

Agro-physiological performance and water-use of maize (*Zea mays*) as influenced by irrigation methods during winter season in Bihar plains*

SANJEEV KUMAR¹, H S GUPTA² and A K SINGH³

ICAR Research Complex for Eastern Region, Patna, Bihar 800 014

Received: 25 November 2007

Key words: Cultivars, Irrigation methods and LEWA system, Maize, Yield

Maize (*Zea mays* L.) is a major winter (*rabi*) season crop in north Bihar which covers about 70% area but average productivity is low. Among various factors responsible for low productivity, soil-moisture availability is the most limiting factor because crops are very much sensitive to soil-moisture stress, particularly at their critical stages. Not only quality of water but ample water availability, time of application, method of water application are also important for producing higher yield (Singh *et al.* 2004).

The success and level of profit from *rabi* maize depend on the choice of maize cultivars (hybrid/composite) to be grown (Kumar *et al.* 2002). Adoption of low-yielding cultivars and inadequate utilization of resources are the major causes of low yield. Timely availability of location-specific suitable cultivar can provide a major breakthrough in production and productivity. Keeping above facts in view the present investigation was undertaken to study the performance of different maize cultivars under different irrigation methods.

The field experiments were conducted during winter (*rabi*) season of 2005–06 and 2006–07 at WALMI farm of ICAR Research Complex for Eastern Region, Patna in split-plot design with 3 replications. The soil was silty clay loam in texture with initial pH value of 7.2, organic carbon 0.61% and available N, P and K: 270.0, 29.0 and 305.2 kg/ha. The average bulk density of the plots was 1.48 Mg/m³. Average evaporation during the crop season was 20.7 and 19.5 mm with a total rainfall of 9.6 and 8.7 cm in both the years respectively. The treatment comprises 2 irrigation methods (main plot: 1) (ridge and furrow method of irrigation 2), Low Energy Water Application (LEWA) system of irrigation and 12 maize cultivars (sub-plot). The LEWA system developed by ICAR-RCER, Patna is used as an overhead emission device in

irrigation system. It is characterized by high application rate (more than infiltration rate of soil) to achieve greater sub-surface uniformity of applied water without facilitating any deep percolation. It works on an operating pressure of 0.4–0.6 kg/cm² and throw diameter is 6–8 m. Water application rate is between 2.6 and 3.1 cm/hr, which can be further adjusted based on crop and soil type. With flexible hosepipes a LEWA unit for 1 000 m² costs approximately Rs 8 100, while, for establishing sprinkler irrigation system for the same area it costs about Rs 22 800 only (Singh *et al.* 2004). As the sub-surface uniformity of the LEWA is more than 90%, so it is very useful to irrigate shallow rooted crops, like potato, rice, wheat, maize, oilseeds, pulses and vegetables. 'Deoki' (composite variety) of maize was taken as control and sown on 24 October in both the years. Cultivars of medium-growing duration (130–140 days) were irrigated 5 times and 6 times for long-duration cultivars (more than 140 days) by ridge and furrow method of irrigation and a water depth of 6 cm was maintained for each irrigation, while LEWA irrigated crop was irrigated 8 times for medium duration cultivars and 9 times for long-duration cultivars by maintaining a water depth of 1.78 cm in each irrigation based on calculation (Singh and Islam 2007). LEWA system operated for 30 min. at each irrigation in both the years and the risers of the LEWA system were kept at 1.8 cm height in the field to avoid any obstructions due to plant height. Row-to-row spacing was maintained at 60 cm with a common fertilizer dose of 140: 80: 60 (N: P: K) kg/ha. All phosphatic and potassic fertilizers were applied as basal while nitrogenous fertilizer was applied in 3 equal splits (1/3 as basal + 1/3 at knee-height stage and 1/3 at tasseling stage). All soil, plant and irrigation observations were recorded by standard procedures and calculations, while yield was calculated on the basis of net plot area. Some physiological parameters related to plant- water status, like relative leaf water content (RLWC) and water saturation deficit (WSD) were calculated by using the following formulae:

$$\text{RLWC} = \frac{\text{Fresh weight of leaves} - \text{dry weight of leaves}}{\text{Saturated weight of leaves} - \text{dry weight of leaves}} \times 100$$

