BIOLOGIJA. 2016. Vol. 62. No. 1. P. 46–57

Plant density and intra-row spacing effects on phenology, dry matter accumulation and leaf area index of maize in second cropping

Raouf Seyed Sharifi[1],

Ali Namvar[2*]

[1] *College of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran*

[2] *Young Researchers and Elite Club, Ardabil Branch, Islamic Azad University, Ardabil, Iran*

Crop phenology is one of the most important aspects of crop yield determination and it is essential to predicting physiological responses under varying field conditions. In order to evaluate plant density and intra-row spacing effects on phenology, dry matter accumulation, and leaf area index of maize in second cropping, a factorial experiment based on randomized complete block design was conducted at the research farm of the University of Mohaghegh Ardabili. Experimental factors were: plant population at three levels (7, 9, and 11 plants m^{-2}) with three levels of intra-row spacing (45, 60, and 75 cm). The results showed that the maximum plant height (179.07 cm), total dry matter (592 g m^{-2}) in 83–91 days after sowing, days to 50% anthesis (45 days), days to 50% silking (50 days), LAI (4.07) in 63–70 days after sowing were observed in the plots with 11 plants m^{-2} and intra-row spacing of 45 cm. Based on the results, it was concluded that application of 11 plants m^{-2} with row spacing of 45 cm can be recommended for profitable maize production.

Key words: corn, growth indices, plant population, phenology

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family of *Poaceae* (*Gramineae*) that has a much higher grain protein content than staple food, rice. The production of maize in developing areas is low as compared to developed countries. There are several causes of low productivity. Among them, mismanagement of plant density is considered to be the major one. Hence, there is a need to improve this major component of the production technology for getting higher maize production. Maize yield is more affected by variations in plant population density than other members of the grass family due to its low tillering ability, monoecious floral organization, and the presence of a brief flowering period (Sangoi et al., 2002; Vega et al., 2000). For each production system, there is a population that optimizes the use of available resources, allowing the expression of maximum attainable grain yield in that environment. The ideal plant number per area will depend on several factors such as water availability, soil fertility, maturity group, and plant density (Sangoi et al., 2002). The relationship between maize yield and plant density is not well established. Trenton and Joseph (2007) suggested that in a dense population most plants remain barren; ear and ear size remains smaller, crop becomes susceptible to lodging, disease and pest,

* Corresponding author. E-mail: Namvar_a60@yahoo.com

while plant population at sub-optimum level resulted in lower yield per unit area. Plensicar and Kustori (2005) reported that the maximum biological yield was found at higher planting density. Iptas and Acar (2006) indicated that plant densities had no significant effects on leaf percentage, but stem percentage increased as plant densities increased (Oktem, Oktem, 2005).

Seed row spacing is an agronomical management strategy used by producers to optimize the husbandry of the soil and plant ecosystem from sowing to harvest with the goal of bolstering the production of crops. Crop row spacing influences canopy architecture, which is a distinguishing characteristic that affects the utilization of light, water, and nutrients (Brenton, Denise, 2005). Westage et al. (1997) reported that light interception was not affected by corn row spacing. They found no yield advantage to growing corn in narrow (spacing of 0.38 m) rows *vs.* conventional (spacing of 0.76 m) rows over two growing seasons in Minnesota. Pedersen and Lauer (2003) found an 11% lower yield for corn grown in 0.19 m rows *vs.* 0.38 and 0.76 m rows in Wisconsin, while Farnham (2001) found a 2% lower yield for corn grown in 0.38 m rows *vs.* 0.7 m.

Crop phenology is one of the most important aspects of crop yield determination and accurate prediction of phenology; therefore, it is essential to predicting physiological responses under varying field conditions (Hodges, 1991). Amanullah et al. (2009) noted that there was not more synchrony in flowering with higher density. They reported that higher plant density delayed days to 50% silking of maize crop. Ritchie and Alagarswamy (2003) stated that lengthening of the time interval between anthesis and barrenness occurred more frequently when plant densities exceeded 10 plants m^{-2}. Hamidi and Nasab (2001) reported that increases in plant densities significantly delayed the duration of the vegetative and reproductive period. Bolanos and Edmeades (1996) observed positive relationship between silk delay and plant density. Edmeades et al. (2000) showed that close synchrony between male and female inflorescence was desirable to improve kernel set and yield of corn. An asynchronous flowering may limit grain production per ear due to lack of pollen, loss of silk receptivity or early kernel abortion caused by the dominance of early formed ovaries from the base of the ear on the late formed from the tips (Carcova, Otegui, 2001).

Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development (Namvar et al., 2011). The physiological indices such as leaf area index (LAI) and total dry matter (TDM) are influenced by genotypes, climate, soil fertility, and plant density. Rao et al. (2002) suggested that leaf area index and leaves architecture are two main characteristics that define light interception in the canopy, and increasing plant density is one management tool for increasing the capture of solar radiation within the canopy. Leaf area index can be improved in two ways: breeding for increased leaf area per plant and increasing plant density (Namvar et al., 2011). Dry matter accumulation is directly related to leaf area index, or the amount of radiation intercepted by the crop and optimum plant density increases total dry matter and delay senescence (Jeffrey et al., 2005). Egli and Guffy (1997) reported that total dry matter is influenced by leaf area index and suggested that a larger leaf area per plant produced more assimilate in the plant, resulting in increased yield. Zhuang and Yu-Bi (2013) reported that leaf area index increases with increasing of plant population and TDM would increase with increased LAI.

Maize forage producers require more information on how plant density practices affect dry matter yield, and studies on proper combination of plant density and intra-row spacing effects on phenology, dry matter accumulation, and leaf area index of maize in second cropping are lacking. Considering the above facts, the present study was undertaken to elucidate the effects of plant density and intra-row spacing on phenology, total dry matter, and leaf area index of maize in second cropping.

