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Response of spring maize to irrigation scheduling and mulching in Punjab

T. Singh, Barkha*, G. Kumari and K. Bokado

Department of Agronomy, Lovely Professional University, Phagwara-144 411, India

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***Corresponding Author Email :** barkhasingh57@gmail.com ***ORCiD:** https://orcid.org/0000-0002-0715-0285

Abstract

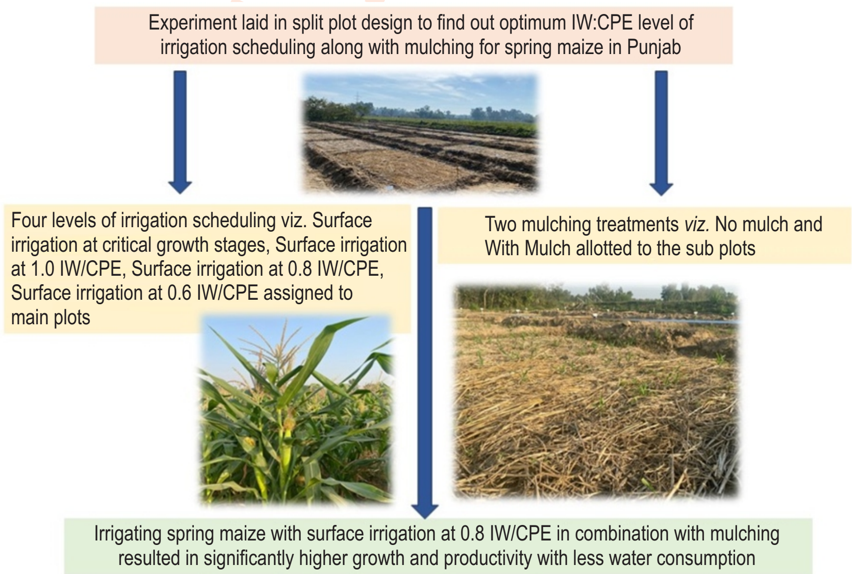
Aim: This study was planned and conducted to find the optimum IW:CPE level of irrigation scheduling along with mulching for spring maize in Punjab.

Methodology: An experiment was conducted in spring, 2022 on agriculture farm of Lovely Professional University, Punjab comprising of four levels of irrigation scheduling *viz.,* I_1 (Surface irrigation at critical growth stages), I_2 (Surface irrigation at 1.0 IW:CPE), I_3 (Surface irrigation at 0.8 IW:CPE), I_4 (Surface irrigation at 0.6 IW:CPE) assigned to main plots and two mulching treatments viz., M_1 (No Mulch), M_2 (With Mulch) allotted to the sub plots, which were replicated 4 times in split plot design.

Results: Application of irrigation at IW:CPE ratio of 1.0 and 0.8 in spring maize were equally good as they recorded higher growth and yield parameters. Among the mulching practices, M_2 resulted in better growth and yield parameters over no mulching. Highest green cob yield, grain yield and stover yield were also attained under irrigation applied at 1.0 IW:CPE combined with mulching, but it remained statistically at par with irrigation at 0.8 IW:CPE with mulching. Highest water use efficiency was seen under 0.8 IW:CPE.

Interpretation: Optimum level of irrigation along with mulching for spring maize was assessed based on the results obtained for growth, yield as well as water use efficiency. It was recorded that irrigation at 0.8 IW:CPE with mulching was found best for higher grain yield of maize hybrid.

Key words: Grain yield, Hybrid maize, Irrigation scheduling, Mulching, Water use efficiency



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Introduction

Cereal grains accounts as a staple food for the world's population and among them maize is the third most important cereal crop after wheat and rice in the world. Cultivation of spring maize is quite popular in the parts of Punjab, especially among the potato growing farmers as maize is sown just after after harvesting of potato. This helps in better resource utilization in the pre-*Kharif* period. Maize planting in the spring season also free up fields previously occupied by toria, potato, and early harvested sugarcane. Also, when compared with *kharif* maize, spring time cultivation offers additional advantages in terms of better sunshine hours and reduced incidence of insect-pest attack. However, water management can be a constraint during spring cultivation owing to higher evapo-transpiration demand and limited water supply especially in Punjab due to less rainfall during spring season (Singh *et al.,* 2015; Singh *et al.,* 2016). In India, agriculture sector consumes the largest amount of water. Most farmers lack basic knowledge of on-farm water management, and generally they tend to over-irrigate their fields leading to water wastage and low water use efficiency (Lal *et al.,* 2019).

