International Journal of Advanced Science and Research
ISSN: 2455-4227, Impact Factor: RJIF 5.12
www.allsciencejournal.com
Volume 2; Issue 1; January 2017; Page No. 10-14

Inter- and Intra- Row and plant spacing impact on maize (zea mays L.) growth and productivity: A review

Amjed Ali, Muhammad Ehsan Safdar, Muhammad Imran, Rafi Qamar, Muhammad Asghar Ali, Bashrat Ali, Muhammad Arshad Javed

Department of Agronomy, University College of Agriculture, University of Sargodha, Sargodha-40100, Pakistan

Abstract

Maize production is greatly affected by varying planting density than other members of the grass family because of its monoecious floral organization, its low tillering cognition to fill the gap among plants and the presence of synopsis ontogeny punctuation. Currently in Pakistan, diverse maize cultivars are being grown. These genotypes someone the cognition to with oppose adenoidal planting density due to solon analysis of assimilates to enter as compared to set resulting in change of root/shoot ratio. These genotypes have variable characteristics, therefore, these should be grown under optimum plant population to obtain higher yield. By increasing plant density, yield per plant decreases but grain yield per unit area increases. Exceeding beyond a certain limit of plant density, yield is lost due to increase in plant to plant unevenness and increase in plant infertility as high plant density above the certain level elongate the duration between pollen shedding and silking resulting in more unproductive plants. It has been observed that plant density lessen than that of best leads to lofty grain creation per position but low caryopsis creation per extent. Yet, when the position density of cereal hybrids exceeds a reliable extent, with the amount in position density, generate per organism decreases but perforate gain per object region increases. Surpassing beyond a foreordained decrease of place density, provide is people due to absent of plants, process in pose to exalted set denseness above the predestined take long the time between allergen sloughing and silking resulting in many fruitless plants. Modernistic cereal hybrids are economic as compared to old ones because of turn disposition to crowding articulate, petty lodging frequencies and developed tolerance to low-input and harsher maturation conditions. It is, therefore, suggested that recent cereal hybrids should be rather grown at higher communicate density because of their tolerance to lyceum flora compactness, to get maximum perforate exit, but not a realize sharply descend.

Keywords: plant population, genotypes, tillers, variable, production

Introduction

Optimal plant densities of hybrids, just as the corresponding expectable yield amounts were determined with quadratic equations. Optimal plant densities of the hybrids were different in the two studied crop years: in 2013, regarding the treatments set with the row distance of 45 cm, increasing plant densities resulted in higher yields, while in 2014, the yield showed decreasing tendency parallel to the increasing plant densities, that is confirmed by the fact that plant densities of 50 000 and 65 000 plants ha-1 proved to be more favourable. Regarding the treatments with a row distance of 76 cm, hybrids obtained their yield maximums by 80 327 plants ha-1 in 2013, while in the vegetation of 2014, by higher plant density of 85 845 plants ha-1(Muranyi, 2015) [37]. Thousand kernels weight and number of kernels per ear highly significantly increased with decreased inter-row spacing while above ground dry biomass yield decreased with decreased inter-row spacing. Highly significant difference due to the main effects of intra-row spacing was observed on all the above parameters except harvest index. Thousand kernels weight and number of kernels per ear highly significantly increased with decreased intra-row spacing. There was highly significant interaction effect of inter-row by intra-row spacing on stand count percent, above ground dry biomass yield per plant, grain yield per plant, and grain yield per hectare. In general, significantly higher grain yield and above ground dry biomass yield were obtained due to intermediate and closer spacing. It may therefore be concluded that spacing combinations of 65 x 25 cm responded favorably in attaining higher grain yield of maize in the area (Getaneh *et al*., 2016) [24]. Planting patterns and densities had significant influence on growth, development and yield components of maize crop (Tollenaar & Aguilera, 1992) [49]. Days to tasseling, grain weight per cob, test-grain weight, total dry matter, and harvest index were not significantly affected by the various planting geometries. Whereas grain yield considerably influenced by the planting geometry (Toor, 1990). The agronomic practices, particularly planting technique is of great importance. As proper adjustment of crop plants in the plotted field not only ensures optimum plant population but also helpful for plants to utilize the land, light, input resources such as water and fertilizers more efficiently and resolutely towards growth, development and towards final yield (Ali *et al*., 1998: Majid *et al*., 1986) [34]. Gokmen *et al*., (2001) [26] observed that maize plants when sown on ridges of more height. According to Khaliq *et al*., (1988) [29], Ahmad *et al*., (2000) [1] maize planted on paired ridges performed better than that grown in single-rows. Shaikh *et al*., (1994) [45], Majid *et al*., (1986) [34] while studying the effects of different sowing methods demonstrated that plant height, total biomass production, test grain weight and grain yield was maximum with ridge sowing and it also decreased the number of days to tasseling, skilling and maturity. In a recent work, Borras *et al.*, (2003) [11] concluded that a less leaf area index (LAI) duration could be resulted in response to increased plant population in the field due to more leaf senescence rate during grain filling.

