Mitigating moisture stress in Indian mustard (B. juncea) through polymer

R. L. Choudhary
Directorate of Rapeseed and Mustard Research

R.s. Jat
Directorate of Rapeseed and Mustard Research

Murli Dhar Meena
Directorate of Rapeseed and Mustard Research

M. L. Dotaniya
Directorate of Rapeseed -Mustard Research

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Mitigating moisture stress in Indian mustard (*B. juncea*) through polymer

RL Choudhary, AK Langadi[1], RS Jat[*], Anupama[2], HV Singh, MD Meena, ML Dotaniya, MK Meena, OP Premi and PK Rai

ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur 321303 (Rajasthan), India
[1]Career Point University, Kota 325003 (Rajasthan), India
[2]ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India
[*]Corresponding authors: rs.jat@icar.gov.in
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Abstract

Under the current changing climate scenario, the development of drought mitigation strategies is the need of the hour to enhance water productivity and minimize the yield losses in the Indian mustard (*Brassica juncea* L.). To address the issue, a field experiment was conducted during 2018-19 to evaluate the field efficacy of the superabsorbent polymer (SAP: Pusa hydrogel) and its application rates 1.5, 2.5 and 5.0 kg ha^{-1} and compared with control under moisture stress and normal moisture conditions in a randomized complete block design and replicated thrice. The values of growth, yield attributes and seed and stover yields of the Indian mustard were significantly (*P=0.05*) reduced due to moisture stress, but improved with the use of SAP. The maximum seed yield (2.88 t ha^{-1}) and stover yield (6.84 t ha^{-1}) were obtained at SAP @ 5.0 kg ha^{-1} with normal moisture which were improved by 48.4 % and 20.6 % over the control, and 15.2–36.5 % and 9.1–16.3 % over the SAP levels (1.5–5.0 kg ha^{-1}) of moisture stress regime, respectively. This indicated that application of SAP (5.0 kg ha^{-1}) reduced the yield penalty due to moisture stress. Seed yield with 5.0 kg SAP ha^{-1} improved by 12.11% and 3.97 % under moisture stress and normal moisture regimes, respectively over the 2.5 kg SAP ha^{-1}. This suggested that application of 5.0 kg SAP ha^{-1} under moisture stress and 2.5 kg SAP ha^{-1} under normal moisture was found beneficial in enhancing the seed yield of mustard. The water productivity (WP) was comparatively higher (~ 6.6 %) under moisture stress over 1.32–1.67 kg m^{-3} recorded under normal moisture. The maximum WP under both the moisture regimes were obtained with the SAP @ 5.0 kg ha^{-1}. The WP improved by 10.6, 20.4 and 26.5 % under normal moisture and by 11.2, 18.7 and 32.8 % under moisture stress with 1.5, 2.5 and 5.0 kg SAP ha^{-1}, respectively over the respective controls. This signifies the beneficial role of SAP in achieving higher WP levels, particularly under moisture stress. Thus, the study recommends the use of SAP @ 2.5 kg ha^{-1} under normal moisture and 5.0 kg ha^{-1} under moisture stress to achieve the maximum seed yield and water productivity with concomitant saving of 16-20 % water with the later.

Key words: Indian mustard, moisture stress, seed yield, superabsorbent polymer (pusa hydrogel), water productivity

Introduction

Oilseeds are the second largest contributor in Indian agricultural economy after the cereals. However, the production of domestic edible oils (10.52 million tonnes) has not been able to keep pace with the growth in consumption, and the gap between availability and demand is being met through imports worth of 74.996 Crores rupees during 2017-18. During the last 5 years, the total domestic demand has been increased from 19.82 million tonnes in 2012-13 to 25.88 million tonnes in 2017-18 with compound annual growth rate. The situation will be more challenging with rising consumption of edible oils up to 2030 with the burgeoning population (Jat *et al.,* 2019). Oilseed brassica shares 24.4 % area and 26.8 % production of total oilseeds in the country. It contributes more than 33 % of vegetable oil production, thus it is playing a pivotal role in meeting the edible oil requirements of the country. However, the productivity of the crop in India is far behind than other developed counties (USDA, 2020) mostly due to large cultivation under rainfed situation. Resources crunch and biotic and abiotic stresses coupled with climate change further influence the crop performance negatively. Rajasthan is holding the sizable area (~ 50 %) of the mustard in the country, where it is cultivated either under rainfed or limited irrigations (mostly one irrigation) and frequently faces drought like situations during critical crop growth periods (Kar and Ashwani, 2007; Rathore *et al.,* 2014). This ultimately resulted into poor seed and oil yields due to moisture stress environment coincided with critical growth stages. Further, the water available for single irrigation is mostly applied at 30-40 days after sowing which fails to meet the water requirement of crop at later critical crop growth stages (Rathore *et al.,* 2019; Choudhary *et al.,* 2019). Thus, there is need to maintain the moisture supply in the root zone throughout the crop growing period to meet the water requirements during the reproductive stages for achieving the higher yields and water productivity.

