Impact of Nitrogen rates on growth and yield attributes of Sweet Corn grown under different Phosphorus levels

Mehrzad Alimohammadi[1], Mohsen Yousefi[2] and Peiman Zandi[1]

[1]Department of Agronomy, Takestan Branch, Islamic Azad University, Takestan, Iran
[2]Young Researchers Club, Takestan Branch, Islamic Azad University, Takestan, Iran
E-mail: z_rice_b@yahoo.com

Abstract: The effect of different nitrogen levels (0, 200 and 400 kg urea ha^{-1}) and phosphorus rates of 0, 100, 200 and 300 kg ha^{-1} in the form of triple superphosphate on growth and yield components of sweet corn was investigated at a research field, in Takestan, Iran, during 2006 growing season. The experiment was carried out using split plots based on randomized complete block design with four replications. Results showed that nitrogen fertilizer effect was significant on number of grains per ear, number of nodes per stalk, ear height, ear diameter, husked green ear weight, 1000-grain weight, plant height and grain yield of sweet corn. Phosphorus rates significantly affected plant height, ear diameter, ear height, grain yield, husked green ear weight and 1000-grain weight. Interaction effect of nitrogen × phosphorus was only affected 1000-grain weight, grain yield and husked green ear weight. whereas the rest of studied traits were remained unaffected. The highest grain yield (7781.10 kg ha^{-1}) was that of application of 200 kg urea ha^{-1} coupled with 200 kg ha^{-1} of triple superphosphate. It is concluded that optimum dose of phosphorus/nitrogen for sweet corn crop is 200 kg ha^{-1}. It is also suggested that further research should be done under different environmental conditions.

[Mehrzad Alimohammadi[1], Mohsen Yousefi[2] and Peiman Zandi **Impact of Nitrogen rates on growth and yield attributes of Sweet Corn grown under different Phosphorus levels.**Journal of American Science 2011;7(10):201-206]. (ISSN: 1545-1003). http://www.americanscience.org

Key words: sweet corn (*Zea mays* L.); nitrogen; phosphorus; grain yield

1. Introduction

Cereals are the main crops and occupied wide range of important parts of the world. Approximately 55% of protein, 15% of fats, 70% of glosides and generally 50 to 55% of calories consumed by humans in the world are provided by the cereals (Normohammadi et al., 2001). The economic importance of corn is clear as it has spread its planting in new world thousands of years ago; because all of its parts such as grain, branches and leaves, even corncob and corn silk is used numerously in human nutrition (20–25%), fed livestock and poultry (70-75%) and pharmaceutical industry (5%)(Mirhadi, 2001).

Sweet corn, which provides consumption, is especially important in food industry and making Tuna. In recent years, the production for fresh consumption and Conversion industries as two valuable careers are considered. Since the significant increase in crop production is achieved, the average yields of crops are yet less than their yield potential. The yield potential with full-product cultivars, under ideal management conditions and with optimal physical and also chemical environment will be achieved. Providing appropriate amount of mineral elements required for plant growth through appropriate distribution methods is one way to increase the crop yield (Fathi, 1999).

Nitrogen is one of the most prevalent elements and it is a component of amino acids, proteins, nucleic acids, chlorophyll and many other metabolites essential for survival of the plant. Numerous field experiments conducted throughout the world has shown that nitrogen is the most important growth-limiting factor. Nitrogen application is one of the important nutrient amendments made to the soil to improve growth and yield of many crop plants (Reddy, 2006). Deficiencies of nitrogen profoundly influence the morphology and physiology of plants. Plants under low levels of nitrogen develop an elevated root: shoot ratio with shortened lateral branches. Higher levels of NO_3^- inhibit root growth and leads to a decrease in the root: shoot ratio (Scheible et al., 1997; Zhang et al., 1999). Under nitrogen deficiency, plants exhibits stunted growth and small leaves. In the beginning of nitrogen deficiency, the older leaves show chlorosis when compared to younger leaves because of high mobility of nitrogen through phloem. Nitrogen deficiency induces the chloroplast disintegration and loss of chlorophyll. Necrosis occurs at later stages and if nitrogen deficiency continues, it ultimately results in plant death.

