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Effect of scheduling irrigation and mulching on growth and yield of maize (*Zea mays* L.)

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Abstract: The experimental results revealed that taller plant height (199.13 cm), higher leaf area (33.97 dm^2/plant) and above ground dry matter (240.87 g/plant) was recorded in irrigation scheduled at 0.8 IW:CPE ratio. Irrigation scheduled at 0.8 IW:CPE ratio recorded higher grain yield (78.66 q/ha) followed by irrigation scheduled at 0.6 IW:CPE ratio (62.27 q/ha). Among the mulches, wheat straw mulching at 5 t/ha recorded significantly higher grain yield (66.28 q/ha) over no mulching and was on par with sunnhemp brown manuring (two rows) (64.27 q/ha). Combination of 0.8 IW:CPE ratio x wheat straw mulching at 5 t/ha recorded higher grain yield (80.85 q/ha) and was at par with 0.8 IW:CPE ratio x sunnhemp brown manuring (two rows) (78.09 q/ha). Among the mulches, wheat straw mulching at 5 t/ha recorded significantly higher WUE (24.92 kg/ha.mm) and was on par with sunnhemp brown manuring (two rows) (24.36 kg/ha.mm). Mulches recorded lower weed dry weight over no mulch. The highest weed control efficiency of 77.97 per cent was recorded in sunnhemp brown manuring (two rows).

Key words: Grain yield, Irrigation, Maize, Mulching, Water use efficiency

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice. Maize is known as "Queen of Cereals" because of its high production potential and wider adaptability. Limited water resources are the major constraints on crop production (Rockström *et al.,* 2007), despite the potential for irrigation, most of the available water for crop growth in semi-arid regions originates from limited precipitation (Wang *et al.,* 2009). Declining precipitation in the future is likely to reduce the yields of a number of important crops and increase the threat to the food supply in semi-arid regions (Lobell *et al.,* 2008). As the global population increases and drought conditions worsen, continuing to improve rain-fed dryland agriculture with optimised water management is a key priority to guarantee food security and sustainability.

Uncertain and ill distributed rainfall and soils with low water holding capacities cause sizable reduction in maize yield. Most of the maize grown in the irrigated areas of the Malaprabha command area suffers from such water shortages at key developmental stages. Crop residues used as mulching are well known to reduce soil evaporation, increase soil water, decrease diurnal soil temperature variations and increase saturated soil hydraulic conductivity (Dahiya *et al.,* 2003). Evaporation data may become an easy and practical tool to Indian farmers for scheduling of irrigation to crop and prevention of water loss through evaporation. Provision of proper quantity of irrigation water coupled with various mulching practices would help in economising water and eventually realizing the water use efficiency. In this context, an investigation was undertaken on the effect of scheduling irrigation and mulching on growth and yield of maize.

Material and methods

The field experiment was conducted at Irrigation Water Management Research Centre (IWMRC), Belavatagi, University of Agricultural Sciences, Dharwad, Karnataka, India during *rabi* 2015-16. The research station is situated in the Northern Dry Zone (zone-3) of Karnataka. It is located at a latitude of $15^0$16' N, longitude of $75^0$23' E with an altitude of 579 m above mean sea level. The soil of the experimental site belongs to *Vertisol,* having bulk density 1.19 Mg/m^3, field capacity 39.32 %, 4.5 g/kg organic carbon, 229.6 kg/ha available nitrogen, 36.64 kh/ha available phosphorus, 718.8 kg/ha available potassium, 0.63 ds/m EC and pH 8.30. The experiment was laid out in split plot design with four replications. The main plots comprised of three irrigation levels I_1-0.4 IW:CPE, I_2-0.6 IW:CPE and I_3-0.8 IW:CPE and sub plots three mulching treatments E_1-Crop residue (wheat straw) at 5 t/ha E_2-30 cm sunnhemp brown manuring (one row) and E_3-20 cm sunnhemp brown manuring (two row) with two control plots (C_1–Weed free check and C_2– Weedy check). The maize hybrid Cargill 900 M Gold was sown with recommended spacing of 60 x 20 cm using a seed rate of 25 kg/ha. In between the rows of maize, one row of sunnhemp with an intra row spacing of 30 cm (E_2) and two rows of sunnhemp were sown with an intra row spacing of 20 cm (E_3) in the respective treatment. In brown manuring treatments plots, sunnhemp and maize were grown together for 35 days and thereafter, sunnhemp was knocked down with the use of 2,4-D spray at 0.5 kg/ha. The wheat residue @ 5 t/ha was spread between the rows after sowing of maize as mulch. Weed free condition was maintained in weed free plot and no weeding was done in rest of the plots. Nitrogen, phosphorus and potassium were applied at the recommended rates of 150, 75 and 37.5 kg/ha in the form of urea, single super phosphate and murate of potash respectively. The entire dose of phosphorus and potassium were applied at planting. Nitrogen was applied in three equal splits: one third of nitrogen was applied at sowing, one third was top dressed at knee high stage and the left one third of nitrogen was top dressed at flower initiation stage. Irrigation was applied manually to a depth of 60 mm. the scheduling of irrigation was done based on progressive total of evaporation, after attaining the pre-determined values of cumulative pan evaporation (CPE). The total water use, depth of irrigation water and the number of irrigations provided are presented in Table 1.