The options are either irrigate the crop as and when required, or conservation and efficient utilization of the available soil moisture in root zone to reduce the yield penalty resulted from the moisture stress. Conservation of moisture in the soil through supply of water-absorbing materials could prove to be a better prospect in this aspect. A superabsorbent polymer (SAP) 'Pusa Hydrogel' has been developed and patented by the ICAR-Indian Agricultural Research Institute, New Delhi (IARI, 2012). Pusa hydrogel is a semi-synthetic, cross linked, derivatized cellulose-graft-anionic superabsorbent polymer. It absorbs a minimum of 350 times of its dry weight in pure water and gradually releases it. Field experiments conducted in different crops in India revealed that use of hydrogel could be helpful in improving soil moisture and crop productivity significantly (IARI, 2012; Jakhar *et al.,* 2017; Rathore *et al.,* 2017; Bana *et al*., 2018; Jat *et al.,* 2018; Singh *et al.,* 2018; Rathore *et al.,* 2019*).* Jat *et al,* (2018) reported that application of hydrogel @ 5.0 kg ha^{-1} had not only improved the mustard yield but also improved the production efficiency (15.0 kg ha^{-1} day^{-1}) and water productivity (8.46 kg ha-mm^{-1}) of the mustard. However, Pal (2019) have reported that a higher dose of hydrogel (5 kg ha^{-1}) neither gave higher yield nor B:C ratio and the higher dose was detrimental for wheat crop establishment as germination at higher moisture content was failed at few sites. Thus, the region and crop specific evaluation of the hydrogel technology is needed to harness the potential benefit of the technology. The efficient use of available water resources is vital in drought prone mustard-growing regions of India. Therefore, keeping the facts in view, the present investigation was undertaken with the objectives to standardize the application rate of SAP, and to assess its efficacy in mitigating the effect of moisture stress in Indian mustard.

Materials and Methods

A field experiment was conducted at the research farm of the ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur during *rabi* season of 2018-19. This is situated at 27°12'8.9" N latitude and 77°27'18.8" E longitude at an elevation of 170 meter above the mean sea level (Arabian Sea). The soil at site was clay loam in texture and it had 0.43 % organic carbon, 237.2 kg $KMnO_4$ oxidizable N ha^{-1}, 19.8 kg 0.5 N $NaHCO_3$ extractable P ha^{-1}, 175.6 kg 1.0 N NH_4OAc exchangeable K ha^{-1}, 8.1 pH and 0.61 dS m^{-1} EC at the start of the experiment. During the crop growing period, the daily values of the maximum and minimum temperature, maximum and minimum relative humidity, bright sunshine hours and wind velocity were ranged between 15-34.8 °C, 0.4-21.8°C, 70.5-97.3 %, 45.3-89.4 %, 0-10 hrs day^{-1} and 0-7.6 km hr^{-1}, respectively. Total rainfall received during the crop growing period was 37.4 mm. The distribution of rainfall and other weather parameters during the crop growing period have been presented in Fig. 1. The combinations of eight treatments consists four levels of superabsorbent polymer (SAP; Pusa hydrogel; 0, 1.5, 2.5 and 5.0 kg ha^{-1}) and two moisture regimes (normal moisture and moisture stress). Treatments were laid out in a factorial randomized block design with three replications. As per the treatments, SAP was drilled in the root zone at sowing time of the crop. To ensure a good crop establishment and boost the initial crop growth, an irrigation was applied uniformly in the all the treatments at 33 days after sowing (DAS). Moisture stress regime was created by with-holding the 2nd irrigation. Second irrigation was applied only to normal moisture treatment at reproductive stage of crop after 70 DAS. Indian mustard variety 'DRMRIJ 31 (Giriraj) was sown on 22 October 2018 in lines at 30 cm row-to-row distance using 5 kg seeds ha^{-1}. Gap filling and thinning operations were performed and a planting geometry of 30 cm × 10 cm was kept to maintain the optimum plant population.