MATERIALS AND METHODS

A factorial experiment based on randomized complete block design with three replications was conducted at the research farm of the University of Mohaghegh Ardabili (lat. 38° 15' N, long. 48° 15' E, alt. 1350 m). Climatically, the area is placed in the semi-arid temperate zone with cold winter and hot summer. Average rainfall was about 385 mm that mostly concentrated between winter and spring. Prior to crop sowing, soil samples were collected with soil auger and analyzed for various physicochemical properties (Table 1). Mean temperature and precipitation in the maize growing season are presented in Fig. 1.

Experimental factors were: different plant densities (7, 9, and 11 plants m^{-2}) with intra-row spacing at three levels (45, 60, and 75 cm). The field was prepared well before sowing by ploughing twice with a tractor followed by planking to make a fine seed bed. The soil was silt loamy with pH of about 8.2. In each plot there were 6 rows 6 m long. Plots and blocks were separated by 0.5 m unplanted distances. Maize seeds were planted in the third week of June. Nitrogen fertilizer (150 kg ha^{-1}) was applied in the form of urea ($^1/_3$ at sowing + $^1/_3$ at 6–7 leaves stage + $^1/_3$ before tasseling). Weeds were controlled manually. All other agronomic operations, except those under study, were kept normal and uniform for all treatments.

The field was immediately irrigated after planting to ensure uniform germination. Two types of measurements are needed for growth analysis: (1) plant weight; this is usually the oven dry weight (g) and (2) the size of the assimilating system; this is usually in terms of leaf area (m^{-2}). In order to estimate these two factors, nine harvests were taken at equal intervals of 7 days at different stages of the maize growth period. In each experimental plot, two marginal rows and 0.5 m from the beginning and end of planting lines were removed as a margin and measurements were done on four rows in the middle lines. For estimation of growth analysis, 3 plants were

Table 1. Soil physicochemical properties at a depth of 0–50 cm

Texture	Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)	Organic Carbon (%)	Total N (%)	Exchangeable K (mg kg^{-1})	Extractable P (mg kg^{-1})	pH	SP
Silt loam	24	70	5	18.3	0.78	0.16	385	16	8.2	46

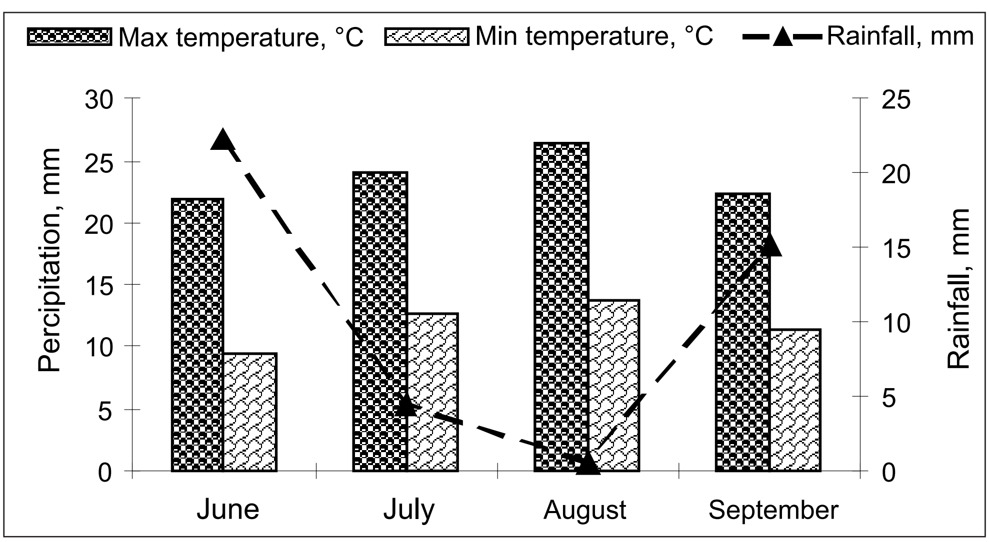

Fig. 1. Minimum and maximum temperatures and rainfall recorded during the period of maize growth (June–September)

sampled randomly in each treatment compound and averaged for recording the changes in shoots' dry weight (above ground). The first harvest was taken 26 days after planting (DAP). To obtain the dry matter weight, samples were oven dried at 70 ± 5 °C for 72 h till they reached constant weight. The variances of total dry matter (TDM) were determined using equation (1). Leaf area index (LAI) was determined by dividing leaf area over ground area and was estimated using equation (2) (Gupta, Gupta, 2005; Namvar et al., 2011):

$$TDM = e^{a+bt+ct^2+dt^3}, \qquad (1)$$

$$LAI = e^{(a+bt+ct^2)}. \qquad (2)$$

In these equations, t is the intervals of sampling or, on the other hand, the beginning and end of the interval sampling and a, b, c and d are coefficient of equations.

Silking refers to the stage when silk emerged on 50% of the observed plants. Anthesis was reached when 50% of the plants shed pollen from the main branch of the tassel and from a few other branches. On the other hand, anthesis date was recorded when 50% of the plants had shed pollen, whereas silking date was recorded when 50% of the plants had visible silks. The anthesis–silking interval (ASI) is the number of days from anthesis to silking. It was calculated as the difference between the recorded anthesis and silking dates (Bolanos, Edmeades, 1993). Forage yield was obtained from 1 m^2 long three middle rows in each plot. The data recorded were statistically analyzed by using computer software SAS (ver 9.1). Analysis of variance technique was used to test the significance, and LSD at 5% probability level was used to compare the treatment means.

RESULTS AND DISCUSSION

Plant density and intra-row spacing had significant effects on phenolgy, total dry matter, and leaf area of maize (Table 2).

