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THE INFLUENCE OF PRE-PLANT TREATMENTS ON SILAGE MAIZE (*Zea mays* L.) YIELD IN NO-TILLAGE SYSTEM

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ABSTRACT

No-tillage agricultural practices and pre-plant applications in agricultural systems have become quite common in recent years. In this study, the effect was examined of pre-plant applications on agronomic characteristics and yield in silage maize cultivation under no-tillage conditions. Plants of the forage legumes (common vetch, narbon vetch and fodder pea) and cereals (barley, triticale and annual ryegrass) were used as pre-plants materials and the values of plant height, green herbage yield, dry matter ratio, dry matter yield, leaf/stem ratio, peak tasselling time and core tasselling time were determined in silage maize. The data obtained demonstrated, that the green herbage yield and dry matter yield of maize was higher when the forage legume plants were used as pre-plants. Among the legumes, common vetch increased maize green herbage yield and dry matter yield more than other plants. On contrast, plants of the in cereals family caused a decrease in the maize yield. It was concluded that legume plants should be selected as pre-plant in no-tillage silage maize cultivation. Good results were obtained especially from common vetch, and the use of cereals as pre-plant had a negative effect on the maize for silage grown subsequently.

Key words: Cereals, legumes, maize, plant residue, stubble sowing.

INTRODUCTION

Soil cultivation is defined as mechanical application to the soil for the production of plants which has significant effects on soil properties such as soil water conservation, soil temperature, infiltration and evaporation (Busari et al., 2015). A good seed bed is prepared with conventional soil tillage systems and ensures the removal of many plant residues from the production area (Briones and Schmidt, 2017). However, conventional tillage systems have significant problems such as heavy machinery traffic, soil compaction and environmental pollution due to carbon emissions from fuel use (Bertolino et al., 2010; Krauss et al., 2010; Shahzad et al., 2016; Priya et al., 2019; Neugschwandtner et al., 2020).

Conservation soil tillage practices (such as reduced tillage and no tillage) provide minimum soil damage to conserve the soil water and improve water use efficiency (Wang and Shangguan, 2015). For example, no-tillage agriculture systems can increase water infiltration and reduce evaporation, thereby providing more soil water protection (Ranaivoson et al., 2019). Studies have shown that tillage technologies such as no tillage and reduced tillage can affect water use efficiency and reduce evapotranspiration in maize (Guo et al., 2019) and wheat (Liu et al., 2020). In other studies, the lint yield in cotton (DeLauna et al., 2020), nitrogen efficiency in soybean (Roy et al., 2019) and grain yield in maize (Ramos et al., 2019) have been shown to be affected by conservation tillage methods. However, reduced tillage becomes meaningful if it provides cost reduction without causing a decrease in yield (Faligowska and Szukala, 2015).

Another important agronomical practice in agricultural production is crop rotation and crop residues are of great importance in crop rotation systems. Mixing the organic crop residues from agricultural products into the soil both improves the physical properties of the soil and increases the organic matter and plant nutrients (Carranca, 2013; Kirkby et al., 2014; Langeroodi, 2015; Ebrahimian et al., 2016). Crop residues play an important role in facilitating the infiltration of rainwater into the soil and reducing evaporation from the soil, increasing the water holding capacity in production areas where irrigation is not provided and the need for water is met by rainwater alone (Verberg et al., 2012). In addition, plant residues (especially legume residues) positively affect soil bulk density, which is an important feature for soil functions (Singh et al., 2011; Nasta et al., 2020; Musa et al., 2020). Low soil mass density provides a good production environment for plants (Wang et al., 2016; Pan et al., 2017; Kool et al., 2019).

The aim of this study was to evaluate the effect of different pre-plant applications on the yield traits of maize plant in no-tillage conditions.

MATERIALS AND METHODS

The study was conducted in the research and application field of Akdeniz University Faculty of Agriculture, Department of Field Crops (36° 54′ N, 30° 38′ E) as a 2-year study in the 2016 and 2017 growing periods. The monthly average air temperature and total precipitation values of the research site are given in Table 1 (Anonymous, 2020). The research area soil has clay-loam texture, is slightly salty, high in lime and strongly alkaline. The soil has low organic matter and absorbable phosphorus and potassium content.

Table 1. Temperature and precipitation values of the study area in Antalya province

	Temperature (°C)			**Precipitation (mm)**		
	2015-2016	**2016-2017**	**Long term** (1930-2020)	**2015-2016**	**2016-2017**	**Long term** (1930-2020)
November	18.4	17.5	15.5	116.9	99.2	131.6
December	13.2	11.2	11.6	0.4	76.3	262.1
January	10.6	10.2	10.0	79.4	132.8	232.6
February	14.6	12.5	10.7	66.7	4.4	153.5
March	15.3	15.0	12.9	57.2	166.9	94.5
April	19.1	17.7	16.4	14.4	54.0	49.9
May	20.4	21.3	20.6	28.2	42.2	32.1
June	26.9	26.3	25.3	24.3	3.4	10.8
July	29.9	30.4	28.5	0.6	0.4	4.5
August	29.5	29.0	28.4	0.0	1.6	4.6

