J. BIOL. ENVIRON. SCI.,
2017, 11(31), 51-58

Original Research Article

Impact of Sowing Date and Tillage Method on Morphophysiological Traits and Yield of Corn

Sara Zaremohazabieh, Seyed Abdolreza Kazemeini*, Hossein Ghadiri and Mohsen Edalat
Department of Crop Production and Plant Breeding, College of Agriculture, Shiraz University, Shiraz, IRAN

Received: 22.02.2017; Accepted: 05.04.2017; Published Online: 16.05.2017

ABSTRACT

Environmental variations related with different sowing dates have an altering effect on the growth and development of corn plants. A field experiments were conducted to evaluate the effect of sowing date and tillage method on corn growth and yield. The treatments included two tillage systems (conventional and no tillage) and seven sowing dates (11-May, 18-May, 25-May, 1-Jun, 8-Jun, 15-Jun and 22-Jun). The interaction between tillage method and sowing date showed that the highest kernel yield (KY), biological yield (BY) and harvest index (HI) were observed at first sowing date and conventional tillage method and the lowest KY, HI and BY were obtained in no-tillage method and latest sowing date in both years. Delay in sowing from 11-May to 22-Jun decreased significantly the plant height, leaf number, leaf area index and yield by 6.43, 7.98, 17.36 and 42.7% in 2014 and 7.93, 8.87, 14.88 and 40.01% in 2015, respectively. The highest crop growth rate (CGR) was observed in conventional tillage (56 and 49 (g day^{-1}m^{-2})) as compared to no-tillage (45.7 and 46.5(g day^{-1}m^{-2})) in 2014 and 2015, respectively. The leaf area index (LAI) had a positive and significant correlation with corn height, leaf number and yield.

Keywords: Sowing date, Tillage methods, Corn, Yield

INTRODUCTION

Maize (*Zea mays* L.) is an important crop grown for both biomass and grain production in a variety of climatic conditions around the world. Several chemical, physical and biological processes in the soil are affected by its thermal conditions, which may affect the plant growth and crop production (Dalmago *et al*. 2004). Increases in the soil temperature reduce the period of germination-emergence of seedlings and increase processes such as microbiological activities, growth and activity of plant roots. The straw on the surface intercepts and reflects a great part of the incoming solar radiation (Baver *et al*. 1972), reducing the heat flux toward the soil profile in comparison to conventional tillage methods (Azzoz *et al*. 1997). Based on a long-term experiment, Boomsma *et al*. (2010) observed that substantial crop residue cover and cool, moist early-season soil conditions are common characteristics of continuous maize NT (no tillage) systems, which often delay seed germination, seedling emergence, and early root and stem development. In another long-term study that was carried out by Videnović *et al*. (2011) results indicated the advantage of the CT (conventional tillage) system for yield of maize. The highest average yield was observed with CT 10.61 t/ha (100.00%), while the yield was lower with RT (reduce tillage) 8.99 t/ha (84.37%) and NT (no tillage) 6.86 t/ha (64.65%).

Sowing dates are very important parameters in crop production. The optimum sowing date paves the way for better-use of time, light, temperature, precipitation and other factors. Rastegar (2004) reported that delay in sowing from April 25 to June 9 decreased total yield of corn by 38%. Also, Kresovic *et al*. (1997) in sweet corn reported that delay in sowing from June 21 to July 11 decreased total yield of corn as second crop. Achieving high maize grain yields requires that full season hybrids are sown early to fully exploit the thermal time available over the growing season (Wilson *et al*. 1994). However, early sowing can be conflicted by low spring soil temperatures, which can reduce seed germination, the rate of seedling emergence and final establishment (Hayhoe *et al*. 1996). Delayed, and poor emergence, can significantly reduce yield and in extreme cases result in paddocks having to be resown (Stone *et al*. 1999). Seedling emergence and early seedling vigor are important characteristics for obtaining a good plant stand and subsequent high yields, particularly in regions where low soil temperatures prevail at the time of sowing (Prasad *et al*. 2006). Amjadian *et al*. (2013) showed that sowing date significantly affects qualities such as height at flowering stage, number of rows, number of kernels in per maize, maize length, grain weight and grain performance while it has no significant effect on the row number, maize diameter and cob dry weight.