Plant height

Plant height is an important component which helps determining the growth attained during the growing period. Plant density and intra-row spacing significantly affected the plant height. The maximum plant height was obtained from the highest plant density (11 plants m^{-2}), while the least value was recorded at application of 7 plants m^{-2}. Similar results had been reported by Turbert et al. (2001). Increase in plant height due to greater plant density may be attributed to better vegetative development that resulted in increased mutual shading and internodal extension. The comparison of means indicated that the maximum plant height was recorded at application of 11 plants m^{-2} in intra-row spacing of 45 cm and the minimum value was obtained from 7 plants m^{-2} in intra-row spacing of 75 cm (Table 3). This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased. Increase in plant height may also be due to prolonged vegetative growth which increased plant height. So, the comparison of means showed that days to tasseling or the vegetative growth period increased when plant density was increased (Table 3). The increase of plant density from 7 to 9 and 11 plants m^{-2} induced a statistically significant increase of the days to tasseling from 40.86 to 42.53 and 43.66 days, respectively. Similar results were reported by Amanullah et al. (2009).

Leaf percentage

The relationship between plant density and leaf percentage was significant. Similar results were reported by Iptas and Acar (2006). The differences in leaf percentage were markedly great and increased as plant density increased. Leaf percentage was the highest (22.06%) at 7 plants m^{-2} and the lowest (19.79%) at 11 plants m^{-2}. Keskin et al. (2005) reported negative correlation between plant density and leaf percentage in maize. Konuskan (2000) reported that lower leaf percentage was obtained at higher plant densities as a consequence of interplant competition.

Table 2. Comparison of means of plant density and intra-row spacing effects on total dry matter and leaf area index of maize

Treatments	0–28 DAS		28–35 DAS		35–42 DAS		42–49 DAS		49–56 DAS	
	TDM	LAI	TDM	LAI	TDM	LAI	TDM	LAI	TDM	LAI
Intra-row spacing (cm)										
$R_1 = 45$	29.81a	0.41a	73.0a	0.37a	145.26a	0.92a	230.66a	1.98a	331.33a	3.04
$R_2 = 60$	24.5b	0.41a	58.0b	0.32b	114.66b	0.84b	185.78b	1.81b	261.00b	2.72
$R_3 = 75$	20.46c	0.395b	45.3c	0.17c	102.78c	0.42c	161.94c	0.94c	222.47c	1.56
LSD ($p < 0.05$)	**0.918**	**0.078**	**2.79**	**0.021**	**4.67**	**0.0492**	**7.01**	**0.099**	**10.45**	**0.14**
Significance	**	**	**	**	**	**	**	**	**	NS
Plant densities (plant m^{-2})										
D_1=7	22.53c	0.08b	53.33c	0.30	109.66c	0.72	177.33c	1.55	256.66b	2.38b
D_2=9	25.1b	0.15b	56.37b	0.286	116.45b	0.72	189.10b	1.57	264.47b	2.4ab
D_3=11	27.12a	0.68a	66.66a	0.28	136.60a	0.74	211.95a	1.61	293.66a	2.53a
LSD ($p < 0.05$)	**0.91**	**0.078**	**2.79**	**0.0213**	**4.68**	**0.049**	**7.01**	**0.099**	**10.45**	**1.4**
Significance	**	**	**	NS	**	NS	**	NS	**	*
Interaction										
R_1D_1	26.4c	0.27b	64c	0.33c	130c	0.87b	210bc	1.8b	300c	2.83b
R_1D_2	30b	0.98a	75b	0.38ab	140b	0.93ab	220b	2.0a	328b	2.99b
R_1D_3	33a	0.98a	80a	0.4a	165.8a	0.98a	262a	2.14a	366a	3.3a
R_2D_1	22e	0.095c	52f	0.22d	105f	0.71c	169.9e	1.65b	240e	2.47c
R_2D_2	24.5d	0.11c	59de	0.36bc	115e	0.88b	173.8e	1.8b	268d	2.75b
R_2D_3	27c	0.15bc	63cd	0.4a	124cd	0.95ab	200cd	2.0a	275d	2.95b
R_3D_1	19.14f	0.02c	37h	0.13e	84g	0.36e	145f	0.87d	202f	1.38e
R_3D_2	20.87e	0.08c	42g	0.16e	104.3f	0.42de	167e	0.92cd	225.4e	1.55de
R_3D_3	21.37e	0.09c	57e	0.22d	120de	0.49d	190.3d	1.05c	240e	1.76d
LSD ($p < 0.05$)	**1.59**	**0.135**	**4.83**	**0.036**	**8.11**	**0.08**	**12.15**	**0.172**	**18.11**	**0.24**
Significance	**	**	**	*	*	**	**	**	**	**

Mean values followed by the same letters in each column and treatment showed no significant difference by LSD ($P = 0.05$). – *, ** and ns showed significant differences at 0.05, 0.01 probability levels and no significant, respectively

Notes: TDM, Total Dry Matter; LAI, Leaf Area Index

Stem percentage

Stem percentage significantly changed due to plant densities and intra-row spacing. Stem percentage increased as plant density increased. The highest stem percentage was obtained at application of 11 plants m^{-2} (Table 3). These results were in agreement with those of Oktem and Oktem (2005). Stem percentage increased with the decrease of intra-row spacing, and the highest (67.5%) was determined at 45 cm intra-row spacing and the lowest (65.09%) at intra-row spacing of 75 cm. Stem percentage is strongly influenced by environmental conditions during elongation. Some researchers reported that stem percentage was higher in higher plant densities as a consequence of inter-plant competition (Konuskan, 2000).

