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Impact of Irrigation and Nitrogen on Determining the Contribution of Yield Components and Morphological Traits on Corn Kernel Yield

[1]M. Edalat, [1]S.A. Kazemeini, [2]E. Bijanzadeh and [1]R. Naderi
[1]Department of Crop Production and Plant Breeding, College of Agriculture, Shiraz University, Shiraz, Iran
[2]Darab College of Agriculture, Shiraz University, Iran

Abstract: This study was conducted to investigate the impact of irrigation and nitrogen on determining the contribution of yield components and morphological traits on corn kernel yield. Treatments were nitrogen in four levels (0, 75, 150 and 225 kg N ha^{-1}) and three irrigation intervals (7, 10 and 14 days) in 2005 and 2006 at the Kooshkak Agricultural Experiment Station, Fars, Iran. The result of stepwise regression between kernel yield and yield components showed that, kernel number per ear (R^2 = 0.8192) and kernel weight per ear (R^2 = 0.0697) had the most proportion in kernel yield variation (Cumulative R^2 = 0.8889). Irrigation levels significantly affected kernel yield. Similar to kernel yield, maximum biological yield (17090 kg ha^{-1}) was obtained at 7 days intervals. With increasing nitrogen levels plant height was increased and its maximum value (201.2 cm) was observed at 225 kg N ha^{-1}. Results of N and irrigation interaction effects showed that the highest kernel yield obtained at 225 kg N ha^{-1} and 7 days intervals irrigation (10213 and 8570 kg ha^{-1}, respectively).

Key words: Corn, irrigation intervals, nitrogen, stepwise regression, yield

INTRODUCTION

Corn is one of the three major cereal crops in the world. Corn is used primarily as a feed kernel for livestock, but it is also the source of an increasing number of important industrial products (Tollenar and Dwyer, 1999).

In Iran, the area under corn cultivation was 200,000 ha, with average kernel yield of 1.2 million tons, in 2005. Fars Province with 600,000 tons kernel corn production is the leading producer in Iran. According to FAO, the world corn production has been 715.8 million tons with the area harvested of about 147.8 million ha. In corn at the pre-pollination stage, treatments such as water deficit inhibit stigma (silk) elongation and floret development that leads to decrease in kernel set (Setter *et al*., 2001).

Drought is a major abiotic constraint responsible for heavy production losses (Khan *et al*., 2007; Ricciardi *et al*., 2001). This stress is considered as one of the most important limiting factors for corn growth and production. The stress affects almost all plant processes (photosynthesis, respiration, stomatal conductivity, etc.); however, stress response depends on the intensity, rate and duration of exposure to stress and the stage of crop growth (Brar *et al*., 1990). Water stress could affect photosynthesis via stomatal closure, enzyme activity reduction or hormonal aspects of this phenomenon. With changing of photosynthesis, plant respiration also take effects and become low.

Nitrogen fertilizer (N) is a key nutrient in the production of non legume crops. It is a component in many biological compounds that plays a major role in photosynthetic activity and crop yield capacity (Cathcart and Swanton, 2003). Reducing nitrogen inputs to crop production is becoming increasingly important with growing awareness of the negative effects of nitrogen in the environment (Hans and Johnson, 2002). Current evidence suggests that, as N application rates are reduced, there is an increase in the relative competitiveness of weed species (Bosnic and Swanton, 1997). In most southern provinces of Iran e.g., Fars, water deficit during the growing season of corn is a serious problem in irrigated agricultural areas.

Al-Suhaibani (2006) conducted an experiment for evaluation the effect of irrigation intervals and nitrogen fertilizer rates on fresh forage yield of sudangrass. The results showed significant effects for growing season and irrigation intervals on the forage yield, while the nitrogen treatments were not effective. Expanding irrigation interval from 3 to 7 and 11 days decreased the potential yield from 143.6 to 123 and 85.3 t ha^{-1}, respectively. Moreover, both 1st and 2nd cut yield was about 85% of the total obtained forage.

