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Research Paper

Performance of summer maize (*Zea mays*) under varying irrigation levels and agro-chemicals in sub-humid southern plains of Rajasthan

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ABSTRACT

A field experiment was conducted during summer season of 2010 and 2011 at Rajasthan college of Agriculture, Udaipur, to evaluate the impact of irrigation levels and agro-chemicals on yield and water-use efficiency (WUE) of maize (*Zea mays* L.). The application of 8 irrigations significantly improved crop-growth rate (CGR) at 25–50 days after sowing (DAS) and 50–75 DAS, relative water and chlorophyll contents. The maximum grain weight/cob (63.6 g), cob length (15.9 cm), 1000-seed weight (176.9 g) and shelling% (76.7) were recorded with 8 irrigations. Similarly, application of 8 irrigations also resulted in significantly higher grain and stover yields, and the highest consumptive use (279.1 ha-mm) and water-use efficiency (9.52 kg/ha-mm). Among the agro-chemicals, application of brassinolide resulted in the maximum CGR at 25–50 (7.06 g/m/day) and 50–75 (19.5 g/m/day) DAS, respectively. Likewise, brassinolide also superior most with respect to all the yield attributes, yields and shelling % as compared to the other chemicals. Brassinolide application also resulted in the highest consumptive use (244.7 ha-mm) and water-use efficiency (9.35 kg/ha-mm) among all the agrochemicals.

***Key words*:** Brassinolide, Irrigation, Maize, Water-use efficiency, Yield

Maize is considered third most important cereal crop after wheat and rice in the world (Fayza *et al.*, 2016). Maize contributes to more than half of the coarse cereal production of the country and used as animal feed as well as industrial raw material in the developed countries, whereas, in the developing countries it is also used as general food for human being. Maize grain is main ration for poultry birds besides it can be used as fodder for domestic animals. With the development of high-yielding varieties and hybrids in this crop which are competitive to rice with respect to farm profitability and the resource-use efficiency under diverse soils and climatic conditions, maize–wheat cropping system is gaining importance in Indo-Gangetic Plains (Yadav and Subba Rao, 2001).

Currently there is a need to give more emphasis on water-management aspect, as water scarcity is a major emerging problem. It is estimated that even after exploration of full irrigation potential of the available water resources in the India, around half of the total cultivated area will remain rainfed. Under this scenario, we need an alternate strategy for sustaining the current maize production. For this purpose there are 2 alternative approaches which may prove rewarding, either we need to optimize available water through judicious use at critical stages of the crop or mitigate injurious effects of water shortage on crop growth with the help of application of some agro-chemicals. Moisture shortage can cause several physio-chemical injuries in the plants which ultimately results in intact loss of final yield. To alleviate such of injurious effects of moisture shortage, agro-chemicals along with adoption of critical stage irrigation approach are a good option and can be used for increasing the crop yield through their uses (as bio-regulator) to modify the various metabolic and physiological processes inside the plant system (Meena *et al.*, 2016).

Various agro-chemicals were reported to modify the growth and yield attributes and ultimately yield and eco-

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nomics of maize production. Among agro-chemicals tested, brassinolide is most important just because of its role in stimulating cell division/ elongation by enhancing carbohydrate activity in stem and leaves. Brassinolide can enhance the growth and yield- contributing characters of the crops under varied environmental conditions (Mandava, 1988). Contrary to this, use of benzyladenine also reported to be antagonistic to moisture-stress environment (Virk *et al.,* 1985). Thiourea is another agro-chemical which may be used to modify the growth behaviour of the crops. Foliar spray of Thiourea @ 1,000 ppm increases growth, yield-attributing characters, yields and quality parameters of various crops (Sareen, 2002; Mehta, 2004). In plants, potassium plays a great role in wider range of physiological processes. Potassium ion (K^+) plays significant role in osmoregulation and turgidity of cells. Potassium has a general role in the regulation of water in plants cells through its major role in stomata closing and opening, which ultimately control transpiration rate of crop plants. Under water-stress conditions, K present in KCl reported to helps the plants to maintain their physiological processes through checking water losses via transpiration (Mukherji and Ghosh, 1996). Regulation and modification of plant-growth behaviour by using growth substance with appropriate rate at different growth stages would results in increase productivity maize under moisture-stress conditions. The main aim of this study is to evaluate the effect of various irrigation levels and agro-chemicals on growth, yield attributes and yields of summer maize.