Table 2. (continued)

Treatments	56–63 DAS		63–70 DAS		70–77 DAS		77–83 DAS		83–91 DAS	
	TDM	LAI	TDM	LAI	TDM	LAI	TDM	LAI	TDM	LAI
Intra-row spacing (cm)										
R_1 = 45	410.00a	3.63	468.23a	3.61a	501.33a	2.71a	523a	1.56a	526.6a	0.73a
R_2 = 60	325.00b	3.31	372.0b	3.07b	402.1b	2.21b	409b	1.38b	408.6b	0.68b
R_3 = 75	288.66c	2.13	331.7c	2.32c	370.52c	2.08c	380c	1.26c	373.7c	0.53c
LSD ($p < 0.05$)	**12.31**	**0.147**	**13.56**	**0.125**	**12.26**	**0.077**	**14.26**	**0.045**	**15.36**	**0.034**
Significance	**	**	**	**	**	**	**	**	**	**
Plant densities (plant m^{-2})										
D_1=7	319.6c	2.96a	372.43b	2.88b	406.0c	2.25b	422b	1.27b	414b	0.54c
D_2=9	333.3b	2.94b	378.96b	2.95b	412.9b	2.25b	423.5b	1.46a	422b	0.67b
D_3=11	372.3a	3.17b	420.0a	3.17a	454.7	2.5a	469a	1.47a	472.5a	0.73a
LSD ($p < 0.05$)	**12.31**	**0.147**	**13.56**	**0.125**	**13.26**	**0.077**	**14.26**	**0.045**	**15.36**	**0.0304**
Significance	**	**	**	**	**	*	**	*	**	*
Interaction										
R_1D_1	368c	3.24d	420c	3.29bc	453c	2.3d	478c	1.26e	408c	0.59d
R_1D_2	406b	3.51bc	463b	3.49b	496b	2.69b	512b	1.55b	508b	0.75b
R_1D_3	456a	4.14a	522a	4.07a	555a	3.15a	579a	1.09f	592a	0.87a
R_2D_1	301ef	3.05d	348e	2.7d	378f	1.89 g	395fe	1.88a	388ef	0.51e
R_2D_2	335d	3.3cd	383d	3.11c	410de	2.28d	409de	1.4d	408c	0.68c
R_2D_3	341d	3.59b	385d	3.4b	418d	2.46c	425d	1.31e	430d	0.85a
R_3D_1	252g	1.99f	306f	2.16f	344g	1.99fg	359g	1.42cd	350g	0.43f
R_3D_2	294f	2.09ef	333e	2.35ef	375f	2.09ef	379fg	1.48bc	375fg	0.53e
R_3D_3	320de	2.32e	355e	2.46e	391ef	2.18de	403def	1.25e	396ef	0.65c
LSD ($p < 0.05$)	**21.33**	**0.25**	**23.5**	**0.21**	**22.97**	**0.134**	**24.7**	**0.07**	**26.61**	**0.05**
Significance	**	**	**	**	**	**	**	**	*	*

Total dry matter

The pattern of dry matter accumulation in all different plant densities was almost similar. The results indicated that TDM increased slowly at the early stages of growth (28–42 days after sowing) because of incomplete plant canopy, low leaf area index, and assimilation and then increased rapidly with the advancement of plant age (Fig. 2). A rapid increase in TDM at the later stages of growth can be due to the development of a considerable amount of leaf area index (Fig. 3) compared to early stages (Yasari, Patwardhan, 2006; Zeidan et al., 2006). Generally, higher plant densities increased TDM at all intra-row spacings. These results indicate close relationship between dry matter yield and plant density. So, the highest values of TDM were observed at application of 11 plants m^{-2} in intra-row spacing of 45 cm, while 7 plants m^{-2} in intra-row spacing of 75 cm showed the lowest amounts of TDM (Table 2). Application of 11 plants m^{-2} in intra-row spacing of 45 cm increased TDM by about 6 and 12.2% compared to application of 7 and 9 plants m^{-2}, respectively,

Table 3. Plant density and intra-row spacing effects on biomass produced and phenology of maize

Treatments	Plant height, cm	Leaf percentage (%)	Stem percentage (%)	Biomass (g m^{-2})	50% tasseling (days)	50% silking (days)	ASI (anthesis–silking interval) (days)
Intra-row spacing (cm)							
R_1 = 45	172.26a	19.78c	67.5a	484.4a	41.2c	45.23c	4.58a
R_2 = 60	167.82b	20.9b	66.4b	446.8b	42.33b	46.97b	4.44b
R_3 = 75	162.07c	21.92a	65.09c	434.2c	43.53a	48.25a	4.36b
LSD (p < 0.05)	**2.25**	**0.485**	**0.546**	**11.82**	**0.32**	**0.373**	**0.0805**
Significance	**	*	*	**	**	**	**
Plant densities (plant m−2)							
D_1 = 7	163.39c	22.06a	64.25c	390.39a	40.86c	45.27c	4b
D_2 = 9	165.78b	20.71b	66.6b	446.49b	42.53b	46.98b	4.65a
D_3 = 11	172.9a	19.79c	68.18a	528.66c	43.66a	48.2a	4.68a
LSD (p < 0.05)	**2.31**	**0.517**	**0.896**	**31.53**	**0.32**	**0.373**	**0.0805**
Significance	**	*	*	**	*	**	**
Interaction							
R_1D_1	169.8c	20.66d	67.9b	432	42cd	46.8d	4.8b
R_1D_2	173.96b	19.86e	68.4b	441.5	43.6b	47.8bc	4.2d
R_1D_3	179.07a	18.67f	69.6a	445	45a	50a	5a
R_2D_1	165.7de	22.4b	65.4cd	449	41.2e	45.7e	4.5c
R_2D_2	167cd	20.6d	66.4c	452	42.3c	47.2cd	4.96a
R_2D_3	168.8g	19.6e	66.4c	467	43.5b	48bc	4.5c
R_3D_1	161.6fg	23.1a	63.4e	450.5	39.4f	43.2f	3.8e
R_3D_2	163.7ef	21.6c	64.4de	455	41.7de	45.8e	4.16d
R_3D_3	165de	21.04d	64.9d	466	42.5c	46.75d	4.25d
LSD (p < 0.05)	**1.87**	**0.481**	**0.703**	**38**	**0.554**	**0.647**	**0.139**
Significance	**	**	**	ns	**	**	*

– Mean values followed by the same letters in each column and treatment showed no significant difference by LSD (P = 0.05).