Al-Kaisi and Yin (2003) showed that a combination of 0.80ET to 1.00ET, 140 to 250 kg N ha^{-1} and 57000 to 69000 plants ha^{-1} population provided optimum corn yield. Irrigation treatment 0.80ET, accompanied by 140 to

Corresponding Author: Mohsen Edalat, Department of Crop Production and Plant Breeding, Shiraz University, Shiraz, Iran

250 kg N ha^{-1} and 57000 to 69000 plants ha^{-1} population was the best management system for optimum Water Use Efficiency (WUE).

In statistics, stepwise regression includes regression models in which the choice of predictive variables is carried out by an automatic procedure. The main approaches are:

- Forward selection, which involves starting with no variables in the model, trying out the variables one by one and including them if they are statistically significant
- Backward elimination, which involves starting with all candidate variables and testing them one by one for statistical significance, deleting any that are not significant
- Methods that are a combination of the above, testing at each stage for variables to be included or excluded. This is an automatic procedure for statistical model selection

The objective of this research was to investigate the impact of irrigation and nitrogen on determining the contribution of yield components and morphological traits on corn kernel yield in Southern of Iran.

MATERIALS AND METHODS

The present study was conducted to investigate the effect of different irrigation intervals and nitrogen levels on yield and yield components of corn. Treatments were 4 levels of nitrogen (0, 75, 150 and 225 kg N ha^{-1}) that were supplied from urea (46% N) and 3 irrigation intervals (7, 10 and 14 days) (irrigation was stopped at the physiological maturity (black layer formation) in 2005 and 2006 at the Kooshkak Agricultural Research Center, Northwest of Shiraz (30°7′ N, 52°34′ E), Iran on clay loam (fine, carbonatic, mesic, aquic calcixerepts) soil. The experimental design was a randomized complete block with 3 replications. The 2005 and 2006 mean monthly and 20 years mean temperature and precipitation in Khooshkak are given in Table 1. Selected soil properties at the experimental site is shown in Table 2. Seedbed preparation consisted of fall disking and plowing. Individual plots were 5 m wide by 6 m long. Commercial corn seed (SC 704) was planted 5 cm deep at 66650 plants ha^{-1} in 75 cm spaced rows on 11 June 2005 and 15 June 2006. One-third of the nitrogen fertilizer (urea, 46% N was hand-broadcasted during seed bed preparation and the remaining was topdressed at 6-leaf stage and before silking applied at bud stage.

Table 1: Khooshkak 2005 and 2006 mean monthly, annual and 20 year mean temperature and precipitation

	Mean temperature (°C)			Precipitation (mm)		
Month	2005	2006	20 years Mean	2005	2006	20 years Mean
April	12.1	12.1	12.6	0.0	64.5	43.50
May	17.3	18.3	17.1	0.0	9.0	17.50
June	21.9	22.1	21.9	0.0	0.0	0.20
July	27.2	27.6	25.1	0.0	0.0	0.30
August	26.6	26.6	24.5	0.0	0.0	0.60
September	24.0	22.6	22.4	0.0	0.0	0.40
October	18.3	19.2	18.3	0.0	0.0	0.43
November	11.1	12.9	13.5	99.0	3.0	23.50
December	9.4	3.6	17.9	1.5	100.5	73.70
January	3.5	1.6	5.2	172.0	37.5	88.60
February	6.6	5.1	5.5	67.0	97.0	86.00
March	9.0	8.3	9.1	6.5	49.0	89.70
Total				346.0	360.5	424.40

Table 2: Selected soil properties of the experimental site

Characteristics	Amount
Sand (%)	20.90
Silt (%)	52.10
Clay (%)	27.00
pH	7.60
Calcium carbonate (%)	34.20
Electrical conductivity (dS m^{-1})	3.10
Total nitrogen (%)	0.179
Phosphorus (mg kg^{-1})	20.00
Potassium (mg kg^{-1})	225.00

