PLANT ECOPHYSIOLOGY

PLANT ECOPHYSIOLOGY
Plant Ecophysiology 2 (2010) 47-52

Plant density and nitrogen effects on some traits of maize (*Zea mays* L.)

A. Hamidi[a], N. Khodabandeh[b], A. Dabbagh Mohammady-nasab[c]

[a]*Member of Seed and Plant Certification and Registration Institute, Karaj, Iran.*
[b]*Professor, Department of Agronomy and Plant Breeding, College of Agriculture, University of Tehran, Karaj, Iran.*
Associate Professor, Department of Agronomy and Plant Breeding, College of Agriculture, University of Tabriz, Tabriz, Iran.

Received on April 22, 2010; accepted on November 7, 2010

Abstract

Maize (*Zea mays* L.) is one of the most important food crops. The study of the effects of plant density and soil fertility on some agronomic traits in newly released hybrids is important. The experiment was conducted at the Agriculture Research Station, University of Tehran, Iran in 1995. It was a split-split plot design with three replications with corn hybrids as the main plots, plant density as the sub-plots and nitrogen levels as the sub-sub-plots. Grain yield per plant and unit area, biomass, harvest index, ear number, kernels per ear and 1000-kernel weight were measured. The interactions of factors were significant. Maximum grain yield.ha^{-1} was achieved by the hybrid KSC601 at the density of 8 plants.m^{-2} with the application of 230 kg N.ha^{-1}. The hybrid KSC601 at the density of 7 plants.m^{-2} with no N fertilizer application showed the maximum harvest index (70.36%). The highest kernel number per ear was obtained at the density of 6 plants.m^{-2}, and the hybrid KSC601 at the density of 6 plants.m^{-2} and 230 kg N.ha^{-1} produced the highest 1000-kernel weight. Increasing N application rate from 0 to 230 kg.ha^{-1} increased 1000-kernel weight by 12%.

Keywords: Maize; plant density; nitrogen fertilizer; grain yield components; harvest index.

Introduction

Maize (*Zea mays* L.) is one of the most important food crops and ranks the third cereal, following wheat and rice, in world food production. However, its production in Iran has become important only in recent years with a total grain production from an area of 307015 ha and mean grain yield of 7697.86 kg.ha^{-1}. The study was carried out to determine the optimum plant density and adequate nitrogen fertilizer rate for two maize hybrids, suitable for general cultivation as a second crop in a double cropping system planted after winter wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) in regions with appropriate growing seasons.

Plant density and soil fertility play important roles in the growth and yield of crops. The yield or biomass can dramatically respond to even a small change in plant density (Radosevich, 1988). However, yield quickly reaches to equilibrium at high densities and does not respond anymore to further change in population density (Radosevich, 1988).

Water, mineral nutrients, CO_2 and light have all been considered as causal factors for the reduction in yield per plant (Cox, 1996; Tollenaar, 1991). Several studies have shown that the yields of both grain and stover per maize plant decrease progressively as the number of plants increases in a given area because the competition between plants makes itself felt and that the production of the individual plant is reduced (Cox, 1996; Tollenaar, 1991). Duncan (1958a) found that the average grain yield of maize per plant logarithmically decreases as the plant population increases.

Tetio-Kagho and Gardner (1988) found that kernel yield per unit area increased to a maximum yield of 1080 g.m^{-2} at the density of about 10 plants.m^{-2}, whereas total dry matter yield asymptotically increased up to 12.5 plants.m^{-2}. They also reported that the harvest index (HI) did not substantially change over a wide plant density range. Lang *et al*. (1956) reported that 1000-

Table 1. Results of soil analysis before planting.

Soil depth (cm)	pH	N (g/100 g soil)	P (ppm)	K (ppm)	Clay (%)	Silt (%)	Sand (%)
0-30	7.4	0.14	15	150	50.88	3.24	45

kernel weight and kernels per ear were affected by plant density. Tollenaar (1991) showed that in new maize hybrids, the increase in plant density did not significantly affect HI. In contrast, Duncan (1958b) and Deloughery and Crookston (1979) observed that HI declined with the increase in plant density.