The recommended doses 80:40:40:40:5:1 kg ha^{-1} of $N:P_2O_5:K_2O:S:Zn:B$ were uniformly applied to all the treatments through urea, SSP, MOP, zinc sulphate and borax fertilizers. Half dose of N and full dose of P, K and other nutrients were applied as basal at the time of sowing, while remaining 50 % dose of N was top dressed after first irrigation. Other recommended crop management practices were followed to harvest a good crop. Standard methods were employed to record the observations on plant height; main shoot length; number of primary and secondary branches; number of siliquae, siliqua length and seeds per siliqua associated with main shoot, primary and secondary branches. Plant height was measured at 45 DAS and at harvest, while observations on different yield parameters were recorded at harvest of the crop from each plot. The crop was harvested on 15 March from 4.5 m × 3.0 m net plot area after removing the two rows from the both side and 0.5 m from remaining other each side of the plot as border. The harvested produce was left in the field for few days for proper sun drying and then weighed the total biomass plot wise which was adjusted at 12 % moisture content. The produce was threshed manually and seeds were cleaned. Stover yield was computed by deducting the seed yield from the total biomass yield of respective plots. The final seed and stover weights were recorded in kg per plot and then expressed as t ha^{-1}. Water productivity (WP, kg m^{-3}) of seed produced was calculated as the ratio of seed yield to crop water use by following the procedure as described by Ali *et al.* (2007). The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a factorial randomized block design using SAS package (*ver.* 9.3). The results have been presented at 5% level of significance (P=0.05).

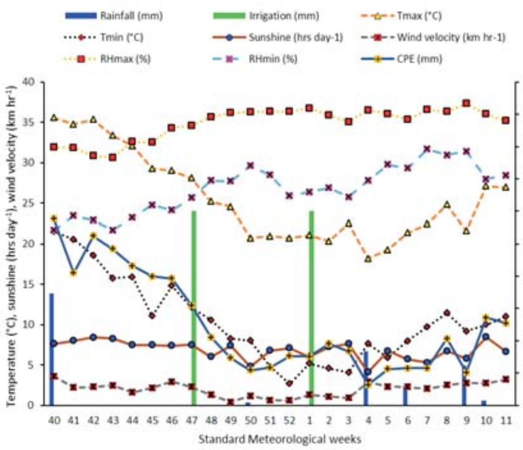

Fig. 1: Weather conditions during the crop growing period in 2018-19

Results and Discussion

Plant characteristics

Plant height did not differ significantly by the SAP levels, but it was influenced significantly due to different soil moisture (SM) regimes (Table 1). Application of irrigation at 33 DAS resulted in non-significant difference in plant height under different SM regimes at 45 DAS. However, it was declined (5 %) significantly at the harvest under moisture stress condition. The deficit moisture supply might have exposed the crop to relatively more water stress at its critical stages of water requirement. The main shoot length (MSL) was significantly influenced due to different SM regimes and SAP levels (Table 1). The MSL was significantly reduced due to moisture stress by 9.67 % over the normal moisture condition. The maximum MSL (86.8 cm) was recorded with 5.0 kg SAP ha^{-1} which was found on par with 2.5 kg SAP ha^{-1} but significantly higher than control and 1.5 kg SAP ha^{-1}. The effect of different SM regimes on number of primary branches was observed non-significant, but it was significant in case of secondary branches. The number of secondary branches was significantly decreased 23.35 % due to moisture stress as compared to normal moisture condition. Both the primary and secondary branches were influenced significantly due to different SAP levels. The maximum numbers of primary and secondary branches were recorded with 5.0 kg SAP ha^{-1} which was significantly higher than control.. This might be due to the use of SAP which favored the development of branches by way of maintaining a better moisture regime in the soil. Similar results have also been reported by Singh *et al.,* 2018.