MATERIALS AND METHODS

The experiment was carried out at the research farm of Rajasthan college of Agriculture, Udaipur (24º35’N and 73º42’E and 582.17 m above the mean sea-level). The soil of experimental field had 263.42 kg N/ha, 21.3 kg/ha available phosphorus and 334.47 kg/ha available potassium. The clay-loam soil of experimental field was slightly alkaline, with *p*H 8.0 value. The experiment was laid out in split-plot design with 5 irrigation levels in main plots, i.e. 4 irrigations [6 leaf stage, knee-high stage (25–30 days after sowing), 50% tasseling and grain formation stages], 5 irrigations (6-leaf stage, knee-high stage, tasseling, 50% silking and grain filling stages), 6 irrigations (6-leaf stage, knee-high, tasseling, 50% silking, grain-formation and grain filling stages), 7 irrigations (6-leaf stage, knee-high, stage before tasseling, 50% tasseling, 50% silking, grain-formation and grain-filling stages) and 8 irrigations (seedling stage, 6-leaf stage, knee-high stage, before tasseling, 50% tasseling, 50% silking, grain-formation and grain-filling stages) and 5 agrochemical treatments were taken in sub-plot, i.e. water spray, brassinolide (0.5 ppm), benzyladenine (45 ppm), thiourea (1,000- ppm) and KCl (1,000- ppm). All treatments were taken in triplicates.

The crop-growth rate (CGR) between 25–50 days after sowing (DAS) and 50–75 DAS were computed on the basis of dry-matter accumulation as per Redford (1967). Relative water content of fresh leaf 7 days after second spray of agro-chemicals (i.e. 55 DAS) was determined (Weatherly, 1950). The total chlorophyll content of fresh leaf samples 7 days after second spray of agro-chemicals (55 DAS) were estimated as:

$$\text{Total chlorophyll (mg/g fresh weight of leaf)} = \frac{20.2\ (A\ 645) + 8.02\ (A\ 663)}{a \times 1000 \times W} \times v$$

where, a = length of light path in cell (1 cm), v = volume of extract, W=weight of leaf sample

Length of 5 selected cobs was measured and after taking average it is expressed as length/cobs in cm. Five cobs were randomly selected from the total cobs of sample plants, and after shelling, grains were counted and expressed in grains/cob. Grain samples were drawn from the produce after weighing the net yield of each plot. From these, 1,000-grains were counted and weighed on electronic top pan balance to record test weight (g). Shelling percentage was computed empirically by using following formula:

$$\text{Shelling (\%)} = \frac{\text{Weight of grains}}{\text{Weight of cobs}} \times 100$$

Consumptive use of was water calculated by adding (a) potential evapo-transpiration value for accelerated water loss for the interval just after irrigation and before soil-moisture sampling, (b) soil moisture used from the profile from the day of sampling to just before the next irrigation, and (c) effective rainfall, computation of consumptive use of water was done as per procedure suggested by Dastane (1972). While the water-use efficiency of crop was calculated using the ratio of crop yield (Y) to the amount of water depleted by the crop in the process of evapo-transpiration (ET) was computed according to the following formula as suggested by Viets (1962). All the experimental data were subjected to statistical analyses using IRRISTAT 4.0 (IRRI, 1999). Whenever, F-test was found significant critical differences were calculated (Gomez and Gomez, 1984).

WUE = Economic yield (kg ha^{-1}) / Consumptive use of water (cm)

Water productivity = Gross returns (Rs ha^{-1}) /Total water used (mm)

RESULTS AND DISCUSSION

Growth analysis

At 25–50 DAS, crop-growht rate was affected significantly by different irrigation levels. Application of 8 irrigations recorded the maximum CGR. In successive crop-growth periods (50–75 DAS), with increasing number of irrigations from 4 to 8 increased CGR significantly. The highest CGR was recorded with 8 irrigations. The lower value of crop-growth parameters with 4 irrigations may be due to water shortage and its effect on physiology and bio-chemical metabolism of crops. The results confirm the findings of Sharma *et al.* (2008). The application of agro-chemicals significantly improved CGR at both crop-growth stages, i.e. 25–50 and 50–75 DAS, over water spray except application of KCl which was at par with water spray at 25–50 DAS (Table 1). Among the agro-chemicals, brassinolide recorded the maximum CGR that noted with at 25–50 and 50–75 DAS, which was statistically at par with benzyladenine. The higher values of CGR with agro-chemicals may be owing to availability of sufficient soil moisture for continued growth which leads to faster metabolism of the plants and resulted into higher crop growth. Kanojia (2006); Mehta *et al*., (2006) and Meena *et al*., (2013) also reported similar results.