Anderson *et al*. (1985) indicated that the grain yield and ears per plant of the semi-prolific class of maize increased as N application increased. However, average grain yield and ears per plant in the prolific class did not increase with N fertilization. Reddy *et al*. (1987) studied the effect of plant density and N fertilizer rate on some characteristics of hybrid maize and observed that grain yield, biological yield, HI and 1000-kernel weight increased with the increase in soil fertility.

The objective of the study was to evaluate the combined effects of plant density and N fertilizer rate on some agronomic traits of new maize hybrids recently improved for Iranian conditions.

Materials and Methods

The experiment was conducted at the Agriculture Research Station, University of Tehran, Karaj (Lat. 35°46´ N., Long. 50°10´ E., Alt. 1321 m). Soil texture was clay whose characteristics are presented in Table 1. The precipitation and mean temperature during growing season were 372 mm and 23.36°C, respectively. The experimental site was in fallow in previous year.

The treatments were arranged following a split-split plot as a randomized complete block design with three replications; the two hybrids were the whole plots, plant population densities (D_1 = 6, D_2 = 7 and D_3 = 8 plants.m^{-2}) constituted sub-plots and N fertilizer (urea, 46%) rates were as the sub-sub-plots (N_1 = 0, N_2 = 300, N_3 = 400 and N_4 = 500 kg urea.ha^{-1}, respectively equivalent to 0, 138, 184 and 230 kg N.ha^{-1}, repectively). Sub-sub-plots consisted of four north-south rows, 8 m in length.

The maize hybrids were: medium-maturity class (115-125 days required for maturity), non prolific (single-ear) dent corn type, single cross hybrids: cv. Zarrin (KSC604), commercial cultivar (and KSC601), improved in Iran by Corn Research Section of Seed and Plant Improvement Institute in Karaj.

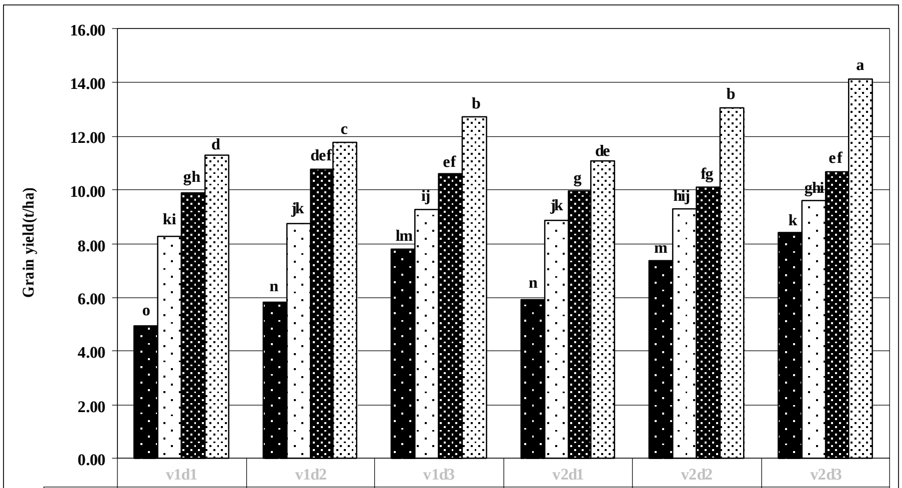
The desired plant densities were achieved by hand drilling of two seeds per hill with 22, 19 and 17 cm intra-row intra-row spacing and 75 cm inter-row spacing. Gaps were filled one week after planting. Finally, the plants were hand-thinned to a single plant per hill at the 3-4-leaf stage.

Nitrogen fertilizer was applied twice (split application), one half broadcasted prior to planting in each plot and the rest was applied as a side dress 5 cm in depth and 3 cm to one side of each row at the 7-9-leaf stage. Phosphorous was added to the soil at a rate of 150 kg P.ha^{-1} (in the form of triple superphosphate).