Observations on plant height, leaf area, leaf area index, leaf area duration, total dry matter production at different growth stages and test weight, grain yield and stover yield was recorded at harvest. Observations on weeds were recorded at 60 DAS to determine the weed control efficiency (WCE). The water use efficiency (kg/ha.mm) was estimated in terms of grain yield as the ratio between grain yield (kg/ha) and total consumptive use of water (mm). The data collected were analyzed using analysis of variance and Fischer's LSD test to determine the significant difference at P=0.05 levels between treatment means. The mean values were separately subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values.

Table 1. Number of irrigations, depth of irrigation water (DIW) and total water used (TWU) under different irrigation levels

Treatment	Number of irrigations	DIW (mm)	TWU (mm)
I_1-0.4 IW:CPE	3	180	261.4
I_2-0.6 IW:CPE	4	240	321.4
I_3-0.8 IW:CPE	6	360	417

Table 2. Growth and growth parameters of maize at harvest as influenced by irrigation schedules and mulching

Treatments	Plant height (cm)	Leaf area (dm^2)	LAI	Total dry matter production (g/plant)
Main plots (Irrigation levels)				
I_1-0.4 IW:CPE ratio	170.95 ^{c}	22.37 ^{c}	1.86 ^{c}	174.54 ^{c}
I_2 -0.6 IW:CPE ratio	185.98 ^{b}	29.27 ^{b}	2.44 ^{b}	215.08 ^{b}
I_3 -0.8 IW:CPE ratio	199.13 ^{a}	33.97 ^{a}	2.82 ^{a}	240.87 ^{a}
S.Em±	2.15	0.18	0.02	5.32
Sub plots (Evaporation control mean/ Mulching)				
E_1-Wheat straw at 5 t/ha	190.30 ^{a}	30.38 ^{a}	2.53 ^{a}	217.31 ^{a}
E_2- Sunnhemp brown manuring (one row)	180.58 ^{c}	26.82 ^{c}	2.24 ^{c}	200.92 ^{b}
E_3- Sunnhemp brown manuring (two rows)	185.19 ^{b}	28.41 ^{b}	2.35 ^{b}	212.26 ^{a}
S.Em±	0.50	0.24	0.02	5.31
Interaction (Irrigation levels X Evaporation control mean/ Mulching)				
I_1X E_1	174.82 ^{g}	24.37 ^{f}	2.03 ^{f}	179.25 ^{b}
I_1X E_2	166.39 ^{i}	20.23 ^{h}	1.69 ^{h}	170.83 ^{b}
I_1X E_3	171.64 ^{h}	22.52 ^{g}	1.88 ^{g}	173.53 ^{b}
I_2X E_1	191.53 ^{d}	31.07 ^{c}	2.59 ^{c}	227.39 ^{a}
I_2X E_2	180.60 ^{f}	27.61 ^{e}	2.30 ^{e}	195.18 ^{b}
I_2X E_3	185.83 ^{e}	29.12 ^{d}	2.43 ^{d}	222.68 ^{a}
I_3X E_1	204.54 ^{a}	35.71 ^{a}	2.98 ^{a}	245.30 ^{a}
I_3X E_2	194.75 ^{c}	32.61 ^{b}	2.73 ^{b}	236.75 ^{a}
I_3X E_3	198.11 ^{b}	33.60 ^{b}	2.76 ^{b}	240.56 ^{a}
S.Em±	0.87	0.42	0.03	9.20
Control plots				
C_1-Weed free	32.86	29.75	2.23	194.23
C_2-Weedy check	28.95	23.42	1.60	161.91
S.Em±	0.94	0.42	0.04	8.57
C.D. at 5%	2.70	1.48	0.124	24.76