As a result, optimal irrigation scheduling would aid in achieving higher efficiency and improved irrigation. Among various scientific approaches for scheduling irrigation, calculating daily evapotranspiration or crop coefficients for assessing crop water requirements in various crops is somewhat difficult practically. The use of IW:CPE (irrigation water applied to cumulative pan evaporation) ratio is suggested as the most common practical basis of scheduling irrigation (Shirazi *et al.,* 2011). This climatological approach is based on the close and direct relationship of crop evapotranspiration with daily pan evaporation. From the point of view of ease and simplicity in adoption by the farmer, this strategy is comparatively better than other approaches for scheduling irrigation. Crop residue mulch is an eco-friendly as well as affordable method for improving crop growth by conserving soil moisture. Soil temperature regulation done by straw mulch can protect the crop from unfavorable temperature, especially during the early phases of crop growth in spring season (Dhaliwal *et al.,* 2019).

Organic mulch also performs additional functions of increasing soil organic matter content, CEC, enhance biological activity, improve soil structure, infiltration, improves water-retention capacity, and increase plant nutrients after decomposition. Mulch application in combination with proper irrigation schedule results in increased crop yields due to improved soil conditions and water use efficiency (Zhang *et al.,* 2017). Currently farmers in this region are not much aware about the scientific management of water.A lot of earlier studies conducted have evaluated the effect of irrigation schedules combined with mulch in kharif season maize but the work done for spring maizein Punjab plains is scarce. So this experiment was conducted with the objectives of finding out the optimum number of irrigations required under different irrigation schedules in maize crop as well as to observe the effect of mulching on irrigated maize under irrigation.

Materials and Methods

A field experiment was conducted during spring season of 2022 at the experimental farm of Lovely Professional University, Jalandhar, Punjab on sandy loam soil. Spring maize *cv.* PMH 10 was sown at a spacing of 60x20 cm. The experiment was laid out in a split plot design with 4 replications. The treatments consisted of four levels of irrigation *viz.,* I_1 (Surface irrigation at critical growth stages); I_2 (Surface irrigation at 1.0 IW:CPE); I_3 (Surface irrigation at 0.8 IW:CPE) and I_4 (Surface irrigation at 0.6 IW:CPE) assigned to main plots and two mulching treatments *viz.,* M_1 (No Mulch) and M_2 (With Mulch) allotted to sub plots. Paddy straw mulch available locally in the field was used for this purpose. The available nitrogen, phosphorus and potassium content in the soil of the experimental plot's soil as analysed prior to sowing was found to be 145.47, 18.32, 109.78 kg ha^{-1}, respectively.

During seed bed preparation, the entire amount of phosphorus and potassium was applied whereas nitrogen was applied in three splits *viz.,* basal, 30 DAS and 60 DAS. Pre-emergence application of atrazine @ 1 kg a.i. ha^{-1} was done 2 days after sowing and as post-emergence,tembotrione @ 120 g a.i. ha^{-1} was applied 25 DAS to prevent weed growth in the maize field. For scheduling irrigation, daily pan evaporation values were measured with the help of USWB class 'A' open pan evaporimeter installed near the experimental field. Based on daily pan evaporation values recorded from local agrometeorological observatory, cumulative pan evaporation (CPE) was worked out starting from the date of crop sowing. From each plot, 5 representative plants were randomly selected and tagged for recording various observations and average of these five values was determined. After harvesting, dried cobs of maize were shelled to separate the kernels. Grain and stover yields were recorded from net plot and then converted on hectare basis. Various observations pertaining to growth parameters, yield attributes, grain yield, stover yield, harvest index, field water use efficiency and soil nutrient status before and after the experiment were recorded. Cobs were picked and the remaining plant material including husk was sun dried, weighed and expressed as stover yield (q ha^{-1}). The harvest index is the ratio of economic yield to the biological yield per plot. The harvest index for each treatment was worked out by the formula of Donald and Hamblin (1976). Field water use efficiency was calculated by the formula of Michael (1978).

