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EFFECT OF INTEGRATED PLANT NUTRITION AND IRRIGATION SCHEDULING ON YIELD AND YIELD COMPONENTS OF MAIZE (*zea mays* L.)

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Effect of three irrigation schedules (4-6 irrigations) and seven integrated plant nutrition levels (control, 125-60-62 kg N-P_2O_5-K_2O ha^{-1}, 125-60-62 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 10 t ha^{-1}, 125-60-62 kg N-P_2O_5-K_2O ha^{-1} + Farm yard manure @ 15 t ha^{-1}, 250-120-125 kg N-P_2O_5-K_2O ha^{-1}, 250-120-125 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 10 t ha^{-1} and 250-120-125 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 15 t ha^{-1}) on grain yield and its components in maize were studied during 2009 and 2010. Plant height, number of cobs $plant^{-1}$, number of grain rows cob^{-1}, number of grains cob^{-1}, 1000-grain weight, grain weight cob^{-1}, grain yield, stover yield and biological yield were significantly affected by irrigation schedules and integrated plant nutrition levels during both years. The crop applied with six irrigations and fertilized by integrated application of chemical fertilizers (250-120-125 kg N-P_2O_5-K_2O ha^{-1}) and farmyard manure (15 t ha^{-1}) produced the highest grain yield of 8.47 t ha^{-1} and 8.22 t ha^{-1} during 2009 and 2010, respectively.
Keywords: Farmyard manure, integrated plant nutrition, irrigation scheduling, maize

INTRODUCTION

Cereal grains are important sources of carbohydrates, protein, vitamins and minerals for an ever increasing world population. It has been estimated that cereal grains provide 56% of the food energy and 50% of the protein consumed on earth (Christie, 1987). Maize is a major crop for both direct and indirect human consumption as it forms a major energy feed for livestock. It is a cheap source of raw material for various agro-based industries and extensively used for preparation of corn starch. Mangelsdorf (1967) tested the approximate starch concentration of cereal grains and found that corn grain contains more starch than that of wheat, barley and oat, but less than that of rice. Economically, the most important product of corn is the grain which is a valuable source of starch as well as it contains more oil than most other cereals (Langer, 1991).

The maize crop has a wide adaptation and is able to grow in regions ranging from the semiarid, with an annual rainfall of 20 to 25 cm to those where annual rainfall may exceed 400 cm (Abuzar *et al*., 2011). In Pakistan, maize crop is cultivated on an area of 1015 thousand hectares with total annual production of 3313 thousand tons and average grain yield of 3264 kg ha^{-1} (Government of Pakistan, 2008). In spite of high yielding potential, the yield obtained at farmer's field in Pakistan is low. There are different causes of low maize yield and the main barrier in exploring the full potential is poor crop nutrition and irrigation management (Government of Pakistan, 2008). After 1960s, due to replacement of recycling of organic wastes and application of inorganic fertilizers with the introduction of new crop varieties, the physical conditions of the soils have been deteriorated. This ultimately has accelerated soil erosion and there have been heavy losses of soil and plant nutrients (Khan *et al*., 2001). Continuous use of only chemical fertilizers in the intensive cropping system has resulted in misbalancing of nutrients in the soil, which has an adverse effect on soil health and the crop yield. Nutrient depletion is the most intense because of high outputs of nutrients in harvested products. In many regions of the 3rd World, the decline of soil fertility is alarming. Almost the entire available soil in the country (Pakistan) is nutrient deficient (Government of Pakistan, 2008). Integrated nutrient management involves the combination of both inorganic and organic fertilizers to increase crop production (Janssen, 1993). A crop production system with high yield targets cannot be sustainable unless balanced nutrient inputs are supplied to soil against nutrient removal by crops (Bhuiyan *et al.*, 1991). Neither organic manure nor chemical fertilizer alone can increase satisfactory yield under intensive farming. Therefore, a judicious combination of organic and chemical fertilizers helps to maintain soil and crop productivity (Kumar *et al.*, 2007).

