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Effects of different tillage systems and plant densities in corn silage yield

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In order to investigate tillage systems and plant densities effects on corn (*Zea mays L.cv.sc704*) silage yield and component after harvesting wheat, an experiment was carried out in randomized complete block design in a strip plot. Treatments were arranged with four replications in Agricultural and Natural Resources Research Center Station of Dashte-Naz in Mazandran, Iran, for two years in 2012 and 2013. Tillage systems had three levels: 1. Plow and Disk system (PDS). 2. Disk system (DS). 3. No tillage (NT). Other factor was plant density in four levels (70000, 80000, 90000 and 100000 plant/ha). The results indicated that most silage yield (55.62 ton ha^{-1}) was obtained from Plow and Disk system (PDS) in density of 70000 plants/ha, that had no significant difference effects in comparison with No tillage system (NT) in density of 90000 plants ha^{-1} with silage yield of 53.39 ton ha^{-1}. The results also indicated that most dry forage yield (18.09 tons ha^{-1}) was obtained from Disk system (PDS) in density of 70000 plants ha^{-1} that had no significant difference effects in comparison to No tillage system (NT) in density of 90000 plants ha^{-1} with silage yield of 17.99 ton ha^{-1}. According to results, best treatment was No tillage system (NT) in density of 90000 plants ha^{-1}.

Key words: Corn, plant density, silage yeild, tillage system.

INTRODUCTION

Conservation tillage systems can be an important part of a sustainable agricultural system, in that they can be used to decrease soil erosion losses ordinarily associated with typical conventional agricultural practices. It is important to remember that anything that is done to decrease erosion losses also decreases need to add as much fertilizer and water soils, given that top soil generally contains most organic matter. Conservation tillage also, ideally, decreases water pollution (via decreasing soil erosion), saves fossil fuel energy and thus decreases CO_2 emissions, compared to conventional tillage systems. Because soil organic matter tends to increase under conservation tillage, as compared to conventional plowing, soils are also more effective to carbon storing.

Conservation tillage systems include a variety of techniques, including "no-till" "minimum till" "ridge till" "chisel plow" and "mulch till". The Soil Conservation Service (now called the Natural Resources Service) refers to these systems as "residue management". Conservation tillage is basically, any system of cultivation that reduces soil or water loss when compared to conventional moldboard plowing, which turns over the soil completely. Most definitions specify that at least 30% of the crop residue must remain on the soil surface at the time of planting. It was designed to conserve soil, water, energy,

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and protect water quality (Mitchel et al., 2015). Soil compaction can cause unfavorable soil physical, chemical and microorganism conditions in subsoil, which hinder root growth and crop yield (Mosaddeghi et al., 2009).

According to survey results from Conservation Technology Information Center (CTIC) (Sare, 2014), most operations in Midwest that use a cover cropping system do so in tandem with no-till practices or organic production, to help mitigate potential negative effects with these particular systems in comparison with traditional tillage or non-organic methods, respectively. Soil tillage also modifies mineralization rates of nutrients, which feeds back on soil carbon input (Barré et al., 2010). No-till is a growing practice for soil conservation (Horowitz et al., 2010).

Soil compaction had negative effect on soybean production (Acuña and Villamil, 2014). Penetration of plant roots through compacted soils is difficult (Chen and Weil, 2010). Corn (*Zea mays* L.) silage production is very important in winter in north of Iran that producer need to forage, but deceasing temperature and solar energy in delay sowing date resulting in low silage yield because farmers used from common plant density, row spacing and plant pattern.

Corn (*Z. mays* L.) is the most important grain-forage crop in Iran. The average grain yield of corn is more than 8 t/ha and it increase annually. In order to optimize moisture use, nutrients and solar radiation and corn seeds must be plant under optimum density and tillage system. Intensive production of field crops practiced until recently to achieve high yields required intensive tillage and application of other high-technology inputs. This concept, however, implies a number of problems, among which relationship between product quality and quantity are in the foreground, along with increase crop production, which shows an important ecological sustainability. Above all, farmers approach production in terms of cost effectiveness of applied system (Kisic et al., 2010).