The statistical analysis of the data of various characters obtained during investigation was carried out through the procedure appropriate to the design of the experiment as described by Snedecor and Cochran (1967). The significance of differences tested by 'F' test at five per cent 29 level of significance was used to test the significance of results. The critical difference was calculated when differences between the treatments were found to be significant by 'F' test. In remaining cases only standard error of means were worked out. The co-efficient of variation (CV %) was also worked out to see the extent of variation within the blocks. For economic analysis of the treatments, the cost of cultivation was determined using local costs for various inputs, such as labour, fertilizer and other required items. Gross income was then calculated based on crop yield and the prevailing market price. Net return was worked out by subtracting the cost of cultivation from gross returns of each treatment.

Net returns (₹ ha^{-1}) = Gross returns (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1}); The B: C ratio was calculated on the basis of the formula given below:

$$\text{B: C ratio} = \frac{\text{Net return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

Results and Discussion

Data on various growth parameters of maize presented in Table 1 revealed that at 30 DAS, plant height was found maximum under irrigation at critical stages, *i.e.,* I_1 (19.97 cm), whereas the lowest height was found under 0.6 IW:CPE *i.e.,* I_4 (16.26), but at 60 DAS and at harvest the highest plant height was recorded under I_2 (82.23 and 183.65 cm), whereas the lowest height was noted in I_4 (70.67 and 160.53 cm). The frequency of irrigation was higher under 1.0 IW:CPE because of which enough soil moisture was available and the rhizosphere became more conducive, allowing greater nutrient absorption, which in turn promotes crop growth. Similar effect of irrigation schedules on growth of maize was reported by Bibe *et al.* (2017) and Prasanna *et al.* (2019). On the other hand, as a result of lower irrigation frequency under 0.6 IW:CPE, crop growth was reduced. Maize plants under irrigation scheduled at 1.0 IW:CPE(I2) noted significantly lesser numbers of days for 50% tasseling (67.49 days) and 50% silking (74.4 days) whereas 0.6 IW:CPE I4 (84.97 days) took maximum days to 50% tasseling (76.74 days) and 50% silking (84.97 days). Better and early development of inflorescence might be a result of improved translocation and partitioning of dry matter between source and sink post peak vegetative growth. Among mulching treatments, M_2 resulted in significantly greater plant height at 30, 60 DAS and at harvest (18.31, 78.74 and 178.25 cm) over M_1 (17.20, 74.69 and 167.66 cm). Mulch-applied plots retained more moisture, thus the plants had access to more water to enhance growth and productivity (Jabran *et al.,* 2015). Although days taken to 50% silking and tasselling was lesser with mulching (69.81, 78.20) as compared to without mulch (73.74, 79.20), the difference was non-significant. Similar results on growth parameters of maize due to mulching was recorded by Shirazi *et al.* (2011), Awasthy *et al.* (2015) and Noor *et al.* (2021). The interaction between irrigation levels and mulching was found to be non-significant for various growth parameters.

Data presented in Table 1 shows the influence of various treatments on yield attributes and maize yield. Various yield attributes *viz.,* number of cobs per plant, number of grains per cob, cob length and seed index were significantly influenced by different irrigation levels as well as mulching. Significantly higher number of cobs per plant (1.83), grains per cob (447.04), cob length (18.11) and seed index (27.82) were observed with irrigation schedule of 1.0 IW:CPE(I_2) and these parameters were least under 0.6 IW:CPE (I_4).Irrigation schedule of 0.8 IW:CPE also produced similar results. Similarly, mulching treatment M_2 showed significantly higher cob length (17.06 cm), number of cobs per plant (1.68) grains per cob (430.38), and seed index (25.38) than M_1 treatment. This might be due to better moisture regime in the root zone maintained under higher irrigation with

Table 1: Effect of irrigation levels and mulching on growth and yield parameters and yield of spring maize