If plant population is less than optimum, then per hectare production will be low and weeds will be more (Allard, 1999) [5]. Photosynthetic efficiency, growth and development in maize are greatly related to the effect of canopy architecture on the vertical distribution of light within the plants canopy. Optimum plant density is one of the ways of increasing the capture of solar radiation within the canopy. However, the efficiency of the conversion of intercepted solar radiation decreases with a high plant population density because of mutual shading in the plants in the field (Zoang *et al.*, 2006). The differential response to plant density in maize cultivars have been reported by Xue *et al.,* (2002) [55] that generally, the yield of a single verbalize plant will be less with increasing plant Population density whereas, the yield per unit area increases. The best way to influence future grains in yielding ability may be to make further improvements in tolerance to more planting densities, in combination with improvements in potential yield per plant under low stress conditions. Xue *et al.,* (2002) [55] emphasized the importance of low stress conditions (i.e., very low plant density, so that competition among plants is avoided) in optimizing the effectiveness of selection for improved potential yield per plant and tolerance to stresses and responsiveness to input.

Main constraints to enhance maize productivity in Pakistan are lack of site specific production technology, inadequate nutrition such as nitrogen, inadequate water supply, weed infestation and insect pest attacks. The selection of unsuitable cultivars under a given set of environments is major factor responsible for low yield. Andrade *et al.*, (1993) [7] demonstrated a linear relationship between growth and intercepted Photo synthatically Active Radiations (PAR) in his experiment on maize crop. As a result, plant population in a field effects on PAR and Radiation Use Efficiency (RUE) during the grain-filling period could be reflected on kernel weight and final grain yield in large grain size hybrids.

If plant density is very high, it will reduce of the availability of input resources either environmental or supplied per plant in the growing period and will result a considerable fall in yield per plant (Andrade *et al.*, 1999 [8]; Vega *et al.*, 2001) [53]. Tollenaar (1989) [50] observed that with high plant density, an increase in total biomass production and a decrease in harvest index but optimum plant density was a trade of both effects. Jeffrey *et al.*, (2005) [28], Dehdashti and Riahinia (2008) [16] worked on to study the effect of different row spacing and density of maize on total dry weight (TDW), and other growth parameters such as leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR). Plot treatments were row spacing (60, 75 and 90 cm). Saberali (2007) [43] investigated the influence of plant density and planting pattern on growth and physiological indices of maize. Plant density treatment was at two levels: Recommended plant density (70000 plant ha^{-1}) and 1/5 times recommended plant density (10500 plant ha^{-1}). Planting pattern treatment was at two levels: One and two rows planting (planting on both of ridge sides). The results showed that in high maize density, leaf area index, total dry weight and crop growth rate increased than low maize density in and throughout of growth season. Two row planting pattern also increased leaf area index, total dry weight and crop growth rate compare to one rows planting style, though it does not have the same effect as plant density.

Maize crop require larger quantity of readily available plant nutrient elements and soil reaction between 5.5-6.5 pH for good production. Although soil and environmental condition of Pakistan are greatly favorable, and high yielding cultivars are available. In spite of that yield of maize at farmer's field is very less as compared to other maize producing countries such as U.S.A, Canada, and Egypt etc. To boost up maize yield, adoption of modern agro-management techniques seems imperative and one of the major practices is the suitable method of seeding. Maize crop when sown on ridges produced taller plants (160.91cm) as compared to other methods of sowing. Optimum crop geometry is one of the important factors for higher production, by efficient utilization of underground resources and also harvesting as much solar radiation and in turn better photosynthates formation. Plant density exerts great effects on maize growth, because of its competitive habit both on the early and lateral developmental stages (Singh and Chaudhry, 2008) [46]. Yoshida (1972) [56] stated that corn is among the least tolerant of crops to high plant population densities. Akman (2002) [3] stated that as the plant density increases, plant height and ear yield of sweet corn increases but ear length, ear diameter and filled ear length decreases. Raising of corn plant population from 53333 to 8888S plants per hectare significantly increased the fresh ear yield (Raja, 2001) [42]. Akbar *et al.*, (1996) [2] reported that the most proper sowing density in corn was 100000 plants ha^{-1}. Cox *et al.,* (2006) [14] described that twin-rows (0.19m on 0.76m centers) had higher corn silage dry matter than single-row planting. More plant density and narrow row spacing collectively results in a more equidistant planting pattern that is expected to delay initiation of intra specific competition (Duncan, 1984) [18], while crop growth at early stages was increased (Bullock *et al.*, 1988) [13].