Siliqua characteristics

Number of siliquae per primary branch did not differ significantly due to different SM regimes. However, these were declined by 5.22 and 15.54 % on secondary and main shoot branches, respectively due to moisture stress over the normal moisture condition (Table 2). The maximum number of siliquae per primary branch (41.1) was recorded

Table 1: Effect of soil moisture regimes and superabsorbent polymer levels on growth and yield attributes of mustard

Treatment	Plant height (cm)		Number of branches		Main shoot length (cm)
	45 DAS	At harvest	Primary	Secondary	
A. Soil moisture regimes					
Normal moisture	62.3	222.9	8.5	16.7	84.8
Moisture stress	60.2	211.8	8.2	12.8	76.6
SEm±	1.11	3.42	0.32	0.57	1.39
LSD (P=0.05)	NS	10.38	NS	1.72	4.23
B. SAP levels (kg ha^{-1})					
0.0	59.9	206.4	7.2	13.2	73.5
1.5	60.3	215.7	8.0	14.3	79.1
2.5	62.7	221.3	8.9	15.1	83.3
5.0	62.2	226.1	9.2	16.3	86.8
SEm±	1.58	4.84	0.45	0.60	1.97
LSD (P=0.05)	NS	NS	1.37	1.80	5.98
A × B					
SEm±	2.23	6.85	0.64	1.13	2.79
LSD (P=0.05)	NS	NS	NS	NS	NS

Table 2: Effect of soil moisture regimes and superabsorbent polymer levels on yield attributes of mustard

Treatment	Number of siliquae			Siliqua length (cm)			Seeds siliqua^{-1}		
	Primary branches	Secondary branches	Main shoot	Primary branches	Secondary branches	Main shoot	Primary branches	Secondary branches	Main shoot
A. Soil moisture regimes									
Normal moisture	38.0	36.4	65.0	5.1	4.8	5.3	13.2	12.2	14.8
Moisture stress	36.2	34.5	54.9	4.9	4.4	4.9	12.7	11.5	13.0
SEm±	0.92	0.60	1.27	0.12	0.07	0.11	0.36	0.37	0.45
LSD (P=0.05)	NS	1.81	3.86	NS	0.21	0.33	NS	NS	1.36
B. SAP levels (kg ha^{-1})									
0.0	33.1	31.4	54.7	4.6	4.2	4.7	11.8	11.0	12.6
1.5	35.7	33.5	57.5	4.9	4.5	5.0	12.1	11.6	13.4
2.5	38.5	36.9	62.2	5.1	4.7	5.2	13.6	12.1	14.2
5.0	41.1	39.8	65.5	5.3	5.0	5.5	14.3	12.8	15.3
SEm±	1.31	0.84	1.80	0.17	0.10	0.15	0.51	0.52	0.63
LSD (P=0.05)	3.96	2.56	5.46	0.52	0.30	0.46	1.55	NS	1.92
A × B									
SEm±	1.85	1.19	2.55	0.24	0.14	0.22	0.72	0.74	0.89
LSD (*P* d" 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

with 5.0 kg SAP ha^{-1} which was found on par with 2.5 kg SAP ha^{-1} but significantly higher than control and 1.5 kg SAP ha^{-1}. Similarly, the maximum number of siliquae per secondary branch (39.8) was recorded with 5.0 kg SAP ha^{-1} which was increased by 7.86-26.75 % than the rest of the levels of SAP. 5.0 kg SAP ha^{-1} being on par with 2.5 kg SAP ha^{-1} had also resulted maximum number of silique per main shoot (65.5) which was also significantly higher than the control and 1.5 kg SAP ha^{-1}. The longest siliquae associated with secondary branches and main shoots were recorded under normal moisture condition, while these were significantly reduced by 8.33 and 7.55 %, respectively due to moisture stress (Table 2). However, siliqua length of primary branches did not differ significantly due to different SM regimes. The longest siliquae associated with primary branches (5.3 cm), secondary branches (5.0 cm) and main shoots (5.5 cm) were observed with 5.0 kg SAP ha^{-1} which was found on par with 2.5 kg SAP ha^{-1} but significantly higher than control and 1.5 kg SAP ha^{-1}. Number of seeds per siliqua associated with primary and secondary branches did not differ significantly due to different SM regimes (Table 2). However, the number of seeds per siliqua associated with main shoot was significantly decreased (12.16 %) due to moisture stress over the normal moisture condition. The maximum number of seeds per siliqua (14.3) of the primary branches was recorded with 5.0 kg SAP ha^{-1} which was found on par with 2.5 kg SAP ha^{-1} but significantly higher than control and 1.5 kg SAP ha^{-1} levels. However, the effect of different SAP levels on seeds per siliqua of the secondary branches was found non-significant. A rate of 5.0 kg SAP ha^{-1} being on par with 2.5 kg SAP ha^{-1} had also resulted maximum number of seeds per siliqua (15.3) of main shoots which was also significantly higher than the control and 1.5 kg SAP ha^{-1}.

