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Influence of Water Stress and Plant Density on some Characteristics in corn

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ABSTRACT: Maize (*Zea mays* L.) production under the semiarid conditions of the Islamic Republic of Iran during the summer requires supplemental irrigation to attain maximum yields. Maize is cultivated in both spring and autumn seasons and it is best suited in existing cropping scheme. However, yield potential of maize is highly prone a biotic stresses. In maize, flowering is the most crucial stage in terms of negative effects of drought on yield. During this stage, one single day of drought can potentially decrease yield up to 8%. Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants. The field experiment was laid out spit plot design with factorial design with three replications. Treatments included cut irrigation (S1: Cut irrigation in 8 leaf, S2:Cut irrigation in 12 leaf, S3: Male flower appearance, S4: Normal irrigation) and density (6 plant/m^2, 8 plant/m^2, 12 plant/m^2). Analysis of variance showed that the effect of water stress and density on all characteristics was significant

Key words: Harvest Index, Biological yield, Seed yield

INTRODUCTION

Maize (*Zea mays* L.) production under the semiarid conditions of the Islamic Republic of Iran during the summer requires supplemental irrigation to attain maximum yields. Maize is cultivated in both spring and autumn seasons and it is best suited in existing cropping scheme. However, yield potential of maize is highly prone a biotic stresses (Drought, salinity, extreme temperatures, flooding, pollutants & poor or excessive irradiation) which are important factors towards limiting the crop productivity (Misovic, 1985; Lawlor, 2002). Among the abiotic stresses, drought is the most severe limitation to maize production (Sallah *et al.*, 2002). To a careful estimate, only drought reasons for 50% or more reduction in average yields worldwide (Wang *et al.*, 2003).Water and N deficit condition, leading to a reduction in crop production by reduce resource capture and resource use efficiency. Several experimenters subjected maize to a water deficit during different developmental stages. It was found that both the degree and the time of stress are important in determining the final grain yield. Water deficit induces a reduction in maize tissue water contents and subsequently water potential, leaf elongation, leaf photosynthesis, and changes in protein synthesis, nitrogen metabolism and cell membrane properties, leading to a reduction in plant productivity (Bogoslavsky and Neumann, 1988, Shangguan *et al.*, 2000, Saneoka *et al.*, 2004, etc.). Under semi arid environment, water deficits imposed during vegetative period (41 and 55 days after planting) reduced leaf, stalk and ear yields of maize, while water deficit during grain filling did not affect leaf and stalk yields (Eck, 1984). Maize is relatively insensitive to water deficit stress imposed during early vegetative growth stages because water demand is relatively low and plants can adapt to water stress to reduce the impact of subsequent periods of water stress (Shaw, 1977). In maize, flowering is the most crucial stage in terms of negative effects of drought on yield. During this stage, one single day of drought can potentially decrease yield up to 8% (Shaw, 1977). Water stress reduces crop yield regardless of the growth stage at which it occurs (Jensen & Mogensen, 1984). Drought causes numerous physiological and biochemical changes in plants like reduced leaf size, stem extension, root proliferation, reduced water use efficiency (Farooq *et al.*, 2009), alteration in metabolic activities (Lawlor & Cornic, 2002), inhibition of enzymatic activities (Ashraf *et al.*, 1995), ionic imbalance and disturbances in solute accumulation (Khan *et al.*, 1999) or a combination of all these factors.