Phosphorus is the second important nutrient required by plants. It is an essential component of nucleic acids, phosphorylated sugars, lipids and proteins, which control all life processes. Phosphorus forms high-energy phosphate bonds with adenine, guanine and uridine, which act as carriers of energy for many biological reactions. Since the phosphate availability is usually low in the soils, the plants have developed special adaptations to acquire the same with the help of multiple high affinity transporters (Raghothama, 1999). Phosphorus deficient plants show stunted growth; leaves develop dark, blue, and green characteristic and sometimes-purplish appearance. Because of the high mobility of phosphorus, older leaves become chlorotic as compared to younger leaves. Leaf shape may be distorted and also leads to reduction in the number of leaves (Lynch et al., 1991). The sweet corn yield depends on yield related trais such as 1000-grain weight, and agronomical factors such as cultivar, plant density and soil fertility, that may be effective on the growth and development stages. In order to achieve high yield of sweet corn, there should be a good combination of essential nutrients.

Keeping in view the importance of these two factors, the present work was designed to assess the effect of different nitrogen levels in combination with varying phosphorus rates on agronomic traits of sweet corn in order to proper consumptive management of these fertilizers.

2. Materials and Methods

This research was undertaken in an experimental area, Takestan, Iran, in growing season of 2006. The site is located at Latitude 36° 04´ N, Longitude 49°39´ E; in a semi-arid zone (mean annual rainfall of 250 mm; relative humidity: 55 to 65% and mean annual temperature15 to 20 ºc). Soil analysis was done before planting (Table1). In this experiment nitrogen fertilizer (in the form of urea) as the main factor including three rates (N_1=0, N_2=200 and N_3=400 kg urea ha^{-1}) and phosphorus (triple superphosphate) as the minor factor at four levels (P_1=0, P_2=100, P_3=200 and P_4=300 kg ha^{-1}) were studied. The experimental units were designed as a split plots based on randomized complete block design (RCBD) with 4 replications and 12 treatment combinations.

Table 1. Physical and chemical properties of experimental soil before planting

SD (cm)	O.C (%)	N (%)	P (ppm)	K (ppm)	ST	pH	EC (ds/m)	S.P (%)
0-30	0.73	0.08	5	230	Clay-loam	7.62	0.95	42

Note. SD–Soil depth; ST– Soil texture

Tillage and complementary operations including disk, land leveling and creating the ridge and furrows (distance of 75cm) was performed before sowing. The sweet corn seeds were selected from hybrid sweet corn namely '*Ksc403su*'.Sowing was done on June 15. In order to control weeds, hand hoeing was carried out during the growth period in two times at 25 and 50 days after sowing (DAS). A thinning operation was performed 30 days after sowing, leaving the more vigorous plants in each plot. Urea fertilizer was used in two splits. The first application (side dressing) was made at 4 to 6 true leaf stages and second application was made as top dressing, at 8 true leaf stage of sweet corn. Triple superphosphate fertilizer (3 Ca $(H_2PO_4)_2$) was distributed under planting rows as the starter fertilizer at the time of sowing. To prevent the effect of fertilizer treatments on each other, a 2 and 6 m distance between adjacent plots as well as blocks was considered, respectively. At physiological maturity stage after discarding margins, ten random samples were selected from each experimental unit and traits consisted of plant height, stalk diameter, number of nodes per stalk, ear height, ear diameter, number of grains per ear and husked green ear weight were measured and their

average in terms of said traits were considered. The distance from ground level to the insertion point of the highest leaf blade was considered as plant height. Stalk diameter was measured with a caliper rule below the ear insertion node. With the aim of estimate, grain yield and 1000-grain weight, a final harvesting was done from the usable area of each experimental plot. After discarding margin plants, the grain yield was evaluated via total grain-weight of green unhusked ears, and by the grain-weight of both marketable unhusked and husked ears per each plot by a 0.001 g digital precise scale, which was expressed as kg ha^{-1}. Data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System SAS computer software at $p<0.01$ (SAS, 2001) and significant treatment means were separated by DMRT.

3. Results & Discussion

Plant height, is indicating growth and exploitation of environmental resources. Results showed that individual effect of nitrogen and phosphorus had significant effect on the plant height at 1% and 5% levels, respectively, whereas their interaction was not significant in this trait (Table 2).

Means comparison with Duncan Multiple Range Test at 1% probability level showed that the highest plant height (169.81 cm) was obtained from plants received 400 kg urea ha^{-1}, which was statistically at par with 200 kg urea ha^{-1}(168.81 cm) (Table 3).