Use of agricultural mechanization was considered the main factor contributing to total energy inputs in agricultural system. Tillage represents half of operations carried out annually in field. Consequently, there is a potential to reduce energy inputs and production costs by reducing tillage (Ozturk et al., 2006). Since land preparation for double-cropping systems requires timeliness, especially when a moldboard plow is used, reduced tillage, mainly NT systems, are becoming widespread.

Beneficial effects of the crop residue maintenance on soil surface include a reduction of soil erosion and runoff, an increase soil water conservation and soil aggregation, and a less use of fossil fuel is not direct effect of crop residue management (Nakamoto et al., 2006).

In order to combat soil loss and preserve soil moisture, a more attention has been focus on conservative tillage involving soil management practices that minimize disruption of soil structure (Samarajeewa et al., 2006). Soil compaction of agricultural soils is a global well recognized problem (Hamza and Anderson, 2005) due to deteriorated soil environment and adverse effects of intensive use of farm machinery on crop yield (Hamza et al., 2011). In China, subsoil compaction was also cause by inappropriate tillage, traffic and field operations on poor time (Zhang et al., 2006). Tillage is one of most effective ways to reduce soil compaction (Daniells, 2012).

Therefore, with selection of desired plant density, appropriate yield can be produced. Corn is among crops least tolerant to high plant population density. Roekel and Coulter (2011) determined a close relationship between maize yield and plant density. The studied hybrid produced maximal yield by a plant density of 81700 plants ha^{-1} or even higher.

On basis of their research, Berzsenyi and Lap (2005) have found that optimal plant density varied between 67483 and 70161 plants ha^{-1} regarding the average of the involved hybrids. Total dry matter increases from 6 to 40% when plant density increases from about 79000 to 165000 plants ha^{-1} in some studies (Turgut et al., 2005; Yilmaz et al., 2007).

According to Pepó and Sárvári (2013), maize is a plant with individual productivity; therefore, plant density determines yield significantly. This experiment was conduct to determine best plant density and tillage system in North of Iran.

MATERIALS AND METHODS

The study was conduct at Agricultural and Natural Resources Research Center Station of Dashte-Naz in MazandranIran for two years 2012-2013 (36°37' N, 53°11' E). The weather in this zone had an average temperature of 24.46°C per month. Receives average rainfall of 231.1 mm from May through October for two years. Weather condition in the experiment site are summarized (Tables 1 and 2).

The soil type was classified as clay loam, with pH 7.2. This experiment was laid out in strip-plot on randomized completely block design basis with four replications. Tillage systems were in three levels: 1. Plow and Disc system (PDS). 2. Disk system (DS) - 3. No tillage (NT). Another factor was plant density in four levels (70000, 80000, 90000 and 100000 plants ha^{-1}).

The previous crop at site was wheat. NPK fertilizers were applied according to yield potentials and soil test levels. N P K (200-100-100) fertilizer used was applied as urea, triple super phosphate and potassium sulfate according to soil test. Hand weeding was used to control weeds. Plants from each plot were harvested in an area of 9 m^2. Cultivar corn was a single cross hybrid (*Z. mays* L. cv. single cross 704) that was popular among growers in Iran. Ear height, plant height, ear length, row number, kernel number in row, ear diameter, wet and dry silage yield, wet and dry ear weight, wet and dry stem weight, wet and dry leaf weight were measured. The site was irrigated with water using a sprinkler irrigation system. Plants were cut at surface from central of four middle rows in plots (area of9 m^2).

Data were analyzed using the MSTAT-C procedure to develop the ANOVA for a split-split plot design. The Duncan's Multiple Range Test (DMRT) procedure was applied to make tests of simple and interaction effects by MSTAT-C, all differences reported are significant at P 0.05 unless otherwise stated.