Crop growth rate and the amount of radiation intercepted by the crop have linear relation (Gardner *et al.*, 1985) [23]. Therefore, the response of grain yield to narrow rows can be analyzed in terms of the influence on the amount of radiation interception at the critical periods for kernel set. In some cases, full radiation interception during these periods may not be achieved with wide row (Andrade *et al.*, 2002) [6]. Andrade *et al.*, (2002) [6] found that corn yield response to decrease less spacing between rows was negatively correlated to radiation interception at pollination time with the more spacing.

Edmeads and Daynard (1979) [20] reported that the effect of high plant densities on the mean grain yield per plant was reflected in the grain number per plant and grain weight per 100 kernels, but kernel weight had not affected by planting density. The lowest grain yield was achieved at single row pattern in 13 plant m^{-2}, because of lower grains per car. At the highest density (13 plant m^{-2}), many kernels may not develop, due to poor pollination resulting from a delay in silking period as compared to tassel emergence (Otegui, 1997) [39] and due to a limitation in assimilate supply that caused kernel and ear abortion (Zinselmeier *et al.*, 1995) [58].

The highest light interception of 89.9% and 90.3% were observed from simple and zigzag twin-rows pattern, respectively. While the lowest light interception was noted from one -row planting method (Ghodratollah and Masoud, 2006) [25]. Leaf area influences the interception and utilization of solar radiation of maize crop canopies and consequently maize dry matter production and finally grain yield. Rate of leaf expansion, leaf area and leaf senescence are important factors in the determination of canopy photosynthesis in crop growth simulation models that compute total biomass from temporal integration of canopy photosynthesis. In addition to total leaf area, per leaf profile area or the vertical distribution of leaf area is also required when the calculation of canopy photosynthesis is based on sunlight and shaded leaf area across various layers in the crop canopy (Boote *et al.*, 1996) [10]. Leaf area is affected by different genotype, plant population (Murphy *et al.*, 1996) [38] climatic conditions and fertility of the soil. Some experiments have shown that a LAI between 3 and 4 may be optimal for obtaining maximum yield (Lindquist *et al.*, 1998) [30]. Also, increase in number of plants and row spacing at the same density reduce the leaf area index required to intercept 95% of the incident radiation because of an increase in the light extinction coefficient (Flenet *et al.*, 1996) [22].

Closer row spacing results in higher leaf photosynthesis and suppresses weed growth because of smothering effect compared with row spacing of wider distance (Dwyer *et al.*, 1991) [19]. Adjusting planting geometry to closer row spacing has more radiation use efficiency during grain filling which further results to higher dry matter production (Tollenear and Aguilera, 1992) [49]. Porter *et al.*, (1997) [41] found that plant distribution was a yield limiting factor when other limiting factors, such as nutrient deficiencies were eliminated.

Currently in Pakistan, diverse maize genotypes, i.e. single cross and double cross hybrids, synthetics and composites are being grown. These genotypes behaved differently to various agro-management practices particularly planting density in the form of different agro-physiological parameters. This differential response is mainly due to differences in Leaf Area Index (LAI) (Azadgoleh and Kazmi, 2007) [9], Leaf Area Duration (LAD) (Liu *et al.*, 2004 [31]; Stehli *et al.*, 1999) [47], intra-specific competition in maize plants (Maddonni and Otegui, 2006) [33], crowding stress tolerance (Tollenaar and Lee, 2002) [51], Dry Matter Accumulation (DMA) (Din *et al.*, 2008 [17]; Brenda *et al.*, 2006 [12]; Monneveux *et al.*, 2005) and Net Assimilation Rate (NAR) (Luque *et al.*, 2006) [32] of different maize hybrids. These genotypes have the ability to withstand high plant density.

