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Short Note

Impact of Irrigation Water Stress and Plant Population on Water Productivity and Maize Yield

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Field investigation was conducted on effect of water deficit and plant populations on maize during *kharif* (2009) season in a split plot design with irrigation as main plot treatments and plant population as sub plot treatments. The irrigation treatments such as normal irrigation water requirement (0.8 IW/CPE ratio) (500 mm) (I_1), 75 % of irrigation water requirement (0.6 IW/CPE ratio) (375 mm) (I_2), 50 % of irrigation water requirement (0.4 IW/CPE ratio) (250 mm) (I_3), with a normal spacing (60x20cm) (80,000 plants ha^{-1}) (S_1), narrow spacing (30x30cm) (1,06,666 plants ha^{-1}) (S_2) and reduced narrow spacing (45x20cm) (1,11,111 plants ha^{-1}) (S_3) were followed. Higher water productivity was observed in 50 % irrigation water requirement followed by 75% of water requirement. Yield increment was registered in narrow spacing than normal spacing. Narrow planting increased the yield by 5 %, 6 %, 13 % over the normal spacing in 50 %, 75% and normal water requirement.

Key words: Relative Water Content, Water Productivity, Harvest Index, Plant population

Maize is a tropical cereal and variations in plant density determines the utilisation of available resources, allowing the expression of maximum attainable yield in that environment (Sangoi, 2000). Extreme water stress at different stages of crop development has been reported to reduce the yield significantly (Dhillon *et al.,* 1995). Plant spacing affects most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition among the plants (Sangakkara *et al*., 2004). Previous experiments conducted to evaluate the effect of row spacing on maize grown under rainfed conditions indicated that grain yield increased with decrease in spacing between rows (Barbieri *et al*., 2000). Several experimental results have shown that biomass yield decreased progressively as the number of plants increased in a given area because of the reduction of per plant yield (Hamidia *et al*., 2010).

Maize is well adapted to deficit irrigation, with the exception of few growth stages (Karam *et al*., 2003). Regulated deficit irrigation could play a beneficial role in developing practical recommendations for optimizing crop water productivity (Schahbazian *et al*., 2007). Oktem (2008) concluded that the relationships between fresh ear yield and irrigation level treatments were statistically significant (Pd"0.05), and the yield decreased with increasing deficit irrigation. Chen *et al*. (2009) revealed that increase of irrigation water resulted in more crop yields, but the water amount required to gain maximum water productivity was much less than that required for obtaining the maximum crop yield. With these in view, the present study was taken up to evaluate the performance of maize growth and yield under reduced water level with increased plant population.

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Materials and Methods

A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* (2009). The maize hybrid COH(M)5 was used for experimental purpose. The parentage of this hybrid is UMI 285 x UMI 61 and the duration of the crop is 100-105 days. The physiochemical characteristics of soil in the experimental site were assessed and the experiment was carried out.

Physico - chemical properties of the experimental field

Parameters	Value / Content
pH (1: 2 of soil : water)	8.34
Electrical conductivity (dS m^{-1})	0.65
Field Capacity (%)	42.25
Permanent Wilting Point (%)	30.05
Available Soil Moisture (%)	10.74
Available Nitrogen (kg ha^{-1})	420
Available Phosphorus (kg ha^{-1})	15.2
Available Potassium (kg ha^{-1})	550
Organic carbon (%)	0.38