Crop water requirement was calculated based on class A daily pan evaporation. Daily evaporation data was multiplied by Kp (pan coefficient) and Kc (crop coefficient) in order to calculate ETp (potential evapotranspiration). Two holes (2 m depth) were dug to investigate water table depth in two part of the farm. Two PVC trepanned pipes (9 cm diameter and 250 cm height) were inserted into the holes. Pipes were covered by fine sand filter to avoid soil pass through the pipes. Soil water content was measured by the gravimetric method before sowing and after harvest at 20, 40 and 60 cm depths. In both years, plots were kept free from pests, disease and weeds during the growing seasons. At corn maturity, 6 m^2 of each plot was harvested to determine yield, yield components and morphological traits. Samples were oven dried at 72°C for 48 h. Data were subjected to analysis of variance (ANOVA) and the mean values were compared by LSD at p = 0.05. Stepwise regression model and linear regression method were used to determine the relationship between yield and yield components and also yield and morphological traits. All statistical analysis were done using SAS software.

RESULTS AND DISCUSSION

Simple linear regression analysis between yield and yield components showed that, kernel number per ear had most effect on kernel yield (R^2= 0.8187) (Table 3). Among morphological traits (biological yield, plant height, ear length and ear weight), biological yield had the highest correlation with kernel yield (R^2= 0.9748) (Table 3). The result of stepwise regression between kernel yield and yield components showed that, kernel number per ear (R^2 = 0.8192) and kernel weight per ear (R^2 = 0.0697) had the largest proportion in kernel yield variation (Cumulative R^2 = 0.8889). 1000 kernel weight of corn had no or little effects on kernel yield (Table 4, 5). These results could be attributed to sink-source relationships in stressed conditions; in stress conditions kernels that in corn are the major sink becomes small due to reduction of kernel number and kernel weight. The highest partial coefficient of determination of morphological traits was related to biological yield (0.9748) and ear weight (0.0014) (Table 7). Other morphological traits of corn had no or little effects on kernel yield (Table 6, 7). It can be concluded that, kernel number per ear, kernel weight per ear and biological yield had significant considerable role on kernel yield of corn under different irrigation and nitrogen treatments (Table 8-11). Shoa Hosseini *et al.* (2008) reported that in the non-stress condition, number of kernel per row, plant height and ear length and in the stress condition, cob diameter, number of kernel per row and ear length are have the most contribution in kernel yield determination.

Table 3: Kernel yield regression equation and coefficient with other characteristic

Characteristic	Regression coefficient (R^2)	Regression equation
1000 kernel weight	0.5247	y = 0.0723x+166.59
Kernel weight/ear	0.558	y = 0.1295x+443.94
Kernel No./ear	0.8187	y = 0.0639x+73.569
Plant height	0.5129	y = 0.0325x+168.71
Biological yield	0.9748	y = 1.7782x+252.97
Harvest index	0.5411	y = 0.0117x+37.229

Results showed that effects of different nitrogen levels and irrigation intervals on kernel yield were significant but year effect was not significant therefore, data in tables represent mean of two years (Table 8). Present results showed that there was highly significant difference in kernel yield for irrigation intervals thus the irrigation levels significantly affected kernel yield (Table 9). Maximum 1000 kernel weight was observed at 7 days intervals however there was no significant difference between 7 and 10 days intervals. Similar to kernel yield, maximum biological yield (17090 kg ha^{-1}) was obtained at 7 days. Maximum plant height (198.9 cm) was obtained at 7 days intervals and minimum plant height (179.7 cm) was obtained at 14 days intervals. Kernel yield decreased by 23 and 29.7% as the irrigation interval increased from 7 to 10 days and 10 to 14 days (Table 9).

With increasing nitrogen level, yield significantly increased (3829 to 10182 kg ha^{-1}). The highest kernel yield and biological yield were observed at 225 kg N ha^{-1} that this treatment was significantly different from other treatments (Table 10). Maximum 1000 kernel weight (236.2 g) was obtained at 225 kg N ha^{-1} however there was no significant difference between nitrogen treatments. With increasing nitrogen levels plant height was increased and its maximum value (202.1 cm) was observed at 225 kg N ha^{-1} (Table 10).