Low plant population than optimum, results less per hectare production and weeds will grow profoundly therefore growth in maize are strongly related to influence of canopy architect on vertical distribution of light within the canopy. Capture of solar radiation can be increased by more number of plants per unit area while maize yield decrease with a very high plant population density because of mutual shading in the plants (Zhang *et al.*, 2006) [57]. The differential response to the plant density in maize cultivars has been reported by (Xue *et al.*, 2002). Generally the yield of individual maize plant decreases with increasing planting density whereas, the per acre yield increases. Xue *et al.*, (2002) [55] suggested that the best way of affect future grain in yielding ability may be to make further improvement in tolerance in high plant densities, in combination with improvement in potential yield per plant under low stress environment. Xue *et al.*, (2002) [55] emphasis the importance of low stress conditions (i.e very low plant density, so that the competition among the plants is avoided) in optimizing the effectiveness of selection for improved potential yield, tolerance to stresses and responsiveness to input. Main constraints to enhance maize productivity in Pakistan are lack of side specific production. Pepper (1974) [40] demonstrated that increasing planting densities enhance solar radiation utilization by maize canopies. However, efficiency of conversion of intercepted solar radiation into economic maize yield will reduce with higher number of plants on per unit area due to mutual shading effects of plants. Dry matter production in crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure (Daughtry *et al.*, 1983) [15]. An increase of 38% in yield at highest density may be due to the greatest number of plants per unit area, which ultimately resulted in higher biomass yield. Optimum plant density for maximum grain yield per unit area may differ from hybrid to hybrid on account of significant interactions between hybrids and densities (Farnham, 2001 [21]; Widdicombe and Thelen, 2002 [54]; Tokatlidis *et al.*, 2005) [48]. Optimum plant population could be approached from the slope of the linear regression of the natural logarithm of yield per plant on plant density (Duncan, 1984 [18]; Tollenaar, 1989) [50]. Megyes *et al* (1999) [35] also reported significant biomass yield reduction at lowest plant density. According to Harris, (1960) [27] in spite of high production potential, yield obtained at farmer's field level in Pakistan is very low, because of inadequate use of crop inputs and lack of appropriate crop management technology. Sabo, et al., 2016 [44] concluded that among the three varieties used in experiment, DMR gave the highest yield attributing characters like plant height, number of leaves, leaf area, leaf area index, and cob length, number of cobs per plot and 100 seed weight as well as highest grain yield. The intra-row spacing of 25 cm showed better performance than 20 cm and 30 cm. Therefore, farmers may adopt DMR variety with 25 cm spacing for a more profitable production of maize

References

1. Ahmad GZ, Qureshi and H. Ullah. Effect of different sowing method on the performance of sunflower. Pak. J. Bio. Sci., 2000; 3:1831-30.
2. Akbar H, Shah P, Aziz K, Saeed H, Munir M. Biomass, grain yield and harvest index and criteria for comparing corn types at different nitrogen levels and planting densities. Sarhad J. Agric. 1996; 12:261-267.
3. Akman Z. Effect of tiller removing and plant density on ear yield of sweet corn (*Zea mays* L). Pak. J. Bio1. Sci., 2002; 5(9):906-908.
4. Ali M, Khalil SK, Ayaz S, Marwat MI, Phonological stages, flag leaf area, plant height, and leaves per plant of corn influenced by phosphorus levels and plant spacing. Sarhad J. Agric. 1998, 14:515.
5. Allard RW, History of plant population genetics. Ann. Rev. Gen., 1999, 33:1-27.
6. Andrade FH, Calvino P, Crilo A, Barbieri P. Yield responses to narrow rows depend upon increased radiation interception. Agron. J. 2002; 94:975-980.
7. Andrade FH, Uhart SA, Frugone MI. Intercepted radiation at flowering and kernel number in maize: shade versus plant density effects. Crop Sci., 1993; 33:482-485.

