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Influence of Moisture Stress Management Practices on the Performance of Summer Irrigated Maize (*Zea mays* L.)

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A B S T R A C T

A field experiment was conducted at Agricultural Research Station, Bhavanisagar, Tamil Nadu, India during summer 2018 and 2019 to study the influence of moisture stress management practices on plant growth and yield of maize. Study revealed that, irrigation scheduling at IW/CPE 1.0 produced higher plant height (217.6 cm), leaf area index (3.77), dry matter production (16159 kg ha^{-1}) and yield (6715 kg ha^{-1}) and was comparable with IW/CPE ratio of 0.8. Among the moisture stress management practices foliar application of PPFM 1% at 25 and 45 DAS recorded significantly higher plant height (209.7 cm), leaf area index (3.62), dry matter production (15505 kg ha^{-1}) and yield (6381 kg ha^{-1}). Higher net return (55535 Rs. ha^{-1}) and benefit cost ratio (2.71) was realized under IW/CPE 0.8. In moisture stress management practices foliar application of PPFM @ 1% recorded higher net return (51455 Rs. ha^{-1}) and benefit cost ratio (2.56). Results from the study indicated that, irrigating at IW/CPE ratio of 0.8 was good enough to produce maximum yield and net return in normal water availability condition. While under water scarcity condition IW/CPE ratio of 0.6 coupled with foliar application of PPFM 1% at 25 and 45 DAS was more reliable for sustaining yield and net return.

Keywords

Deficit irrigation, Irrigation scheduling, PPFM, Silicic acid, Brassinolide

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Introduction

Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat and plays important role in agricultural economy as food for larger section of population, raw materials for industries and feed for animals. Drought is the main constraint for maize crop, causing severe yield reductions by 40% on a global scale (Daryanto *et al.*, 2016). Irrigation water is becoming critical scarce resource and expensive due to higher demand by industry and urban consumption. The ground water is depleting at an alarming rate (GOR, 2007) and therefore framing strategies to reduce irrigation water losses and enhance crop water productivity has driven special attention.

Deficit irrigation is an option where water availability limits conventional irrigation and reduces the risk of yield reduction due to terminal dry spell (Singh *et al*., 2010).

Pink pigmented facultative methylotrophic bacteria (PPFM) are associated with the roots, leaves and seeds of most terrestrial plants and utilize volatile C_1 compounds such as methanol generated by growing plants at cell division phase (Irvine *et al*., 2012), increasing CO_2 concentration inside stomata leading to accelerated rate of photosynthesis and decreased the rate of photorespiration in C_3 plants (Wingler *et al*., 2000). During dry spell PPFM exudates osmo protectants (sugars and alcohols) on the surface of host plants and this matrix helps to protect the plants from desiccation and high temperature (Irvine *et al*., 2012).

Silicon is an important element, and plays an important role in inducing tolerance to the plants from environmental stresses (Tripathi *et al.,* 2014). Increased Silicon (Si) supply improves the structural integrity of crops and may also improve plant tolerance to diseases, drought and metal toxicities (Ma, 2004). Si-induced growth improvement under water-deficit conditions has been observed in different species such as wheat (Gong *et al*., 2012), rice (Chen *et al*., 2011), and soybean (Shen *et al*., 2010).

Brassinolide is a steroidal growth regulator has emerged as a new phytohormone with pleiotropic effect (Sasse, 1997), and influences varied physiological processes like germination, growth, flowering, senescence and confers resistance to the plant against various abiotic stresses. Brassinosteroids have been identified to improve the resistance of plants against environmental stresses such as water stress, salinity stress, low temperature stress and high temperature stress (Rao *et al*., 2002). Moreover brassinolides have also been picked out as plant growth and development signals (Ryu *et al*., 2007)

In this regard the present study was aimed at identifying suitable irrigation regime and investigating the effect of moisture stress management practices plant on the growth and yield stability of maize.