* Corresponding author: kazemin@shirazu.ac.ir

While effects of sowing date and tillage have been studied in many plants; most of these studies were done separately for each of the factors. Therefore, the objectives of this study were to investigate the effects of sowing dates and tillage methods and their interactions on corn growth and yield.

MATERIALS AND METHODS

Experiment was carried out in 2 years (2014 and 2015) at research farm of College of Agriculture, Shiraz University. The experiment was arranged as a split-plot based on randomized complete block design with three replications. The treatments in main plots consisted of two tillage systems (conventional (mold board plow and two harrow disks) and no-tillage), and seven sowing dates as sub plots (11-May, 18-May, 25-May, 1-June, 8-June, 15-June and 22-June). Plots were located on a silty clay loam soil (9.28% sand, 34.72% clay and 56% silt) with 2.38% organic matter, 1.382% organic carbon, 0.132% total N, 32 p.p.m phosphorus, 420 p.p.m potassium, pH of 7.36, and EC of 0.682 dS m^{-1}. Corn seeds (hybrid SC704) were planted by Baldar Seed Drill (SPD) in 3×5 m plots at 5 cm depth. Each sub plot consisted of five 4 m rows with 75 cm and 15 cm between and within rows in wheat stubble mulch for no-tillage and without mulch for conventional tillage. 150 kg ha^{-1} triple super phosphate was used and 600 kg ha^{-1} urea was top-dressed in three times as sowing time, when the plants had 6-8 fully exposed leaves and beginning of grain filling. During the growing season, all plots were irrigated (every seven days interval) and all weeds were controlled by herbicides Paraquat or Gromoxone (1kg ha^{-1}) used two weeks before first sowing date and 2,4-D MCPA(1.5 kg h^{-1}) was used when the height of plant was 15-25 cm.
To assess the effect of sowing date and tillage method on growth of corn, LAI (leaf area index and CGR (crop growth rate (g day^{-1} m^{-1})) were measured during each growing season based on developmental stages of corn. These stages included vegetative stages (1- when the plants had 3-4 fully exposed leaves, 2- when the plants had 6-8 fully exposed leaves, 3- tassel initiation), reproductive stage (beginning stage of grain filling (blister)) and dough. To measure leaf area we used leaf area meter (Delta-T Device) after that for calculated the LAI (leaf area index) we used equation 1 and for CGR used equation 2:

Equation (1): $$\mathrm{LAI} = \frac{LA}{GA}$$
LA was leaf area per plant and GA was ground area that used by plant
Equation (2): $$\mathrm{CGR} = [\frac{(W2-W1)}{(T2-T1)} * (\frac{1}{\mathrm{GA}})]*100$$

Where W_1= total dry matter of plant at time T_1, W_2= total dry matter of plant at time T_2, T_1= time of first observation, T_2= time of second observation, GA= ground area. Corn final leaf number and final plant height (cm) were measured at the end growing season. Three plants were harvested at random from each plot to measure heights and counted the number of leaves on each plant. At corn physiological maturity, the $1m^2$ from middle of each plot was sampled for determination of biological yield, kernel yield and harvest index, oven-dried at 75˚C for 72h, and weight. At the end, the data were analyzed by statistical software SAS (9.1) and the means were compared by Duncan Multiple Range Test at 5% level. The graphs were drawn by MS-Excel. As the year effect was significant in combine analysis, the results of each year were reported separately.

RESULTS AND DISCUSSION

Leaf area index and crop growth rate

The photosynthetic capacity of crops is a function of leaf area. Leaf area is important for crop light interception and therefore has a large influence on crop yield (Dwyer and Stewart 1986). The results showed that change in sowing date and tillage method significantly affected LAI at all sampling time (Figure 1 and 2.). The highest LAI was observed in conventional tillage method (4.73 in 2014 and 4.72 in 2015) in comparison with no-tillage method (4.51 in 2014 and 4.46 in 2015) (Figure 1.). Delay of sowing because of the shortening of the growing cycle caused reduction of LAI, so the highest LAI was obtained in early sowing date (5.07 and 4.84 at 11-May in both years) as compared to delay in sowing date (4.19 and 4.12 at 22- Jun in both years) (Figure 2.).