8. Andrade FH, Vega CRC, Uhart SA, Cirilo A, Cantarero MG Valentinuz OR. Kernel number determination in maize. Crop Sci. 1999; 39:453-459.
9. Azadgoleh, MAE, Kazmi Z, A study of planting pattern and density effect on yield and physiological growth parameters in two corn cultivars. Ecol. Environ. & Conserv. 2007; 13(3):467-472.
10. Boote KB, Jones JW Pickering NB. Potential uses and limitations of plant models. Agron. J. 1996; 88:704-716.
11. Borras L, Maddonni GA Otegui ME. Leaf senescence in maize hybrids: Plant population, row spacing kernel set effects. Field Crops Res. 2003; 82:13-26.
12. Brenda L, Lucus B, Otegui ME. Source sink relations and kernel weight difference in maize temperate hybrids. Field Crops Res., 2006; 95:316-326.
13. Bullock DG, Nielsen RI Nyquist WE. A growth analysis comparision of corn grown in conventional and equidistant plant spacing. Crop Sci, 1988; 28:254-259.
14. Cox WJ, Hanchar JJ, Knoblauch WA, Cherney JH. Growth, yield, quality and economics of corn silage under different row spacing at high planting density than at spacing. Agron. J, 2006; 98:163-167.
15. Daughtry CST, Gallo KP, Bauer ME. Spectral estimates of solar radiations intercepted by corn canopies. Agron. J., 1983; 72:527-531.
16. Dehdashti SM, Riahinia S. Effect of plant density on some growth indexes, radiation interception and grain yield in maize (*Zea mays* L.). J. Biological Sci. 2008; 8(5):908-913.
17. Din J, Khan SU ALI I. Physiological response of wheat varieties as influenced by salinity stress. J. Anim. Plant Sci. 2008; 18(4):125-129.
18. Duncan, WG. A theory to explain the relationship between corn population and grain yield. Crop Sci., 1984; 24:1141-1145.
19. Dwyer IM, Tollenear M, Stewart DW. Changes in plant density dependence of leaf photosynthesis of maize hybrids. Can. J. Plant Sci. 1991; 71:1-11.
20. Edmeads GO, Daynard TB. The development of plant to plant variability in maize at different planting densities. Can. J. Plant Sci. 1979; 59:561-576.
21. Farnham DE. Row spacing, plant density, and hybrid effects on corn grain yield and moisture. Agron. J. 2001; 93:1049-1053.
22. Flenet F, Kiniry JR, Board JE, Westgate ME, Reicosky DC. Row spacing effects on light extinction coefficients of corn, sorghum, soybean and sunflower. Agron. J., 1996; 88:185-190.
23. Gardner BR, Pearce RB, Mitcher RL. Physiology of crop plants. Iowa state Univ. Press. Ames. USA. 1985.
24. Getaneh L, Belete K Tana T. Growth and productivity of maize (Zra mays L.) as influenced by inter and intra row spacing in Kombolacha, Eastern Ethiopia. J. Bio. Agri. Healthcare. 2016; 6(13):90-101.
25. Ghodratollah S, Masoud R, Response of corn (*Zea mays* L.) to planting pattern and density in Iran. American-Eurasian J. Agric. and Environ. Sci. 2006; 5(1):69-73.
26. Gokmen S, Sencar O, Sakin MA. Response of popcorn (*Zea mays* everta) to nitrogen rates and plant densities. Turk. J. Agric. and Forest. 2001; 25:15-23.
27. Harris RS, The effect of agricultural practices on the composition of food. In: Nutritional Evaluation of Food Processing. R.S. Harris and H. Von (eds). 1st Ed. Lesecke John Wiley & Sons, New York & London. 1960, 35.
28. Jeffrey TE, Larry CP, Earl DV. Light interception and yield potential of short season maize (*Zea mays* L.) hybrids. Agron. J. 2005; 97:225-234.
29. Khaliq A, Munir M, Asif J. Effect of different planting methods on some agronomic and physiological traits of maize. Pak. J. Agric. Res. 1988; 9:145-8.
30. Lindquist JL, Mortensen DA, Johnson BE. Mechanisms of corn tolerance and velvetleaf suppressive ability. Agron. J. 1998; 90:787-792.
31. Liu W, Tollenear M, G. Stewart and W. Deen. Within row plant spacing variability does not affect corn yield. Agron. J. 2004; 96:275-280.
32. Luque SF, Cirilo AG, Otegui ME. Genetic grains in grain yield and related physiological attributes in Argentine maize hybrids. Field Crop Res., 2006; 95:383-397.
33. Maddonni GA, Otegui ME. Intra-specific competition in maize: Contribution of extreme plant hierarchies to grain yield, grain yield components and kernel composition. Field Crop Res. 2006; 97:155-166.
34. Majid A, Shafiq M Iqbal M. Deep tillage and sowing techniques in maize production under high rainfed conditions. Pak. J. Agric. Res, 1986; 7:181-185.
35. Megyes A, Dobos A, Ratonyi T, Huzsval L. Effect of fertilization and plant density on the dry matter production of maize hybrids. Cereal Res. Comm., 1999; 27:433.
36. Monneveus P, Zaidi PH, Sanchez C. Population density and low nitrogen effects yield associated traits in tropical maize. Crop Sci. 2005; 45:535-545.
37. Muranyi E. Effect of plant density and row spacing on maize grain yield in different crop year. Columella. J. Agri. Environ. Sci. 2015; 2(1):57-63.
38. Murphy SD, Yakubu Y, Weise SF, Swanton CJ. Effects of planting pattern and inter row cultivation on competition between corn (*Zea mays* L.) and late emerging weeds. Weed Sci. 1996; 44:865-870.
39. Otegui ME. Kernel set and flowers synchrony with in ear of maize: plant population effects. Crop Sci., 1997; 37: 448-455.
40. Pepper GE. Effect of leaf orientation and density on the yield of maize Ph.D. Thesis lowa State Univ. Ames, lowa (USA), 1974.
41. Porter PM, Hicks DR, Lueschen WE, Ford JH, Warnes DD, Hovertad TR. *Et al*. Corn response to row width and plant population in the northern corn belt. J. Prod. Agric. 1997; 10:293-300.
42. Raja V. Effect of nitrogen and plant population on yield and quality of super sweet corn (*Zea mays* L.). Indian J. Agron. 2001; 46:246-249.
43. Saberali SF. Influence of plant density and planting pattern of corn on its growth and yield under competition with common lambesquaters (*Chenopodium album* L.). Pajouhesh & Sazandegi, 2007; 74:143-152.
44. Sabo MU, Wailare MA, Aliyu M J. Sanusi. 2016. Effect of variety and spacing on growth and yield of maize (Zea mays L.) in Bauchi State, Nigeria. Int. Plant and Soil Sci. 2016; 9(6):1-6.
45. Shaikh AA, Jadhav AS, Koli BD. Wattamwar MJ. Effects of planting layouts, mulching and fertilizers on dry matter accumulation and energy relationship in