Materials and Methods

The experiment was conducted at Agricultural Research Station, Bhavanisagar (11^o29` N, $77^o$08` E, and 256 m above the mean sea-level), Tamil Nadu, India during 2018 and 2019. The soil at experimental site was sandy loam (28.0 % clay, 20.6 % silt, 22.3% course sand and 29.1 % fine sand) medium in organic carbon (0.51%), low in available nitrogen (245.0 kg ha^{-1}), medium in phosphorus (12.8 kg ha^{-1}) and high potassium (446.2 kg ha^{-1}). During the crop growth (Feb – May) of 2018 and 2019, monthly mean maximum and minimum temperature ranged between 35.6^0 C and 24.3^0 C; 37.1^0 C and 23.7^0 C respectively. The experimental site received rainfall of 79.3 mm in seven rainy days during summer 2018 and 118.3 mm in five rainy days during summer 2019. The mean evaporation was 4.4 to 7.2 mm and 3.5 to 7.2 mm in summer 2018 and 2019 respectively.

The experiment was laid out in split plot design comprised of four irrigation regimes based on IW/CPE ratio as main factor *viz*., IW/CPE ratio of 1.0 ($I_{1.0}$), IW/CPE ratio of 0.8 ($I_{0.8}$), IW/CPE ratio of 0.6 ($I_{0.6}$) and IW/CPE ratio of 0.4 ($I_{0.4}$) and four treatments in the sub plot *viz*., foliar application of pink pigmented facultative methylobacteria at 1% (F_{PPFM}), Foliar application of Brassinolide 0.1 ppm (F_{Br}), Foliar application of silicic acid 0.2% (F_{Sl}) and control (F_{cont}) as a sub factor. Foliar application was given on 25 DAS and 45 DAS for each treatment in the sub plot.

Maize cultivar CO(H)M 6 was used as a test variety with 60 cm row spacing and 25 cm between the plants. Recommended dose of NPK for maize hybrid 250:75: 75kg ha^{-1} was adopted as per crop management practices.

Irrigation was given at the time of sowing and the life irrigation on the fifth day and following subsequent irrigations were scheduled based on the irrigation regimes of the main plot as per the IW/CPE ratio and irrigated at a depth of 50 mm measured using parshall flume.

Results and Discussion

Plant height at harvest

Irrigation regime and water deficit management exerted significant influence on the plant height of maize (Table 1). IW/CPE 1.0 recorded significantly higher (217.6 cm) and comparable plant height with IW/CPE 0.8. There was progressive increase in plant height with increase in soil moisture content and was justified with the findings of Alagar Pandyan and Iruthayaraj (1991).

Among the moisture stress management treatments significantly higher plant height (209.7 cm) was recorded in foliar application of PPFM 1% 25 and 45 DAS and was at par with foliar application of silicic acid 0.2%. The increased plant height due to PPFM was confirmed by the research of Suresh Reddy (2002). Increase in plant height in the present study might have been due to the combined effect of auxin and cytokinin production by PPFM, which allowed a balanced growth of shoot and root system.

Leaf area index at harvest

The leaf area index (LAI) at the crop growth stages varied significantly with irrigation regime and management practices (Table 1). Among the irrigation regimes IW/CPE 1.0 recorded higher leaf area index of 3.77 at harvest stage which was comparable with IW/CPE 0.8 (3.73). The increased LAI obtained at the higher regime was due to favorable soil moisture supply, which led to an increase in LAI.

The effect of moisture stress on cell expansion and cell division has been known for a long time and a direct consequence of such effect has adversely affected the LAI (Farooq *et al*., 2010).

Foliar application of PPFM 1% registered higher leaf area index of 3.62 which was at par with foliar application of silicic acid 0.2%. Pink pigmented facultative methylobacteria produced plant growth regulators, resulting in diverse physiological effect over the crop stimulating the division, extension and differentiation of plant cells eventually enhancing plant growth parameters like plant height, total leaf area, number of branches (Muromtsev *et al.*, 1987).

Total Dry Matter Production

Irrigation scheduling and drought management practices significantly influenced the crop dry matter production. IW/CPE 1.0 and 0.8 recorded significantly higher and comparable dry matter production of 16159 kg ha^{-1} and 15873 kg ha^{-1} respectively. IW/CPE 0.4 recorded distinctly lower dry matter production (12647 kg ha^{-1}).