Values followed by different letters in a column significantly differ as per DMRT

Results and discussion

Irrigation significantly influenced the plant height, leaf area, LAI and total dry matter production of maize at harvest (Table 2). The growth of maize increased with increasing level of irrigation. Irrigation scheduled at 0.8 IW:CPE ratio produced taller plants with maximum leaf area and LAI. Significantly maximum total dry matter production was recorded in irrigation level of 0.8 IW:CPE ratio over rest of the irrigation levels. This might be due to better vegetative growth as soil moisture was relatively sufficiently available at root zone due to frequent irrigation. These results are in conformity with the findings of Shinde *et al.* (2014) and Bozkurt *et al*. (2011). Among the mulches, mulching with wheat straw at 5 t/ha recorded significantly higher plant height, leaf area, LAI and dry matter production over brown manuring treatments. The interaction effects of irrigation levels and mulching influenced the growth of maize. The combination of 0.8 IW:CPE ratio with wheat straw mulching at 5 t/ha found significant over other treatment combinations. Yi *et al.* (2011) also found that mulch promoted vigorous early growth of the maize seedlings, with much greater plant height and leaf and stem biomass being attained during the early vegetative stages.

Yield attributes *viz.,* test weight, grain yield and stover yield were significantly influenced by irrigation levels (Table 3). Among various irrigation levels irrigation scheduled at 0.8 IW:CPE ratio recorded significantly higher test weight (31.60 g), grain yield (78.66 q/ha) and stover yield (107.35 q/ha). The results were in agreement with the findings of Adamu *et al.* (2014) who reported that the favourable effect of moisture is through its effect on initiating vigorous growth leading to relatively higher seed weight and consequently increased grain yield. Water stress causes a decrease in the leaf area index, resulting in a decrease in the photosynthesis, and this might have contributed to a reduction in grain yield of maize under limited irrigation levels (Awasthy *et al.*, 2015). Among mulches significantly higher test weight (29.21 g), grain weight per plant (150.25 g), grain yield (66.64 q/ha) and stover yield (96.34 q/ha) was observed in mulching with wheat straw at 5 t/ha. Same results were obtained by Shen *et al.,* 2012. This might be due to application of mulch in maize maintained adequate soil moisture through reducing soil evaporation which in turn helped in increasing yield attributing parameters like grain weight/plant and test weight. The results are in conformity with the findings of Singh *et al. (*2015) who reported that mulching may prove beneficial for crop growth because of complex change in soil environment through modifying soil temperature, reduction in evaporation, weed competition, soil compaction. Significantly higher growth parameters also recorded in wheat straw mulching which might be due to suppression of weeds, as the result of which the competition for available resources was greatly reduced. Alijani *et al.* (2012) found the highest maize plant height, leaf area and total dry matter production with chisel treatment and 50% wheat residue incorporation. Among different treatment

Table 3. Yield, yield parameters and water use efficiency (WUE) of maize as influenced by irrigation schedules and mulching