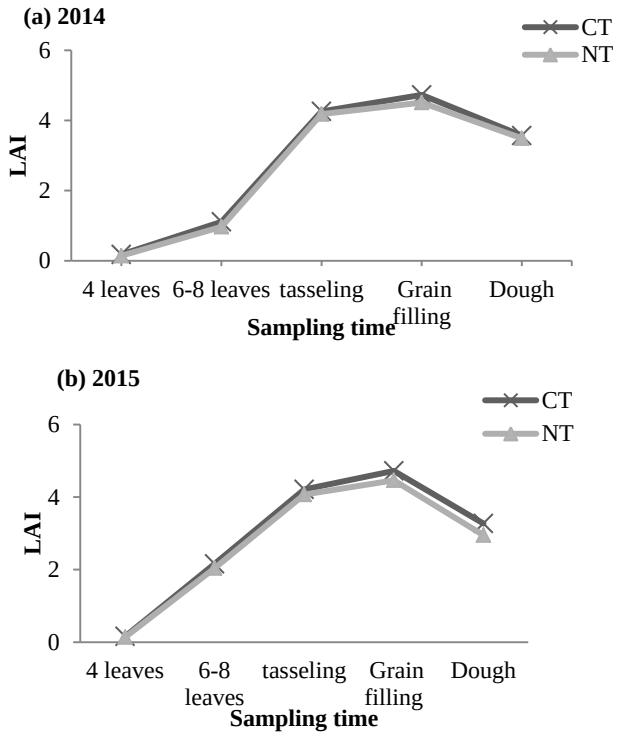

Figure 1. Effect of tillage method on LAI in (a) 2014 and (b) 2015.

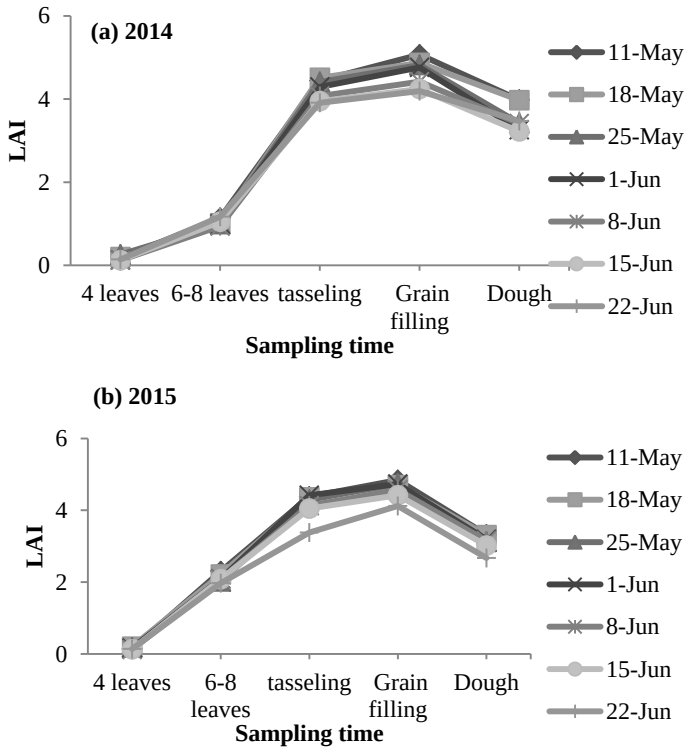

Figure 2. Effect of sowing date on LAI, (a) 2014 and (b) 2015.

