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Water productivity of *rabi* maize (*Zea mays* L.) as influenced by planting geometry and moisture regimes

KKK Reddy, AK Singh and RS Singh

Abstract

A field experiment with maize was conducted during *rabi* 2016-2017 on silty loam soils at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.). The experimental design was split plot design with three replicates. The objective of this study was to determine the effect four planting geometry *viz.*, 60 × 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and four moisture regimes *viz.*, 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season on water productivity of *rabi* maize. Among the planting geometry, highest irrigation water productivity (1.01 kg/m^3), input water productivity (0.98 kg/m^3) and real water productivity (1.29 kg/m^3) was recorded in 60 × 25 cm, while the lowest irrigation water productivity (0.88 kg/m^3), input water productivity (0.85 kg/m^3) and real water productivity (1.00 kg/m^3) was recorded in 60 × 10 cm. With respect to different moisture regimes tried highest irrigation water productivity (1.36 kg/m^3), input water productivity (1.30 kg/m^3) and real water productivity (1.40 kg/m^3) was recorded in 0.6 IW/CPE ratio, while the lowest irrigation water productivity (0.83 kg/m^3), input water productivity (0.81 kg/m^3) and real water productivity (1.01 kg/m^3) was recorded in 1.2 IW/CPE ratio.

Keywords: Water productivity, *rabi* maize, planting geometry, IW/CPE ratio, moisture regimes

Introduction

Maize (*Zea mays* L.) is the third most important grain crop in India after rice and wheat with respect to area and productivity. Globally maize is cultivated in an area of 177 million hectares with a production and productivity of 989 and 5.5 metric t ha^{-1}, respectively (Commodity profile-maize, 2015) [1]. In India it is grown in an area of 9.43 million hectares with production of 24.35 Mt and 2562 kg ha^{-1} productivity (CMIE, 2016) [5]. It has wide ecological adaptability and is grown in extreme semi-arid to sub-humid and humid regions as a staple crop for human beings, feed for animals and as a basic raw material for production of starch, oil, protein, alcoholic beverages, food sweeteners and more recently bio-fuel (Dass *et al*., 2008) [2]. The average grain yield of maize is not only substantially lower compared with other important maize growing countries but also less than the production potential of existing genotypes. Traditionally maize is a rainy/*kharif* season crop in India and is extensively grown under rainfed conditions, but *kharif* crop suffers due to vagaries of monsoon, excessive rainfall leading to water stagnation, poor drainage, erratic and insufficient rainfall leading to moisture stress condition, severe infestation of pests and diseases, fertilizer losses, greater weed menace and high temperature throughout the growth period which tend to reduce grain yield. On the contrary, the risk of damage to the crop from excessive rainfall, water stagnation, inadequate soil moisture, pest and disease infestation during winter/*rabi* season is less. The average grain yield of maize is not only substantially lower compared with other important maize growing countries but also less than the production potential of existing genotypes. Low yield of maize is due to many constraints but among them, cultivation of local genotypes, imbalanced use of fertilizers, traditional sowing methods, improper water management, lack of optimal crop stand and optimum planting geometry are the factors of prime importance. Planting geometry and water management play an important role in enhancing the crop productivity. Planting geometry *i.e.* plant population per unit area have immense role since it is a non tillering crop. Sub optimal plant stand *i.e.* wider spacing leads to poor yield per unit area. While higher plant populations have greater competition for growth resources and leads to poor yield. In order to produce higher yields of maize, optimum soil moisture should be maintained as it is susceptible to both water logging and water deficit. Among the different approaches for scheduling, the climatological approach based on IW/CPE ratio (IW - irrigation water, CPE - cumulative pan evaporation) has been found most appropriate as it integrates all weather parameters that determine water use by the crop and is likely to increase production by at least 15-20% (Dastane, 1972) [3]. The main challenge of the agricultural sector is to produce more food with less water use, which can be achieved by increasing crop water productivity (Kijne *et al*., 2003) [6]. Water is the most limiting factor for agricultural production in many regions, maximizing crop water productivity may be economically more profitable for the farmers than maximizing yield (English and Raja, 1996). With this background information the present study was conducted to determine the effect four planting geometry *viz.*, 60 × 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and four moisture regimes *viz.*, 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season on water productivity of *rabi* maize.