Treatments	Test weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	WUE kg/ha.mm
Main plots (Irrigation levels)				
I_1-0.4 IW:CPE ratio	25.40 [c]	53.49 [c]	73.33 [c]	20.46 [a]
I_2 -0.6 IW:CPE ratio	27.97 [b]	62.27 [b]	88.44 [b]	19.37 [b]
I_3 -0.8 IW:CPE ratio	31.60 [a]	78.66 [a]	107.35 [a]	18.86 [b]
S.Em±	0.23	0.97	5.41	0.28
Sub plots (Evaporation control mean/ Mulching)				
E_1-Wheat straw at 5 t/ha	29.21 [a]	66.64 [a]	96.34 [a]	20.13 [a]
E_2- Sunnhemp brown manuring (one row)	27.43 [b]	62.78 [b]	84.14 [b]	18.90 [b]
E_3- Sunnhemp brown manuring (two rows)	28.33 [ab]	64.99 [a]	88.64 [b]	19.67 [ab]
S.Em±	0.28	0.69	2.47	0.22
Interaction (Irrigation levels X Evaporation control mean/ Mulching)				
I_1X E_1	26.13 [ef]	55.36 [d]	77.77 [de]	21.18 [a]
I_1X E_2	24.50 [g]	50.40 [e]	69.04 [e]	19.28 [cd]
I_1X E_3	25.58 [fg]	54.70 [d]	73.16 [e]	20.93 [ab]
I_2X E_1	29.09 [c]	63.72 [c]	97.59 [bc]	19.82 [bc]
I_2X E_2	27.18 [de]	60.91 [c]	81.95 [de]	18.95 [cd]
I_2X E_3	27.66 [cd]	62.19 [c]	85.79 [cd]	19.35 [cd]
I_3X E_1	32.43 [a]	80.85 [a]	113.65 [a]	19.39 [cd]
I_3X E_2	30.62 [b]	77.03 [b]	101.42 [ab]	18.47 [d]
I_3X E_3	31.75 [ab]	78.09 [ab]	106.98 [ab]	18.73 [cd]
S.Em±	0.49	1.20	4.27	0.38
Control plots				
C_1-Weed free	26.90	56.89	77.44	17.70
C_2-Weedy check	23.50	45.10	61.92	14.03
S.Em±	0.46	1.30	5.43	0.40
C.D. at 5%	1.34	3.76	15.69	1.151

Values followed by different letters in a column significantly differ as per DMRT

combinations significantly higher test weight (32.43 g), grain yield (80.85 q/ha) and stover yield (113.65 q/ha) was recorded with irrigation scheduled at 0.8 IW:CPE ratio with wheat straw mulching at 5 t/ha and the grain yield was found on par with irrigation scheduled at 0.8 IW:CPE with sunnhemp brown manuring.

Water use efficiency was influenced by irrigation levels and mulching. Significantly higher WUE (20.46 kg/ha.mm) was recorded in irrigation level 0.4 IW:CPE ratio followed by 0.6 IW:CPE (19.37 kg/ha.mm). The water consumed per unit area in these treatments was less and yields were fairly good though not higher, leading to higher water use efficiency. The results are in accordance with the findings of Singh and Sudanshu, 2005. Water use efficiency of maize significantly increased with mulching over no mulching. WUE was significantly high with wheat straw mulching treatment (20.13 kg/ha.mm) and was at par with sunnhemp brown manuring (two rows) (19.67 kg/ha.mm). Mulch produced a more favourable soil water regime compared with the bare soil treatments that significantly increased yield. Straw mulching can decrease soil evaporation, reduce water consumption, and increase crop yield and water use efficiency significantly compared to no mulch (Wen Yin *et al.,* 2015).

Weed free check registered significantly lower weed dry weight whereas weedy check recorded higher total dry weight of weeds. Sunnhemp brown manuring (two rows) recorded significantly lower weed dry weight (4.03 g/m^2) followed by wheat straw mulching. Reduction in weed density was reported

Table 4. Weed dynamics and Weed control efficiency (WCE) at 60 DAS as influenced by irrigation schedules and mulching