In maize, drought reduces leaf area, leaf chlorophyll contents, photosynthesis and ultimately lowers the grain yield (Athar & Ashraf, 2005). At flowering, drought widens the anthesis silking interval (ASI) in maize, which severely reduces the kernel set (Emeadeas *et al.*, 2000). Under drought leaf senescence is also accelerated to decrease the canopy size (Moony & Duplesis, 1970) severely affecting the crop yield. However delayed leaf senescence affects positively for reducing the harmful effects of drought on crop yield (Rivero *et al.*, 2007). Doorenbos and Kassam (1979) have reported that the greatest decrease in grain yields is caused by water deficit in the soil profile during the flowering period. The accumulation of solutes to decrease water potential may allow plants to maintain a water potential gradient as the soil becomes drier and thus maintain the positive pressure potential required to keep stomata open and sustain gas exchange and growth (White *et al.*, 2000). Protein content is significantly increased under water deficit (Guttieri *et al.*, 2000; Ozturk and Aydin, 2004), mainly due to higher rates of accumulation of grain N and lower rates of accumulation of carbohydrates. Ozturk and Aydin (2004) observed that late water deficit stress increased grain protein and wet gluten content relative to the fully irrigated treatment. Soil–water depletion and plant water use efficiency (WUE) are critical factors affecting agricultural productivity in arid and semiarid areas around the world. Hence, various soil and crop management practices have been developed to increase crop yields (Huang *et al.*, 2005; Fang *et al.*, in press), notably plastic or straw mulching, which may efficiently improve the microclimate and crop growth conditions (Albright *et al.*, 1989) by promoting plant transpiration at the expense of evaporation from the soil (Raeini-Sarjaz and Barthakur, 1997; Wang *et al.*, 2009). Thus, both crop yields and WUE have often been reported to be increased by mulching treatments (Li *et al.*, 2001; Li and Gong, 2002). Irrigation may also have beneficial effects on plant water relations and yields, but Kang et al. (2002) found that grain yield (GY) and WUE responses to irrigation varied considerably with differences in soil–water contents and irrigation schedules. Further, Wang *et al.* (2002) and Fang *et al.* (in press) showed that scheduled irrigation based on crop responses to water stress at different development stages can improve WUE, but Olesen *et al.* (2000) found that although irrigation increased yields, there were no significant differences in WUE and harvest index in wheat subjected to three different irrigation strategies, since the increases were almost solely due to increased transpiration. In addition, excessive irrigation can reduce crop WUE (Jin *et al.*, 1999). There are a number of biotic and abiotic factors those affect maize yield considerably; however, it is more affected by variations in plant density than other member of the grass family (Vega *et al.*, 2001). Maize differs in it's responses to plant density (Luque *et al.*, 2006). Liu *et al.* (2004) also reported that maize yield differs significantly under varying plant density levels due to difference in genetic potential. Correspondingly maize also responds differently in quality parameters like crude starch, protein and oil contents in grains (Munamava *et al.*, 2006). Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants (Sangakkara *et al.*, 2004). The grain yield per plant is decreased (Luque *et al.*, 2006) in response to decreasing light and other environmental resources available to each plant (Ali *et al.*, 2003).

Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production. At low densities, many modern maize varieties do not tiller effectively and quite often produce only one ear per plant. Whereas, the use of high population increases interplant competition for light, water and nutrients, which may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi, 2001). Hiebsch *et al.* (1995) stated that collective production from the component crops may be greater in intercropping than in sole cropping from a unit land area. The beneficial effects of intercropping soybean/maize have not been fully exploited by farmers in the major soybean producing areas of the southern guinea savannah agro-ecological zone (Kalu and Omojor, 1991). Many vegetative and yield variables of crops are potentially influenced by competition of the plant with the second crop in an intercropping system and by competition with other plants of the same species. This influence may be affected by changes in plant population density. One of the major constraints of soybean production has been the dearth of information on the relative plant population densities of the non-legume components where soybean is grown in the intercropping system especially in the southern guinea savannahagro-ecosystem typified by Otukpo area of Benue State, Nigeria. Maize is an important component crop in the inter-cropping systems of the area.

MATERIAL AND METHODS

The experiment was conducted at the mirjaveh (Iran) which is situated between 29° North latitude and 30° East longitude. Composite soil sampling was made in the experimental area before the imposition of treatments and was analyzed for physical and chemical characteristics. The field experiment was laid out spit plot design with factorial design with three replications.