Table 2: The mean squares of ANOVA for pant height, stalk diameter, number of nodes per stalk, ear height and ear diameter of sweet corn

S.O.V	df	Plant height	Stalk diameter	Number of nodes / stalk	Ear height	Ear diameter
R	3	111.576 ^{ns}	0.109 ^{ns}	1.568 ^{ns}	14.703 ^{ns}	0.284 ^{ns}
N	2	788.083 **	0.013 ^{ns}	5.141 *	28.797 *	0.947 *
E_a	6	61.889	0.044	0.603	5.4	0.097
P	3	88.229 *	0.006 ^{ns}	0.822 ^{ns}	24.27 **	0.499 **
N×P	6	62.458 ^{ns}	0.019 ^{ns}	0.150 ^{ns}	1.399 ^{ns}	0.109 ^{ns}
E_b	27	28.104	0.034	0.6	4.691	0.103
CV%		4.48	11.75	7.2	10.43	6.75

Note. * – $p < 0.05$, ** – $p < 0.01$, ns – $p > 0.05$. R – Replication, N – Nitrogen effect, P –Phosphorus effect. N×P represent interaction terms between the treatment factors

Table 3. Individual effect of nitrogen and phosphorus levels and interaction thereof on plant height, stalk diameter, number of nodes /stalk, ear height and ear diameter of sweet corn in estimated means

Nitrogen (kg urea ha^{-1})	Phosphorus (kg TS* ha^{-1})	Plant height (cm)	Stalk diameter (cm)	Number of nodes /stalk	Ear height (cm)	Ear diameter (cm)
0		157.18 b	1.554 a	10.10 b	19.325 b	4.525 b
200		168.81 a	1.594 a	11.10 a	21.981 a	5.006 a
400		169.81 a	1.539 a	11.06 a	20.981 ab	4.703 b
	0	162.6 c	1.592 a	10.37 a	19.075 b	4.458 b
	100	163.69 bc	1.543 a	10.80 a	20.142 ab	4.792 ab
	200	168.17 a	1.546 a	10.97 a	21.625 ab	4.942 a
	300	166.79 ab	1.568 a	10.87 a	22.208 a	4.787 ab
0	0	155.06 a	1.550 a	9.75 a	17.875 a	4.2 a
	100	156.12 a	1.555 a	10.35 a	18.425 a	4.550 a
	200	158. a	1.530 a	10.20 a	19.750 a	4.675 a
	300	159 a	1.580 a	10.10 a	21.250 a	4.675 a
200	0	160.62 a	1.715 a	10.75 a	19.8 a	4.725 a
	100	165.5 a	1.495 a	10.92 a	21.125 a	4.900 a
	200	175.37 a	1.610 a	11.55 a	23.625 a	5.200 a
	300	173.75 a	1.555 a	11.17 a	23.375 a	5.200 a
400	0	170.25 a	1.510 a	10.62 a	19.550 a	4.450 a
	100	170.25 a	1.580 a	11.12 a	20.875 a	4.925 a
	200	171.12 a	1.498 a	11.15 a	21.500 a	4.950 a
	300	167.62 a	1.570 a	11.35 a	22 a	4.487 a

* –TS: triple superphosphate. Means not sharing a common letter in a column differ significantly at 0.05 level of probability

It seems that an increase in the number of nodes caused an elevation in the plant stem due to nitrogen application. The results are in conformity with the findings of Tsai et al. (1978), Grazia et al. (2003) and Normohammadi et al. (2001) that expressed plant height can be increased by nitrogen application.

Application of 200 kg $ha^{-1}$of triple superphosphate (TS) produced the tallest plant height at maturity (168.17 cm). The results of 200 kg ha^{-1} and 300 kg ha^{-1} of TS were statistically at par with each other (Table 3). However, Grazia et al. (2003) found contradictory results. They found that phosphorus fertilization did not affect plant height.

The results in Table 2 indicated that, stalk diameter, was not significantly affected by different nitrogen rates, phosphorus levels and interaction thereof. However, the interaction between 200 kg urea ha^{-1} and non-application of phosphorus fertilizer (0 kg TS ha^{-1}) produced maximum stalk diameter (1.715 cm). The effect of nitrogen fertilizer on number of nodes per stalk showed a significant difference ($p<0.05$), hence the application of 200 and 400 kg urea ha^{-1} were placed at superior group with means of 11.10 and 11.06 respectively. Likewise, the lowest value of this trait was that of 0 kg urea ha^{-1} (Table 3). Last, it must be mentioned that, phosphorus levels and interaction of nitrogen× phosphorus did not influence number of nodes per stalk.