Combined application of available organic sources along with optimal dose of inorganic fertilizers assures high and sustained productivity due to regulated nutrient supply and reduced losses (Manna *et al.*, 2003). Balanced usage of fertilizer helps increasing crop yield from 30 to 60 percent in different regions of the country (Government of Pakistan, 2008).

Traditional irrigation scheduling practices consider soil and/or crop monitoring. Unmeasured irrigation tends to waste water, nutrients, energy and may cause soil degradation by water-logging and salinization, particularly where drainage is poor. Significant quantities of water could be saved by adopting irrigation scheduling which is an important practice in the management of valuable water resources in agricultural regions (Kirk and Blad, 1982). Irrigation scheduling is the procedure used to determine the time and amount of water application for each irrigation (Ashraf *et al.*, 2002). Keeping in view the above facts, this study was designed to investigate and quantify the effect of different irrigation schedules and integration of NPK levels with farmyard manure on the yield and yield components of maize.

MATERIALS AND METHODS

The study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during 2009 and 2010. The experiment was laid out in a randomized complete block design (RCBD) with split-plot arrangement keeping the irrigation schedules in main plots and integrated plant nutrition in sub plots. Experiment was replicated three times. The net plot size was 3m x 5m. The treatments were three irrigation schedules i.e. I_1: four irrigations (1st at three-leaf stage, 2nd at ninth-leaf stage, 3rd at tasseling stage, 4th at milking stage), I_2: five irrigations (1st at third leaf stage, 2nd at ninth leaf stage, 3rd at tasseling, 4th at milking stage, 5th at dough stage) and I_3: six irrigations (1st at third leaf stage, 2nd at ninth leaf stage, 3rd at tasseling, 4th at blister stage, 5th at milking stage, 6th at dough stage) and seven integrated plant nutrition levels (N_0: control, N_1: 125-60-62 kg N-P_2O_5-K_2O ha^{-1}, N_2: 125-60-62 kg N-P_2O_5-K_2O ha^{-1} + Farm yard manure @ 10 t ha^{-1}, N_3: 125-60-62 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 15 t ha^{-1}, N_4: 250-120-125 kg N-P_2O_5-K_2O ha^{-1}, N_5: 250-120-125 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 10 t ha^{-1} and N_6: 250-120-125 kg N-P_2O_5-K_2O ha^{-1} + Farmyard manure @ 15 t ha^{-1}). The hybrid maize R-2331 was sown in 75 cm apart rows with the help of single row hand drill using a seed rate of 30 kg ha^{-1}. The plant-to-plant distance was maintained approximately 20 cm by thinning out the surplus plants at four-leaf stage. Fertilizer and irrigation was applied according to the treatments. All other agronomic practices were kept normal and uniform for all treatments. Observations on growth and yield parameters were recorded using standard procedures.

The data recorded were analyzed by "MSTAT" statistical computer package (Freed and Eisensmith, 1986). When a significant treatment effect was found, least significance difference (LSD) test at 5% probability was used to compare the treatment's means (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Plant height at harvest (cm)**:** The data given in Table 1 revealed that both the factors under study had a significant effect on plant height of maize at maturity. Among different irrigation schedules, I_3 (six irrigations) showed maximum plant height of 217.83 cm and 209.43 cm during 2009 and

Table 1. Effect of irrigation schedules and integrated plant nutrition levels on plant height, number of cobs plant^{-1} and number of grain rows cob^{-1}

