mediated increase in nutrient availability in soil) will increase by using super absorbent polymers [5]. Therefore, keeping these facts in view, the present study was executed with the objectives to assess the efficacy of hydrogels and irrigation on productivity of mustard and their impact on soil micro-biological properties.

II. MATERIALS AND METHODS

A field experiment was carried out in *rabi* season of 2019-20 and 2020-21 at Research Farm of Bihar Agricultural College, Sabour, Bhagalpur situated at latitude 25°15’40” N and longitude 87°2’42” E with an altitude of 37.46 meters above mean sea level with the aim to assess the effect of super absorbent polymers and irrigation on grain yield and soil microbial counts in mustard. The soil of experiment was sandy loam in texture, having a pH 7.27, low organic carbon 0.44 %, available low N 120.53 kg ha^{-1}, available medium P 25.43 kg ha^{-1} and K 151.29 kg ha^{-1}. The experiment was laid out in split plot design with three irrigation levels *viz*., one irrigation, two irrigations and three irrigations in main plot and ten super absorbent polymers *viz*., P_1- Control, P_2- Magic hydrogel @ 5.0 kg acre^{-1}, P_3- Alsta hydrogel @ 6.0 kg acre^{-1}, P_4- Vedic hydrogel @ 3.0 kg acre^{-1}, P_5- Eco sarovar hydrogel @ 3.0 kg acre^{-1}, P_6- Stockosorb 660 hydrogel @ 8.0 kg acre^{-1}, P_7- Vaaridhar G1 hydrogel @ 1.0 kg acre^{-1}, P_8- Nano hydrogel @ 8.0 kg acre^{-1}, P_9- Solid rain hydrogel @ 6.0 kg acre^{-1} and P_{10}- Zeba hydrogel @ 5.0 kg acre^{-1} in subplots, replicated thrice.

To carry out the experiment, the land preparation operations *viz*., pre sowing irrigation, ploughing and levelling were done. Mustard variety, Pusa bold was sown with recommended seed rate of 5 kg ha^{-1} on 15th November, 2019 during first year and on 17th November, 2020 during second year. The recommended dose of nitrogen, phosphorus and potash was 80-60-60 kg ha^{-1}, respectively, which was applied through urea, single superphosphate and muriate of potash. The basal fertilizers in all the treatments including all the P and K fertilizers and 1/2 N fertilizer were applied, remaining half dose of N fertilizer was top-dressed. Hydrogel at different doses, well mixed with sufficient quantity of soil was applied to allotted experimental plots in furrows just before sowing of crop. While, hydrogel applied at the time of sowing of the crop. Other management practices including weeding and hoeing were adopted as per package and practices of the crop.

Yield parameters were recorded at the time of harvest. Five plants were selected randomly from each treatment to record the observations of yield. The crop was harvested on 09th March, 2020 and 11th March, 2021 during first and second year, respectively. Soil microbial counts *i.e*., fungi, bacteria and actinomycetes was done by using standard procedures. The data were analysed using analysis of variance (ANOVA) technique [8].

III. RESULTS AND DISCUSSION

Grain yield. The data on grain yield of mustard under the influence of irrigation and super absorbent polymer revealed that application of solid rain hydrogel @ 6.0 kg acre^{-1} along with two irrigations (P_9I_3) in mustard exhibited significantly maximum grain yield (17.53 and 17.62 q ha^{-1}) of the crop during 2020 and 2021, respectively which was found statistically at par with P_6I_3 and P_8I_3 (Stockosorb 660 hydrogel @ 8.0 kg acre^{-1} and Nano hydrogel @ 8.0 kg acre^{-1} along with two irrigations) during both the years (Table 1 & Table 2).

Table 1: Interaction effect of super absorbent polymers and irrigation on grain yield (q ha^{-1}) of mustard during 2019-20.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	8.40	11.68	11.85	11.16	11.31	12.14	10.53	11.93	12.25	11.58	**11.28**
I_2	9.25	12.79	13.34	11.24	12.12	14.66	10.67	14.45	14.71	12.85	**12.61**
I_3	11.60	15.78	15.89	15.35	15.57	17.12	13.81	16.71	17.53	15.17	**15.45**
MEAN	**9.75**	**13.42**	**13.69**	**12.58**	**13.00**	**14.64**	**11.67**	**14.36**	**14.83**	**13.20**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.16	0.18	0.31	0.33							
CD (P=0.05)	0.62	0.50	1.00	1.08							

Table 2: Interaction effect of super absorbent polymers and irrigation on grain yield (q ha^{-1}) of mustard during 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	8.42	10.70	10.87	11.18	10.33	11.16	9.55	10.95	11.27	11.60	**10.60**
I_2	10.36	13.90	14.45	14.01	13.23	15.77	11.78	15.56	15.82	13.96	**13.88**
I_3	11.68	15.87	15.97	15.11	15.66	17.21	13.90	16.79	17.62	14.25	**15.41**
MEAN	**10.16**	**13.49**	**13.76**	**13.43**	**13.07**	**14.71**	**11.74**	**14.43**	**14.90**	**13.27**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.27	0.20	0.35	0.43							
CD (P=0.05)	1.06	0.58	1.22	1.49							

This may be due to fact that hydrogel might have resulted in absorption/storage of moisture during the period of abundant supply *viz.*, field capacity for release during the time of moisture stress thereby, with increased soil matric potential providing the crop with sufficient moisture supply during entire vegetative and reproductive phase thereby, augmenting the photosynthates accumulation in the crop which results in significant increase in seed yield of mustard during both the years of experimentation. Similar results have also been reported by [3].