* Short note

¹Senior Scientist (Agronomy), (E-mail: shiv_sanjeev@yahoo.co.in), ²Director, VPKAS, Almora 263 601 (E-mail: hsgupta@lycos.com)

³Senior Scientist (SWCE) E mail: atulsinghk@yahoo.com).

$$\text{WSD} = \frac{\text{Saturated weight of leaves} - \text{fresh weight of leaves}}{\text{Saturated weight of leaves} - \text{dry weight of leaves}} \times 100$$

Among the cultivars, 'Deoki' a composite variety achieved significantly higher plant height (180.6 and 185.4 cm), whereas cultivar 'Shaktiman 4' resulted in more leaf length (84.7 and 88.0 cm) over all other cultivars (Table 1). LEWA system of irrigation resulted in significantly more dry matter production/plant (706.11 and 757.4 g) over ridge and furrow methods of irrigation (672.9 and 693.5 g) respectively in both the years. Cultivar 'FH 3352' gave significantly higher dry matter production/plant (832.3 and 864.2 g) and was followed by cultivars 'FH 3245', 'Deoki', 'FH 3248' and 'FH 3311'. This is because availability of optimum soil-moisture at different stages of growth increased the production of photosynthates and resulted in increased growth and weight.

Crop under LEWA system of irrigation showed maximum relative leaf water content (89.3 and 91.8%) and was found higher over ridge and furrow methods of irrigation during both the years respectively (Table 1). Maximum water saturation deficit was recorded in ridge and furrow irrigated maize (6.4 and 5.5%) over LEWA irrigated maize (4.6 and 4.4%) during 2005–06 and 2006–07 respectively indicating the efficacy of LEWA system towards contribution of moisture to the crop. It may be attributed towards increased water and nutrient absorption at critical growth stages due to greater root-soil-water contact. However, no significant differences were observed in respect of relative leaf water content and water saturation deficit due to cultivars but long-duration cultivars

tends towards more water saturation deficit than medium duration cultivars in general during both the years.

Water-use efficiency was found significantly higher under LEWA irrigated maize (241.0 and 255.2 kg/ha-cm) which was 39 and 41% more over the ridge and furrow irrigated maize (147.2 and 150.3 kg/ha-cm) respectively in both the years. Here, the result again indicates the efficacy and utility of LEWA system for maize crop over ridge and furrow methods of irrigation (Table 1). Among the cultivars 'FH 3352' showed significantly higher water-use efficiency (232.7 and 244.4 kg/ha-cm) and was followed by the cultivars 'FH 3245' (220.6 and 235.4 kg/ha-cm), FH 3248 (218.1 and 228.4 kg/ha-cm) and 'Vivek 17' (208.8 and 216.8 kg/ha-cm) respectively in both the years. This might be due to LEWA system of irrigation had supplied optimum moisture to the plants because lesser or negligible percolation loss for longer period at each stages of growth by maintaining better soil-water-plant continuum and resulted in increased water-use efficiency.

Yield attributes like cob length and test weight were significantly influenced by different irrigation methods and cultivars. LEWA irrigated maize significantly produced longer cobs with higher test weight over ridge and furrow irrigated maize during both the years of experimentation. However, no significant differences were observed in case of number of cobs/plant due to irrigation methods and cultivars. This indicates that cob number/plant is a genetic character and cannot be altered easily. While cultivar 'FH 3352' showed superior in respect of cob length and test

Table 1 Effect of irrigation methods and different cultivars on plant height, leaf length, relative leaf water content, water saturation deficit at 120 days after sowing and dry matter production/plant and water-use efficiency at harvest