Materials and Methods

A field experiment was conducted during *rabi* 2016-2017 at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) (26° 47' N latitude, 82° 12' E longitude and 113 m above mean sea level) to investigate **"**Water productivity of *rabi* maize as Influenced by planting geometry and moisture regimes". The soil of the experimental field was silty loam with bulk density (1.35 g cm^{-3}), pH (8.10), organic carbon (0.32%) and available N, P and K contents were 185.0, 15.2 and 265 kg ha^{-1} respectively. The moisture content at field capacity and permanent wilting point was 23.69% and 11.28% respectively. The experiment was laid out in split-plot design and replicated thrice. Main plots treatments consisted of 4 planting geometry, *viz.*, 60 × 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and the sub-plots with 4 levels of moisture regimes *viz.*, 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season. Recommended doses of N: P_2O_5: K_2O ha^{-1} @ 150:60:40 kg ha^{-1} were applied in the form of urea, single super phosphate and muriate of potash, respectively. Full dose of P_2O_5, K_2O and one fourth dose of nitrogen was applied as basal and half N was applied as topdressing after 35 DAS while the remaining one fourth N was applied at tasseling stage. The maximum and minimum temperatures were 25.64ºC and 11.59ºC respectively during crop growing season. Maize variety 'Shakthi' was sown during 3rd week of October. Plant protection measures were taken as and when required. Other cultural operations were carried out as per recommendations. Harvesting of Maize was done during 1st week of March. A common irrigation was given at 30 DAS. Remaining irrigations were scheduled as per treatments when CPE reached at respective levels. 60 mm depth of irrigation water was maintained with the help of parshall flume. Number of irrigations at 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season were 6, 9, 11 and 10 respectively. Total rainfall during the crop growth period was 17.5 mm

Total water used (mm)

The amount of water applied under each irrigation treatment was measured through parshall flume. The effective rain fall received in the crop growth period was added to this and expressed as total water used in mm.

Water productivity

Irrigation water productivity

Irrigation water productivity (WP_I) was calculated as the ratio of the recoded grain yield (kg) to the amount of water applied irrigation water (m^3) and expressed as kg/m^3

Input water productivity

Input water productivity (WP_{I+R}) was calculated as the ratio of the recoded grain yield (kg) to the sum of irrigation water and rainwater amount (m^3) and expressed as kg/m^3

Real water productivity

The Real water productivity (WP_{ET}) as the ratio of the recoded grain yield (kg) to the total water used for evapotranspiration (m^3) and expressed as kg/m^3

Table 1: Details of the treatments

S. No.	Treatment	Symbol used
Planting geometry (main plots)		
1	60 × 10 cm	P_1
2	60 × 15 cm	P_2
3	60 × 20 cm	P_3
4	60 × 25 cm	P_4
Moisture regimes (sub plots)		
1	0.6 IW/CPE ratio	M_1
2	0.9 IW/CPE ratio	M_2
3	1.2 IW/CPE ratio	M_3
4	0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season	M_4

Table 2: Details of Irrigation

Moisture regimes	No of irrigations	Depth of irrigation (mm)	Total water applied (mm)	Rainfall (mm)	Total water received (mm)
I_1	6	60	360	17.5	377.50
I_2	9	60	540	17.5	557.50
I_3	11	60	660	17.5	677.50
I_4	10	60	600	17.5	617.50

Results and Discussion

Total water used (mm)

Total water used (mm) was calculated for each treatment and presented in Table 3.

During the crop growth period, an amount of 17.50 mm of effective rainfall was received. Among the irrigation schedules, the total water consumed including effective rainfall received was less (377.50 mm) in irrigation treatment scheduled at 0.6 IW/CPE ratio as compared to the other irrigation schedules. Whereas, highest amount of applied water (677.50 mm) was used in irrigation scheduled at 1.2 IW/CPE ratio. It was due to frequent irrigation schedules as a result of higher IW/CPE adopted, for this whenever the cumulative pan evaporation reached 60 mm, irrigation was scheduled. These findings were in accordance with findings of Ramamoorthy *et al.* (1998) [7].