As regards ear height it should be noted that, ear height of sweet corn is strongly affected by soil, water, nutrients and light situation and plant competition (intra-inter competition) due to plant density. Optimization of these conditions in order to maximize utilization of cultivars genetic potential is necessary. At full maturity stage, according to results in Table 2, ear height, was significantly/highly significantly affected by nitrogen rates and phosphorus levels, respectively. Application of 200 kg urea ha^{-1} with 21.981 cm ear height had the highest mean value, which was statistically at par with 400 kg urea ha^{-1}. The least ear height (19.325 cm) was also recorded for non-application of nitrogen (urea). Data on Table 3 show that maximum ear height (22.208 cm) was recorded at higher phosphorus levels (300 kg TS ha^{-1}), in contrast, non-application of this fertilizer produced minimum (19.075 cm). Nitrogen and phosphorous interaction was not significant on this trait and all related means were on par (Tables 2 and 3). The result of 100 kg TS ha^{-1}, 200 kg TS $ha^{-1}$and 300 kg TS ha^{-1} were statistically at par with each other.

One of evaluated traits in this study was ear diameter, which results of statistical analysis showed that this trait was significantly affected by nitrogen rates ($p<0.05$) and different phosphorus levels ($p<0.01$) (Table 2). Lesser nitrogen application (0 kg urea ha^{-1}) recorded significantly lower ear diameter by 5.006 cm over higher nitrogen levels (200 and 400 kg urea ha^{-1}). The results of Table 3 show that, among all applied phosphorus levels, 200 kg TS ha^{-1} (4.942 cm) was placed in superior group as compared to other phosphorus levels. Interaction of N × P revealed non-significant effect on produced ear diameter (Table 2). In this study, ear diameter followed similar trend as that of ear height in interactions section (Table 3).

In this research, nitrogen fertilizer had highly significant effect ($p<0.01$) on number of grains per ear, while, phosphorus and interaction between nitrogen and phosphorus showed no-significant effects (Table 4). In this regard, Fontanetto (1993) found that phosphorus deficiency reduced the number of grains per ear, which is inconsistent with these results. Means comparison of nitrogen rates using Duncan test at the probability level of 1% showed that 200 kg urea ha^{-1}produced the highest number of grains per ear (564.851). Based on Duncan grouping method, it was placed in the first group, which was statistically at par with 400 kg urea ha^{-1}. In addition, the control treatment (N_1) had the least number of grains per ear (Table 5). In this regard, Reed et al. (1988) reported that grain number ear^{-1} (sink size) determined by formation of grain on ear during silking period.

Nitrogen ($p<0.01$), phosphorus ($p<0.05$) and their interaction ($p<0.05$) had significant effect on husked green ear weight (Table 4). Since the interaction of N rate × P was significant; mean values for each treatment combination are presented in Table 5. Means Comparison of interaction effect indicated that among all interactions, the highest husked green ear weight (84.668 g) was recorded in the combination of 200 kg urea ha^{-1} with phosphorus application of 200 kg TS ha^{-1}followed by the combinations of similar nitrogen level with higher rate of P (300 kg TS ha^{-1}).

Table 4. The mean squares of ANOVA for number of grains /ear, husked green ear weight, 1000-grain weight and grain yield of sweet corn

S.O.V	df	Number of grains /ear	Husked green ear weight	1000-grain weight	Grain yield
R	3	4054.787 *	3.154 ^{ns}	7.225 ^{ns}	161007.748 ^{ns}
N	2	7939.815 **	718.095 **	4491.063 **	64.9430.143 **
E_a	6	552.49	32.815	2.482	245129.536
P	3	971.238 ^{ns}	131.897 *	38.356 **	1754413.96 **
P × N	6	339.066 ^{ns}	94.281 *	5.445 *	740025.126 *
E_b	27	428.6	34.739	1.769	296239.989
CV%		3.78	8.37	0.78	8.59

Note. * – $p < 0.05$, ** – $p < 0.01$, ns – $p > 0.05$. R – Replication, N – Nitrogen effect, P –Phosphorus effect. N×P represent interaction terms between the treatment factors

Table 5. Individual effect of nitrogen and phosphorus levels and interaction thereof on number of grains /ear, husked green ear weight, 1000-grain weight and grain yield of sweet corn in estimated means