	Growth parameters					Yield parameters and yield						
Treatments	Plant height (cm)			Days to 50% tasseling	Days to 50% silking	Cob length (cm)	No. of cobs/ plant	No of grains/ cob	Seed index (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index
	30 DAS	60 DAS	At harvest									
I1: irrigation at critical stages	19.97	74.99	168.54	74.81	80.97	15.65	1.60	403.27	22.66	65.84	113.86	0.37
I2 : 1.0 IW:CPE	18.09	82.23	183.65	67.49	74.44	18.11	1.83	447.04	27.82	78.35	123.44	0.39
I3 : 0.8 IW:CPE	16.69	78.95	179.10	68.06	75.01	17.08	1.81	444.49	26.05	77.21	121.90	0.39
I4 : 0.6 IW:CPE	16.26	70.67	160.53	76.74	84.37	14.65	1.29	379.98	21.14	62.76	106.00	0.37
S.Em. ±	0.60	2.16	4.88	2.38	2.36	0.73	0.07	12.86	0.77	3.12	4.08	0.01
C.D. (P=0.05)	1.92	6.90	15.62	7.61	7.57	2.34	0.21	41.13	2.47	9.97	13.06	NS
M1: No Mulch	17.20	74.69	167.66	73.74	79.20	15.69	1.59	407.11	23.46	68.59	111.73	0.38
M2: Mulch	18.31	78.74	178.25	69.81	78.20	17.06	1.68	430.38	25.38	73.48	120.87	0.38
S.Em. ±	0.36	1.11	2.08	1.76	1.37	0.36	0.02	7.18	0.27	1.08	1.27	0.00
C.D. (P=0.05)	1.11	3.43	6.40	5.43	4.23	1.10	0.05	22.11	0.84	3.34	3.93	NS
I×M interaction			**NS**				**S**	**NS**	**S**	**S**	**S**	**NS**

Table 2: Interaction effect of irrigation schedules and mulching on grain and straw yield of maize

I × M table	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	M1: No mulch	M2: Mulch	M1: no mulch	M2: mulch
I_1 : irrigation at critical stages	64.06	67.61	104.77	122.94
I_2 : 1.0 IW:CPE	77.99	78.71	118.80	128.07
I_3 : 0.8 IW:CPE	70.55	83.87	118.32	125.48
I_4 : 0.6 IW:CPE	61.78	63.74	105.02	106.97
SEm ±	2.17		2.55	
CD (P=0.05)	6.69		7.85	

Table 3: Effect of irrigation schedules and mulching levels on available nitrogen, phosphorous and potassium in soil

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Irrigation levels			
I1 : irrigation at critical stages	153.58	19.34	117.89
I2 : 1.0 IW:CPE	166.25	24.50	138.22
I3 : 0.8 IW:CPE	160.07	23.07	129.01
I4 : 0.6 IW:CPE	146.94	17.82	113.29
S.Em. ±	3.29	0.47	2.89
C.D. (P=0.05)	10.52	1.50	9.26
C.V.(%)	5.93	6.28	6.57
Mulching			
M1: No Mulch	154.67	20.14	121.8
M2: Mulch	158.75	22.23	127.4
S.Em. ±	1.32	0.32	1.07
C.D. (P=0.05)	4.06	0.98	3.31
I×M interaction	NS	NS	NS
NS: non-significant			

reduced evaporative losses due to mulching which improved partitioning and translocation of photosynthates to the yield attributing parts. The interaction effect of irrigation schedules and mulching was found to be non-significant for yield attributes except numbers of grains per cob and cob length. Similar findings were reported by Kamar *et al.* (2010), Lakshmi *et al.* (2019) and Prasanna *et al.* (2019). Yield of any crop is a resultant effect of various yield attributing characters. A perusal of data given in Table 2 shows that significantly higher grain yield (78.35 q ha^{-1}) and stover yield (123.44 q ha^{-1}) in spring maize was attained with scheduling irrigation of 1.0 IW:CPE (I_2). Data further revealed that irrigation at 0.8 IW:CPE produced at par results for grain yield (77.21 q ha^{-1}) and stover yield (121.90 q ha^{-1}).