Treatments included cut irrigation (S1: Cut irrigation in 8 leaf, S2: Cut irrigation in 12 leaf, S3: Male flower appearance, S4: Normal irrigation) and density (6 plant/m2, 8 plant/m2, 12 plant/m^2). Data collected were subjected to statistical analysis by using a computer program MSTATC. Least Significant Difference test (LSD) at 5 % probability level was applied to compare the differences among treatments` means.

RESULTS AND DISCUSSION

A. Harvest Index

Analysis of variance showed that the effect of water stress on harvest index was significant (Table 1). The maximum of harvest index (30.94) of treatments male flower appearance was obtained (Table 2).

The minimum of harvest index (24.95) of treatments 8 leaf was obtained (Table 2). Analysis of variance showed that the effect of density on harvest index was significant (Table 1).

The maximum of harvest index (30.27) of treatments 6 plant was obtained (Table 2). The minimum of harvest index (27.89) of treatments 12 plant was obtained (Table 2).

B. Biological yield

Analysis of variance showed that the effect of water stress on biological yield was significant (Table 1). The maximum of biological yield (24463.3) of treatments normal irrigation was obtained (Table 2). The minimum of biological yield (8042.8) of treatments 8 leaf was obtained (Table 2). Analysis of variance showed that the effect of density on harvest index was significant (Table 1). The maximum of biological yield (19846.6) of treatments 12 plant was obtained (Table 2). The minimum of biological yield (16133.8) of treatments 6 plant was obtained (Table 2).

C. Seed yield

Analysis of variance showed that the effect of water stress on seed yield was significant (Table 1). The maximum of seed yield (7448.1) of treatments normal irrigation was obtained (Table 2). The minimum of seed yield (2006.7) of treatments 8 leaf was obtained (Table 2). Analysis of variance showed that the effect of density on seed yield was significant (Table 1). The maximum of seed yield (5690.6) of treatments 12 plant was obtained (Table 2). The minimum of seed yield (5129.3) of treatments 6 plant was obtained (Table 2).

Table 1: Anova analysis of the corn affected by water stress and plant density.

		Ms			
S.O.V	**df**	**Harvest Index**	**Biological yield**	**Seed yield**	**Protein (%)**
R	2	16.847^{ns}	74.971^{ns}	683413^{ns}	0.321^{*}
Water stress (S)	3	77.778^{**}	451239321^{**}	50859980.4^{**}	9.281^{**}
Error a	6	4.719	153526	152605.5	0.031
Density (D)	2	7.686^{*}	41372251^{**}	947802^{**}	0.771^{**}
S*D	6	31.099^{**}	4922261^{**}	7401.2^{ns}	0.074^{ns}
Error b	16	1.688	252791	18361.2	0.029
CV (%)	-	4.426	2.791408	2.509	3.492
*, **, ns: significant at p<0.05 and p<0.01 and non-significant, respectively.					

Table 2: Comparison of different traits affected by water stress and plant density.

Ms				
Treatment	**Harvest Index**	**Biological yield**	**Seed yield**	**Protein**
Water stress				
8 leaf	24.95b	8042.8d	2006.7d	3.77d
12 leaf	30.86a	18501.1c	5669.1c	4.35c
Male flower appearance	30.94a	21040b	6482.3b	5.49b
Normal irrigation	30.67a	24463.3a	7448.1a	5.98a
density				
6 plant	30.27a	16133.8c	5129.3b	4.69b
8 plant	29a	18055.1b	5384.8b	4.82b
12 plant	27.89a	19846.6a	5690.6a	5.8a
Any two means not sharing a common letter differ significantly from each other at 5% probability				

D. Protein

Analysis of variance showed that the effect of water stress on protein was significant (Table 1). The maximum of protein (5.98) of treatments normal irrigation was obtained (Table 2). The minimum of protein (3.77) of treatments 8 leaf was obtained (Table 2). Analysis of variance showed that the effect of density on protein was significant (Table 1). The maximum of protein (5.8) of treatments 12 plant was obtained (Table 2). The minimum of protein (4.69) of treatments 6 plant was obtained (Table 2).