Nitrogen (kg urea ha^{-1})	Phosphorus (kg TS* ha^{-1})	Number of grains /ear	Husked green ear weight (g)	1000-grain weight (g)	Grain yield (kg ha^{-1})
0		522.447 b	63.526 b	163.54 b	5694.02 b
200		564.851 a	76.902 a	173.46 a	6959.08 a
400		555.488 a	70.884 ab	171.71 a	6365.03 ab
	0	537.313 a	66.174 b	167.05 b	5853.62 b
	100	552.947 a	69.822 ab	169.56 a	6285.78 ab
	200	556.999 a	73.999 a	170.95 a	6773.88 a
	300	543.121 a	71.754 a	170.72 a	6444.23 ab
0	0	511.005 a	59.285 d	162.80 f	5254.85 e
	100	525.860 a	63.513 cd	163.20 f	5697.75 de
	200	534.547 a	64.847 bcd	163.67 f	5864.37 cde
	300	518.375 a	66.458 bcd	164.47 f	5959.10 cde
200	0	554.635 a	68.318 bcd	170.20 d	6086.42 cde
	100	559.747 a	72.362 bc	173.07 bc	6559.40 bcd
	200	572.248 a	84.668 a	175.80 a	7781.10 a
	300	572.773 a	82.260 a	174.77 ab	7409.40 ab
400	0	546.300 a	70.920 bc	168.15 e	6219.60 cd
	100	573.233 a	73.590 b	172.40 c	6600.20 bcd
	200	564.202 a	72.482 bc	173.37 bc	6676.12 bc
	300	537.215 a	66.545 bcd	172.92 bc	5964.20 cde

***** –TS: triple superphosphate. Means not sharing a common letter in a column differ significantly at 0.05 level of probability

The least husked green ear weight (59.285 g) was recorded in combinations of no nitrogen/phosphorus application i.e., N_1P_1 (Table 5).

According to the results in Table 4, 1000-grain weight was highly significantly affected (p<0.01) by nitrogen rates and different phosphorus levels. Data on Table 5 show that the 1000-grain weight increased with increasing in nitrogen application rates (N1→N2) as well as phosphorus rates (P1→P3). Thus, the highest (173.46 g) and lowest (163.54 g) values of 1000-grain weight were obtained from 200 and 0 kg urea ha^{-1}, respectively. Maximum 1000-grain weight (170.95 g) was recorded at 200 kg TS ha^{-1} against the minimum (167.05 g) at control (P=0 kg TS ha^{-1}). All phosphorus application levels (i.e., 100, 200 and 300 kg TS ha^{-1}) were placed in superior group. In terms of this trait, it should be noted that, 1000-grain weight is constituent of grain yield that is affected by genetic and environmental factors. The N_2P_3 interaction recorded significantly higher 1000-grain weight (175.8 g) compared to rest of the interactions; whereas it was on par with N_2P_4 interaction (Table5). Significantly lower 1000-grain weight of 162.80 g was recorded with N_1P_1 interaction.

The grain yield is an economical part of the plant, which is available to human and livestock consumption and is affected by environmental factors and genetic potential of plant. Finally, based on obtained results in Table 4, grain yield was also significantly affected by nitrogen levels (p<0.01), P rates (p<0.01) as well as interaction thereof (p<0.05) (Table4). Nitrogen application at the rate of 200 kg urea ha^{-1} produced the highest grain yield (6959.08 kg ha^{-1}), but statistically at par with 400 kg urea ha^{-1} (6365.03 kg ha^{-1}) (Table 5). The higher grain yield in nitrogen application of N_2 was mainly due to higher grain number in ear as well as achieving the most husked green ear weight in this study (Table 5). These results are in conformity with the findings of Reed et al. (1988),who reported that, grain yield in corn is mainly due to grain number and ear weight. Moreover, they stated that, ear height, grain number in row and grain number in ear are the main factors of the increased grain yield (Reed et al., 1988). Anderson et al. (1985) expressed that nitrogen consumption resulted in increased number of rows of grain, grain number in ear, 1000-grain weight, ear weight and grain yield as well as harvest index. Present results support the previous study of Fathi (1999), who asserted that the use of nitrogen could increase sweet corn grain yield.