Relative water content

Relative water content increased significantly with the increasing levels of irrigation and 8 irrigations resulted in the maximum RWC (Table 1). The lower RWC under limited supply of irrigation water may be due to the fact that water shortage reduces crop growth under stressed condition, while 8 irrigations provides sufficient soil moisture that in turns leads to higher RWC in plants. Likewise, application of all agro-chemicals also showed significantly higher RWC over water spray. Application of brassinolide resulted in significantly highest RWC over rest of the chemicals (Table 1). However, benzyladenine and thiourea were found significantly superior to water spray. Application of agro-chemicals improves water availability that enhanced water absorption through roots and ultimately leads to higher RWC. Mehta (2004) and Mehta *et al.,* (2006) also reported higher RWC with the application of agro-chemicals.

Chlorophyll content

Chlorophyll content in maize leaves increased significantly with the increasing levels of irrigation, and the maximum chlorophyll content was recorded with application of 8 irrigations (Table 1). The water deficit with 4 irrigations may negatively affect the metabolic activities of plants, resulting in declined crop growth, nitrogen metabolism which led to reduction in chlorophyll content of leaves, while reverse is true in case of 8 irrigation (Farooq *et al*., 2009). All the agro-chemicals tested (Table 1) showed significant superiority to water spray with respect to chlorophyll content. Application of brassinolide resulted in maximum chlorophyll content over rest of the chemicals. The increase in chlorophyll content of leaves with the application of agro-chemicals may be owing to higher growth and development which leads to higher uptake of nitrogen that is essential for the formation of chlorophyll in the plants (Meena *et al.,* 2014).

Yield attributes

Yield attributes like grain weight/cob, cob length, 100-seed weight and shelling % were also significantly influ-

Table 1. Effect of irrigation levels and agro-chemicals on crop-growth rate (CGR), relative water content (RWC), chlorophyll contents (mg/g fresh weight) and yield attributes of maize (pooled over 2 year)

Treatment	CGR 25–50 DAS	CGR 50–75 DAS	RWC (%) at 55 DAS	Chlorophyll contents at 55 DAS	Grains/cob	Weight of grains/cob (g)	Cob length (cm)	1000 seed weight (g)	Shelling (%)
Irrigation level									
4 irrigations	5.27	17.65	69.90	1.38	262.7	46.9	9.6	155.1	66.2
5 irrigations	5.95	18.07	73.92	1.46	284.4	51.8	12.1	171.8	72.9
6 irrigations	6.69	18.65	78.63	1.64	294.7	59.0	13.6	173.7	74.3
7 irrigations	7.92	19.78	84.17	1.81	302.0	62.6	15.7	175.7	75.7
8 irrigations	8.20	20.41	88.61	1.88	308.8	63.6	15.9	177.0	76.7
SEm±	0.09	0.26	0.19	0.01	1.93	0.44	0.03	0.07	0.09
CD (P=0.05)	0.27	0.78	0.58	0.04	5.78	1.33	0.08	0.20	0.26
Agro-chemicals									
Water spray	6.53	18.33	77.50	1.56	271.2	51.7	13.0	169.7	71.6
Brassinolide	7.06	19.48	81.07	1.74	312.5	59.3	13.8	171.6	74.3
Benzyladenine	6.90	19.26	79.70	1.66	298.7	58.3	13.6	170.8	73.7
Thiourea	6.94	18.85	79.00	1.64	289.7	57.7	13.4	170.6	73.4
KCl	6.61	18.64	77.80	1.57	280.4	56.9	13.2	170.5	72.8
SEm±	0.04	0.11	0.16	0.11	1.54	0.19	0.02	0.05	0.07
CD (P=0.05)	0.12	0.31	0.45	0.02	5.25	0.55	0.07	0.13	0.21

enced by irrigation levels and agrochemicals (Table 1). Maximum grains/cob, weight of grain/cob, cob length, 1000-seed weight and shelling % were observed with the application 8 irrigations. Among the agro-chemicals, brassinolide resulted in the maximum number of grains/ cob, weight of grains/cob, cob length, 100-seed weight and shelling %. Foliar application of the brassinolide increased cob length by 5.84, 1.54, 2.76 and 4.39% over water spray, benzyladenine, thiourea and KCl respectively. The combined effect of irrigation and agrochemicals facilitate sufficient moisture for higher growth and development of the plants, and enhanced photosynthetic efficiency by improving source-sink relationship leads to improvement in yield attributes. These findings confirm those of Parihar *et al.,* (1998) and Mehta (2004).