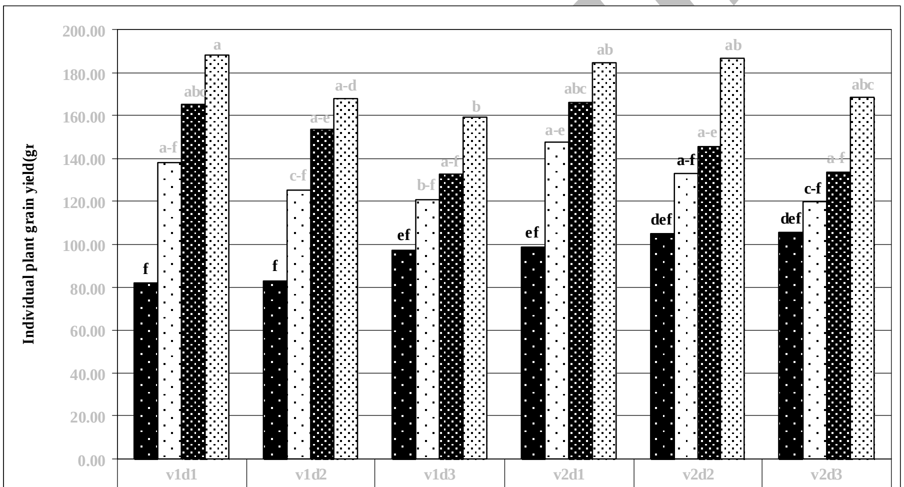
The field was irrigated at 7-day intervals. The weeds were controlled by a combination of one pre-emergence application of EPTC (*S-ethyl dipropyl carbamothioate* plus R-25788, trade name: Eradikan) at 1.8 kg a_i.ha^{-1} and hand weeding. Earthing up was done 30 days after planting, which also helped in uprooting and burial of weeds and in covering the side-dressed urea. There was no incidence of major pests or diseases during the maize growth period.

All plants from the two middle rows of each sub-sub-plot were hand-harvested a few days after physiological maturity to determine grain yield, total dry matter (biomass) and harvest index (HI). At harvest, the ears were separated from the stover. Twenty ears per plot (sub-sample) were used to measure yield components (ears per plant, kernels per ear and 1000-kernel weight). After oven-drying for 48 hours at 70°C, the ears from each plot were shelled and the grains were cleaned before recording grain weight. Stover and cobs were dried and weighed to measure biomass. The HI values, defined as the ratio of grain dry matter to total above-ground dry matter, were calculated. Finally, kernels were counted and weighed to estimate kernels per ear and 1000-kernel weight.

All data were analyzed with the analysis of variance (ANOVA) procedure and differences among treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 0.05 probability level using MSTAT-C statistical software.



	v1d1	v1d2	v1d3	v2d1	v2d2	v2d3
Series1	4.92	5.82	7.78	5.91	7.36	8.42
Series2	8.29	8.75	9.28	8.87	9.31	9.60
Series3	9.89	10.76	10.60	9.96	10.10	10.67
Series4	11.29	11.76	12.72	11.06	13.06	14.14

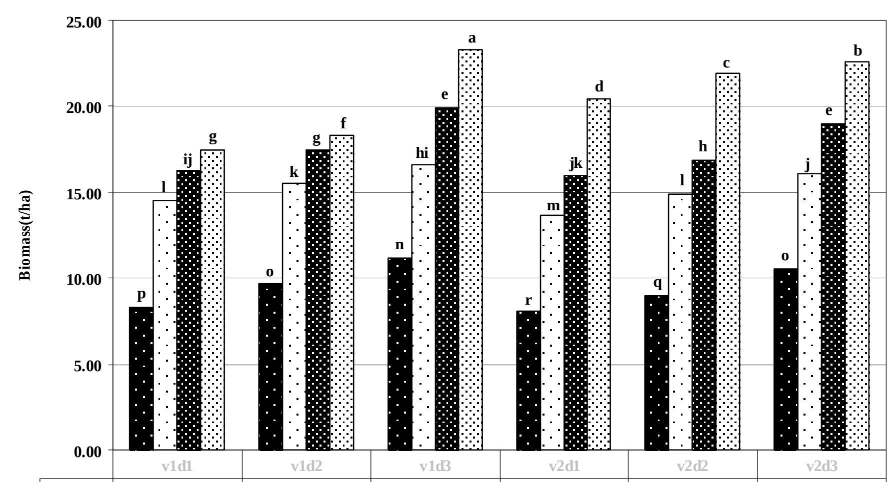


	v1d1	v1d2	v1d3	v2d1	v2d2	v2d3
Series1	82.15	83.21	97.27	98.43	105.10	105.31
Series2	138.20	125.02	120.87	147.76	133.05	119.69
Series3	164.95	153.72	132.45	166.00	145.55	133.31
Series4	188.19	168.04	159.12	184.29	186.61	168.27