Reduction in dry matter accumulation under lower irrigation regime is because of reduced water availability which leads to water deficit condition for most of the crop growing period. Biomass accumulation is sensitive to water stress and the degree of reduction of biomass accumulation depended on the severity of water stress. The results are in line with the Guo *et al.,* (2010).

Table.1 Influence of moisture stress management practices on growth and yield of summer irrigated maize (Pooled data of two years)

Treatment	Plant height (cm)	LAI	DMP (kg ha^{-1})	Yield (kg ha^{-1})
Irrigation regimes				
$I_{1.0}$	217.6	3.77	16159	6715
$I_{0.8}$	215.6	3.73	15873	6684
$I_{0.6}$	194.3	3.34	14067	5940
$I_{0.4}$	178.8	3.07	12647	4728
SEm ±	1.9	0.04	135	54
CD (p=0.05)	6.7	0.11	468	186
Moisture stress management practices				
F_{PPFM}	209.7	3.62	15505	6381
F_{Br}	198.6	3.42	14322	5869
F_{Sl}	205.2	3.54	14898	6138
F_C	192.8	3.32	14020	5679
SEm ±	1.7	0.03	120	54
CD (p=0.05)	5.0	0.09	348	158
Interaction				
$I_{1.0}$ F_{PPFM}	221.4	3.83	16604	6819
$I_{1.0}$ F_{Br}	216.4	3.74	16125	6708
$I_{1.0}$ F_{Sl}	218.1	3.77	16311	6743
$I_{1.0}$ F_C	214.5	3.71	15594	6589
$I_{0.8}$ F_{PPFM}	220.5	3.82	16475	6784
$I_{0.8}$ F_{Br}	217.2	3.76	15568	6670
$I_{0.8}$ F_{Sl}	218.0	3.77	15840	6724
$I_{0.8}$ F_C	206.8	3.57	15608	6557
$I_{0.6}$ F_{PPFM}	202.9	3.50	14899	6491
$I_{0.6}$ F_{Br}	189.1	3.25	13597	5675
$I_{0.6}$ F_{Sl}	197.9	3.41	14369	6153
$I_{0.6}$ F_C	187.2	3.22	13402	5443
$I_{0.4}$ F_{PPFM}	194.0	3.34	14043	5432
$I_{0.4}$ F_{Br}	171.6	2.94	11998	4424
$I_{0.4}$ F_{Sl}	187.0	3.21	13070	4932
$I_{0.4}$ F_C	162.7	2.77	11475	4127
SEm ±	3.5	0.06	248	108
CD (p=0.05)	10.9	0.19	762	330

Note: $I_{1.0}$, $I_{0.8}$, $I_{0.6}$ and $I_{0.4}$ are Irrrigation regimes of IW/CPE ratio 1.0, 0.8, 0.6 and 0.4 respectively
F – Foliar application at 25 and 40 DAS; PPFM – Pink pigmented facultative methylobacteria 1%;
Sl-Silicic acid 0.2%; Br – Brassinolide 0.1ppm and C – Control

Table.2 Influence of moisture stress management practices on economics of summer irrigated maize (Pooled data of two years)