Effect of interaction between sowing date and tillage method on final LAI showed that the highest LAI was obtained in conventional tillage method and at first sowing date (5.38 and 4.96) in 2014 and 2015,

respectively. The lowest LAI was observed in no-tillage method and at seventh sowing date (4.16 and 4.06) in 2014 and 2015, respectively. The increase or decrease in LAI has a direct effect on plant growth rate. The LAI had a positive and significant correlation with plant height, leaf number and kernel yield (Table 1.). This index is the main tool for enhancing photosynthesis capacity and assimilates production. Also, Lizaso *et al*. (2003) stated that the average absorbed photosynthetic active radiation (PAR) by leaf area at reproductive stage was the determining factor of corn yield and the decrease in yield had a high correlation with the decrease in corn leaf area. Delay of sowing because of shortening of the growing cycle caused reduction of LAI that is agreement with Noferesti (2006) report. Aikins *et al*. (2012) showed that the highest LAI was observed in the disc harrowing treatment and the no-tillage plots produced the smallest LAI. Moosavi *et al* (2012), showed that change in sowing date and plant density significantly affected LAI at tasseling stage, but their interaction was not significant on LAI. The mean LAIs in sowing dates of July 4, July 21and August 6 were 2.85, 2.12 and 1.65 respectively. Delay in sowing from July 4 to August 6 decreased significantly the leaf area index (42.1%).

Table 1. Correlation coefficient between traits of corn in 2014 and 2015.

Traits 2014	Biological yield	Harvest index	Kernel yield	Leaf number	Plant Height	LAI
Biological yield	1					
Harvest index	0.189^{ns}	1				
Kernel yield	0.954**	0.472**	1			
Leaf number	0.324*	0.208^{ns}	0.360*	1		
Plant Height	0.335*	0.256^{ns}	0.376*	0.249^{ns}	1	
LAI	0.756**	0.473**	0.823**	0.398**	0.422**	1
Traits 2015						
Biological yield	1					
Harvest index	0.567**	1				
Kernel yield	0.977**	0.726**	1			
Leaf number	0.328*	0.286^{ns}	0.352*	1		
Plant Height	0.598**	0.408**	0.600**	0.330*	1	
LAI	0.746**	0.513**	0.748**	0.286*	0.682**	1

ns Non Significant and *, ** Significant at 0.05 and 0.01 probability levels, respectively.

Crop growth rate is a prime dynamic growth factor to study since it reflects canopy assimilatory capacity, and affects total DM levels and equilibrates through adjustments of LAI and/or net assimilation rate (Imsande 1989). Our results indicated that tillage systems had a significant influence on the CGR in first and end sampling in 2014 and third sampling in 2015 (Figure 3.). Corn under NT had lower CGR as compared to conventional tillage in both years. At the silking stage and throughout the grain-filling period, corn under CT system had a higher CGR compared with no-tillage method in two years. The highest CGR was observed at the silking stage and throughout the grain-filling period in all sowing dates in both years (Figure 4.). Baghdadi *et al*. (2012) indicated that tillage systems had a significant influence on the CGR but did not significantly influence LAI. Corn under no-tillage had lower CGR as compared to other tillage systems. At the silking stage and throughout the grain-filling period, corn under conventional tillage system had a higher CGR compared with other tillage practices. In general, an increase in CGR is generally due to an increase in LAI. Yusuf *et al*. (1999), found soybean grown in the central Corn Belt in conventional tillage methods to have an initial higher CGR than those in no-tillage methods before R2. Pedersen and Lauer (2004) showed that LAI at R1 was 76% greater for the late sowing date compared with the early sowing date. The early planted soybean had a 6% higher LAI at R6 than delayed planting. Delayed planting resulted in a more rapid CGR after emergence than early planting likely because the temperature was warmer. During R1 to R5, CGR averaged 8% higher for delayed planting. At R6, CGR for the delayed planting was 61% lower than the early sowing date. From R1 to R5, soybean had averaged 9% lower CGR in conventional tillage method compared with no-tillage method. Pedersen and Lauer (2004) showed that the early planted soybean had a 6% higher LAI at R6 than delayed planting. Delayed planting

resulted in a more rapid CGR after emergence than early planting likely because the temperature was warmer. From R1 to R5, soybean had averaged 9% lower CGR in conventional tillage method compared with no-tillage method.