Treatments	Plant height (cm)		Number of cobs plant^{-1}		Number of grain rows cob^{-1}	
	2009	2010	2009	2010	2009	2010
Irrigation schedules (I)						
I_1	207.31 c	201.02 c	1.17 b	1.14 b	12.52 c	11.67 c
I_2	215.40 b	207.84 b	1.18 ab	1.15 ab	13.47 b	12.59 b
I_3	217.83 a	209.43 a	1.19 a	1.16 a	13.83 a	13.09 a
LSD 5%	0.2234	0.7797	0.0171	0.0148	0.1626	0.1692
Integrated plant nutrition levels (N)						
N_0	167.95 g	157.82 g	1.04 f	1.01 f	10.62 f	10.41 f
N_1	200.63 f	196.03 f	1.11 e	1.08 e	12.12 e	11.12 e
N_2	215.66 e	206.75 e	1.18 d	1.13 d	13.01 d	12.27 d
N_3	221.29 d	213.83 d	1.22 c	1.17 c	13.80 c	12.92 c
N_4	227.29 c	219.45 c	1.23 bc	1.20 b	14.20 b	13.30 b
N_5	229.97 b	223.49 b	1.24 ab	1.22 a	14.48 ab	13.50 ab
N_6	231.80 a	225.29 a	1.25 a	1.23 a	14.68 a	13.62 a
LSD 5%	0.564	0.989	0.0191	0.0165	0.2868	0.3083
I × N	NS	NS	NS	NS	NS	NS

Means sharing different letters in a column differ significantly at P = 0.05

NS = Non significant

2010, respectively; however, the minimum plant height of 207.31 cm and 201.02 cm was recorded in I_1 (four irrigations) treatment during 2009 and 2010, respectively. These results are similar to the findings of El-Gizawi and Nasser (2005) who found taller plants by decreasing irrigation interval. Plant height increased linearly as the levels of integrated plant nutrition levels were increased and maximum plant height of 231.80 cm in 2009 and 225.29 cm in 2010 were obtained in case of N_6 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}) treatment. While the minimum plant height was obtained in control treatment. These results are inline as the results of Qasim *et al.* (2001) who reported an increase in plant height with farmyard manure application due to more availability and uptake of nutrients. The interactive effect on plant height was non significant during both years.

***Number of cobs plant^{-1}*:** Effect of different irrigation schedules on number of cobs $plant^{-1}$ was found to be significant (Table 1). Maximum number of cobs $plant^{-1}$ (1.194 in 2009 and 1.16 in 2010) was found by six irrigations which was statistically at par with I_2 (five irrigations) during both the years (2009 and 2010). The minimum number of cobs $plant^{-1}$ (1.173 in 2009 and 1.14 in 2010) was obtained in treatment I_1 (four irrigations). Similar results were reported by Espinosa *et al.* (2007) who reported a decrease in number of cobs $plant^{-1}$ with a limited supply of irrigation. Integrated plant nutrition levels response was also significant during 2009 and 2010. The highest number of cobs $plant^{-1}$ (1.254 in 2009 and 1.234 in 2010) was found in treatment N_6 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}) which was at par with N_5 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 10 t ha^{-1}) treatment during both years. However, minimum number of cob $plant^{-1}$ was exhibited in control treatment during both years. These results prove the findings of Phanitkun *et al.* (1985) who also reported the encouraging effect of combined use of manure and NPK fertilization on number of cobs $plant^{-1}$. The interaction between irrigation schedules and integrated plant nutrition levels were found to be statistically non-significant.

***Number of grain rows cob^{-1}*:** Significant differences in number of grain rows cob^{-1} were evident between different irrigation schedules and integrated plant nutrition levels in both the years (Table 1). Six irrigations (I_3) produced the highest (13.83 and 13.09) number of grain rows cob^{-1} during 2009 and 2010, respectively. These results are in line according to the results of El-Gizawi and Nasser (2005) who reported that decreasing the irrigation interval increased number of grain rows cob^{-1}. Among integrated plant nutrition levels N_6 (250-120-125 kg N-P_2O_5--K_2O ha^{-1} + FYM @ 15 t ha^{-1}) treatment showed the highest number of rows cob^{-1} (14.68 in 2009 and 13.62 in 2010) and it was statistically at par with N_5 (250-120-125 kg N-P_2O_5--K_2O ha^{-1} + FYM @ 10 t ha^{-1}) in both seasons. These results are inline with the findings of Rezvantalab *et al.* (2008) who obtained higher number of rows by integrated use of organic and chemical fertilizers. These finding are also supported by Lu *et al.* (2010) who reported an increase in number of grain rows cob^{-1} as the levels of manure was increased. The interactive effect between irrigation schedules and intergraded plant nutrition levels was found to be non-significant in 2009 and 2010.