Fig. 1. (a) Grain yield and (b) individual plant grain yield (b) of two corn hybrids (Vl =KSC604 and V2=KSC601) at three densities and four N levels

Results and Discussion

The yields of the two hybrids were different for grain yield pe unit area. Maximum grain yield.ha^{-1} was achieved by KSC601 at the plant density of 8 plants.m^{-1} with the application of 230 kg N.ha^{-1} (Fig. 1a). Comparison of means of grain yield per plant showed that KSC604 produced the maximum grain yield per plant at 6 plants.m^{-2} and 230 kg N.ha^{-1} (Fig. 1b). Anderson *et al*. (1985) and Tollenaar (1991) reported that the various corn hybrids differently respond to nitrogen rates. Combined effects of plant population and nitrogen rates on grain yield has been reported (Lang *et al*., 1956). As plant density increased, the intra-specific competition for growth factors such as water, CO_2, mineral resources and light increased. In contrast, at low densities, the space per plant was large and resources were not completely used. In this experiment, the grain yield per unit area had an additive trend, and the highest density could produce the highest yield. These results indicated an opportunity to increase grain yield with higher plant density (beyond 8 plants.m^{-2}). Plant density affected the amount of photosynthetically active radiation (PAR) in canopy of maize and its increase could decrease the crop growth rate and grain yield per plant (Cox, 1996). Cox (1996) also reported interaction of



	v1d1	v1d2	v1d3	v2d1	v2d2	v2d3
Series1	8.29	9.69	11.15	8.08	8.99	10.53
Series2	14.55	15.53	16.59	13.68	14.89	16.08
Series3	16.26	17.44	19.90	15.96	16.89	19.02
Series4	17.44	18.32	23.31	20.44	21.91	22.58

Fig. 2. Biological yield of two corn hybrids (Vl =KSC604 and V2=KSC601) at three densities and four N levels.

cultivar and plant population density on plant grain yield.

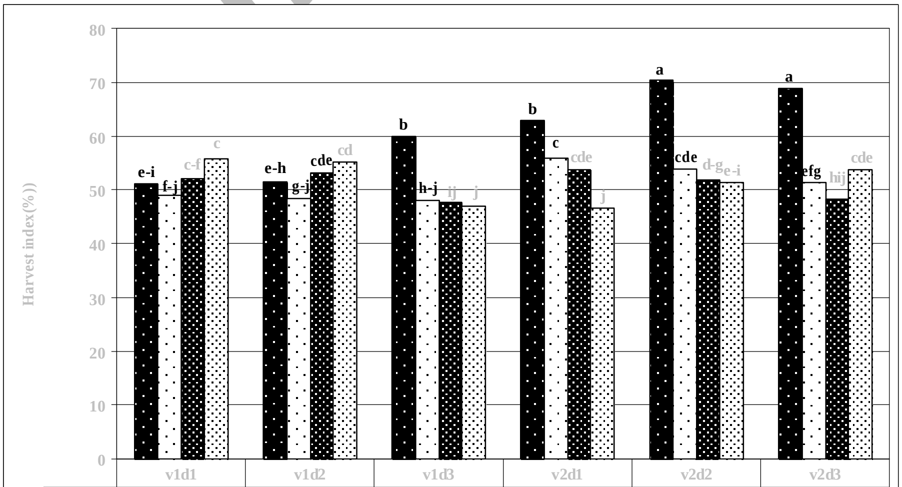
In all densities, the increase in N application reduced the limitation for plant growth and yield. Combined effects of plant density and N rate were positive and the increased levels o both parameters led to the increase in grain yield.