REFERENCES

Albright, L.D., Wolfe, D., Novak, S., (1989). Modelling row straw mulch effects on microclimate and yield II. *J. Am. Soc. Hort. Sci.*, **114**, 569–578.

Ashraf, M.Y., A.R. Azmi, A.H. Khan, S.S.M. Naqvi and S.A. Ala, (1995). Effect of water stress on different enzymatic activities in wheat. *Acta. Physiol. Plant.,* **17**: 615–620

Athar, H.R. and M. Ashraf, (2005). Photosynthesis under drought stress. In: Pessarakli, M. (ed.), Handbook of Photosynthesis, pp: 793–804. Taylor and Francis, New York

Barrs HD, Weatherley PE, (1962). A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian Journal of Biology Science,* **15**: 413-428.

Blackmer TM, Schepers JS. (1996). Use of a chlorophyll meter to monitor nitrogen status and schedule fertigation of corn. *Journal of Production Agiculture,* **8**: 56-60.

Boyle MG, Boyer JS, Morgan PW. (1991). Stem infusion of liquid culture medium prevents reproductive. Failure of maize at low water potential. *Crop Science,* **31**: 1246-1252.

Bradford MM. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of proteindye binding. *Ann. Biochem,* **72**: 248- 254.

Cakir R. (2004).. Effect of water stress at different development stage on vegetative and reproduction growth of corn. *Field Crop Research,* **86**: 95-113.

Chen G, Zhou Y, Shen Q. (2007). Ammonium nutrition increases photosynthesis rate under water stress at early development stage of rice (*Oryza sativa* L.). *Plant Soil,* **296**: 115–124.

Delauney AJ, Verma DPS, (1993). Proline biosynthesis and osmoregulation in plant. *Plant Journal* **4**: 215-223.

Emeadeas, G.O., M. Banziger and T.M. Ribaut, (2000). Maize improvement for drought limited environments. In: Physiological Basis for Maize Improvement, pp: 75–111. Food Products Press, New York

Eppendorfer WH, Bille SW, Patipanawattana S. (1985). Protein quality and amino acid-protein relationships of maize, sorghum and rice grain as influenced by nitrogen, phosphorus, potassium and soil moisture stress. *Journal of the Science of Food and Agriculture,* **36**: 453- 462.

Fandika IR, Kadyampakeni D, Bottomani C, Kakiwa H. (2007). Comparative response of varied irrigated maize to organic and inorganic fertilizer application. *Physics and Chemistry of the Earth,* **32**: 1107–1116.

Farooq, M., A. Wahid, N. Kobayashi, D. Fujita and S.M.A. Basra, (2009). Plant drought stress, effects, mechanisms and management. Agron. Sustain. Dev., 29: 185–212

Gubiš J, Vaková R, ervená V, Dragúová M, Hudcovicová M, Lichtnerová H, Dokupil T, Jureková Z. (2007). Transformed tobacco plants with increased tolerance to drought. *South African Journal of Botany,* **73**: 505–511.

Hall AJ, Lemcoff JH, Trapani N. (1981). Water stress before and during flowering in maize and its effects on yield, its components, and their determinants. *Maydica,* **26**: 19-38.

Huang, Y.L., Chen, L.D., Fu, B.J., Huang, Z.L., Gong, J., (2005). The wheat yields and water-use efficiency in the Loess Plateau: straw mulch and irrigation effects. *Agric. Water Manag.* **72**, 209–222.

Huguet-Robert V, Sulpice R, Lefort C, Maerskalck V, Emery N, Larcher FR. (2003). The suppression of osmoinduced 740 tresse response of *Brassica napus* L. var. oleifera leaf discs by polyunsaturated fatty acids and methyljasmonate. *Plant science,* **164**: 119-127.