The maximum and minimum mean temperature of cropping period were 31.0 ^{o}C and 22.5 ^{o}C. The mean maximum and minimum RH of cropping

period were 88.3 % and 56.3%. The mean evaporation rate of cropping period was 4.7 mm. The mean solar radiation of cropping period was 346.7 Cal cm^{-2} day^{-1}. Mean rainfall during the cropping season was 4.1 mm. Field experiment was carried out in *kharif* (2009) with three levels of water deficit and three plant populations and quad replicated in Spilt-Plot Design. The treatments under main plot were Normal Irrigation water requirement (0.8 IW/CPE ratio) (500 mm) (I_1), 75 % of Irrigation water requirement (0.6 IW/CPE ratio) (375 mm) (I_2) and 50 % of Irrigation water requirement (0.4 IW/ CPE ratio) (250 mm) (I_3). The treatments in sub plots were normal spacing (60x20cm) (80,000 plants ha^{-1}) (S_1), narrow spacing (30x30cm) (1,06,666 plants ha^{-1}) (S_2) and reduced narrow spacing (45x20cm) (1,11,111 plants ha^{-1}) (S_3). The amount of irrigation water to the crop was given by Parshall flume apparatus with a throat with of 7.5cm. Water productivity was calculated as the weight of grains produced per unit of water input (irrigation and rainfall) as per the following formula of Yang *et al*. (2005) and expressed as (kg m^{-3}). Water productivity = Grain yield / (Irrigation + Rainfall).

Results and Discussion

The reduced irrigation water level on maize crop showed increased water productivity at all the growth stages. The maximum water productivity recorded was in I_3 (10.7 kg m^{-3}) (50% water requirement) followed by I_2 (7.6 kg m^{-3}) (75% water requirement) at silking stage of maize. Among the combination of irrigation and spacing treatments, higher water productivity was observed under 50 % irrigation water requirement along with narrow spacing (I_3S_2) at all phenophases (Table 1) . This indicates that regulated deficit irrigation can play a useful role in developing practical recommendations for optimizing crop water productivity under conditions of scarce water supply influenced by *Schahbazian et al*. (2007).

Table 1. Effect of irrigation level and plant population on water productivity (kg m^{-3}) at different growth stages of maize

Treatment	Vegetative (35 DAS)	Tasseling (55DAS)	Silking (60DAS)	Grain filling (85DAS)	Mean	Treatments	Vegetative (35 DAS)	Tasseling (55DAS)	Silking (60DAS)	Grain filling (85DAS)	Mean
Irrigation						I_1S_1	1.3	4.2	4.8	7.8	4.53
I_1	1.3	4.5	5.4	8.3	4.88	I_1S_2	1.4	4.6	6.1	10.0	5.53
I_2	1.6	6.4	7.6	8.6	6.05	I_1S_3	1.2	4.7	5.3	7.0	4.55
I_3	3.4	7.5	10.7	14.6	9.05	I_2S_1	1.4	4.7	6.4	7.8	5.08
Mean	2.08	6.14	7.91	10.49		I_2S_2	1.8	6.7	8.3	9.1	6.48
Spacing						I_2S_3	1.6	7.7	8.1	8.9	6.58
S_1	1.9	5.4	6.7	9.0	5.75	I_3S_1	3.0	7.4	8.9	11.3	7.65
S_2	2.2	6.9	8.8	12.1	7.50	I_3S_2	3.4	9.4	11.9	17.2	10.48
S_3	2.1	6.1	8.2	10.4	6.70	I_3S_3	3.6	5.9	11.3	15.2	9.00
Mean	2.08	6.14	7.91	10.49		Mean	2.08	6.14	7.91	10.49	
I SEd	0.258	0.161	0.107	0.173		I x S SEd	0.319	0.281	0.171	0.372	
CD (0.05)	0.631	0.393	0.261	0.424		CD (0.05)	NS	0.621	0.382	0.809	
S SEd	0.133	0.163	0.095	0.232		S x I SEd	0.231	0.282	0.164	0.403	
CD (0.05)	NS	0.342	0.199	0.488		CD (0.05)	NS	0.592	0.344	0.846	

I_1 - Normal Irrigation (0.8 IW/CPE ratio); I_2 - 75 % of Water requirement (0.6 IW/CPE ratio); I_3 - 50 % of Water requirement (0.4 IW/CPE ratio); S_1- Normal spacing (60x20cm); S_2 - Narrow spacing (45x20cm); S_3 - Reduced narrow spacing (30x30cm); IxS - Irrigation level x Plant population; Sxl - Plant population x Irrigation level; NS Non Significant