Biomass

Maximum biomass (22.3 t.ha^{-1}) was achieved by cv. KSC604 at the density of 8 plants.m^{-2} with the application of 230 kg N.ha^{-1} (Fig. 2). Reddy *et al*. (1987) showed that the increase in N fertilizer rates increased plant biomass per unit area.

Harvest Index

The hybrid KSC601 at a density of 7 plants.m^{-2} with no fertilizer application had the maximum HI (70.37%), whereas the minimum HI was achieved by cv. KSC604 at the density of 8 plants.m^{-2} with the application of 230 kg N.ha^{-1}. The HI declined at all densities for KSC601 and at the high density of KSC604, with the increase in N application rate (Fig. 3).



	v1d1	v1d2	v1d3	v2d1	v2d2	v2d3
Series1	51.06	51.52	60	62.83	70.37	68.83
Series2	49.03	48.47	48.1	55.8	53.8	51.3
Series3	52.03	53.07	47.73	53.7	51.87	48.2
Series4	55.70	55.20	46.97	46.53	51.27	53.72

Fig. 3. Effects of plant density and N level on HI of two corn hybrids (Vl =KSC604 and V2=KSC601).

Table 2. Results of analysis of variance for the studied characters

Source of variation	df	Means of square						
		Kernel yield.ha^{-1}	Kernel yield.plant^{-1}	Ear no.	Kernel no.	1000-kernel weight	Biomass	Harvest index
Replication	2	275258.831	8.836	0.513	1386.034	7286.883	146274.8594	92.083
Variety (A)	1	5526565.695*	657.376	1.027	10432.901	14.133	250976.669	298.983*
Error a	2	133579.706	71.057	0.163	1078.827	911.897	65051.662	8.518
Plant density (B)	2	15920122.003**	1480.422**	0.144	23336.51*	3841.092*	53429778.828**	12.247
A × B	2	2209297.503	91.826	0.24	3102.592	2301.121*	16187786.067**	8.805
Error b	8	84577.755	46.380	0.298	3825.253	462.495	55091.584	4.250
Nitrogen (C)	3	100752893.552**	20488.814**	0.058	19539.394**	4140.731**	401142137.163**	406.675*
A × C	3	1231123.362**	251.703**	0.013	831.428	68.391	6863596.646**	205.717**
B × C	6	1532484.060**	544.804**	0.017	3680.870	16.198	11176857.950**	47.625**
A × B × C	6	535020.773**	124.006**	0.014	2965.589	45.367	2281986.781**	45.738**
Error c	36	79770.908	38.202	0.042	3014.708	61.39	4933.802	2.775
Total	71							
C.V. (%)		2.94	4.47	16.22	8.64	2.83	1.42	3.11

* and ** show significance at 5 and 1% probability levels.

Table 3. Means comparison for 1000-kernel weight and kernels per ear

Treatments	1000-kernel weight (g)	Kernels per ear
D1	-	671.477 a
D2	-	619.713 b
D3	-	615.473 b
N1	259.464 d*	599.65 b
N2	2969.736 c	617.783 ab
N3	281.291 b	652.117 ab
N4	294.703 a	672.667 a
KSC604: D1	277.895 ab	-
D2	289.97 ab	-
D3	268.36 ab	-
KSC601: D1	300.17 a	-
D2	270.107 ab	-
D3	260.29 b	-

* Difference of means having at least one common letter is not significant at 5% level of probability.
* Means, within the same column and factors, followed by the same letter are not different ($p < 0.05$) by Duncan's Multiple Range Test.