– *, **, and ns showed significant differences at 0.05, 0.01 probability levels, and no significant, respectively.

at the same intra-row spacing in 83–91 days after planting (Table 2). The increase in total dry matter with the increasing of plant densities and decreasing of intra-row spacing indicates the favourable response of maize biomass produced to increasing plant density. It is perhaps related to accelerating the photosynthesis activity due to a higher leaf area index (Fig. 3) which caused dry matter accumulation increase. Numerous workers have determined different plant densities for the maximum dry matter yield changing from 79,000 to 16,5000 plants ha^{-1} (Turgut et al., 2005; Azam et al., 2007). Jeffrey et al. (2005) suggested that dry matter accumulation is directly related to leaf area index and the optimum plant density increases total dry matter. Winter and Ohleroch (1999) reported that leaf area index is a predictor of total biomass and is one of the ways of increasing the capture of solar radiation within the canopy and production of dry matter. It seems that increases in plant density significantly delay the duration of the vegetative and reproductive period (Table 3) and could be a possible reason for increasing of total dry matter (Hamidi, Nasab 2001). Our findings are in agreement with observations made by Winter and Ohleroch (1999) in maize. Namvar et al. (2011) suggested that TDM would increase with increase of LAI. The reason of decreasing in TDM at the final stage can be related to decreasing of leaf area index. Similar

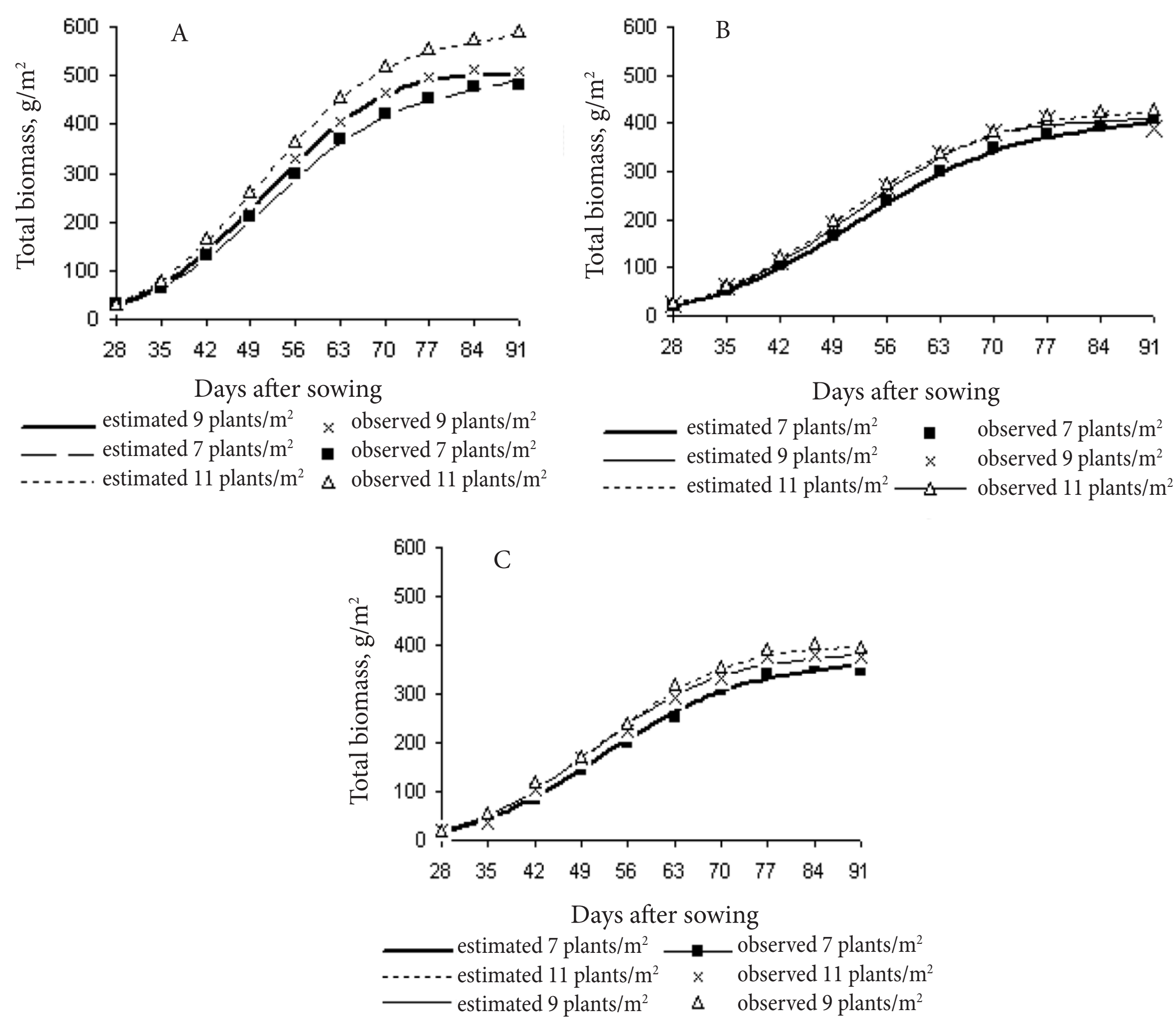

Fig. 2. Effects of different plant densities on total dry matter in intra-row spacing of 45 cm (A), 60 cm (B), and 75 cm (C)

observations have been reported by Jeffrey et al. (2005) in maize.

Leaf area index

LAI is an important parameter of maize. The data regarding LAI as affected by plant population densities and intra-row spacing are given in Table 2. Effects of plant density and intra-row spacing on LAI are shown in Fig. 3. We can see that LAI starts from low values, reaches a certain peak and then declines with plant aging (Fig. 3). The treatments having plant population of 9 and 11 plants m^{-2} produced higher LAI of 2.95 and 3.17, respectively, 63–70 days after planting. Valadabadi and Farahani (2010) stated that leaf area is influenced by genotype, plant population, climate, and soil fertility. They further reported that the highest physiological growth indices are achieved under high plant density, because photosynthesis increases by development of leaf area. In our research, increase in LAI explains the general crop trends that increasing plant density increases leaf area index on account of more area occupied by green canopy of plants per unit area. On the other hand, increasing leaf area index is one of the ways of increasing the capture of solar radiation within the canopy and accumulation of dry matter. Responses of dry matter accumulation and leaf area index were similar when plant density was increased or intra-row spacing was decreased.

