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Response of Indian mustard (*Brassica juncea* L) to drought alleviating microbes under different irrigation regimes in North Gujarat region

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Abstract

A field experiment was conducted during the *Rabi* 2022-23 in a split plot design with twelve treatment combinations comprising three irrigation schedules (0.6, 0.8 and 1.0 IW/CPE ratio) and four drought alleviating microbes (control, MRD-17, CRIDA MI-I and CRIDA MI-II). The results revealed that significantly higher seed yield (2045 kg/ha), stover yield (5204 kg/ha), higher total N, P, K and S uptake by crop were recorded with irrigation scheduled at 1.0 IW/CPE ratio. However, higher field water use efficiency (FWUE) was found with irrigation scheduled at 0.6 IW/CPE ratio. Inoculation of seed with CRIDA MI-I secured significantly higher oil yield (782.7 kg/ha) seed yield (2018 kg/ha), stover yield (5277 kg/ha), FWUE and nutrient uptake.

Keywords: *Drought alleviating microbes, Indian mustard, irrigation scheduling, productivity*

Introduction

Mustard productivity has improved remarkably in India over the last ten years, from 1185 kg/ha in 2008-09 to 1524 kg/ha in 2020-21 and production has increased from 7.20 million tonnes in 2008-09 to 10.21 million tonnes in 2020-21 (Anonymous, 2021a). Currently the area, production and productivity of rapeseed-mustard in Gujarat is 2.14 lakh ha, 4.24 lakh tonnes and 1976 kg/ha, respectively (Anonymous, 2021b). The crop can be raised well under both irrigated and rainfed conditions. The major constraint attributing to low production of mustard are inadequate water supply, poor fertility status of soil and infestation of weeds. Irrigation scheduling is one of the important managerial activities and affects the effective and efficient utilization of water by crops. It determines the process to decide when to irrigate the crop and how much water is to be applied. It optimizes agricultural production with minimizing yield loss due to water shortage and improving performance and sustainability of any irrigation system through conserving moisture. Scheduling of irrigation on the basis of evaporative demand results not only in efficient utilization of water, but also in considerable water saving. Among different approaches for irrigation scheduling, climatological approach based on the ratio between depth of irrigation water (IW) and cumulative pan evaporation (CPE) is found the most appropriate and practicable, as it integrates all the weather parameters giving their natural weightage in a given soil-water-plant continum. Irrigation applied at 0.8 IW/CPE ratio to mustard produced maximum dry matter accumulation as well as improved growth indices in comparison to 0.6 and 0.4 IW/CPE (Rana *et al*., 2020). In the recent scenario of agriculture, drought stress is considered one of the major problems reducing crop yield and productivity in various arid and semi-arid regions of the world (Vurukonda *et al*., 2016). Several strategies to improve the plant's potential to tolerate drought stress, such as improved agronomic practices, traditional breeding and transgenic approach, have been explored. However, these strategies involve high technical aspect and are labor and cost-intensive (Niu *et al*., 2018). An efficient alternative to combat drought stress in plants is the use of plant growth promoting *rhizobacteria* (PGPR). These confer beneficial effects to the plants under drought stress conditions by various direct and indirect mechanisms (Lim and Kim, 2013; Jayakumar *et al*., 2020). Recent studies indicate that microorganisms can also help the crops to cope with drought stresses which are an eco-friendly and cost-effective method. Meena *et al.* (2017) reported that bacteria belonging to different genera *i.e. Bacillus, Pseudomonas, Rhizobium, Paenibacillus, Burkholderia, Achromobacter, Azospirillum, Enterobacter etc*. have been reported to provide drought tolerance to host plants and also improve their growth under drought condition. The last two decades have witnessed many reports on the utilization of such microbes for induction of tolerance against drought stress. Therefore, identification and development of eco-friendly strategies using microbes, that can be improve plant growth under water stress condition are an urgent need in agricultural systems hence this study was carried out.