Treatment	Plant height (cm)		Leaf length (cm)		Dry matter production/plant (g)		Relative leaf water content (%)		Water saturation deficit (%)		Water-use efficiency (kg/ha-cm)	
	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07	2005–06	2006–07
<i>Irrigation</i>												
R/F method	141.4	142.2	70.5	72.9	672.9	693.5	82.5	84.6	6.4	5.5	147.2	150.3
LEWA system	150.7	151.7	74.6	75.6	706.1	757.4	89.3	91.8	4.6	4.4	241.0	255.2
CD (P=0.05)	NS	NS	NS	NS	47.6	53.6	3.21	3.36	1.2	0.9	17.5	46.2
<i>Cultivar</i>												
'Deoki'	180.6	185.8	73.4	75.5	701.1	744.2	82.5	84.6	6.5	6.0	189.7	199.9
'Shaktiman 4'	163.8	160.8	84.7	88.0	668.6	696.2	85.4	87.9	6.7	5.9	181.7	184.1
'FH 3288'	135.6	137.8	67.3	67.6	662.6	695.5	84.2	86.5	6.1	5.4	185.6	192.9
'FH 3210'	135.4	136.1	67.9	68.0	559.5	620.0	89.2	90.3	6.2	5.5	135.3	140.7
'FH 3352'	149.2	151.2	74.9	76.5	832.3	864.2	86.2	88.9	4.2	3.9	232.7	244.4
'FH 3289'	155.5	154.8	76.5	77.5	619.6	670.2	88.2	90.9	6.2	5.6	191.0	199.8
'FH 3245'	146.5	148.1	75.8	76.5	812.2	847.3	81.2	83.8	6.1	5.4	220.6	235.4
'FH 3294'	133.5	134.1	69.2	71.5	638.8	656.4	86.2	88.6	4.6	4.4	195.9	205.2
'FH 3248'	128.4	129.8	72.4	73.6	772.2	810.1	86.2	88.8	4.4	3.8	218.1	228.4
'FH 3311'	159.6	158.3	74.4	75.7	717.8	757.8	88.1	90.8	4.5	4.4	175.8	187.9
'Vivek 17'	131.0	131.8	66.8	70.4	671.8	705.2	85.2	86.3	5.2	4.6	208.8	216.8
'FH 3277'	133.5	135.2	67.3	70.1	617.5	638.3	88.2	91.0	5.3	4.7	194.0	197.5
CD (P=0.05)	21.4	22.8	8.0	10.2	145.4	163.2	NS	NS	NS	NS	28.7	35.2

Table 2 Effect of irrigation methods and different cultivars on number of cobs/plant, cob length, test weight (100 grains), grain yield and maturity period

Treatment	Cob no./plant		Cob length (cm)		Test weight (g)		Grain yield (tonnes/ha)		Protein content (%)		Maturity period (days)
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	
<i>Irrigation</i>											
R/F method	1.3	1.4	26.7	27.3	36.0	37.2	6.84	7.12	8.02	8.10	139
LEWA system	1.8	1.8	28.7	29.4	37.1	40.6	7.30	7.86	8.11	8.13	146
CD ($P=0.05$)	NS	NS	1.76	1.62	0.5	1.2	0.47	0.58	NS	NS	
<i>Cultivar</i>											
'Deoki'	1.6	1.6	29.7	27.7	38.7	41.2	7.60	8.17	8.25	8.35	169
'Shaktiman 4'	1.8	1.9	26.6	25.5	37.8	39.5	7.26	7.49	7.92	8.08	162
'FH 3288'	1.6	1.6	29.5	29.8	31.9	33.9	6.67	7.07	7.73	8.0	136
'FH 3210'	1.4	1.4	23.1	25.6	31.0	33.7	4.75	4.91	7.15	7.19	130
'FH 3352'	1.5	1.6	30.7	31.2	39.8	42.3	8.38	8.98	8.61	8.59	140
'FH 3289'	1.6	1.6	29.2	29.4	36.3	37.8	6.80	7.26	7.91	7.81	136
'FH 3245'	1.7	1.8	29.0	30.8	38.7	42.0	7.97	8.46	8.52	8.55	147
'FH 3294'	1.5	1.5	26.6	27.0	35.7	38.2	6.98	7.29	7.93	7.80	140
'FH 3248'	1.6	1.6	27.4	30.2	38.7	41.3	7.79	8.33	8.46	8.50	140
'FH 3311'	1.3	1.4	26.6	27.8	36.0	38.0	6.25	6.83	7.90	7.92	132
'Vivek 17'	1.6	1.7	28.9	29.2	37.5	39.9	7.47	7.92	8.23	8.31	136
'FH 3277'	1.4	1.5	25.1	26.0	36.5	39.0	6.92	7.19	8.20	8.28	140
CD ($P=0.05$)	NS	NS	3.28	3.82	1.9	2.1	0.40	0.52	0.2	0.18	