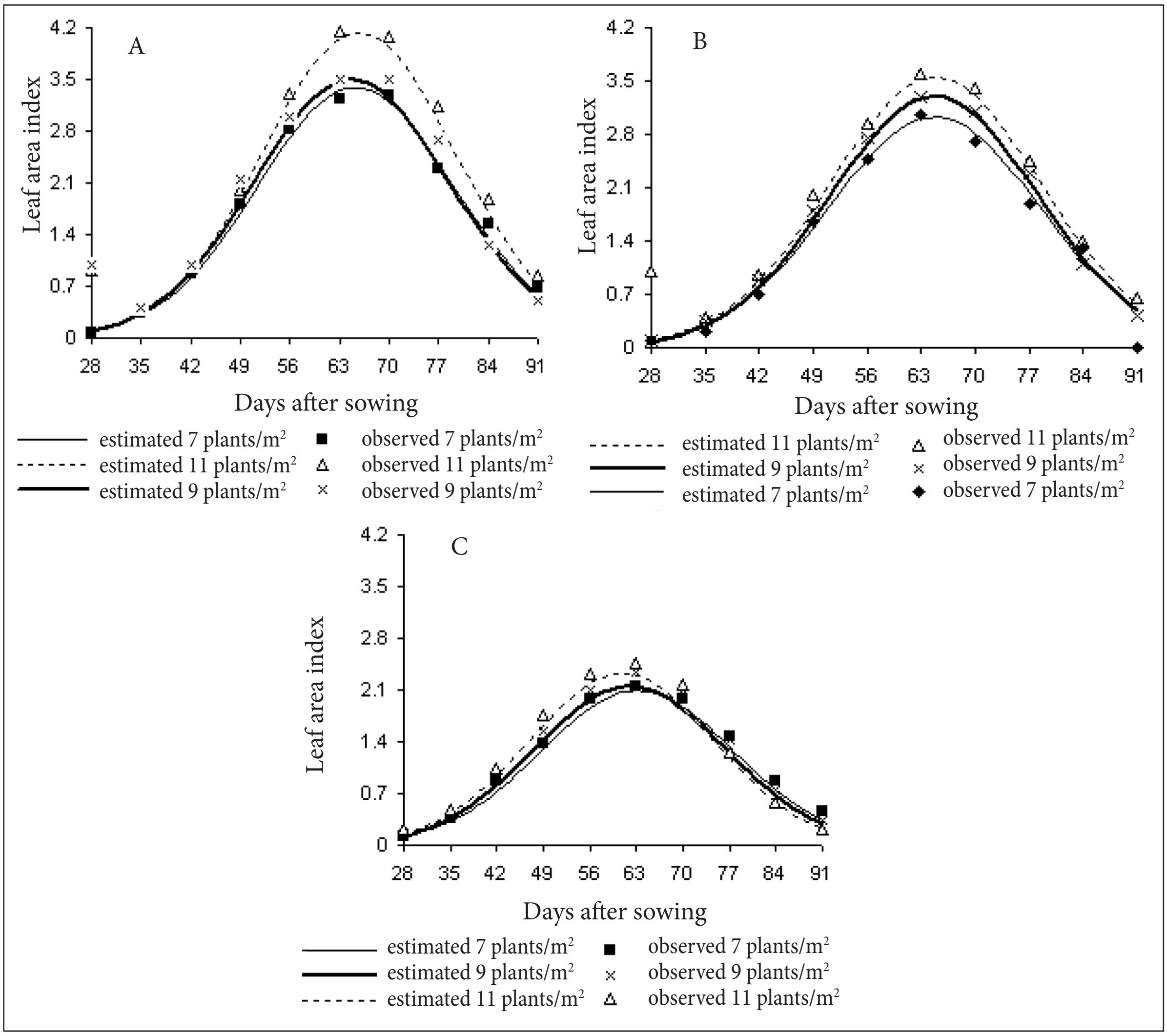

Fig. 3. Effects of different plant densities on leaf area index in intra-row spacing of 45 cm (A), 60 cm (B), and 75 cm (C)

These results are in close conformity with the results obtained by Winter and Ohleroch (1999) who found that LAI in maize increases with increase in plant density. The increasing of LAI was attributed to the rise in total leaf area/plant (Alam, Haider, 2006; Yasari, Patwardhan, 2006). Application of 11 plants m^{-2} in intra-row spacing of 45 cm increased by about 14.3 and 20.5% higher LAI compared to application of 7 and 9 plants m^{-2}, respectively, at the same intra-row spacing 63–70 days after planting (Table 2). Previous research findings also indicated that at high maize density, leaf area index and total dry matter increased compared to low maize density throughout the crop growth season.

Days to 50% tasseling

The comparison of means of days to 50% tasseling showed a significant difference between plant density and intra-row spacing at 5% probability level (Table 3). Maize took more time to tasseling when plant density was increased (Table 3). The comparison of means indicated the maximum of days to 50% tasseling (45 days) was recorded at application of 11 plants m^{-2} in intra-row spacing of 45 cm and the minimum (39.4 days) was recorded at application of 7 plants m^{-2} in intra-row spacing of 75 cm (Table 3). Gungula et al. (2003) suggested that increase in plant density might have increased the rate of photosynthesis and delayed phenological characteristics such as tasseling in maize.

Amanullah et al. (2009) reported that plots maintained at high density took slightly more time to tasseling, silking, and physiological maturity than the plots maintained at low density. They suggested that dense planting might have slightly slowed down the rate of plant development because of more competition in dense populations (Hamidi, Nasab, 2001).