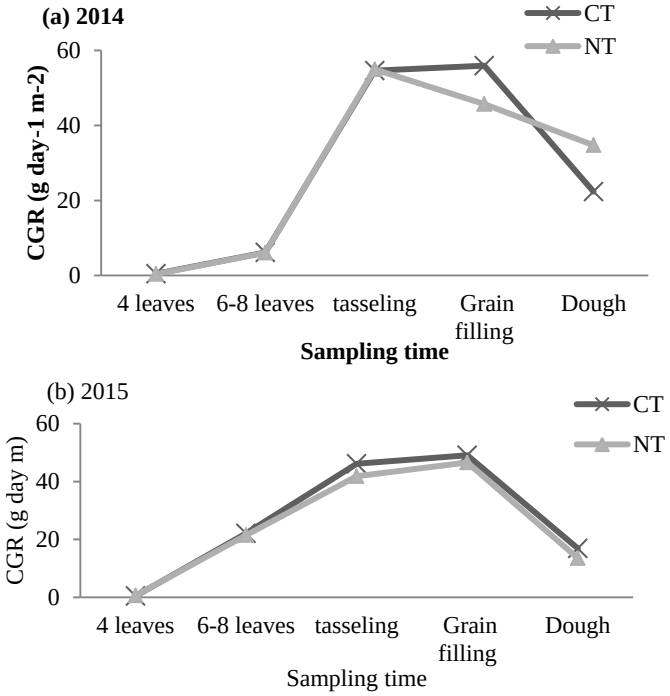

Figure 3. Effect of tillage method on CGR in (a) 2014 and (b) 2015.

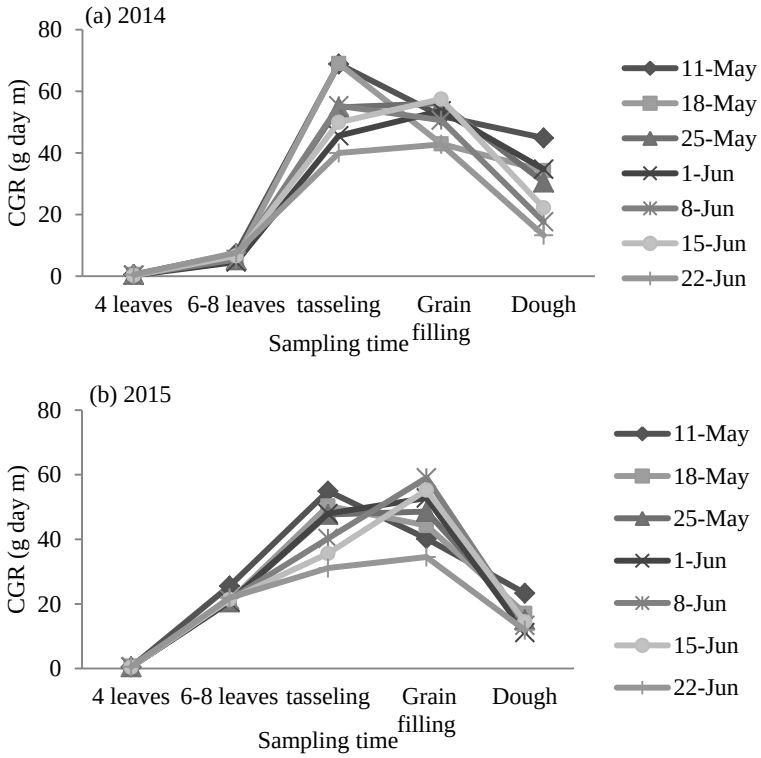

Figure 4. Effect of sowing date on CGR, (a) 2014 and (b) 2015.