The amount of irrigation water applied was 360, 540, 660, 600, mm respectively among the Irrigation treatments. The total water consumed including effective rainfall of 17.5 mm was 317.5, 557.5, 677.5 and 617.5 mm in 0.6, 0.9, 1.2 and 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season, respectively.

Water productivity

Water productivity (kg/m^3) was calculated for each treatment and presented in Table 4.

With respect to planting geometry highest irrigation water productivity (1.01 kg/m^3), input water productivity (0.98 kg/m^3) and real water productivity (1.29 kg/m^3) was recorded in P_4 (60 × 25 cm), while lowest irrigation water productivity (0.88 kg/m^3), input water productivity (0.85 kg/m^3) and real water productivity (1.00 kg/m^3) was recorded in P_1 (60 × 10 cm).

Among the different moisture regimes tried highest irrigation water productivity (1.36 kg/m^3), input water productivity (1.30 kg/m^3) and real water productivity (1.40 kg/m^3) was recorded in M_1 (0.6 IW/CPE ratio). Though the grain yield is realized at higher level of irrigation, but the irrigation water productivity (0.83 kg/m^3), input water productivity (0.81 kg/m^3) and real water productivity (1.01 kg/m^3) was less in M_3 (1.2 IW/CPE ratio) when compared to low levels of irrigation. Decreased trend of water productivity was observed by increased frequent of irrigations. This was might be due to even at permanent wilting point condition also the plant able to with stand and produce a minimum yield attributes.

Table 3: Irrigation water applied and total crop water requirement under different planting geometry and moisture regimes of maize during *rabi*, 2016-17

Treatments	No of irrigations	Effective Rainfall (m^3)	Applied irrigation water (m^3)	Total water used (m^3)
Planting geometry				
P_1	9	175	5400	5575.00
P_2	9	175	5400	5575.00
P_3	9	175	5400	5575.00
P_4	9	175	5400	5575.00
Moisture regimes				
M_1	6	175	3600	3775.00
M_2	9	175	5400	5575.00
M_3	11	175	6600	6775.00
M_4	10	175	6000	6175.00

Table 4: Irrigation water productivity (WP_I), Input water productivity (WP_{I+R}) and Real water productivity (WP_{ET}) of *rabi* maize as influenced by planting geometry and moisture regimes

Treatments	Evapotranspiration (m^3)	Grain yield (kg)	WP_I (kg/m^3)	WP_{I+R} (kg/m^3)	WP_{ET} (kg/m^3)
Planting geometry					
P_1	4740.00	4775	0.88	0.85	1.00
P_2	4507.00	5174	0.95	0.92	1.14
P_3	4372.00	5261	0.97	0.94	1.20
P_4	4260.00	5498	1.01	0.98	1.29
Moisture regimes					
M_1	3501.00	4909	1.36	1.30	1.40
M_2	4157.00	5154	0.95	0.92	1.23
M_3	5435.00	5538	0.83	0.81	1.01
M_4	4795.00	5180	0.86	0.83	1.08

Conclusion

Among the planting geometry, highest irrigation water productivity (1.01 kg/m^3), input water productivity (0.98 kg/m^3) and real water productivity (1.29 kg/m^3) was recorded in 60 × 25 cm, while the lowest irrigation water productivity (0.88 kg/m^3), input water productivity (0.85 kg/m^3) and real water productivity (1.00 kg/m^3) was recorded in 60 × 10 cm. With respect to different moisture regimes tried highest irrigation water productivity (1.36 kg/m^3), input water productivity (1.30 kg/m^3) and real water productivity (1.40 kg/m^3) was recorded in 0.6 IW/CPE ratio, while the lowest irrigation water productivity (0.83 kg/m^3), input water productivity (0.81 kg/m^3) and real water productivity (1.01 kg/m^3) was recorded in 1.2 IW/CPE ratio.

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