Higher grain yield was due to the cumulative effect of improvement in growth and yield attributes under higher irrigation frequency as mentioned earlier. Secondly, increase in yield might be due to more irrigations providing constant wetting of root zone which might have favoured greater release of nutrients from soil (Datta *et al.*, 2020). It was also found that with sufficient moisture in the soil profile under higher irrigation, plant nutrients particularly nitrogen, phosphorus and potassium were more available and might have been transported to produce more dry matter. The increment observed under 1.0 and 0.8 IW:CPE schedules over control (irrigation at critical stages) was 12.5 % and 11.3 % in grain yield and 9.5 % and 8 % in straw yield, respectively.

On the contrary, yield reduction over control was observed under 0.6 IW:CPE. Among mulching treatments, significantly higher grain (73.48 q ha^{-1}) and stover yield (120.87 q ha^{-1}) were observed under mulching. Mulching resulted in approximately, 7% and 8% increase in grain and straw yield, respectively. The role of mulching in regulation of soil temperature as well as improving crop yield was also reported by Bandopadhyay *et al.* (2023). Mulching causes the soil temperature to rise in the crop's initial stages, which enhances the growth and development, subsequently crop yield (Fang *et al.,* 2021). Similar findings in maize, wheat, and rice were reported where impact of mulching on yield statistics was evaluated, and it was discovered that the average grain yield of the mulched treatment was greater than the yield of the un-mulched treatment (Wang *et al.,* 2019). The interaction effect of irrigation schedules and mulching was significant on cobs per plant, seed index, grain yield and stover yield and data for the same is presented in Table 2. Among various treatment combinations, I_2M_2 *i.e.,* irrigation

Table 4: Economics of spring maize as influenced by interaction of irrigation levels and mulching

Treatment combinations	Total cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BC ratio
I1M1:Surface irrigation at critical growth stage + No mulching	28233	94814	66581	2.36
I1M2:Surface irrigation at critical growth stage + straw mulching	38233	100061	61828	1.62
I2M1:Surface irrigation at 1.0 IW:CPE + No mulching	28233	115426	87193	3.09
I2M2:Surface irrigation at 1.0 IW:CPE + straw mulching	38233	116495	78262	2.05
I3M1:Surface irrigation at 0.8 IW:CPE + No mulching	28233	104407	76174	2.70
I3M2:Surface irrigation at 0.8 IW:CPE + straw mulching	38233	124128	85895	2.25
I4M1:Surface irrigation at 0.6 IW:CPE + No mulching	28233	91432	63199	2.24
I4M2:Surface irrigation at 0.6 IW:CPE + straw mulching	38233	94335	56102	1.47

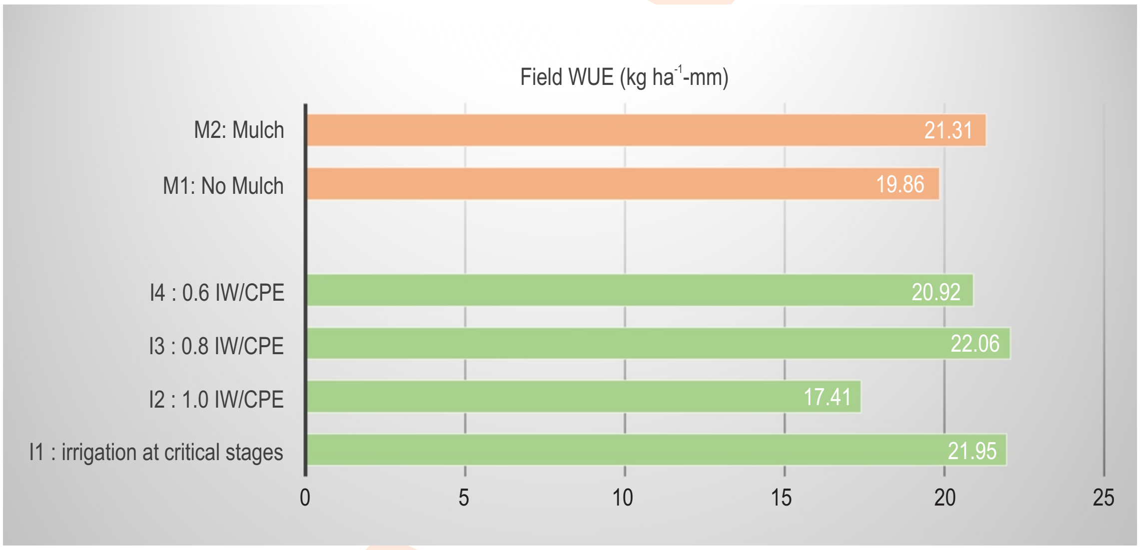

Fig.1: Water use efficiency under spring maize as influenced by various irrigation levels and mulching.

scheduling at 1.0 IW:CPE along with mulching produced significantly higher number of cobs per plant,seed index, grain and stover yield.