Table 4: Model parameters for relationship between yield and yield components

Variable	Parameter estimate	SE	Type II sum of squares	F-value	Pr>F
Intercept	-1516.89547	106.85928	2458565	201.51	<0.0001
Kernel No./ear	10.10059	0.60302	3423143	280.56	<0.0001
Kernel wt./ear	1.86846	0.24472	711271	58.30	<0.0001

Table 5: Summary of stepwise selection for yield and yield components

Step	Variable entered	Number vars. In	Partial R^2	Cumulative R^2	F-value	Pr>F
1	Kernel number/ear	1	0.8192	0.8192	425.96	<0.0001
2	Kernel wt./ear	2	0.0697	0.8889	58.30	<0.0001

Table 6: Model parameters for relationship between kernel yield and morphological traits

Variable	Parameter estimate	SE	Sum of squares	F-value	Pr>F
Intercept	-91.85488	19.37859	58689	22.47	<0.0001
Ear weight	-0.02286	0.00983	14127	5.41	<0.0222
Biological yield	0.55126	0.00898	9850713	3771.16	<0.0001

Fitted model: Y = -91.85488 - 0.02286 (ear weight) + 0.55126 (biological yield)

Table 7: Summary of stepwise selection for biological yield and morphological traits

Step	Variable entered	Number vars. In	Partial R^2	Cumulative R^2	F-value	Pr>F
1	Biological yield	1	0.9748	0.9748	3639.97	<0.0001
2	Ear weight	2	0.0014	0.9762	5.41	<0.0222

Table 8: ANOVA of studied characteristics of corn in two years (2005-2006)

		MS					
SOV	df	Kernel yield	1000 kernel weight	Kernel weight/ear	Kernel No./ear	Plant height	Biological yield
Irrigation	2	1207318.5*	23914.8*	1277.30*	3470.30	3067.90*	3239072.8*
Year	1	5280.7	565.5	145.00	3528.40	450.70	24897.0
Block (year)	6	38042.9	1002.5	371.90*	283.50	411.40	188072.6
Nitrogen	3	1947574.4*	7135.8*	6204.10*	50993.30*	2163.50*	6334700.2*
Nitrogen×year	3	237.7	1.2	0.57	5.40	0.20	767.8
Nitrogen×irrigation	6	140234.1*	159.1	125.10	3769.40	80.70	402869.2*
Irrigation×year	2	138.3	3.9	1.70	0.22	0.33	390.1
Error	72	12189.9	347.4	52.60	1699.40	73.90	56441.0

*: Significant difference (5%)

Table 9: Effect of irrigation intervals on growth, yield and yield components in corn

Irrigation intervals	Kernel yield (kg ha^{-1})	1000 kernel weight (g)	Kernel wt./ear (g)	Kernel No./ear	Biological yield (kg ha^{-1})	Plant height (cm)
7	8570	237.8	134.2	545.6	17090	198.9
10	6600	226.7	121.3	462.0	14470	191.4
14	4636	196.3	95.0	360.2	10890	179.7
LSD (0.05%)	1794	31.7	13.5	73.2	172	6.4

Mean of two years

Table 10: Effect of nitrogen levels on growth, yield and yield components in corn

Nitrogen levels (kg ha^{-1})	Kernel yield (kg ha^{-1})	1000 kernel weight (g)	Kernel wt./ear (g)	Kernel No./ear	Biological yield (kg ha^{-1})	Plant height (cm)
0	3829.0	201.2	92.7	412.0	10336.7	178.70
75	4997.0	215.5	101.7	441.0	12773.7	186.70
150	7395.0	226.3	127.7	477.3	14178.0	193.00
225	10182.0	237.1	144.7	492.3	19310.3	201.30
LSD (0.05%)	315.0	16.3	10.8	11.8	645.0	7.39