Materials and Methods

The field experiment was conducted during *Rabi* season of 2022-23 at CP College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat. Geographically, Sardarkrushinagar comes under North Gujarat Agro-climatic region situated at 24°19′ North latitude and 72°19′ East longitude, with an elevation of 154.5 m above the mean sea level. The soil of experimental field was loamy sand in texture, having normal EC (0.11 dS/m), 7.3 pH, low in organic carbon (0.30%) and available nitrogen (159 kg/ha), medium in available phosphorus (38.5 kg/ha), available potash (230 kg/ha) and available sulphur (9.55 mg/kg) with total bacterial counts of 4.62 CFU$\times10^8$/g soil and total fungal counts of 1.12 CFU$\times10^6$/g soil. The experiment consisted twelve treatment combinations of three irrigation schedules *viz.* 0.6, 0.8 and 1.0 IW/CPE ratio in main plots and four drought alleviating microbes *viz.* control (without microbes), MRD-17, CRIDA MI-I and CRIDA MI-II in sub-plots of split-plot design and replicated four times. Initial two common irrigations (50 mm and 40 mm) were applied for proper crop establishment thereafter 50 mm each conventional irrigation was applied as per treatment schedule. A rate of 75 g microbial culture per kg seed was used for the seed treatment. Accordingly, seeds were dipped into each microbial suspension as per treatment and incubated for 4-5 hours in shed. The recommended dose of 50 kg nitrogen/ha, 50 kg phosphorus/ha, 40 kg sulphur/ha were applied uniformly to all the plots. Full dose of phosphorus, sulphur and half dose of nitrogen were applied as basal through urea, Di-ammonium phosphate and bentonite sulphur and the remaining half dose of the nitrogen was top dressed at 35 DAS in moisturized field by urea. The remaining crop management practice were followed as per standard package of practices. The oil content in seed was determined by FT-NIR (Fourier Transferable Near Infra-Red) technique (Model Bruker) as per standard procedure suggested by Tiwari *et al.* (1994). The oil yield was computed by multiplying the seed yield with oil content. It was computed by using the following formula

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil content (\%)} \times \text{Seed yield (kg/ha)}}{100}$$

Field water use efficiency is the ratio of seed yield of crop (Y) to the total amount of water used in the field (Irrigation + Rainfall).

$$\text{FWUE (kg/ha-mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Water applied (mm)}}$$

The standard analysis of variance (ANOVA) technique prescribed for the split plot design was performed to compare the treatment means. Treatment means were compared at the 5% level of significance (P=0.05) using least significant difference (LSD) and hence results are presented here to draw logical inferences.

Results and Discussion

Seed and stover yield

Scheduling of irrigation at 1.0 IW/CPE ratio produced higher seed yield (2045 kg/ha) and stover yield (5204 kg/ha) proved significantly superior over 0.6 IW/CPE ratio but remained statistically on par with 0.8 IW/CPE ratio (Table 1). The positive influence of irrigation scheduling was due to adequate soil moisture in the rhizosphere of mustard crop which results in higher photosynthates and translocation of photosynthates towards reproductive structures. The highly significant and positive correlation established between seed yield and yield attributes confirmed the above findings by Chaudhari *et al.* (2016), Choudhary *et al*. (2023), Digra *et al.* (2016), Parmar *et al.* (2016), Jat *et al.* (2018) and Saini *et al.* (2023). The stover yield also significantly increased with successive increase in number of irrigations. This increase attributed to enhanced availability of moisture which led to better nutritional environment and better moisture availability, which in turn resulted in better vegetative growth. Similar results were also reported by Parmar *et al.* (2016), Barrick *et al.* (2020) and Saini *et al.* (2023).

Among the different drought alleviating microbes, seed treatment with CRIDA MI-I recorded significantly higher seed yield (2018 kg/ha) and stover yield (5277 kg/ha) which remained statistically on par with CRIDA MI-II. Higher seed yield in these treatments might be due to cumulative effect of elevated growth and yield attributes. Increment in seed yield was mainly because of improved yield attributes which ultimately resulted from drought alleviating microbes could produced osmolytes, which are small molecules that helped to protect plant cells from dehydration, increasing nutrient uptake and produced growth hormones that provide nutrition to the plant ultimately resulted in maximum seed yield. The similar results have also been reported by Vikram *et al.* (2022). Drought alleviating microbes had a higher percentage of soil aggregate formation in the *rhizospheric* soils. This might have helped in the soil moisture retention and increased uptake by the plants under low moisture conditions, as evidenced from the higher relative water content in the inoculated treatments. Thus, as a result of better relative water content and chlorophyll content, there was improved vegetative growth, and ultimately higher stover yield was obtained.