This indicates that the SAP alleviated the impact of moisture stress by way of maintaining optimal water supply and thus, increased the yield of mustard. Application of irrigation increased the yield of mustard significantly over no irrigation [20]. SAP application increased the yield significantly over the control through optimal supply of water. Consequently, availability of adequate moisture to plants might have resulted in production of more photosynthates, helping in translocation of more photosynthates to the seeds and thus, improved these agronomic traits [14].

The seed, stover and biological yields decreased significantly by 11, 7 and 8%, respectively due to moisture stress but compensated with the use of SAP either alone or in combinations with plant bio-regulators [4]. Significant increase in seed yield with the application of hydrogel over the control [21].

The application of super absorbent polymer could reserve different amounts of water for itself and increase the soil water storage and preservation, and, at the last, under water deficiency, augments the plant water need, improving its growth. Thus, in drought stress, application of super absorbent affects the seed yield [14]. The maximum seed yield of mustard was recorded with super absorbent polymer through seed + soil was on a par with its soil application [2].

Table 3: Effect of super absorbent polymers and irrigation levels on fungi, bacteria and actinomycetes count in mustard during 2019-20.

Treatments	Fungi count (CFU×10^4)	Bacteria count (CFU×10^6)	Actinomycetes count (CFU×10^5)
Levels of irrigations			
I_1 - Control	9.02	17.10	11.46
I_2 - One irrigation	10.63	20.87	12.97
I_3 - Two irrigations	12.12	24.23	14.53
SEm±	0.27	0.31	0.22
CD (P=0.05)	1.05	1.23	0.85
Super absorbent Polymer			
P_1- Control	8.31	17.56	12.00
P_2- Magic hydrogel @ 5.0 kg/ $acre^{-1}$	10.81	20.11	12.75
P_3- Alsta hydrogel @ 6.0 kg/ $acre^{-1}$	11.31	21.56	12.98
P_4- Vedic hydrogel @ 3.0 kg/ $acre^{-1}$	11.29	20.00	12.67
P_5- Ecosarovar hydrogel @ 3.0 kg/ $acre^{-1}$	11.17	20.56	13.05
P_6- Stockosorb hydrogel @ 8.0 kg/ $acre^{-1}$	11.32	22.22	13.53
P_7- Vaaridhar hydrogel @ 1.0 kg/ $acre^{-1}$	9.30	18.22	12.53
P_8- Nano hydrogel @ 8.0 kg/ $acre^{-1}$	11.16	22.89	13.48
P_9- Solid rain hydrogel @ 6.0 kg/ $acre^{-1}$	11.26	22.78	13.90
P_{10}- Zeba hydrogel @ 5.0 kg/ $acre^{-1}$	10.00	21.44	12.98
SEm±	0.40	0.58	0.49
CD (P=0.05)	1.13	1.64	NS
Interaction			
SEm±	0.69	1.00	0.85
CD (P=0.05)	NS	NS	NS

Soil microbial properties at initial: Fungi (6.48 CFU×10^4), bacteria (14.76 CFU×10^6) and actinomycetes (10.47 CFU × 10^5).

In 2020, fungi, bacteria and actinomycetes population were enhanced with increasing irrigation level. In 2020, fungi population was significantly highest under P_6 (Stockosorb hydrogel @ 8.0 kg $acre^{-1}$) being at par with rest of the hydrogels except P_1, P_7 and P_{10}. Bacteria population was significantly highest under P_8 (Nano hydrogel @ 8.0 kg acre^{-1}) being at par with P_9, P_6, P_3 and P_{10}. Actinomycetes population was found non significant owing to application of hydrogels (Table 3).

Rudzinski *et al.*, (2002) [18] showed that the diversity of microbes increased with the addition of SAPs and that soil moisture content played a greater role in deciding the degradation of SAPs. Saturated water treatment showed release of toxic compounds, while severe drought treatment showed decrease in pH. This discourages the use of PAAm based hydrogels for agricultural purposes. However, polyacrylate-based PUSA hydrogels were used as bioinoculants by Suman *et al.*, (2016) [21] where shelf life of microorganisms was boosted from 3 months to 2 years in controlled condition and the treatment of the select cultures of microbes and hydrogel showed positive effect on plant growth.

Micro-organisms in soil matrix play crucial role in nutrient pathway for plant uptake. Many bacteria break down complex nutrients inside soil and release it to the roots of the plant in its vicinity. A plant root system has a complex interaction with its environment such as *rhizobium* fauna, fungi, and bacteria. Hence, a healthy population of nitrogen and other nutrient fixing bacteria is tantamount to optimizing the overall yield of the plant [10]. This ecosystem is important for sustainable environment for plant growth. As most of these organisms propagate in aqueous situation, the availability of moisture in the form of entrapped water in hydrogels help create incubation tanks for the same.