***Number of grains cob^{-1}*:** Maximum number of grains cob^{-1} of 388.24 and 372.71 were recorded by six irrigations (I_3) during 2009 and 2010, respectively, while the least number

Table 2. Effect of irrigation schedules and integrated plant nutrition levels on number of grains cob^{-1}, 1000-grain weight and grain weight cob^{-1}

Treatments	Number of grains cob^{-1}		1000-Grain weight (g)		Grain weight cob^{-1} (g)	
	2009	2010	2009	2010	2009	2010
Irrigation schedules (I)						
I_1	378.43 c	357.24 c	200.18 b	196.84 c	75.79 c	72.44 c
I_2	384.90 b	367.43 b	207.93 a	203.53 b	81.15 b	78.41 b
I_3	388.24 a	372.71 a	208.79 a	205.33 a	82.61 a	81.35 a
LSD 5%	0.4944	1.195	0.8995	0.5491	0.2613	0.1935
Integrated plant nutrition levels (N)						
N_0	248.89 g	234.33 g	158.91 g	160.87 g	42.83 g	38.58 g
N_1	338.78 f	324.44 f	189.31 f	184.21 f	64.79 f	61.56 f
N_2	387.33 e	379.11 e	205.84 e	203.80 e	76.81 e	76.60 e
N_3	412.22 d	396.44 d	215.35 d	209.97 d	86.98 d	85.50 d
N_4	426.56 c	403.22 c	220.40 c	215.47 c	92.88 c	90.49 c
N_5	434.22 b	409.44 b	223.86 b	218.35 b	96.45 b	93.41 b
N_6	439.01 a	413.56 a	225.77 a	220.64 a	98.18 a	95.67 a
LSD 5%	0.5434	1.395	0.6255	0.6940	0.3114	0.2565
I × N	NS	NS	NS	NS	NS	NS

Means sharing different letters in a column differ significantly at P = 0.05
NS = Non significant

of grains cob^{-1} (378.43 in 2009 and 357.24 in 2010) were noticed in plots receiving four irrigations (Table 2). Confirmatory results regarding number of grains cob^{-1} were given by El-Tantawy *et al.* (2007) who reported significant differences among different irrigation schedules. Among integrated plant nutrition levels, the maximum number of grains cob^{-1} (439.01) were recorded in treatment receiving higher levels of organic and inorganic nutrients (N_6) in 2009. Same trend was noticed in 2010. The minimum number of grains cob^{-1} was recorded in control treatment receiving no fertilizer in both the seasons of 2009 and 2010. Rezvantalab *et al.* (2008) also reported higher number of grains cob^{-1} with application of farmyard manure and mineral fertilizers. Interaction between irrigation schedules and integrated plant nutrition levels was found to be non significant during both the years (2009 and 2010).

1000-grain weight (g)**:** Significant results of both factors under study during both the years of experimentation were found. The maximum 1000-grain weight of 208.79 g in 2009 and 205.33 g in 2010 was found in case of six irrigations. As the number of irrigations was reduced, the 1000-grain weight also decreased (Table 2). The decrease in 1000-grain weight with reducing the number of irrigations was in agreement with the previous findings of Kashiani *et al.* (2011). In case of plant nutrition treatments, the highest 1000-grain weight (225.77 g) was noted in treatment N_6 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}) as compared to all other integrated plant nutrition treatments in 2009. Same trend were observed during 2010. The increase in 1000-grain weight might be due to integrated use of farmyard manure and NPK fertilizers which increased concentration of N and P in the soil. Reports supporting the present results have appeared in the literature by Sharif *et al.* (2004). The non-significant interaction between irrigation schedules and integrated plant nutrition levels was detected in 2009 and 2010.