Among the P fertilizer levels 200 kg TS ha^{-1} produced highly significantly higher grain yield (6773.88 kg ha^{-1}) while 100 and 300 kg TS ha^{-1} gave 6285.78 and 6444.23 kg ha^{-1}, respectively (Table5). Among all treatment combinations, 200 kg urea ha^{-1} coupled with 200 kg TS ha^{-1} (N_2P_3) produced the highest grain yield (7781.10kg ha^{-1}). The higher grain yield in this interaction was due to significantly higher husked green ear weight (84.668 g) and 1000-grain weight (175.80 g). However, N_2P_3 and N_2P_4 interactions were on par. Clearly, for treatments fertilized with N_2, phosphorus application levels (P1→ P3) determined a significant increase in yield. Furthermore, the lowest grain yield (5254.85 kg ha^{-1}) was that of the control treatment (no nitrogen application) coupled with not applying TS (N_1P_1). In the other hand, within the N_1 level, lower yields were measured with the decrease in phosphorus application. The results are in disagreement with the results of Grazia et al. (2003), who stated that the greatest yield of sweet corn was belonged to N_2P_2 (N_2=200 kg/ ha^{-1} of pure nitrogen, P_2=80 kg/ha of P_2O_5) treatment combination.

Conclusion

The salient findings of the investigation are summarized:

Significantly higher grain yield, husked green ear weight and thousand grain weight was recorded with N_2P_3 interaction over rest of the interactions. The individual effects of nitrogen (N_2) and phosphorus (P_3) were also significantly higher leading to considerably higher grain yield, husked green ear weight and thousand-grain weight.

For treatments fertilized with level N_2, a significant superiority was shown in estimated traits except for stalk diameter.

Among the phosphorus levels, P_3, influenced the main yield components (thousand-grain weight, grain yield and husked green ear weight) yield related (ear height and ear diameter) and height of sweet corn.

Acknowledgments

The Authors would like to thank Dr Jahanfar Daneshian and respect chancellor of Takestan University (I.A.U) as well as research board for their collaboration and support.

9/26/2011

References

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

[2] Fathi, Gh., 1999. Crop growth and nutrient. Jahade Daneshgahi Publications, p. 372.

[3] Fontanetto, H.B., 1993. Efecto del método de aplicación del fertilizante fosfórico en maíz a dos niveles de disponibilidad hídrica. M.Sc. Thesis, Fan Ciencias Agrarias, Univ Nal Mar del plata. Balcarce, Buenos Aires, Argentina.

[4] Grazia, J.de., Tittonell, P.A., Germinara, D. and Chiesa, A.,2003. Short communication: Phosphorus and nitrogen fertilization in sweet corn *(Zea mays* L. var.saccharata Bailey). Span J Agric Res., 1(2), 103-107.

[5] Lynch, J., Lauchli, A. and Epstein, E., 1991. Vegetative growth of the common bean in response to phosphorus nutrition. Crop Sci. 31, 380-387.

[6] Mirhadi, M.G., 2001.Corn (*Zea mays* L). Agricultural Research, Education & Extension Organization (AREEO) PUB, p. 214.

[7] Normohammadi, G., Siadat, A. and Kashani, A., 2001. Agronomy (Cereal), First Edn, Ahvaz, Iran, Shahid Chamran University publication, p. 468.

[8] Raghothama, K.G., 1999. Phosphate acquisition. Annu. Rev. Plant Physiol. Plant Mol. Biol., 50,665-693.

[9] Reddy, K.J., 2006. Nutrient stress. In: Physiology and Molecular Biology of Stress Tolerance in Plants, Madhava Rao KV, Raghavendra A S. and Janardhan Reddy K, (Eds.). Springer, pp. 187-217.

[10] Reed, A.J., Singletary, G.W., Schussler, J.R., Williamson, D.R. and Christy, A.L., 1988. Shading effects on dry matter and

nitrogen partitioning, kernel number, and yield of maize. Crop Sci. 28, 819-825.
[11] SAS Institute., 2001. SAS/STAT user's guide. SAS Ins., Cary, North Carolina.
[12] Scheible, W.R., Lauerer, M., Schulze, E.D., Caboche, M. and Stitt, M., 1997. Accumulation of nitrate in the shoot acts as a signal to regulate shoot – root allocation in tobacco. Plant J., 11, 671 – 691.
[13] Tsai, C.Y., Huber, D.M. and Warren, H.L., 1978. Relationship or the kernel sink N to maize productivity. Crop Sci. 18, 399-404.
[14] Zhang, H., Jennings, A., Barlow, P. W. and Forde, B. G., 1999. Dual pathways for regulation of root branching by nitrate. Proc. USA, Natl. Acad. Sci. 96, 6529-6534.