The experiment was performed with 3 replications according to the Randomized Complete Blocks Design (RCBD). Maize (*Zea mays* L. ‘Kilowatt’ (FAO 700)) was used as the main material. Plants from the legume family such as common vetch (*Vicia sativa* L. ‘Gulhan 2005’), narbon vetch **(***Vicia narbonensis* L. ‘Balkan’) and fodder pea (*Pisum arvense* L. ‘Tore’), and from the cereal family such as barley (*Hordeum vulgare* ‘Sladoran’), triticale (*xTriticosecale Wittmack* ‘Karma 2000’) and annual ryegrass (*Lolium multiflorum* ‘Trinova’) were used as pre-plant material.

Traditional soil tillage practices were applied while sowing the pre-plants. Fertilization (for legumes: 50 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5, for cereals: 100 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5) was applied before sowing these plants. All plants except annual ryegrass were planted on the same date, and annual ryegrass, which is a multiple cuts plant, was planted 2 weeks earlier in order to equalize the date of the second cutting with other plants. When the plants came to the shape period for green herbage, they were cut with a sickle at a height of 5 cm. In order to be able to sow the maize plant, which was the main subject of the study, on the same date in all applications the cutting time of some pre-plants was delayed.

Maize sowing was carried out after the pre-plants were cut. Seeds were sown on the 3rd of May in the first year and the 5th of May in the second year. The maize was sown directly into the stubble with no tillage applied. Rows were opened using a pickaxe, to imitate the direct seed drill, with 70 cm row spacing. Seeds were sown with 3-5 cm in-row spacing and thinned to 12 cm in-row spacing after emergence. At the time of sowing, for 100 kg ha^{-1} of nitrogen, phosphorus and potassium elements, 15*15*15 fertilizer was applied to the plots, and when the plants were 30-40 cm, 100 kg ha^{-1} nitrogen was applied with 33% ammonium nitrate fertilizer for upper fertilization.

During the trial, irrigation was applied as necessary, and weed removal was done manually without the use of herbicides. No other process was applied except these process. The peak tasselling time (day) and core tasselling time (day) were recorded during the growing season.

When the cobs reached the dough maturation period, the harvesting process was started. Plant height (cm) was measured in 10 plants from each parcel before the harvest. During the harvest, 1 row was removed from the edges of the parcels and 25 cm from the beginning and end of each row. The harvested plants were weighed and the parcel yield was calculated, and using the obtained value, green herbage yield (t ha^{-1}) was determined. In addition, 200 g samples were taken for each parcel and dried in a drying oven at 75 ° C for 48 hours (Shirvanian et al., 2004). The dry matter ratios (%) were determined, and dry matter yield (t ha^{-1}) was calculated using dry matter ratios and green herbage yield. In addition, the leaves and stems of 10 of the harvested plants were separated and the leaf / stem ratio per plant was determined (Yildiz and Erdogan, 2018).

Statistical analysis of the obtained data was made using the SAS statistics program and DUNCAN multiple comparison test was applied to the averages (Oten, 2017).

RESULTS

When the two-year results obtained from the study were compared in terms of legumes and cereals, it was seen that the applications had statistically significant effects on all characteristics except plant height and leaf / stem ratio (Table 2). When the green herbage yield values are evaluated, 45.14 t ha^{-1} of yield was obtained from legume applications and 40.18 t ha^{-1} from cereal applications. In terms of dry matter ratio and dry matter yield, the highest values were obtained with 33.79% and 15.34 t ha^{-1}, respectively, from legume applications, while the same values were determined as 32.00% and 12.97 t ha^{-1} in cereal applications. Higher values were recorded for legume applications then cereal applications in respect of the features of peak tasselling (64 vs 67 days) and core tasselling days (68 vs 70 days). Although the applications had an effect on plant height and leaf / stem ratios, these effects were not significant statistically.

Table 2. Agronomical characteristics of maize grown after legumes and cereals in the field trial run in 2016 and 2017 (means of two years)

	Green Herbage Yield (t ha^{-1})	Plant Height (cm)	Dry Matter Ratio (%)	Dry Matter Yield (t ha^{-1})	Leaf/ Stem Ratio	Peak Tasseling Time (days)	Core Tasseling Time (days)
Legumes	45.14 A	261 A	33.79 A	15.34 A	0.37 A	64 B	68 B
Cereals	40.18 B	257 A	32.00 B	12.97 B	0.36 A	67 A	70 A
F	7.72*	2.19	7.16*	9.94**	1.17	34.70**	13.21**
LSD ($p<0.05$)	3.85	5.28	1.80	1.80	0.02	0.97	0.85

F: * significant at the $p<0.05$ levels of probability, F: ** significant at the $p<0.01$ levels of probability
LSD: means with different letters indicates significant differences