Huilian Xu, Shii I, Xu H. (1996). Wheat cultivar differences in photosynthetic response to low soil water potentials. I. Maintenance of photosynthesis and leaf water potential. *Japanese Journal of Crop Science,* **65**: 509-517.

Irigoyen JJ, Emerrich DW, Sanchez-Diaz M. (1992). Water stress induced changes in concentrations of total soluble sugars in nodulated alfalfa plant. *Physiologia Plantarum,* **84**: 55-60.

Jagtap VS, Bhargava P, Feierabend J. (1998). Comparative effect of water, heat and light stresses on photosynthetic reaction in Sorghum bicolor Moench. *Journal of Experimental Botany* **327**: 1715-1721.

Kameli A, Lösel DM. (1996). Growth and sugar accumulation in durum wheat plants under water stress. New Phytol **132**: 57-62.

Khan, A.H., S.M. Mujtaba and B. Khanzada, (1999). Response of growth, water relation and solute accumulation in wheat genotypes under water deficit. *Pakistan J. Bot.,* **31**: 461–468

Klute A. (1998). Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods, 2nd ed. American Society of Agronomy, Soil Science Society of America, Madison, WI, pp. 635-653.

Lawlor, D.W. and G. Cornic, (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant Cell Environ.,* **25**: 275–294.

Misovic, M.S., 1985. Maize breeding methodologies for environmental stress. In: Breeding Strategies for Maize Production Improvement in the Tropics, Florence and Bergam, pp: 207–227. Italy

Monreal JA, Jim´enez ET, Remesal E, Morillo-Velarde R, Garc´ıa-Mauri˜no S, Echevarr´ıa C. (2007). Proline content of sugar beet storage roots: Response to water deficit and nitrogen fertilization at field conditions. Environ. *Exp. Bot.,* **60**: 257–267.

Moony, H.A. and E.L. Duplesis, (1970). Convergent evolution of Mediterranean climate evergreen sclerophyll shrubs. *Evolution,* **24**: 292–303

Nesmith DS, Ritchie JT. (1992). Mize response to a severe soil water deficit during grain filling. *Field Crop Research* **29**: 23-35.

Osborne SL, Schepers JS, Francis DD, Schlemmer MR. (2002). Use of spectral radiance to estimate in-season biomass and grain yield in nitrogen and water 740tressed corn. *Crop Science,* **42**: 165-171.

Pessarakli M. (2001). Handbook of plant and crop physiology. Marcel Dekker, press. 997 pp. Saneoka H, Moghaieb REA, Premachandra GS, Fujita K. 2004. Nitrogen nutrition and water stress effects on cell membrane stability and leaf water relations in *Agrostis palustris* Huds. *Environmental and Experimental Botany* **52**: 131–138.

Raeini-Sarjaz, M., Barthakur, N.N., (1997). Water use efficiency and total dry matter production of bush bean under plastic straw mulchs. *Agric. For. Meteorol.* **87**, 75–84.

Rivero, M.R., K. Mikiko, G. Amira, S. Hitoshi, M. Ron, G. Shimon and B. Eduardo, (2007). Delayed leaf senescence induces extreme drought tolerance in a flowering plant. *PNAS,* **104**: 19631–19636

Robson, P.R.H., I.S. Donnison1, K. Wang, B. Frame, S.E. Pegg, A. Thomas and H. Thomas, (2004). Leaf senescence is delayed in maize expressing the Agrobacterium IPT gene under the control of a novel maize senescence-enhanced promoter. *Plant Biotech. J.,* **2:** 101–112

Sallah, P.Y.K., K.O. Antwi and M.B. Ewool, (2002). Potential of elite maize composites for drought tolerance in stress and non drought stress environments. *African Crop Sci. J.,* **10**: 1–9