Table 1. Weather condition in experiment site during corn growth stages (2012).

Variable	May	June	July	August	September	October
Minimum temp. (°C)	13.2	18.7	21.2	21.4	21.4	16.5
Maximum temp. (°C)	24.6	29.1	31.7	30.3	31.1	26.7
Evaporation (mm)	134.9	166.4	217.3	133.4	122.2	101.1
Precipitation (mm)	24.1	7.5	0	7.3	10.8	205.9

Table 2. Weather condition in experiment site during corn growth stages (2013).

Variable	May	June	July	August	September	October
Minimum temp. (°C)	15.7	20	23.1	22.5	22.8	15.2
Maximum temp. (°C)	27.2	30.8	31.8	33.8	32.4	26.0
Evaporation (mm)	151.7	165.2	183.8	208.5	158.2	93.2
Precipitation (mm)	4.4	136.1	5.2	8.8	1.2	50.9

Table 3. Means comparison of some traits of corn in three years.

Treatment	Dry forage yield (ton/h)	Dry stem weight (ton ha^{-1})	Dry ear weight (ton ha^{-1})	Dry leaf weight (ton ha^{-1})	Silage yield (ton ha^{-1})	Wet stem weight (ton ha^{-1})	Wet ear weight (ton ha^{-1})	Wet leaf weight (ton ha^{-1})
Tillage system								
Plow and Disck	17.02[a]	7.11[a]	2.06[a]	7.85[a]	52.40[a]	22.23[a]	21.23[a]	8.94[a]
Disck	16.31[a]	6.50[ab]	2.12[a]	7.69[a]	50.13[a]	20.27[ab]	20.71[a]	9.16[a]
No tillage	15.50[a]	6.30[b]	1.92[a]	7.34[a]	47.23[a]	19.30[b]	19.60[a]	8.32[a]
Density plant/ha								
70000	16.35[b]	6.56[b]	2.08[ab]	7.70[ab]	50.39[b]	20.51[b]	20.82[ab]	9.06[ab]
80000	15.33[b]	6.31[b]	1.89[b]	7.12[b]	47.20[b]	19.72[b]	19.25[b]	8.24[b]
90000	17.77[a]	7.32[a]	2.18[a]	8.26[a]	53.88[a]	22.52[a]	21.94[a]	9.42[a]
100000	15.66[b]	6.29[b]	1.96[ab]	7.14[ab]	48.21[b]	19.66[b]	20.04[ab]	8.51[ab]

Treatment	Ear height (cm)	Plant height (cm)	Ear length (cm)	Row number	Kernel number in row	Ear diameter (cm)
Tillage system						
Plow and Disk	87.31[a]	193.3[a]	17.59[a]	13.66[a]	27.04[a]	4.268[a]
Disk	89.21[a]	195.9[a]	17.80[a]	13.52[a]	25.52[a]	4.35[a]
No tillage	85.63[a]	193.7[a]	17.13[a]	13.54[a]	26.76[a]	4.29[a]
Density plant ha^{-1}						
70000	87.70[a]	194.6[a]	18.67[a]	13.63[a]	27.33[a]	4.341[a]
80000	85.28[a]	191.1[a]	16.85[b]	13.42[a]	25.91[a]	4.246[a]
90000	86.26[a]	195.6[a]	17.34[b]	13.69[a]	26.63[a]	4.305[a]
100000	90.29[a]	196.0[a]	17.17[b]	13.57[a]	25.90[a]	4.330[a]

Different letters in each column shows significant difference at 5% probability.

RESULTS AND DISCUSSION

Tillage system

Tillage system had significant effect on dry and wet stem weight at 0.05 probability level (Table 3). The highest dry stem weight was obtained in plow and disk (PDS) system with 7.11 tons ha^{-1}. Dry stem weight (6.50 tons ha^{-1}) in disk system (DS) had no significant difference with No-tillage system (NTS) with 6.30 t/ha (Table 3). Highest dry

Table 4. Means comparison of interaction of some traits of corn in two years.