Field water use efficiency

Irrigation scheduled at various IW/CPE ratio exert significant influence on field water use efficiency (FWUE). Each higher level of irrigation from 0.6 to 1.0 IW/CPE ratio decreased field water use efficiency. Numerically, higher FWUE (5.41 kg/ha-mm) was recorded at 0.6 IW/CPE ratio while lowest value (3.94 kg/ha-mm) was recorded at 1.0 IW/CPE ratio (Table 1). The FWUE declined with successive increase in IW/CPE ratio was due to greater expense of water by evapotranspiration without proportionate increase in seed yield. While, under stress condition, the crop might have developed a deep root system and have utilized some moisture from deeper soil layers than frequent irrigation and achieved higher yield per unit of water which in turn resulted to higher FWUE. Similar results were also reported by Parmar *et al.* (2016), Jat *et al.* (2018) and Singh *et al.* (2019). Higher FWUE (4.95 kg/ha-mm) was recorded with CRIDA MI-I but it was on par with CRIDA MI-II due to higher seed yield, while lowest value (4.32 kg/ha-mm) was recorded in control (without microbes). Drought alleviating microbes produces a compound called ACC deaminase, which breaks down the plant hormone ethylene. Ethylene is a stress hormone that can cause plants to wilt and die under drought conditions. By breaking down ethylene, ACC deaminase helps to protect plants from drought stress and improve their ability to take up water. This finding has been corroborated by Rathi *et al*. (2018) and Bandeppa *et al*. (2019).

Table 1: Effect of irrigation scheduling and drought alleviating microbes on yield, quality and field water use efficiency (FWUE) of mustard

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	FWUE (kg/ha-mm)	Oil content (%)	Oil yield (kg/ha)
IW/CPE ratio						
0.6	1722	4461	27.9	5.41	39.0	671
0.8	1905	4906	28.1	4.55	38.5	735
1.0	2045	5204	28.3	3.94	37.9	774
SEm±	54	127	1.0	0.12	0.8	27
LSD (*P*=0.05)	186	439	NS	0.42	NS	NS
Drought alleviating microbes						
Control	1762	4438	28.5	4.32	38.2	673
MRD-17	1887	4774	28.44	.62	38.4	721
CRIDA MI-I	2018	5277	27.8	4.95	38.7	783
CRIDAMI-II	1897	4939	27.9	4.65	38.6	730
SEm±	45	133	0.8	0.11	0.9	22
LSD (*P*=0.05)	129	386	NS	0.31	NS	64

Oil content and oil yield

Oil content and oil yield was statistically unaffected due to different irrigation levels. Even though, marginally higher oil content (39.0%) was recorded at 0.6 IW/CPE ratio, while the maximum oil yield (774 kg/ha) was recorded at 1.0 IW/CPE ratio (Table 1). Oil content was also did not influence significantly due to different drought alleviating microbes. While, oil yield was recorded significantly higher under CRIDA MI-I which was remained statistically at par with CRIDA MI-II and MRD-17. This might be due to higher seed yield in drought alleviating microbes inoculated seed as compared to without inoculated seed.

Total nutrients uptake

The data revealed that increase in the level of irrigation significantly increased the total N, P, K and S uptake by mustard. Significantly higher total N, P, K and S uptake (122.7, 12.9, 87.0 and 14.5 kg/ha, respectively) by mustard was recorded by 1.0 IW/CPE ratio (Table 2). This might be due to fact that increases in level of irrigation increased nutrient uptake by seed and stover of mustard which results into higher total N, P and K uptake by mustard. The results are close conformity with the finding of Bhatt and Kushwaha (2019) and Singh *et al*. (2021). Seed treatment with drought alleviating microbes increased the total N, P, K and S uptake by mustard. Significantly higher N, P, K and S uptake (122.1, 13.0, 86.2 and 14.2 kg/ha, respectively) was recorded CRIDA MI-I. Drought alleviating microbes facilitated the release and availability of nutrients in the soil. These microbes break down organic matter, solubilized mineral nutrients, and improved nutrient cycling processes. Microbes contributed to the release of bound or unavailable forms of nutrients into a soluble form that could be taken up by the mustard plants. These results are in agreement with the finding of Ray *et al.* (2015), Cengiz *et al.* (2017) and Singh *et al.* (2023).