Sayd, S.S., A.A.H. Taie and L.S. Taha, (2010). Micropropagation, antioxidant activity, total phenolics and flavonoids content of Gardenia jasminoides ellis as affected by growth regulators. *Int. J. Acad. Res.,* **2**: 184–191

Schuppler, U., P.H. He, P.C.L. John and R. Munns, (1998). Effects of water stress on the cell division and cell-division-cycle-2-like cell-cyclekinase activity in wheat leaves. *Plant Physiol.,* **117**: 667–678

Senaratna, T., D. Touchell, E. Bunn and K. Dixon, (2000). Acetyl salicylic acid (aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plant. *Plant Growth Regul.,* **30**: 157–161

Sharp, R.E., W.K. Silk and T.C. Hsiao, (1988). Growth of maize primary root at low water potential. I. Spatial distribution of expansive growth. *Plant Physiol.,* **87**: 50–57

Siddique, M.R.B., A. Hamid and M.S. Islam, (2000). Drought stress effects on water relations of wheat. *Bot. Bull. Acad. Sin.,* **41**: 35–39

Sinclair, T.R., (1986). Water and nitrogen limitations in soybean grain production. I. Model development. *Field Crops Res.* **15**, 125–141.

Souza RP, Machado EC, Silva JA, Lagoa AMM, Silveira JAG. (2004). Photosynthetic gas exchange, chlorophyll fluorescence and some associated metabolic change in cowpea (*Vigna unguiculata*) during water stress and recovery. *Environmental and Experimental Botany,* **51**: 45-56.

Steel, R.G.D., J.H. Torrie and D.A. Dickey, (1997). Principles and Procedures of Statistics: A Biometrical Approach, 3rd edition. McGraw Hill Book Inc. Co., New York

Synkova, H., N. Wilhelmova, Z. Sestak and J. Pospislova, (1997). Photosynthesis in transgenic plants with elevated cytokinin contents. In: Pessarakli, M. (ed.), Handbook of Photosyntheisis. Marcel Deckker, New York.

Taiz, L. and E. Zeiger, (2006). Plant Physiology, 4th edition. Sinauer Associates Inc. Publishers, Massachusetts, USA.

Ta C, Weiland RT. (1992). Nitrogen partitioning in maize during ear development. *Crop Science,* **32**: 443-451.

Tan, D.K.Y., Birch, C.J., Wearing, A.H., Rickert, K.G., (2000a). Predicting broccoli development I. Development is predominantly determined by temperature rather than photoperiod. *Sci. Hort.* **84**, 227–243.

Tan, D.K.Y., Birch, C.J., Wearing, A.H., Rickert, K.G., (2000b). Predicting broccoli development II. Comparison and validation of thermal time models. *Sci. Hort.* **86**, 89–101.

Teixeira J, Pereira S. (2007). High salinity and drought act on an organ-dependent manner on potato glutamine synthetase expression and accumulation. *Environmental and Experimental Botany,* **60**: 121–126.

Teulate B, Rekika D, Nachit MM, Monneveux P. (1997). Comparative osmotic adjustments in barley and tetraploid wheats. *Plant Breeding,* **116**: 519-523.

Thakur, P.S., G. Singh and V.K. Rai, (1981). Peroxidase isozymes in relation to developing water deficits in two Zea mays cultivars. *New Phytol.,* **89**: 25–32

Tian, Y., Su, D.R., Li, F.M., Li, X.L., (2003). Effect of rainwater harvesting with ridge and furrow on yield of potato in semiarid areas. *Field Crops Res.* **84**, 385–391.

Uhart SA, Andrade FH. (1995). Nitrogen deficiency in maize, effect on crop growth, development, drymatter partitioning and kernel set. *Crop Science Society of America*, **33**: 1376-1383.

Wang, H.X., Liu, C.M., Zhang, L., (2002). Water-saving agriculture in China: an overview. *Adv. Agron.* **75**, 135–171.