Application of irrigation water under normal moisture regime, and SAP under moisture stress condition resulted in the higher values of yield attributes over moisture stress and without SAP. Application of irrigation and SAP not only enhanced the growth and development of crop plants but also ensured a higher availability of nutrients which resulted in a greater number of branches and culminated in a better sink development leading to more siliquae per plant (Singh *et al.,* 2018). The optimum soil moisture maintained during the crop growth stages with SAP application signiûcantly improves growth parameters, leaf area index, number of branches per plant, number of pods per plant and yield attributes of Indian mustard (Rathore *et al.,* 2017; Rathore *et al.,* 2019). The improved growth of Indian mustard with better irrigation water management has also been reported by Rathore *et al.* (2014) and Kalhapure *et al.* (2016).

Seed and stover yields

The highest seed yield (2.63 t ha^{-1}) was obviously obtained under normal moisture condition, which was higher by 19.5 % over the moisture stress condition (Fig. 2). The maximum decrease in seed yield due to moisture stress was recorded at the control and lower levels of SAP (d" 2.5 kg SAP ha^{-1}) which was ranged between 17.09 to 19.49 %, while the least decrease in seed yield was recorded with 5.0 kg SAP ha^{-1} (13.19 %). This indicated that application of SAP (5.0 kg ha^{-1}) reduced the yield penalty due to moisture stress. Similarly, the highest stover yield (6.56 t ha^{-1}) was obtained under normal moisture condition, while moisture stress decreased the stover yield by 9.15 % over normal moisture condition (Fig. 3). Comparatively better performance of the growth and yield attributing characters led to significant increase in the seed and stover yields of the mustard under normal moisture condition over the moisture stress condition. Singh *et al.* (2018) reported that application of irrigation increased the seed yield significantly over no irrigation. Averaged across different SM regimes, the maximum seed yield (2.69 t ha^{-1}) was recorded with 5.0 kg SAP ha^{-1}, being on par with 2.5 kg SAP ha^{-1} but significantly higher by 25.70 and 15.45 %

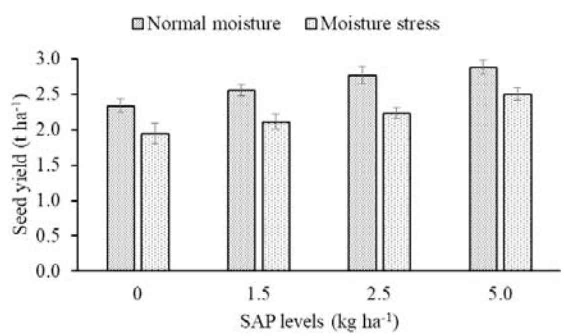

Fig. 2: Effect of soil moisture regimes and superabsorbent polymer levels on seed yield of mustard

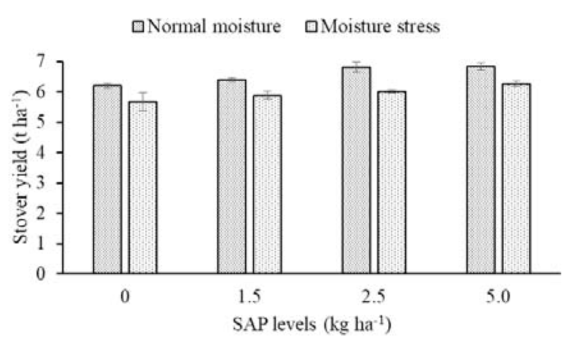

Fig. 3: Effect of soil moisture regimes and superabsorbent polymer levels on stover yield of mustard

than that obtained with the control and 1.5 kg SAP ha^{-1}, respectively (Fig. 2). Similarly, the maximum stover yield (6.55 t ha^{-1}) was recorded with 5.0 kg SAP ha^{-1}, being on par with 2.5 kg SAP ha^{-1} but significantly higher by 10.27 and 6.68 % over the control and 1.5 kg SAP ha^{-1}, respectively (Fig. 3). The seed and stover yields were also enhanced significantly with 2.5 kg SAP ha^{-1} over the control, but it was similar with 1.5 kg SAP ha^{-1}. The control and 1.5 kg SAP ha^{-1} levels produced statistically similar seed and stover yields.