Final plant height and leaf number

Final plant height and final leaf number was observed in the beginning stage of grain filing. Means comparison indicated that final plant height and final leaf number were significantly affected by interaction between tillage method and sowing date (Table 2.). Results showed that the highest leaf number (15.3 and 16 in 2014 and 2015 respectively) and the tallest plant (262.8 cm in 2014 and 247.7 cm in 2015) was obtained in the earlier sowing dates in conventional tillage compared with other treatments. Earlier planting increases the length of time that plants can take advantage of favorable growing conditions and accumulate biomass. Corn plants approximately had similar leaf number because they had adequate elements and adequate opportunity for photosynthesis and growth. In the beginning stage of grain filing conventional tillage plots produced the highest leaf number (14.6 in 2014 and 14.9 in 2015) and tallest plant height (254.3 cm in 2014 and 240.8 cm in 2015). On the other hand, the no-tillage plots presented the smallest plant height (242.5 cm in 2014 and 234.7 cm in 2015) and lowest leaf number (13.98 in 2014 and 13.96 in 2015). A significant decrease in plant height was observed at the latest sowing date as compared with the other treatments (Table 2.). This decrease following the delay in sowing date can be associated with higher temperatures that the plants at the seventh sowing date experienced which limited their growing period and assimilate-building because of the early maturity of plants. Thus, the plants did not have adequate opportunity for photosynthesis and their height capacity decreased. These results are in agreement with the results of Morin and Dormancy (1993), and Imholte and Carte (1987) reported that delay of sowing caused a decline in plant height. Moosavi *et al*. (2012) reported that leaf number per plant was not significantly affected by sowing date and plant density. Aikins *et al*. (2012) showed that the disc harrowing only plots produced the highest number of leaves per plant and the no-tillage plots produced the lowest number of leaves per plant. Baghdadi *et al*. (2012) reported that the highest number of leaves was obtained in CT (12.78) and the lowest number of leaves was obtained in NT (11.00). Similar results were shown by Albuquerque *et al*. (2001), who concluded that plant height, number of green leaves, weight and numbers of grains per ear were reduced with no tillage as compared with conventional tillage.

Table 2. Effect of tillage method and sowing date on corn leaf number, height, biological yield (BY), harvest index (HI) and kernel yield (KY) during of the growing season in 2014 and 2015.

	Sowing date	Leaf number		Plant height (cm)		BY (kg ha^{-1})		HI		KY (kg ha^{-1})	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
CT	11-May	15.3 a	15.3abc	259.7a	246.5ab	47000a	42000a	48.5a	47.3ab	23000a	20000a
	18-May	15.3 a	16 a	259.2a	246.6ab	38000b	40000ab	47.9a	45.7abcd	18000bc	18000bc
	25-May	14.7ab	15.7ab	262.8a	245.2ab	35000bc	41000ab	48.1a	47.2abc	17000c	19000ab
	1-Jun	14.3ab	15bcd	249.3abc	247.7a	31000de	38000abc	48.3a	44.5bcde	15000d	17000cd
	8-Jun	13 b	14 def	257.0ab	238.7abc	32000cde	32000ef	46.4ab	44.4bcde	15000d	14000e
	15-Jun	14.7ab	14.7cde	259.5a	239.5abc	27000e	28000fg	44.4ab	44.0def	12000e	12000f
	22-Jun	14.7ab	13.7ef	232.6d	221.3d	27000e	26000g	44.5ab	44.3de	12000e	12000f
NT	11-May	14ab	14 def	241.2dc	238.1abc	39000b	38000bcd	47.6a	48.0a	18000b	18000bc
	18-May	14ab	13.7ef	245.5bcd	235.4abcd	39000b	37000bcd	44.9ab	46.1abcd	18000bc	17000cd
	25-May	14.3ab	14.3 def	244.7bcd	243.0ab	39000b	36000ed	44.7ab	46.6abcd	17000bc	17000d
	1-Jun	14.3ab	14.7cde	243.6bcd	237.2abc	32000cd	34000de	47.8a	44.3cde	15000d	15000e
	8-Jun	14ab	14 def	243.2bcd	233.5abcd	31000de	29000fg	45.8ab	42.1ef	14000d	12000f
	15-Jun	13.3 b	13.3 f	243.2bcd	231.0bcd	30000de	28000g	42.3b	43.6def	12000e	12000f
	22-Jun	14ab	13.7ef	236.0cd	224.8cd	28000de	27000g	41.9b	41.4f	12000e	11000f

Means followed by the same letters in each column-according to Duncan's multiple range tests are not significantly ($P<0.05$), CT: conventional tillage, NT: no-tillage method.