Available Nutrients status after harvest

Available nutrient content in soil after harvest of crop showed decreasing trend and found to be non-significant with respect to different IW/CPE ratio (Table 2). The 0.6 IW/CPE found numerically higher available N, P_2O_5, K_2O and S status after harvest with the corresponding value of 155 kg/ha, 36 kg/ha, 205 kg/ha and 9.0 mg/kg, respectively. Drought alleviating microbes did not exert significant effect on available N, P_2O_5, K_2O and S after harvest. Numerically the maximum value of available N, P_2O_5, K_2O and S after harvest were recorded under control.

Table 2: Effect of irrigation scheduling and drought alleviating microbes on total nutrients uptake and available nutrients status after harvest of mustard

Treatment	Total nutrients uptake (kg/ha)				Available nutrients status (kg/ha)			
	N	P	K	S	N	P_2O_5	K_2O	S*
IW/CPE ratio								
0.6 IW/CPE	97.1	10.1	68.8	11.0	155	36	205	9.0
0.8 IW/CPE	109.7	11.7	79.2	13.0	144	34	194	8.6
1.0 IW/CPE	122.7	12.9	87.0	14.5	142	33	186	7.9
SEm±	1.9	0.3	2.2	0.3	4.4	0.9	4.5	0.3
LSD (*P*=0.05)	6.4	0.9	7.5	1.0	NS	NS	NS	NS
Drought alleviating microbes								
Control	98.1	10.2	70.4	11.3	158	35	201	8.7
MRD-17	107.0	11.4	76.7	12.5	146	34	198	8.5
CRIDA MI-I	122.1	13.0	86.2	14.2	141	33	187	8.3
CRIDA MI-II	112.2	11.7	80.0	13.2	143	34	194	8.5
SEm±	2.5	0.3	2.4	0.3	4.8	0.9	5.1	0.3
LSD (*P*=0.05)	7.3	0.7	6.9	0.8	NS	NS	NS	NS

* mg/kg

Microbial status in soil

Irrigation scheduling did not exert significant influence on total microbial counts of mustard (Fig. 1). Irrigation given at 1.0 IW/CPE ratio recorded higher total bacterial counts (5.25 CFU×10^8/g soil) and total fungal counts (1.28 CFU×10^6/g soil). Different drought alleviating microbes did not exert significant influence on total microbial counts of mustard. CRIDA MI-I recorded higher total bacterial counts (5.39 CFU×10^8/g soil) and total fungal counts (1.32 CFU×10^6/g soil).

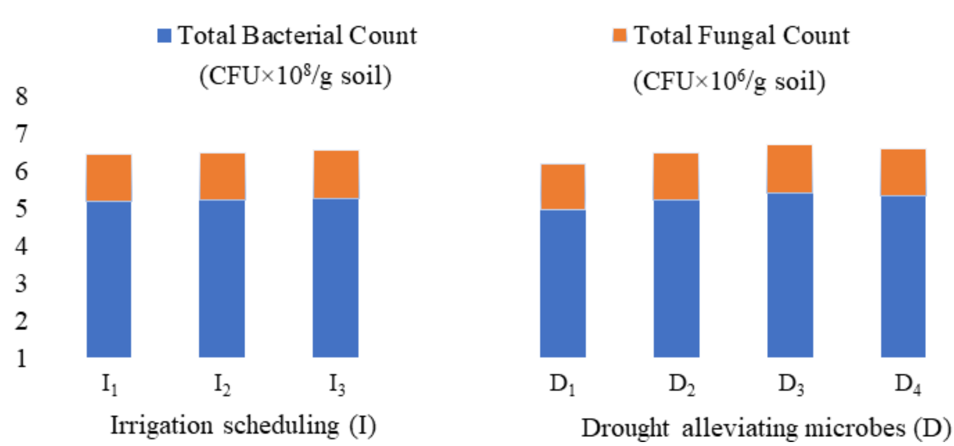

Fig. 1: Effect of IW/CPE ratio and drought alleviating microbes on total bacterial and fungal counts in soil after harvest of mustard

Conclusion

It can be concluded that scheduling of irrigation based on water availability and seed treatment with drought alleviating microbes CRIDA MI-I or CRIDA MI-II could be beneficial in achieving higher yield and field water use efficiency.

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