Yields and harvest index

Application of 8 irrigations resulted in the highest grain, stover, biological yield and harvest index. The magnitude of increase in grain yield with 8 irrigations was 82.3, 45.8, 13.4 and 10.5% over 4, 5, 6 and 7 irrigations respectively (Table 2). Application of agro-chemicals proved significantly superior to water spray in terms of maize yields and harvesting index. Among the agro-chemicals, brassinolide application resulted in significantly higher grain, stover, biological yields and harvesting index. The application of brassinolide recorded 15.49, 7.92, 9.03 and 1.33% higher grain yield over water spray, benzyladenine, thiourea and KCl respectively. Eight irrigations improves moisture availability that increases source-sink relationship and facilitates higher translocation of photosynthetic substances from leaves to grain which ultimately reflected in maize yields. Moisture stress in crops with shortage of water leads to decrease in translocation of carbohydrates and growth substances, disturbed nitrogen metabolism, forced loss of turgor which consequently reduce in sink size and its growth (Farooq *et al*., 2009). The reduction in aforesaid physiological and biochemical activities led to lower photosynthetic rate per unit area, ultimately lower yields and harvesting index with lower levels of irrigations. Our results confirm the findings of Kalpana and Krishnarajan (2003).

Consumptive use and water-use efficiency

Increase in irrigation levels from 4 to 8 significantly increased consumptive use and water-use efficiency (Table 2). Application of 8 irrigations increased the consumptive use by 88.24, 48.21, 21.10 and 11.40% and water-use efficiency by 14.70, 8.68, 6.13 and 3.82% over 4, 5, 6 and 7 irrigations respectively. Likewise, application of agro-chemicals had significant effect on consumptive use and water-use efficiency over water spray. Brassinolide application recorded the highest consumptive use and water-use efficiency and was superior to rest of the agro-chemicals. However, benzyladenine remains statistically at par with KCl in case of consumptive use of water. Application of brassinolide increased the consumptive use by 23.97, 9.01, 13.57, 13.96% and water-use efficiency by 10.13, 3.20, 6.98 and 2.75% over water spray, benzyladenine, thiourea and KCl respectively. This increase might be owing to

Table 2. Effect of irrigation levels and agro-chemicals on yields, harvest index, consumptive use and water-use efficiency in maize (pooled over 2 years)

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Consumptive use (ha-mm)	Water use efficiency (kg/ha-mm)
Irrigation level						
4 irrigations	1.59	2.76	4.36	36.73	148.30	8.30
5 irrigations	1.99	3.33	5.32	37.53	188.36	8.76
6 irrigations	2.56	4.16	6.72	38.10	230.51	8.97
7 irrigations	2.63	4.29	6.92	38.01	250.60	9.17
8 irrigations	2.90	4.62	7.52	38.60	279.17	9.52
SEm±	0.28	0.39	0.65		2.39	0.07
CD (P=0.05)	0.84	1.16	1.94		7.16	0.23
Agro-chemicals						
Water spray	2.20	3.70	5.90	37.28	197.42	8.49
Brassinolide	2.55	3.98	6.52	38.79	244.75	9.35
Benzyladenine	2.36	3.89	6.25	37.72	224.52	9.06
Thiourea	2.33	3.84	6.18	37.75	215.49	8.74
KCl	2.25	3.75	5.99	37.43	214.76	9.10
SEm±	0.14	0.25	0.37		1.70	0.05
CD (P=0.05)	0.41	0.72	1.04		4.79	0.15

availability of more water to fulfil evapotranspiration and metabolic requirement of the plant which leads to higher growth and dry-matter production of plants. It can be concluded that for obtaining the maximum yield and profit from summer maize crop in sub-humid southern plain of the Rajasthan, it should be grown with 8 irrigations and 2 foliar sprays of brassinolide at 0.50 ppm at 45 DAS and 55 DAS.

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