weight, followed by 'FH 3245', 'FH 3248', 'FH 3288', 'Vivek 17', 'Deoki' and 'FH 3311' during both the years of experimentation. 'FH 3210' exhibited the minimum cob length and test weight during both the years (Table 2).

LEWA irrigated maize gave significant higher grain yield (7.3 and 7.8 tonnes/ha) which were found 6.7 and 10.4% higher over ridge and furrow irrigated maize respectively in both the years. Among the cultivars, 'FH 3352' recorded significantly higher yield (8.38 and 8.98 tonnes/ha) in both the years, followed by cultivar 'FH 3245', 'FH 3248' and 'Deoki'. 'FH 3210' recorded minimum yield (4.7 and 4.91 tonnes/ha) respectively during the years of experimentation. The maximum grain yield and yield attributes obtained by LEWA irrigated maize may be due to lesser water saturation deficit at grain-filling stage and more leaf water content and increased water-use efficiency which in combination helped yield attributes in a positive manner. The results are in conformity with the findings of Wang *et al.* (2006).

Protein content in grains did not differ significantly due to different irrigation methods. However, cultivars exhibited significant higher protein content (8.61 and 8.59%), followed by 'FH 3245' and 'FH 3248' over other cultivars during 2005-06 and 2006-07 respectively as protein content in grain is also governed by genetic constitutions of the cultivars (Kumar *et al.* 2002).

SUMMARY

A field experiment was conducted during winter (*rabi*) seasons of 2005-06 and 2006-07 to evaluate the performance of different maize cultivars under ridge and

furrow method of irrigation and Low Energy Water Application (LEWA) system of irrigation in winter season. The results revealed that among the cultivars 'FH 3352' produced significantly higher grain yield and protein content over all other cultivars in both the years. LEWA irrigated maize produced 6.7 and 10.4% more grain yield and higher water-use efficiency (241.0 and 255.2 kg/ha-cm) over ridge and furrow irrigated maize respectively in both the years. Relative leaf water content was also found significantly higher (89.3 and 91.8%) in LEWA irrigated maize and reverse trend in case of water saturation deficit. It is imperative to say that LEWA system of irrigation is quite efficient for maize crop over ridge and furrow method of irrigation. Among the cultivars, 'FH 3352' a medium duration cultivar can be grown successfully as winter crop in the eastern plains for higher yield.

REFERENCES

- Wang Di, Jiu Sheg Li and Minjie Rao. 2006. Sprinkler water distributions as affected by corn canopy. *Transactions of the Chinese Society of Agricultural Engineering* **22** (7): 43-47.
- Kumar Manish, Tripathi R S and Srivastava G K. 2002. Quality and yield of winter maize as affected by varying genotypes, nitrogen levels and irrigation schedules. *Madras Agricultural Journal* **88** (10-12): 693-6.
- Singh A K and Islam A. 2007. Development of low pressure and low energy sprinkling nozzles. *Journal of Agricultural Engineering* **44** (1): 26-32.
- Singh S R, Singh A K, Islam A and Bharali MA. 2004. Low energy water application device. *Technical Bulletin*, ICAR Research Complex for Eastern Region, Patna.