Mean of two years

Table 11: Interaction effect of irrigation intervals and nitrogen levels on growth, yield and yield components in corn

	Nitrogen levels	Kernel yield	1000 kernel	Kernel	Biological	Plant	
Irrigation intervals	(kg ha^{-1})	(kg ha^{-1})	weight (g)	wt./ear (g)	kernel No./ear	yield (kg ha^{-1})	Height (cm)
7	0	4308.0d	219.6b	110.0c	500.0c	12000d	189.4b
	75	6157.0c	227.6ab	119.0c	534.0bc	14580c	197.5ab
	150	9618.0b	235.6ab	145.0b	563.0ab	16900b	203.3a
	225	13830.0a	244.5a	162.0a	583.0a	22500a	205.5a
10	0	4038.0c	200.6b	97.0c	425.0b	11380d	179.4b
	75	4929.0c	217.4ab	106.0c	446.0b	15280c	189.0b
	150	7212.0b	232.9a	132.0b	483.0a	17230b	192.1b
	225	9953.0a	246.1a	149.0a	494.0a	21280a	205.0a
14	0	2775.0b	156.8b	71.0c	311.0b	10030d	168.3b
	75	3904.0b	173.6ab	80.0c	343.0b	11830c	173.3b
	150	5348.0a	188.9a	106.0b	386.0a	13730b	184.4ab
	225	6516.0a	197.9a	123.0a	400.0a	16480a	193.0a
LSD (0.05%)		1643.0	24.45	11.8	33.8	488.7	12.79

Mean of two years, Mean values followed by the same letter(s) are significantly different

Results of nitrogen and irrigation intervals interaction effects, indicated that, at each irrigation interval by adding nitrogen from 0 to 225 kg ha^{-1}, kernel yield, kernel number/ear, biological yield and plant height significantly increased. 1000 kernel weight slight changed with different treatments. The highest kernel yield (13830 kg ha^{-1}) was obtained at 7 day irrigation intervals and 225 kg N ha^{-1} following by 10 day irrigation intervals and 225 kg N ha^{-1} (9953 kg ha^{-1}) (Table 11). The highest 1000 kernel (244.5 g) weight was obtained at 10 day intervals and 225 kg N ha^{-1}. In each irrigation intervals with increasing nitrogen levels, biological yield was increased and maximum biological yield was observed at 7 (22500 kg ha^{-1}) and 10 day (21280 kg ha^{-1}) irrigation intervals and 225 kg N ha^{-1}. Finally, the highest plant height was observed at 7 and 10 day intervals and 225 kg N ha^{-1} (Table 11).

Sepehri *et al*. (2002), reported in a study on corn that by decreasing nitrogen levels from 200 kg N ha^{-1} biological yield was decreased and this reduction was about 1858 kg ha^{-1}. Also, these researchers reported that kernel yield and 1000 kernel weight were affected by different nitrogen levels. Present results confirmed the results of Osborne *et al*. (2002). Studying the effects of irrigation intervals on sorghum, Kohan Moo and Mazaheri (2003) reported that maximum biological yield was obtained at 7 and 12 day irrigation intervals compared to 17 and 22 day intervals. Mustafa and Abdelmajid (1982) also reported similar results. Al-Suhaibani (2006) in a study on sudangrass (*Sorghum sudenense*) expanding irrigation interval from 3 to 7 and 11 days decreased the potential yield from 143.6 to 123 and 85.3 t ha^{-1}, respectively.

CONCLUSION

Present result suggested that, 225 kg N ha^{-1} and 7 days irrigation intervals are the best treatments in this area, because of highest kernel and biological yield. On the other hand, kernel number per ear, kernel weight per ear and biological yield had significant considerable role on determination the kernel yield of corn under different irrigation and nitrogen treatments. Such data are useful for farm managers and plant breeders due to determination the critical parameters involved to kernel yield.

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