Further, it was noted that the seed yield improved considerably under moisture stress (12.11 %), but not under normal moisture condition (3.97 %) with 5.0 kg SAP ha^{-1} over the 2.5 kg SAP ha^{-1}. This suggested that application of 5.0 kg SAP ha^{-1} under moisture stress and 2.5 kg SAP ha^{-1} under normal moisture condition was found beneficial in enhancing the seed yield of mustard. Bana *et al.* (2018) had also reported 6.7 % and 14.8 % yield improvements in wheat with pusa hydrogel (2.5 kg ha^{-1}) under normal irrigation and limited irrigation conditions, respectively.

Water productivity

The water productivity (WP) was comparatively higher (up to 6.6 %) and ranged between 1.34 to 1.78 kg m^{-3} under moisture stress over 1.32–1.67 kg m^{-3} recorded under normal moisture condition. It indicates that the response to soil moisture regimes was modified by the SAP levels (Fig. 4). Marginally higher WP under moisture stress might be due to less evapotranspiration, and most of the applied water remains in the root zone (Fereres and Soriano, 2007). Choudhary *et al.* (2020) reported that the WP increased with N and irrigation levels up to a certain level but then decreased. They further revealed that even higher WP with lesser quantity of water could be achieved with judicious management of N by keeping water availability under consideration. The highest values of WP under both the moisture regimes were obtained with the application of SAP @ 5.0 kg ha^{-1}. However, the WP improved by 10.6, 20.4 and 26.5 % under normal moisture and by 11.2, 18.7 and 32.8 % under moisture stress condition with 1.5, 2.5 and 5.0 kg SAP ha^{-1}, respectively over the respective control treatments. This signifies the beneficial role of SAP in achieving higher WP levels, particularly under moisture stress. This also indicates that higher levels of SAP could alleviate the adverse effect of moisture stress as these improved the WP and also reduced the water requirement by 16.0–19.8 %. Bharat *et al.* (2019) reported the higher seed yield and water-use efficiency of Indian mustard with hydrogel @ 5.0 kg/ha and irrigation scheduling at 0.8 and 0.6 IW/CPE ratios than without hydrogel treatments. Jat *et al.* (2018) also observed that application of hydrogel @ 5.0 kg ha^{-1} has not only improved the mustard yield but also improved the production efficiency (15.0 kg ha^{-1} day^{-1}) and water productivity (8.46 kg ha-mm^{-1}) of the mustard.

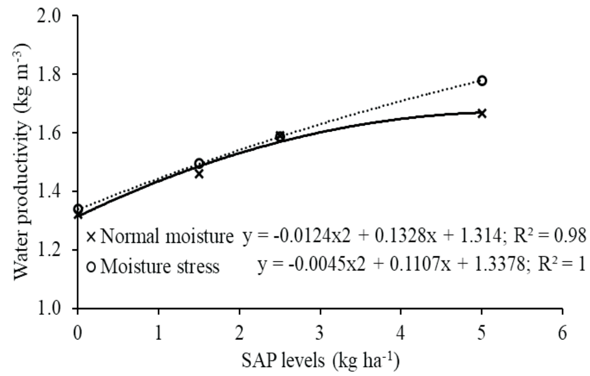

Fig. 4: Effect of soil moisture regimes and superabsorbent polymer levels on water productivity of mustard

Conclusion

The study highlighted that under limited supply of irrigation water, superabsorbent polymer (pusa hydrogel) can be a good alternative option to achieve higher mustard yield and water productivity and reduce the impact of moisture stress in semi-arid fragile ecologies of Rajasthan and drought prone areas of the country. The study suggested that application of 5.0 kg SAP ha^{-1} under moisture stress and 2.5 kg SAP ha^{-1} under normal moisture conditions was found beneficial in enhancing the productivity of the Indian mustard. A marginal yield reduction due to moisture stress could be compensated by higher water productivity and saving of water (16–20 %) with the use of SAP @ 5.0 kg ha^{-1}.

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