In 2020, bacteria and actinomycetes population were enhanced with increasing irrigation level, however, fungi population was found in decreasing trend from control to one irrigation, thereafter, its population increased significantly over control and one irrigation. In 2021, fungi population was significantly highest under P_3I_3 (Alsta hydrogel @ 6.0 kg acre^{-1} along with two irrigations) being at par with P_2I_3, P_4I_3, P_5I_3, P_8I_3 and P_9I_3. Bacteria population was significantly highest under P_8I_2 (Nano hydrogel @ 8.0 kg acre^{-1} along with one irrigation) being at par with P_9I_2 and P_3I_2.

Table 4: Interaction effect of super absorbent polymers and irrigation on soil fungi count (CFU×10^4) of mustard in 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	18.89	20.28	18.55	21.08	21.11	21.02	19.43	20.99	21.54	20.07	**20.30**
I_2	18.11	20.09	21.06	20.06	17.97	19.84	18.70	21.78	20.56	19.66	**19.78**
I_3	20.04	22.54	23.84	23.79	22.67	19.74	17.60	22.26	22.64	19.98	**21.51**
MEAN	**19.01**	**20.97**	**21.15**	**21.64**	**20.58**	**20.20**	**18.58**	**21.67**	**21.58**	**19.90**	
	I	**P**	**P within I**	**I within P**							
SEm±	1.34	0.53	0.91	1.60							
CD (P=0.05)	NS	1.49	3.41	5.96							

Table 5: Interaction effect of superabsorbent polymers & irrigation on soil bacteria count (CFU×10^6) of mustard in 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	29.34	30.14	27.98	30.40	34.05	32.24	30.76	29.23	34.02	31.64	**30.98**
I_2	35.99	38.09	40.18	38.68	34.42	36.36	36.15	42.98	41.18	35.22	**37.93**
I_3	31.14	32.62	35.61	31.02	27.71	33.75	25.81	35.78	36.39	33.31	**32.31**
MEAN	**32.16**	**33.62**	**34.59**	**33.37**	**32.06**	**34.12**	**30.91**	**36.00**	**37.20**	**33.39**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.33	0.61	1.06	1.06							
CD (P=0.05)	1.30	1.74	3.22	3.21							

Table 6: Interaction effect of superabsorbent polymers & irrigation on soil actinomycetes (CFU×10^5) of mustard in 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	24.08	23.91	20.52	24.68	23.15	25.01	23.52	21.69	26.23	23.31	**23.61**
I_2	29.67	29.21	30.07	29.11	29.74	30.92	21.24	23.84	25.44	24.96	**27.42**
I_3	30.62	32.33	31.73	29.91	26.98	30.96	30.03	30.39	32.86	30.56	**30.64**
MEAN	**28.12**	**28.48**	**27.44**	**27.90**	**26.62**	**28.96**	**24.93**	**25.31**	**28.17**	**26.28**	
	I	**P**	**P within I**	**I within P**							
SEm±	1.68	0.97	1.69	2.32							
CD (P=0.05)	NS	NS	6.05	8.31							

Actinomycetes population was significantly highest under P_9I_3 (Solid rain hydrogel @ 6.0 kg acre^{-1} along with two irrigations) which was found at par with rest of the treatments (Table 4, Table 5 & Table 6). The interaction of microbes with hydrogel involves complex reactions and exchange of enzymes. The microbes are exposed to nutrient release and degradation products of hydrogel. Since symbiosis is essential for plant growth, hydrogels applied for agricultural productivity should pose no toxicity to the symbiotic organisms [13]. The hydrogels thus require to be tested for any sort of negative effects on microbes. Cytotoxicity test and high through-put genome sequencing of soil microbes are popular methods adopted for evaluation of hydrogel on microbial communities [18, 19].

Although positive effects are observed in crop production as shown in many studies, the toxicity at longer time period after degradation requires to be given sufficient scrutiny. Starch based hydrogels undergo fermentation, producing sugars, which serve as food for microbe species. Total microbial count for Actinomycetes, Azotobacter, total fungi, phosphate dissolving bacteria, and Azospirillum progressed when applied to sandy calcareous soil [7]. There is an increased microbial activity with the application of hydrogels under deficit condition [1]. Many micro-organisms contributed majorly to the degradation of the hydrogels themselves, and promote microbial survival.

CONCLUSION

Thus it might be concluded that application of solid rain hydrogel @ 6.0 kg acre^{-1} along with two irrigations recorded highest grain yield of mustard being at par with stockosorb hydrogel @ 8.0 kg acre^{-1} and nano hydrogel @ 8.0 kg acre^{-1} at same irrigation level. There was no adverse impact of super absorbent polymers and irrigation on soil micro-biological properties resulting into improved attributes.

FUTURE SCOPE

Future research study may be emphasized on the basis of mustard responded to super absorbent polymers and irrigation intervals in resource conservation technique.

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