Days to 50% silking

Maize took more time to silking in plots that received the highest plant density and the lowest intra-row spacing (Table 3). Increasing plant density increased days to 50% silking (Table 3). A similar trend (as for tasseling) for silking was observed with decreasing of intra-row spacing. The comparison of means indicated the maximum of days to 50% silking (50 days) was recorded at application of 11 plants m^{-2} in intra-row spacing of 45 cm and the minimum (43.7 days) was recorded at 7 plants m^{-2} in intra-row spacing of 75 cm (Table 3). Similar results are reported by Hamidi and Nasab (2001) and Amanullah et al. (2009) who investigated that higher plant density may cause delay phenology such as silking. Our results are in line with the finding of Edmeades et al. (2000) who noted that phenological events like tasseling, silking, and maturity in maize were significantly delayed by increasing plant density. Bolanos and Edmeades (1996) observed positive relationship between silk delay and plant density.

Time gap between anthesis and silking (ASI)

Plant density and intra-row spacing significantly affected anthesis and silking interval. The results indicated that the maximum of ASI (5 days) was recorded at application of 11 plants m^{-2} with intra-row spacing of 45 cm and the minimum of it (3.8 days) was recorded at application of 7 plants m^{-2} with intra-row spacing of 75 cm (Table 2). A shorter ASI with a higher intra-row spacing was because of inducing early and rapid growth. Hamidi and Nasab (2001) reported that there will be more synchrony in flowering with lower plant density. Bolanos and Edmeades (1996) showed that close synchrony between male and female inflorescence is desirable to improve yield and yield components. An asynchronous flowering may limit grain production per ear due to lack of pollen, lost of silk receptivity or early kernel abortion caused by dominance of early formed ovaries from the base of the ear on the late formed from the tips (Carcova, Otegui, 2001). In agreement with the results of the present study, increase in ASI was reported with increase in plant density (Amanullah et al., 2009).

Biomass production

Produced biomass is the main target of crop production. It was significantly affected by both plant density and intra-row spacing. The results indicated that the maximum of biomass produced was recorded at application of 11 plants m^{-2} and the minimum of it was recorded at application of 7 plants m^{-2} (Table 2). Our findings are in agreement with observations made by many researchers such as Amanullah et al. (2009) who reported that maize biomass increased with increasing plant density. Maximum biomass was produced in intra-row spacing of 45 cm (484.4 g m^{-2}) while minimum in intra-row spacing of 75 cm (434.28 g m^{-2}). Hamidi and Nasab (2001) reported that increases in plant density significantly delay the duration of the vegetative and reproductive period and could be a possible reason for increasing of maize yield. Vega et al. (2000) reported that maize yield is affected to a greater extent by variations in plant density than other members of the grass family due to its tillering capacity

CONCLUSIONS

The influence of plant density and intra-row spacing effects on phenology, dry matter accumulation, and leaf area index of maize in second cropping can be summarized as follows:

(1) Maize biomass changed with plant density and intra-row spacing. Maximum biomass was obtained in the plots with 11 plants m^{-2} and intra-row spacing of 45 cm.

(2) The maximum of days to 50% anthesis and days to 50% silking were obtained from 11 plants m^{-2} with intra-row spacing of 45 cm,

and it was vice versa in ASI. On the other hand, application of higher plant density decreased close synchrony between male and female inflorescence or increased ASI, and this is not desirable to improve biomass production.

(3) The highest values of total dry matter and leaf area index were observed at high levels of plant density and low levels of intra-row spacing.

(4) Based on the results, it was concluded that application of 11 plants m^{-2} with intra-row spacing of 45 cm can be recommended for profitable production of maize in second cropping

Received 28 December 2015
Accepted 1 March 2016

References

1. Ahmad Z, Khan AZ. Effect of zinc and plant population on yield and yield components of maize. M. Sc. Thesis, Dept. Agron. NWFP Agric. Univ. Peshawar, Pakistan, 2002.
2. Alam MZ, Haider SA. Growth attributes of barley (*Hordeum Vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. J Life Earth Sci. 2006; 1(2): 77–82.
3. Amanullah K, Riaz A, Shad K. Plant density and nitrogen effects on maize phenology and grain yield. J Plant Nutr. 2009; 32(2): 246–60.
4. Azam S, Ali M, Amin M, Bibi S, Arif M. Effect of plant population on maize hybrids. J Agric Biol Sci. 2007; 2(1): 13–20.
5. Bolanos J, Edmeades G. The importance of the anthesis–silking interval in breeding for drought tolerance in tropical maize. Field Crop Res. 1996; 31: 233–52.
6. Carcova J, Otegui ME. Ear temperature and pollination timing effects on maize kernel set. Crop Sci. 2001; 49: 1809–15.
7. Edmeades GO, Bolanos J, Elings A, Ribaut JM, Banziger M. The role and regulation of the anthesis silking interval in maize. In: Westgate ME, Boote KJ, editors. Physiology and Modelling Kernel Set in Maize. Madison, WI: CSSA; 2000. p. 43–73.
8. Egli DB, Guffy RD. Factors associated with reduced yields of delayed planting of soybean. Agron J. 1997; 159: 176–85.
9. Farnham DE. Row spacing, plant density, and hybrid effects on corn grain yield and moisture. Agron J. 2001; 93: 1049–53.
10. Gungula DT, Kling JG, Togun AO. Predictions of maize phenology under nitrogen-stressed conditions in Nigeria. Agron J. 2003; 95: 892–9.
11. Gupta NK, Gupta S. Pant Physiology. Oxford and IBH Publishing Co. Pvt. Itd.; 2005. p. 580.
12. Hamidi A, Nasab ADM. The effect of various plant densities and N levels on phenology of two medium maturity corn hybrids. Iran J Agric Sci. 2001; 32: 857–74.
13. Hodges T. Temperature and water stress effects on phenology. In: Predicting Crop Phenology, ed. T. Hodges, p. 7–13. Boca Raton, FL: CRC Press, 1991.
14. Iptas SA, Acar A. Genotype and row spacing influence on corn silage yield and some agronomic characters. Turkey V. Field Crop Congress, 13–17 October 2003. 2003. p. 458–462.
15. Jeffrey TC, Edwards Purcell E, Earl D. Light interception and yield potential of short season maize (*Zea mays* L.) hybrids in the midsouth. Agron J. 2005; 97: 225–34.
16. Keskin BH, Akdeniz IH, Turan N. Yield and quality of forage corn (*Zea mays* L.) as influenced by cultivar and nitrogen rate. Agron J. 2005; 4(2): 138–41.
17. Konuskan O. Effects of plant density on yield and yield– related characters of some maize hybrids grown in hatay condition as second crop. M. Sc. Thesis, Science Institute. M. K. U. 2000. p. 71.
18. Namvar A, Seyed Sharifi R, Khandan T. Growth analysis and yield of chickpea (*Cicer arietinum* L.) in relation to organic and inorganic nitrogen fertilization. Ekologija. 2011; 57(3): 97–108.
19. Oktem A, Oktem AG. Effect of Different Intra Row Spaces to Forage Value of Three Silage Corn (*Zea mays* L. indentata) Genotypes. III. National Animal Nutrition Congress in Turkey, 7–10 September, 523–527, Adana. 2005.