Grain weight cob^{-1} (g)**:** There was a significant effect of irrigation scheduling and integrated plant nutrition on grain weight cob^{-1} during 2009 and 2010 as shown in Table 2. Six irrigations (I_3) produced the heavier grains followed by 5 and 4 irrigations (I_2 and I_1) in both the seasons. These data confirm that of El-Tantawy *et al.* (2007) who reported significant response of supplementary irrigation on grain weight cob^{-1}. Among integrated plant nutrition levels the maximum grain weight cob^{-1} was recorded with higher rates of organic and chemical fertilizers application (N_6). This is consistent with the study by Kang *et al.* (1985) and Suksri (1992). They found that compost application increased grain weight cob^{-1} strikingly with an increase in N rates. Non significant interaction between irrigation schedules and integrated plant nutrition levels was found during 2009 and 2010.

Grain yield (t ha^{-1})**:** Reduction in grain yield was noted with a decrease in number of irrigations (Table 3). Treatment I_3 (six irrigations) produced the maximum grain yield of 6.22 t ha^{-1} in 2009 and 6.04 t ha^{-1} in 2010 as compared to other two irrigation schedules. These facts are comparable with the study of Zhang *et al.* (2007) who obtained higher yield with the increase in number of irrigations. This is probably due to the increased concentration and accumulation of certain nutrients by increase in irrigation frequency (Hussaini *et al.*, 2008). Data also showed that all the plant nutrition treatments produced more grain yield over control in both the years (2009 and 2010). It is obvious from Table 3 that in

Table 3. Effect of irrigation schedules and integrated plant nutrition levels on grain, stover and biological yield of maize

Treatments	Grain yield (t ha^{-1})		Stover yield (t ha^{-1})		Biological yield (t ha^{-1})	
	2009	2010	2009	2010	2009	2010
Irrigation schedules (I)						
I_1	4.38 c	4.22 c	10.87 c	10.54 c	15.25 c	14.76 c
I_2	5.55 b	5.39 b	11.94 b	11.81 b	17.49 b	17.20 b
I_3	6.22 a	6.04 a	12.56 a	12.53 a	18.78 a	18.57 a
LSD 5%	0.2267	0.2166	0.1838	0.2028	0.1935	0.2028
Integrated plant nutrition levels (N)						
N_0	2.72 g	2.70 g	7.72 f	7.74 e	10.43 g	10.44 g
N_1	4.11 f	4.04 f	10.46 e	10.39 d	14.57 f	14.43 f
N_2	4.69 e	4.54 e	11.90 d	11.63 c	16.59 e	16.17 e
N_3	5.09 d	4.91 d	12.17 c	11.83 c	17.26 d	16.74 d
N_4	6.42 c	6.15 c	12.83 b	12.63 b	19.25 c	18.78 c
N_5	7.15 b	6.83 b	13.67 a	13.52 a	20.82 b	20.35 b
N_6	7.52 a	7.36 a	13.78 a	13.64 a	21.29 a	21.00 a
LSD 5%	0.2529	0.2456	0.2116	0.3678	0.2116	0.3678
I × N	**	**	NS	NS	NS	NS

Means sharing different letters in a column differ significantly at P = 0.05
*NS = Non-significant; ** = Significant at 5% probability level*

both the years the maximum grain yield (7.52 t ha^{-1} in 2009 and 7.36 t ha^{-1} in 2010) was recorded with the highest levels of FYM and inorganic NPK (N_6:250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}). The increase in grain yield most likely was the result of balanced use of crop nutrients (Kiver and Onopriyenko, 1998). There was a significant interaction between irrigation schedules and integrated plant nutrition levels during both years (Table 4 & 5). I_3N_6 (six irrigations and 250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}) interaction produced maximum grain yield (8.47 t ha^{-1} in 2009 and 8.22 t ha^{-1} in 2010). It may be due to the high efficiency of mineral fertilizers under adequate irrigation as described by Shammari (1985). Contrarily, the minimum grain yield (2.03 t ha^{-1} in 2009 and 2.00 t ha^{-1} in 2010) was produced by crop raised with four irrigations and without any crop nutrition (I_1N_0).