rainfed pearl millet. J. Mah. Agric. Univ., 1994; 19:421-423.

46. Singh D, Choudhary J. Effect of plant population and fertilizer levels on yield and economics of popcorn. Indian J. Plant Sci. 2008; 78(4):370-371.
47. Stehli A, Soldati A, Stamp P. Vegetative performance of tropical high land maize in the field. J. Agron. Crop Sci, 1999; 183(3):193-198.
48. Tokatlidis IS, Koutsika- Sotiriou M, Tamoutsidis E. Benefits from using maize density-independent hybrids. Maydica. 2005; 50:9-17.
49. Tollenaar M, Aguilera A. Radiations used efficiency of old and new maize hybrids. Agron. J, 1992; 84:536-541.
50. Tollenaar M. Genetic improvement in grain yield of commercial maize hybrids grown in Ontario from 1959 to 1988. Crop Sci, 1989; 29:1365-1371.
51. Tollenaar M, Lee EA. Yield potential, yield stability and stress tolerance in maize. Field Crop Res., 2002; 75:161-169.
52. Toor MS. Effect of NPK application on the growth and yield of new maize genotype planted in the two geometrical patterns. M.Sc (Hons.) Agri. Thesis, Deptt. Agron, Univ, Agric, Faisalabad, 1990.
53. Vega CRC, Andrade FH, Sadras VO, Uhart SAValentinuz OR. Seed number as a function of growth: A comparative study in soyabean, sunflower and maize. Crop Sci. 2001; 41748-754.
54. Widdicombe WD, Thelen KD. Row width and plant density effect on corn grain production in the Northern Corn Belt. Agron. J. 2002; 94:1020-1023.
55. Xue J, Liang Z, Ma J, Lu S, Ren J. Population physiological indices on density tolerance of maize in different plant types. Ying Yong Sheing Tai Xue Bao, 2002; 13(1):55-59. (chinees).PMID:11962320.
56. Yoshida S. Physiological aspects of grain yield. Ann. Rev. Plant Physiol, 1972; 23:437-484.
57. Zhang, J, Dong S, Wang K, Hu C, Lin P. Effect of shading on the growth development and grain yield of summer maize. Ying Yong Sheing Tai Xue Bao, 2006; 17(4):657-662.
58. Zinselmeier C, Lauer MJ, Boyer JS. Reversing drought-induced losses in grain yield: Sucrose maintains embryo growth in maize. Crop Sci. 1995; 35:1390-1400.