20. Pedersen P, Lauer JG. Corn and soybean responses to rotation sequence, row spacing, and tillage system. Agron J. 2003; 95: 965–71.

21. Plensicar M, Kustori R. Corn yield and water use as influenced by irrigation level, N-rate and planting populations. Trans. Kansan Acad. Science. 2005; 53(4): 121–7.

22. Rao MSS, Bhagsari AS, Mohaammad AI. Fresh green yield and seed nutritional of vegetable soybean genotypes. Field Crop Res. 2002; 42: 1950–8.

23. Ritchie JT, Alagarswamy G. Model concepts to express genetic differences in maize yield components. Agron J. 2003; 95: 4–9.

24. Sangoi L, Gracietti MA, Rampazzo C, Bianchetti P. Response of Brazilian maize hybrids from different eras to changes in plant density. Field Crop Res. 2002; 79: 39–51.

25. Brenton S, Denise A. Microclimatic and Rooting Characteristics of narrow-row vs. conventional-row corn. Agron J. 2005; 97: 1129–35.

26. Trenton FS, Joseph GL. Corn stalk response to plant population and the Bt–European corn borer trait. Agron J. 2007; 99: 657–64.

27. Turgut I, Duman A, Bilgili U, Acikgoz E. Alternate row spacing and plant density effects on forage and dry matter yield of corn hybrids (*Zea mays* L.). J Agron Crop Sci. 2005; 191(2): 146–51.

28. Valadabadi SA, Farahani HA. Effects of plant density and pattern on physiological growth indices in maize (*Zea maize* L.) under nitrogenous fertilizer application. J Agric Ext Rural Dev. 2010; 2(3): 40–7.

29. Vega CR, Sadras VO, Andrade FH, Uhart SA. Reproductive allometry in soybean, maize and sunflower. Annual Botany. 2000; 85: 461–8.

30. Westage ME, Forcella F, Riecosky DC, Somsen J. Rapid canopy closure for maize production in the northern US Corn Belt; Radiation use efficiency and grain yield. Field Crop Res. 1997; 49: 249–58.

31. Widdicombe WD, Thelen KD. Row width and plant density effects on corn grain production in the northern Corn Belt. Agron J. 2002; 94: 1020–3.

32. Winter SR, Ohlrogge AJ. Leaf angle, leaf area, and corn yield. Agron J. 1993; 65: 395–7.

33. Yasari E, Patwardhan AM. Physiological analysis of the growth and development of canola (*Brassica napus* L.) under different chemical fertilizer application. Asian J Plant Sci. 2006; 5(5): 745–52.

34. Zeidan MS, Amany A, El-Kramany MF. Effect of N-fertilizer and plant density on yield and quality of maize in sandy soil. Res J Agric Biol Sci. 2006; 2(4): 156–61.

35. Zhuang L, Yu-Bi H. Function analysis of phytochrome b gene in maize. Pakistan J Botany. 2013; 45(4): 1215–20.

Raouf Seyed Sharifi, Ali Namvar

AUGALŲ TANKUMO IR VIDINIŲ EILIŲ TARPŲ POVEIKIS FENOLOGIJAI, SAUSOSIOS MEDŽIAGOS KAUPIMAS IR KUKURŪZŲ LAPO PLOČIO INDEKSAS ANTROJO DERLIAUS METU

Santrauka

Kukurūzų fenologija yra vienas svarbiausių aspektų nustatant kukurūzų derlių, taip pat svarbi prognozuojant fiziologines reakcijas įvairiomis lauko sąlygomis. Siekiant įvertinti augalų tankumą ir vidinių eilių tarpų poveikį fenologijai, sausosios medžiagos kaupimą ir kukurūzų lapo pločio indeksą antrojo derliaus metu, Mohaghegh Ardabili universiteto (Iranas) mokslinių tyrimų ūkyje buvo atliekami eksperimentai, pagrįsti atsitiktinio visiško blokavimo schema. Pasirinkti šie eksperimentiniai veiksniai: trijų lygmenų augalų populiacijos (7, 9 ir 11 augalų / m^2) su trijų lygių vidinių eilių tarpais (45, 60 ir 75 cm). Gauti sklypo su 11 augalų / m^2 ir 45 cm vidinių eilių tarpais rezultatai: maksimalus augalų aukštis – 179,07 cm, bendras sausosios medžiagos kiekis – 592 g/m^2 (83–91 dienomis po sėjos), 45 dienos iki 50 % žydėjimo, 50 dienų iki šilko tarpsnio, kukurūzų lapo pločio indeksas buvo 4,07 (63–70 dienomis po sėjos). Remiantis gautais rezultatais padaryta išvada, kad, siekiant gausaus kukurūzų derliaus, rekomenduojama auginti 11 augalų / m^2 su 45 cm tarpais tarp eilių.

Raktažodžiai: kukurūzas, augimo indeksas, augalų populiacija, fenologija