Treatment Tillage systemX Density (plant ha^{-1})	Silage yield (ton ha^{-1})	Dry forage yield (ton ha^{-1})
Plow and Disk X70000	55.62^{a}	18.09^{a}
Plow and Disk X80000	48.88^{bcd}	15.92^{bc}
Plow and Disk X90000	54.38^{ab}	17.65^{ab}
Plow and Disk X100000	50.70^{abcd}	16.44^{abc}
Disk X70000	50.65^{abcd}	16.44^{abc}
Disk X80000	47.35^{cd}	15.30^{c}
Disk X90000	53.86^{ab}	17.68^{ab}
Disk X100000	48.67^{bcd}	15.81^{bc}
No tillage X70000	44.90^{d}	14.53^{c}
No tillage X80000	45.37^{d}	14.75^{c}
No tillage X90000	53.39^{abc}	17.99^{a}
No tillage X100000	45.25^{d}	14.75^{c}

Different letters in each column shows significant difference at 5% probability.

forage yield (17.02 tons ha^{-1}) was obtained in plow and disk (PDS) system with 17.02 tons ha^{-1} that had no significant difference with disk and No-tillage system with 16.31 and 15.50 tons ha^{-1} respectively (Table 3). The highest silage yield (52.40) was obtained in plow and disk (PDS) that had no significant difference with disk and No-tillage system with 50.13 and 47.23 tons ha^{-1}t/ha respectively (Table 3).

Plant density

Plant density had significant effect on dry forage yield, dry stem weight, dry ear weight, dry leaf weight, silage yield, stem yield, ear and leaf yield at 0.05 probability levels (Table 3).

The highest dry forage yield (17.77 tons ha^{-1}) and silage yield (53.88 tons ha^{-1}) were produced in 90000 plants ha^{-1}. Plant density had no significant difference in 70000, 80000 and 100000 densities on dry forage yield and silage yield (Table 3). With an increase of density from 70000 to 80000 plants ha^{-1}, ear length decreased. The highest dry stem (7.32 t/ha), dry ear (2.18 t/ha) and dry leaf (8.26 tons ha^{-1}) yield were obtained from the density of 90000 plants ha^{-1} (Table 3).

High silage yield (53.88 tons ha^{-1}) was achieved from ear (21.94 tons ha^{-1}), stem (22.52 tons ha^{-1}) and leaf (9.42 tons ha^{-1}) fresh weight had significant difference in ear, stem and leaf fresh weight. The effect of plant density had significant difference for silage yield (Table 3).

Shakarami and Partners (2009), in investigating three plant densities (7, 10 and 13 plants m^{2}) of corn recognized that highest grain yield, harvest index, number of grain row and number of grain ear was produced in 10 plant m^{2} and the highest biological yield obtained from 13 plant m^{2}. Kisic et al. (2010), in the study of crop yield and plant density under different tillage systems found that the plant density and yields of maize, soybean, oilseed rape, winter wheat and spring barley point to the conclusion that high density crop (winter wheat, spring barley and oilseed rape) are suitable for growing under reduced tillage systems. Yield of low-density spring crops (maize and soybean) obtained under no tillage system are not satisfactory, especially in climatically extreme years.

Interaction between tillage system and plant density

The results indicated that most silage yield (55.62 tons ha^{-1}) was obtained from Plow and Disc system (PDS) in density of 70000 plants ha^{-1} that had no significant difference effects with No tillage system (NT) in density of 90000 plants ha^{-1} with silageyield of 53.39 tons ha^{-1}. The results also indicated that the most dry forage yield (18.09 tons ha^{-1}) was obtained from Disck system (PDS) in density of 70000 plants ha^{-1} that had not significant difference effects with No tillage system (NT) in density of 90000 plants ha^{-1} with silage yield of 17.99 tons ha^{-1} (Table 4).

Conflict of Interests

The authors have not declared any conflict of interests.

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