Wang, S.S., Deng, G.Y., (1991). A study on the mechanism of soil temperature increasing under plastic mulch. *Sci. Agric. Sin.* **24**(3), 74–78 (in Chinese with English abstract).

Wang, X.Q., Li, S.X., Gao, Y.J., (1998). Effects of filmmulch on physi-ecology and yield of spring corn. *Acta Agron. Sin.* **24** (3), 348–353 (in Chinese with English abstract).

Wang, Y.J., Xie, Z.K., Malhi, S.S., Vera, C.L., Zhang, Y.B., Wang, J.N., (2009). Effects of rainfall harvesting and mulching technologies on water use efficiency and crop yield in the semi-arid Loess Plateau, China. *Agric. Water Manag.* **96**, 374–382.

Warman A. (2003). Corn and capitalism. The University of North Carolina Press. 287 pp. Zarco-Tejada PJ, Miller JR, Mohammad GH, Noland TH, Sampson

Ali R., S. K. Khalil, S. M. Raza and H. Khan (2003). Effect of herbicides and row spacing on maize. *Pak. J. Weed Sci. Res.* **9**(3-4): 171-178.

Emam Y (2001). Sensitivity of grain yield components to plant population density in non-prolific maize (*Zea mays*) hybrids. *Indian J. Agric. Sci.* **71**(6): 367-370.

Hamidia A., N. Khodabandehb and A. D. Mohammadynasabc (2010). Plant density and nitrogen effects on some traits of maize (*Zea mays* L.). *Plant Ecophysiol.* **2**: 47-52.

Liu W., M. Tollenaar and G. Smith (2004). Within row plant spacing variability does not affect corn yield. *Agron. J*. **96**: 275-280.

Luque S. F., A. G. Cirilo and M. E. Otegui (2006). Genetic gains in grain yield and related physiological attributes in Argentine maize hybrids. *Field Crop Res.* **95**: 383-397.

Munamava M. R., A. S. Goggi and L. Pollak (2006). Seed quality of maize inbred lines with different composition and genetic backgrounds. *Crop Sci.* **44**: 542-548.

Saberali S F (2007). Influence of plant density and planting pattern of corn on its growth and yield under competition with common Lambesquarters (*Chenopodium album* L.). *Pajouhesh and Sazandegi*. **74**: 143-152.

Sangakkara U. R., P. S. R. D. Bandaranayake, J. N. Gajanayake and P. Stamp (2004). Plant populations and yield of rainfed maize grown I wet and dry seasons of the tropics. *Maydica.* **49**: 83-88.

Sangoi L (2001). Understanding plant density effects on maize growth and development: an important issue to maximize grain yield. *Ciencia Rural*. **31**(1): 159-168.

Steel R. G. D., J. H. Torrie and D.A. Dicky (1997). Principles and Procedures of Statistics, A Biometrical Approach. 3rd Ed. McGraw Hill, Inc. Book Co. N.Y. (USA.) pp. 352-358.

Tahir M., M. R. Javed, A. Tanveer, M. A. Nadeem and A. Wasaya, S.A.H. Bukhari and J. U. Rehman (2009). Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays* L.). *Pak. J. Life Soc. Sci.* **7**(2): 168-174.

Valadabadi S. A. and H. A. Farahani (2010). Effects of planting density and pattern on physiological growth indices in maize (*Zea mays* L.) under nitrogenous fertilizer application. *J. Agric. Ext. and Rural Dev.* **2**(3): 40-47.

Vega C. R. C., F. H. Andrade and V. O. Sadras (2001). Reproductive partioning and seed set efficiency in soybean, sunflower and maize. *Field Crop Res.* **72**: 165-173.

Zamir M. S. I., A. H. Ahmad, H. M. R. Javeed and T. Latif (2011). Growth and yield behaviour of two maize hybrids (*Zea mays* L.) towards different plant spacing. *Cercetări Agronomice în Moldova.* **14**(2): 33-40.