The maximum harvest index (HI) of maize was observed under normal irrigation (I_1) (34.3 %) and narrow plant spacing treatments (S_2) (32.9 %). Very low HI was observed under reduced narrow planting with 50 % irrigation water requirement (I_3S_3) (29.10 %). The decrease in water level caused a reduction of harvest index of maize. Present result was supported by the study of Prihar and Stewart (1990) in irrigated maize under environmental stress. Kernel yield recorded 6477 kg ha^{-1} in the normal irrigation with narrow spacing (I_1S_2) and also separately I_1 (5960 kg ha^{-1}) and S_2 (4951 kg ha^{-1}) (Table 2). The results of stover yield also followed the same trend. The lower yield was registered in 50 % water requirement with reduced narrow planting pattern I_3S_3 (2918 kg ha^{-1}). Maize kernel yield was reduced by 25.8% and 45.9% when plants were subjected to water deficits of 75 % water requirement (I_2) and 50 % water requirement (I_3), respectively, when compared with normal irrigation. The results are in conformity with the findings of Abo-El-khair & Mekki (2007) in maize. Regarding plant spacing effect on maize crop, maximum yield recorded in narrow spacing (S_2) (4951 kg ha^{-1}) than the other spacing treatments. Among the treatment combinations, the narrow spacing with normal irrigation (I_1S_2) outperformed other treatments in kernel yield (6477 kg ha^{-1}).

The narrow planting increased the yield by 13% over the normal planting pattern under normal irrigation. Narrow planting increased the yield by 5% over the normal spacing in 50 % water requirement and 6 % over the normal spacing in 75% water requirement. Results of this study are in conformity with findings of Barbieri *et al*. (2000) who reported a 10% yield response to narrow rows. The narrow planting pattern with normal irrigation gave

Table 2. Effect of irrigation level and plant population on yield of maize

Treatment	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)	Treatment	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
Irrigation				I_1S_1	5592	11290	33.1
I_1	5960	11428	34.3	I_1S_2	6477	12602	34.0
I_2	4429	9410	31.9	I_1S_3	5811	10391	35.9
I_3	3221	7232	30.8	I_2S_1	4612	9746	32.1
Mean	4537	9357	32.33	I_2S_2	4918	10022	32.9
Spacing				I_2S_3	3755	8462	30.7
S_1	4497	9412	32.2	I_3S_1	3286	7201	31.3
S_2	4951	10007	32.9	I_3S_2	3458	7395	31.8
S_3	4162	8651	31.9	I_3S_3	2918	7100	29.1
Mean	4537	9357	32.3	Mean	4537	9357	32.3
I SEd	102	127	0.3	I x S SEd	242	213	0.6
CD (0.05)	252	311	0.9	CD (0.05)	525	475	1.4
S SEd	155	121	0.3	S x I SEd	269	210	0.6
CD (0.05)	326	255	NS	CD (0.05)	566	442	1.4

I_1 - Normal Irrigation (0.8 IW/CPE ratio); I_2 - 75 % of Water requirement (0.6 IW/CPE ratio); I_3 - 50 % of Water requirement (0.4 IW/CPE ratio); S_1- Normal spacing (60x20cm); S_2 - Narrow spacing (45x20cm); S_3 - Reduced narrow spacing (30x30cm); IxS - Irrigation level x Plant population; SxI - Plant population x Irrigation level; NS Non Significant

better performance. Emam and Ranjbar (2000) studied the same effects of plant density and water stress on grain yield of maize hybrid.

Conclusion

Higher water productivity was recorded in 50 % water requirement along with narrow plant spacing of 30 x 30cm.

The normal irrigation water requirement with narrow plant spacing (30 x 30cm) recommended for higher (0.8lw/cpe) yield of maize. Under water limited environment, growing maize at 75% water requirement or 50 % water requirement along with narrow plant spacing (30 x 30 cm)to achieve higher water productivity.

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