Field water use efficiency was significantly influenced by varying levels of irrigation as well as mulching treatments (Fig. 1). Highest field water use efficiency was observedunder irrigation scheduled at 0.8 IW:CPE (22.06 kg ha^{-1}-mm) and treatment with mulch (21.31 kg ha^{-1}-mm) over no mulching. However, there was no significant interaction between irrigation schedules and mulching. Comparatively, less water was applied under 0.8 IW:CPE which resulted in higher yield leading to better water use efficiency. Similarly, straw mulching aided in soil moisture conservation, thus making more water available for crop's uptake. Mulch on the soil surface also serve as a barrier against evaporation losses from soil (Yaseen *et al.,* 2014). Mulching and irrigation together significantly increased water use efficiency because soil water was utilised more for crop growth and yield rather than soil evaporation (Tolk *et al.,* 1999). These findings corroborate with the studies of Reddy *et al.* (2012), Ajamirali and Halagalimath (2017), Chandrawanshi *et al.* (2016) and Jing *et al.* (2020).

Data in Table 3 shows that available soil nitrogen (166.25 kg ha^{-1}), phosphorus (24.50 kg ha^{-1}) and potassium (138.22 kg ha^{-1}) were reported under irrigation scheduled at 1.0 IW:CPE, which remained at par with 0.8 IW:CPE. The least values of available nitrogen (146.94 kg ha^{-1}), phosphorus (17.82 kg ha^{-1}) and potassium (113.29 kg ha^{-1}) were observed in 0.6 IW:CPE. Likewise, mulching treatment resulted in significantly higher available nitrogen (158.75 kg ha^{-1}), phosphorous (20.14 kg ha^{-1}) and potassium (127.40 kg ha^{-1}) in soil as compared to without mulching. There was no significant interaction between irrigation schedules and mulching for soil available nutrient status post-harvest. Higher availability of nutrients may be due to enhanced microbial activity under more soil moisture maintained due to proper irrigation and mulched condition. It has also been reported that more moisturized condition result into improved physical properties of soil, which helps in mobilisation of soluble nutrients (Bhatt *et al.,* 2022). Proper irrigation combined with mulching may also have facilitated nutrient recycling within soil which led to better nutrient availability. Further, uses of paddy straw mulch may have boosted potassium content in the soil up to some extent. (Bhardwaj, 2013; Shivakumar *et al.,* 2019).

The data of effect of irrigation scheduling and mulching on economics of maize is presented in Table 4. According to the results, the treatment combination I3M2; *i.e.,* surface irrigation at 0.8 IW:CPE+ straw mulch gave highest gross returns (124128 ₹ ha^{-1}), netreturns (85895 ₹ ha^{-1}) and BC ratio (2.25) which was closely followed by I_2M_2 *i.e.,* surface irrigation at 1.0 IW:CPE + straw mulch with gross returns of 116495 ₹ ha^{-1} net returns of 78262.58.88 ₹/ha and BC ratio of 2.05. Profitable returns and BC ratio is a result of higher marketable crop yield under these treatment combinations. Singh *et al.* (2015) and Ramachandiran and Pazhanivelan (2016) also reported similar findings.

Based on the results of the present investigation, it can be concluded that irrigating spring maize with surface irrigation scheduled at 1.0 IW:CPE in combination with mulching resulted in significantly higher productivity. However, irrigation scheduled at 0.8 IW:CPEalso performed equally good in terms of production but with better water use efficiency that helped in water saving. Thus, to get higher productivity and profitability along with better water use efficiency, spring maize should be irrigated at 0.8 IW:CPE surface irrigation combined with mulching.

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