These results indicated that nitrogen increased the vegetative growth; hence, the proportion of the vegetative part of the plant was greater than the reproductive part. In cv. KSC604 with no application of N, the densities of 6 and 7 plants.m^{-2} were not different, whereas those treatments had lower than 8 plants.m^{-2} (Fig. 3). However, at N_4 (230 kg N.ha^{-1}), the HI of cv. KSC604 at the densities of 6 and 7 plants.m^{-2} was equal to 55%, while at the density of 8 plants.m^{-2}, HI decreased to 46.9%. For hybrid KSC601 with no application of N, the HI for D_1 was 62.83%, lower than D_2 and D_3 (70 and 68%, respectively). Our results revealed that at a low N level (N_1), the increase in plant density increased HI. However, in high levels of N (N_2, N_3 and N_4 for cv. KSC604 and N_2 and N_3 for KSC601) with the increase in plant density, HI decreased. For the hybrid KSC601 at N_4 an additive trend was observed for HI with increasing plant density. Harvest index was affected by plant density but not by interaction of nitrogen rate and plant density. Therefore, the increase in plant population density or the decrease in nitrogen rates reduced HI.

Yield Components

There was a hybrid × density interaction for 1000-kernel weights. The highest number of kernels per ear was achieved at the density of 6 plants.m^{-2}, while values for D_2 and D_3 were not different. The comparison of means for kernels per ear showed that the maximum occurred at N_4 level (230 kg N.ha^{-1}) with no significant difference between N_3 and N_2 levels, whereas those treatments statistically differed at N_1 level (Table 2). Increases in plant density and therefore increased competition within plants affect these traits. However, the addition of N rate reduced competition for nitrogen and kernels per ear increase. Lang *et al*. (1956) showed that the increase in nitrogen rate increased kernels per ear and grain yield per plant. Kernels per ear reduced by increase in plant density (Lang *et al*., 1956).

Maximum 1000-kernel weight was obtained by KSC601 at the density of 6 plants.m^{-2} and this was not different from the value at D_2 and all densities of cv. KSC604. Plant that received 230 kg N.ha^{-1} had the highest 1000-kernel weights, followed by N_3, N_2 and N_1, respectively. Increases in N rate application from 0 to 230 kg N.ha^{-1} increased 1000-kernel weight by 12% (Table 3).

Reddy *et al*. (1987) indicated that the increase in nitrogen amount increased 1000-kernel weight. In single-ear maize plants, the grain yield was the product of the number and weight of the kernels on the ear. Kernel number is established during silking and early post-silking periods by abortion of kernels at the ear tip. Kernel weight is determined during the early silking periods, when endosperm cell number is established, and during the grain filling period. Assimilate supply to the developing ears is an important determinant of both kernel number and kernel weight. Nitrogen can play an important role in photosynthetic activity of leaves and assimilation supply for developing grains (Anderson *et al*., 1985).

References

Anderson, E.L., E.J. Kamprath, and R.H. Moll. 1985. Prolificacy and N fertilizer effects on yield and N utilization in maize. Crop Sci. 25: 598-602.

Cox, W.J. 1996. Whole-plant physiological and yield responses of maize to plant density. Agron. J. 88: 489-496.

Deloughery, R.L., and R.K. Cookston. 1979. Harvest index of corn affected by population density, maturity rating and environment. Agron. J. 71: 577-580.

Duncan, W.G. 1958a. The relationship between corn population and yield. Agron. J. 50: 82-89.

Duncan, W.G. 1958b. A theory to explain the relationship between corn population and grain yield. Crop Sci. 24: 1141-1145.

Lang, A.L., J.W. Pendelton, and G.H. Dungan. 195[illegible]. Influence of population and nitrogen level on yield and protein and oil contents of nine corn hybrids. Agron. J. 48: 284-289.

Radosevich, S.R. 1988. Methods to study crop and weed interactions. (pp. 121-144. In: Altieri, M.A., and M. Leds. Liebman) Weed management in Agroecosystems: Ecological approaches. CRC Press.

Reddy, B.B., S.N. Reddy, V.N. Reddy, M.R. Reddy, A. Kumar, and K.B. Swamy. 1987. Effect of plant population on the performance of maize hybrids at different fertility levels in semi-arid environment. Indian J. of Agric. Sci. 5[illegible](10): [illegible]-709.

Tetio-Kagho, F., and F.P. Gardner. 1988. Response of maize to plant population density II. Reproductive development, yield, and yield adjustments. Agron. J. 80: 935-940.

Tollenaar, M. 1991. Physiological basis of genetic improvement of maize hybrids in Ontario from 1959-1988. Crop Sci. 31: 119-124.