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	Benefit: cost ratio
Irrigation regimes				
$I_{1.0}$	33448	88656	55208	2.65
$I_{0.8}$	32611	88146	55535	2.71
$I_{0.6}$	31436	78318	46882	2.49
$I_{0.4}$	30848	63065	32216	2.04
Moisture stress management practices				
F_{PPFM}	32875	84330	51455	2.56
F_{Br}	31969	77593	45624	2.42
F_{Sl}	33175	81103	47929	2.44
F_{C}	30325	75158	44833	2.47
Interaction				
$I_{1.0}$ F_{PPFM}	34237	90130	55892	2.63
$I_{1.0}$ F_{Br}	33331	88557	55225	2.66
$I_{1.0}$ F_{Sl}	34537	89068	54531	2.58
$I_{1.0}$ F_{C}	31687	86870	55182	2.74
$I_{0.8}$ F_{PPFM}	33400	89647	56248	2.68
$I_{0.8}$ F_{Br}	32494	87829	55335	2.70
$I_{0.8}$ F_{Sl}	33700	88613	54913	2.63
$I_{0.8}$ F_{C}	30850	86494	55644	2.80
$I_{0.6}$ F_{PPFM}	32225	85339	53114	2.65
$I_{0.6}$ F_{Br}	31319	74902	43583	2.39
$I_{0.6}$ F_{Sl}	32525	81017	48492	2.49
$I_{0.6}$ F_{C}	29675	72012	42337	2.43
$I_{0.4}$ F_{PPFM}	31637	72202	40565	2.28
$I_{0.4}$ F_{Br}	30731	59083	28352	1.92
$I_{0.4}$ F_{Sl}	31937	65715	33778	2.06
$I_{0.4}$ F_{C}	29087	55258	26170	1.90

Statistically not analysed
Note: $I_{1.0}$, $I_{0.8}$, $I_{0.6}$ and $I_{0.4}$ are Irrrigation regimes of IW/CPE ratio 1.0, 0.8, 0.6 and 0.4 respectively
F – Foliar application at 25 and 40 DAS; PPFM – Pink pigmented facultative methylobacteria 1%;
Sl-Silicic acid 0.2%; Br – Brassinolide 0.1ppm and C – Control.

Foliar spray of PPFM produced substantially higher DMP of 15505 kg ha^{-1} around 12.4 per cent over control. In water deficit condition under IW/CPE ratio of 0.4 increased the dry matter production by 20.4 per cent over the control. The increase might have been due to the production of growth hormones *viz.*, IAA, cytokinin and gibberellic acid influencing dry matter production. Moreover cytokinin antioxidant properties protected the leaves from stress induced oxidation. This was justified by finding of Zhang and Ervin (2008).

Yield

Irrigation scheduling and drought management significantly influenced the yield of the crop (Table 1). IW/CPE 1.0 and 0.8 recorded conspicuously higher and comparable grain yield of 6715 and 6684 kg ha^{-1}. The increase in yield could be attributed to greater and consistent available soil moisture due to increased level of irrigation that resulted in better crop growth and yield components. Similar findings were reported by Zhao *et al.,* (2010).

The lower yield in irrigation at IW/CPE of 0.4 might be attributed to the decrease in synthesis of metabolites and reduction in absorption and translocation of nutrients from soil to plant under deficit moisture supply. Among the foliar application treatments foliar application of PPFM recorded distinctly higher grain yield of 6381 kg ha^{-1} followed by foliar application of silicic acid 6138 kg ha^{-1}. The yield increase with the foliar application of PPFM was due to the increased plant growth parameters like plant height, leaf area, and total biomass, corroborating the results of Madhaiyan *et al.,* (2005).

Economics

Higher net return (INR 55,535) and B: C ratio (2.71) was attained under IW/CPE ratio 0.8 and was followed by IW/CPE ratio of 1.0. Among the foliar application treatments foliar application of PPFM 1% recoded higher net return and BC ratio (INR 51,455; 2.56 respectively) followed by silicic acid 0.2%. This might be due to higher grain yield even under water stressed (IW/CPE 0.6) condition (Sumathi and Rao 2008) (Table 2).

In interaction effect irrigating at IW/CPE 0.8 with foliar application of PPFM 1% recorded higher net return (Rs. 56,248) however higher BC ratio were obtained in IW/CPE 0.8 with no moisture stress management practice (2.80). Under mild or no moisture stress condition the foliar application treatments will not be cost effective hence control recorded higher benefit cost ratio.

From the present study it can be concluded that irrigating at IW/CPE 0.8 (12 days interval) is ideal for obtaining higher yield, net return and cost benefit under normal condition. While under water scarcity condition irrigating at IW/CPE ratio of 0.6 (16 days interval) with foliar application of PPFM 1% on 25 and 45 DAS was found to be suitable for sustaining the yield, net return and cost benefit.

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