Corn harvest index, biological yield, kernel yield

Environmental variations related with different sowing dates have an altering effect on the growth and development of corn plants. The results showed that change in tillage method didn't have significant effect on corn kernel yield (KY), harvest index (HI) and biological yield (BY) in 2014 but change in tillage method had significant effect on them in 2015 (Data not shown). The highest KY (16000 and 16000 kg ha^{-1}), BY (34000 and 35000 kg ha^{-1}) and HI (46.87 and 45.35) were observed at conventional tillage method in 2014 and 2015, respectively. Change in sowing date had significant effect on KY, BY and HI in both years. The highest KY (21000 and 19000 kg ha^{-1}), BY (43000 and 40000 kg ha^{-1}) and HI (48.03 and 47.63) were observed at earlier

sowing date (11-May) and the lowest KY (12000 and 11000 kg ha^{-1}), BY (27000 and 26000 kg ha^{-1}) and HI (43.20 and 42.85) were obtained at later sowing date (22- Jun) in 2014 and 2015 respectively, as compared to the others (Data not shown). The interaction between of tillage method and sowing date showed that the highest KY, BY and HI were observed at 11-May (first sowing date) and conventional tillage method and the lowest KY and HI were obtained in no-tillage method and latest sowing dates (15-Jun and 22-Jun) and the lowest BY was obtained in conventional tillage method and latest sowing dates (15-Jun and 22-Jun) in both years (Table 2.).This is partly due to the fact that no-tillage environments are more likely to exhibit non-uniform germination, emergence and early growth and development, which causes great plant-to-plant variability for multiple morpho-physiological traits, which are associated with yield reduction.

These results are in agreement with that of Videnović *et al*. (2011) who indicated that the highest average yield was observed with CT(conventional tillage) 10.61 t/ha (100.00%), while the yield was lower with RT (reduce tillage) 8.99 t/ha (84.37%) and NT (no tillage) 6.86 t/ha (64.65%). The highest yields in maize generally result where the growing season is longest and soil moisture is not limiting (Kucharik 2006). Nafziger (1994) showed accelerating decline in yield as planting date is advanced or delayed from the optimum. Cirilo and Andrade (1994) reported that early-planted maize had lower radiation use efficiency from emergence to silking compared with later-planted maize.

CONCLUSIONS

The results showed that delay in sowing from 11-May to 22-Jun decreased significantly the plant height, leaf number, leaf area index and kernel yield by 6.43, 7.98, 17.36 and 42.7% in 2014 and 7.93, 8.87, 14.88 and 40.01% in 2015, respectively and change tillage method from CT to NT decreased them 4.64, 3.58, 4.65 and 3.64% in 2014 and 2.54, 6.38, 5.5 and 8.54% in 2015, respectively. The LAI had a positive and significant correlation with corn height, leaf number and yield. At the silking stage and throughout the grain-filling period, corn under conventional method had a higher CGR compared with no-tillage method in two years. Results showed that maize planted earlier than normal for the region can produce yield equal to or greater than maize planted later than normal and conventional tillage produced yield greater than no-tillage.

REFERENCES

Aikins SHM, Afuakwa JJ, and Owusu-Akuoko O (2012). Effect of four different tillage practices on maize performance under rainfed conditions. Agric Bio J North Am. 3(1): 25-30.

Albuquerque JA, Sangoi L, and Ender M (2001). Modification in the soil physical properties and maize parameters including by cropping and grazing under two tillage systems. Revista-Braseilera-de-Cienciado- Solo. 25: 717–723.

Amjadian M, Farshadfar M, and Gholipoor M (2013). The effects of planting date on the yield and yield components of corn (*zea mays L.*) cultivar, single cross 704 in Gorgan region. Annual Bio Res. 4(4): 38-41.

Azzoz RH, Lowery B, Daniel TC, and Arshad MA (1997). Impact of tillage and residue management on soil heat flux. Agric Forest Met. 84: 207-222.