Treatments	At 60 DAS		WCE (%)
	Weed count (m^{-2})	Total dry weight of weeds (g/m^2)	
Main plots (Irrigation levels)			
I_1-0.4 IW:CPE ratio	3.92 [c] (15.08)	3.95 [b] (15.47)	78.88 [a]
I_2 -0.6 IW:CPE ratio	4.17 [b] (17.08)	4.26 [b] (17.91)	75.54 [a]
I_3 -0.8 IW:CPE ratio	4.73 [a] (22.17)	4.91 [a] (23.88)	67.35 [b]
S.Em±	0.07	0.09	1.10
Sub plots (Evaporation control mean/ Mulching)			
E_1-Wheat straw at 5 t/ha	4.22 [b] (17.67)	4.32 [b] (18.60)	74.60 [b]
E_2- Sunnhemp brown manuring (one row)	4.62 [a] (21.08)	4.76 [a] (22.52)	69.20 [c]
E_3- Sunnhemp brown manuring (two rows)	3.97 [c] (15.58)	4.03 [c] (16.13)	77.97 [a]
S.Em±	0.05	0.07	0.79
Interaction (Irrigation levels X Evaporation control mean/ Mulching)			
I_1X E_1	3.82 [fg] (14.25)	3.92 [e] (15.28)	79.17 [b]
I_1X E_2	4.33 [cd] (18.25)	4.42 [cd] (19.20)	73.74 [cd]
I_1X E_3	3.62 [g] (12.75)	3.51 [f] (11.93)	83.72 [a]
I_2X E_1	4.10 [de] (16.50)	4.17 [de] (17.15)	76.59 [bc]
I_2X E_2	4.46 [c] (19.50)	4.59 [bc] (20.75)	71.64 [de]
I_2X E_3	3.95 [ef] (15.25)	4.02 [e] (15.83)	78.39 [b]
I_3X E_1	4.75 [b] (22.25)	4.87 [b] (23.38)	68.03 [e]
I_3X E_2	5.08 [a] (25.50)	5.29 [a] (27.60)	62.23 [f]
I_3X E_3	4.35 [c] (18.75)	4.56 [bc] (20.65)	71.79 [de]
S.Em±	0.08	0.12	1.36
Control plots			
C_1-Weed free	1.18 (1.00)	1.12 (0.83)	98.86
C_2-Weedy check	8.11 (65.25)	5.95 (73.07)	0.00
S.Em±	0.14	0.18	1.83
C.D. at 5%	0.41	0.50	5.27

- Figures are transformed values calculated by using the equation $\sqrt{X+0.5}$.
- Figures in parenthesis indicate original values.

Values followed by different letters in a column significantly differ as per DMRT.

with brown manuring by Ramachandran *et al.* (2012). Similar results were obtained by Samar Singh *et al.* (2007) who reported that sesbania intercropping for 30 days combined with pre-emergence application of pendimethalin (1000 g a .i ha^{-1}) were effective in controlling weeds in dry seeded rice. Weed control efficiency (77.97 %) was higher in sunnhemp brown manuring treatment and was followed by wheat straw mulching (74.60 %). This might be due to the suppression of weeds by the shade effect of sunnhemp crop residue. The highest weed control efficiency in sunnhemp brown manuring (two rows) and wheat straw mulching was evident from greater reduction in weed density and weed dry weight in these treatments. This was in agreement with the findings of Kumar and Mukherjee (2011).

Conclusion

It was concluded that frequent irrigations in maize are helpful in maintaining economically viable grain yield. Irrigation scheduling at 0.8 IW:CPE ratio for maize is helpful in obtaining higher yield under sufficient water available condition. The per cent increase in grain yield with 0.8 IW:CPE ratio was 26.32 and 47.05 % over 0.6 and 0.4 IW:CPE ratio, respectively. Application of mulch in maize maintained adequate soil moisture through reducing soil evaporation which in turn helped in increasing growth, yield-attributing parameters and grain yield. Higher grain yield was obtained from wheat straw mulching (66.64 q/ha) which was closely followed by sunnhemp brown manuring (two rows) (64.99 q/ha). Water-use efficiency (WUE) of maize significantly increased with mulching over no mulching. WUE was increased to a maximum of 20.46 kg/ha.mm with decreased frequency of irrigation at 0.4 IW:CPE. Mulching recorded a maximum of 20.13 kg/ha.mm WUE compared to no mulch (14.03 kg/ha.mm). Mulching was found beneficial in control of weeds over no mulching besides conservation of soil moisture.

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