Stover yield (t ha^{-1}): The effect of irrigation schedules and plant nutrition treatments on stover yield of maize was significant in 2009 and 2010 (Table 3). In 2009 and 2010, there was a significant increase in stover yield with increase in number of irrigation and the maximum values of 12.56 t ha^{-1} in 2009 and 12.53 t ha^{-1} in 2010 were achieved in case of six irrigations (I_3). Our results are in conformity with the findings of Patel *et al.* (2006) who also observed improvement in stover yield with increased irrigation. Among integrated plant nutrition levels, the N_6 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}) treatment exhibited the maximum stover yield but was statistically on a par with N_5 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 10 t ha^{-1}) in both years of study. On the contrary the minimum stover yield was recorded for the crop without any application of plant nutrients. These results are also verified by Shah *et al.* (2007) who obtained higher stover yield by integrative use of compost and urea. Non-significant interaction between irrigation schedules and integrated plant nutrition levels was found for stover yield in both years.

Biological yield (t ha^{-1}): Maize crop irrigated with six irrigations produced maximum biological yield of 18.78 t ha^{-1} while five and four irrigations produced 17.49 t ha^{-1} and 15.25 t ha^{-1}, respectively in 2009. In 2010, the similar trend was found for different irrigation schedules (Table 3). Total biological yield produced in this study was similar to that of Igbadun *et al.* (2008), and Farre and Faci (2009) who reported that deficit irrigation at any crop growth stage of the maize crop led to decrease in biological yield. In case of integrated plant nutrition levels the maximum biological yield (21.29 t ha^{-1} in 2009 and 21.0 t ha^{-1} in 2010) was recorded in treatment N_6 (250-120-125 kg N-P_2O_5-K_2O ha^{-1} + FYM @ 15 t ha^{-1}). This effect may be a result of more microbial activity in soil by application of NPK fertilizers along with farmyard manure (Kanchikerimath and Singh, 2001). Takeshi *et al.* (2003) also obtained higher biological yield of maize with combined application of NPK and organic fertilizers. Interactive effect of both the factors (irrigation schedules and integrated plant nutrition levels) was non-significant in 2009 and 2010.

Conclusion: On the basis of two years study, it may be concluded that in order to obtain higher grain yield of hybrid maize under agro-ecological conditions of Faisalabad, the crop should be irrigated with 6 irrigations and fertilized with integrated application of chemical fertilizers (250-120-125 kg N-P_2O_5-K_2O ha^{-1}) and organic manures (15 t farmyard manure ha^{-1}).

Table 4. Interaction between irrigation schedules and integrated plant nutrition levels affecting grain yield (t ha^{-1}) during 2009

Irrigation schedules	**Integrated plant nutrition levels**						
	N_0	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**
I_1	2.03 m	3.01 l	3.58 jk	3.98 ij	5.36 gh	6.22 de	6.47 d
I_2	2.85 l	4.27 i	4.98 h	5.34 gh	6.58 d	7.22 c	7.61 bc
I_3	3.27 kl	5.05 h	5.51 fg	5.94 ef	7.32 c	8.01 b	8.47 a

LSD 5% = 0.4381

Means sharing different letters in a column differ significantly at P = 0.05

Table 5. Interaction between irrigation schedules and integrated plant nutrition levels affecting grain yield (t ha^{-1}) during 2010

Irrigation schedules	**Integrated plant nutrition levels**						
	N_0	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**
I_1	2.00 n	2.93 m	3.49 kl	3.78 jk	5.16 hi	5.86 ef	6.35 d
I_2	2.84 m	4.21 j	4.74 i	5.21 h	6.24 de	6.99 c	7.52 b
I_3	3.25 lm	4.98 hi	5.38 gh	5.75 fg	7.04 c	7.65 b	8.22 a

LSD 5% = 0.4684

Means sharing different letters in a column differ significantly at P = 0.05

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