Baghdadi A, Abd Halim R, Majidian M, Wan Daud W, and Ahmad I (2012). Forage corn yield and physiological indices under different plant densities and tillage systems. J Food Agric and Environ. 10(3&4): 707-712.

Baver LD, Gardner WH, and Gardner WR (1972). The thermal regime of soils. In 'Soil physics'. New York, John Wiley. pp 253-280.

Boomsma CR, Santini JB, West TD, Brewer JC, McIntyre LM, and Vyn TJ (2010). Maize grain yield responses to plant height variability resulting from crop rotation and tillage system in long-term experiment. Soil and Tillage Res. 106: 227–240.

Cirilo AG, and Andrade FH (1994). Sowing date and maize productivity: I. Crop growth and dry matter partitioning. Crop Sci 34: 039-1043.

Dalmago GA, Bergamaschi H, Comiran F, Bianchi CAM, Bergonci JI, and Heckler BMM (2004). Soil temperature in maize crops as function of soil tillage systems. Conserv Soil and Water for Society: Sharing Solutions. 13th International Soil Conservation Organization Conference – Brisbane. 20: 761-773.

Dwyer LM, and Stewart DW (1986). Leaf Area Development in Field-Grown Maize, Agro J. 78: 334-343.

Hayhoe HN, Dwyer LM, Stewart DW, White RP, and Culley JBL (1996). Tillage, hybrid and thermal factors in corn establishment in cool soils. Soil Till Res. 40: 39-54.

Imholte AA, and Carte PR (1987). Planting date and tillage effects on corn. Agro J. 79: 746-751.

Imsande J (1989). Rapid dinitrogen fixation during soybean pod fill enhances net photosynthetic output and seed yield: A new perspective Agro J. 81: 549–556.

Kresovic B, Vasic C, Tolimikr M, and Pajic Z (1997). Growing of sweet corn as second or stubble crop J of Sci Agri Res. 58: 23-30.

Kucharik CJ (2006). A multidecadal trend of earlier maize (*Zea mays* L.) planting in the central USA. Agro J. 98: 1544-1550.

Lizaso JI, Batchelor WD, Westgate MF, and Echarte L (2003). Enhancing the ability of CERES-Maize to compute light capture. Agric Syst. 76: 293-311.

Moosavi SG, Seghatoleslami MJ, and Moazeni A (2012). Effect of planting date and plant density on morphological traits, LAI and forage corn (Sc. 370) yield in second cultivation. Inter Res J Applied Basic Sci. 3(1): 57-63.

Morin CD, and Dormancy H (1993). Limits of a simple model to predict yield losses in maize. Weed Res. 33: 248-261.

Nafziger ED (1994). Maize (*Zea mays* L.) planting date and plant population. J Prod Agric 759-762.

Noferesti M (2006). Effect planting date on yield and yield components of forage corn as second cultivation in Birjand, Iran region. M.Sc. Thesis on Agriculture, Islamic Azad University, Birjand Branch, Iran, 103 P.

Padersen P, and Lauer J G (2004). Soybean growth and development in various management systems and planting dates. Crop Sci. 44:508–515.

Prasad PVV, Boote KJ, Thomas JMG, Allen Jr L H, and Gorbet DW (2006). Influence of soil temperature on seedling emergence and early growth of peanut cultivars in field conditions. J Agro Crop Sci. 192: 168—177.

Rastegar M (2004). Cultivation of forage crops. Berahmand Publication, pp. 501.

Stone PJ, Sorenson IB, and Jamieson PD (1999). Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool-temperate climate. Field Crops Res. 63: 169-178.

Videnović Ž, Simić M, Srdić J, and umanović Z (2011). Long term effects of different soil tillage systems on maize (Zea mays L.) yields. Plant Soil Environ. 57(4): 186–192.

Wilson DR, Johnstone JV, and Salinger M J (1994). Maize production potential and climatic risk in the South Island of New Zealand. New Zealand J Crop Hort Sci. 22: 321-334.

Yusuf RI, Siemens JC, and Bullock DG (1999). Growth analysis of soybean under no-tillage and conventional tillage systems. Agro J. 91: 928–933.