When the legume plants were evaluated, it was determined that the pre-plant applications had statistically significant effects on all traits except plant height and core tasselling time (Table 3). While the maize green herbage yield values varied between 38.65 t ha^{-1} and 49.98 t ha^{-1}, the highest yield was obtained from parcels where common vetch was grown as pre-plant. The differences between plant heights according to the applications were not found to be statistically significant. Dry matter ratios varied between 30.23 and 36.13, with the lowest ratio determined for field pea, and the highest value was obtained from the application without pre-plant application, but this value was in the same group with the values obtained from common vetch and narbon vetch. Dry matter yield values were also similar to dry matter ratios. The lowest yield was obtained from the pre-plant application of field pea with 11.68 t ha^{-1}. The highest dry matter yield (17.38 t ha^{-1}) was determined in the common vetch application, but there was no statistical difference between this value and the values obtained from narbon vetch (16.05 t ha^{-1}) and without pre-plant applications (16.23 t ha^{-1}). The highest leaf / stem ratio values were determined as 0.38, 0.38 and 0.37 in common vetch, narbon vetch and fodder pea applications, respectively, but the differences between these values were not statistically significant. The lowest leaf / stem ratio 0.34 was obtained without pre-plant application. A similar situation was observed for peak tasselling time, with common vetch, narbon vetch and fodder pea applications in the same group at 63 days, and the highest value was determined as 67 days without pre-plant application. The core tasselling time, values varied between 68 and 70 days, with no statistical difference between the applications.

Table 3. Agronomical characteristics of maize grown after legumes in the field trial run in 2016 and 2017 (means of two years)

	Green Herbage Yield (t ha^{-1})	Plant Height (cm)	Dry Matter Ratio (%)	Dry Matter Yield (t ha^{-1})	Leaf/ Stem Ratio	Peak Tasselling Time (days)	Core Tasselling Time (days)
Common vetch	49.98 A	265A	34.76 A	17.38 A	0.38 A	63 B	68 A
Narbon vetch	47.13 AB	260A	34.05 A	16.05 A	0.38 A	63 B	68 A
Fodder pea	38.65 B	258A	30.23 B	11.68 B	0.37 A	63 B	68 A
Without pre-plant	44.85 AB	262A	36.13 A	16.23 A	0.34 B	67 A	70 A
F	4.21*	0.45	7.64**	5.89**	8.27**	6.76**	2.88
LSD ($p<0.05$)	5.86	39.49	3.73	3.15	0.03	3.42	2.61

F: * significant at the $p<0.05$ levels of probability, F: ** significant at the $p<0.01$ levels of probability
LSD: means with different letters indicates significant differences

According to the two-year averages, with the exception of peak tasselling time and core tasselling time in cereal pre-plant applications, the pre-plant applications were effective on all properties (Table 4). The green herbage yield of maize varied between 44.85 t ha^{-1} and 34.20 t ha^{-1} and while the highest yield was obtained without pre-planting treatment, the yield decreased in the pre-planted plots and the lowest yield was recorded in plots where annual ryegrass was used as a pre-plant. A similar situation was observed in plant height, with the highest plant height value of 262 cm recorded without pre-planting treatment and the lowest plant height value of 246 cm recorded in the annual ryegrass application. The highest dry matter ratio and dry matter yield values for maize were obtained with 36.23% and 16.23 t ha^{-1}, respectively, in plots without pre-plant, while the lowest values were obtained from annual ryegrass application with 28.74% and 9.85 t ha^{-1} for both properties. While annual ryegrass application gave the highest value of 0.39 leaf / stem ratio, other applications varied between 0.34 and 0.36, but the differences between these applications were not statistically significant. The features of peak tasselling time and core tasselling time were not affected by pre-plant applications

Table 4. Agronomical characteristics of maize grown after cereal crops in the field trial run in 2016 and 2017 (means of two years)

	Green Herbage Yield ($t\ ha^{-1}$)	Plant Height (cm)	Dry Matter Ratio (%)	Dry Matter Yield ($t\ ha^{-1}$)	Leaf/ Stem Ratio	Peak Tasselling Time (days)	Core Tasselling Time (days)
Annual ryegrass	34.20 B	246 B	28.74 B	9.85 B	0.39 A	67 A	70 A
Triticale	38.35 AB	262 A	31.91 AB	12.29 AB	0.36 B	66 A	71 A
Barley	43.33 AB	259 AB	31.23 AB	13.50 AB	0.36 B	67 A	70 A
Without pre-plant	44.85 A	262 A	36.13 A	16.23 A	0.34 B	67 A	70 A
F	4.17*	5.99**	4.49*	5.61**	10.73**	0.39	0.36
LSD ($p<0.05$)	6.79	5.71	3.15	2.61	0.02	2.47	3.16

F: * significant at the $p<0.05$ levels of probability, F: ** significant at the $p<0.01$ levels of probability
LSD: means with different letters indicates significant differences

DISCUSSION

The results obtained from this study, which was carried out to determine suitable pre-planting in maize cultivation in a no-tillage system, demonstrated that selecting legume family plants as the pre-plant provides good results in terms of green herbage yield, dry matter ratio, dry matter yield, peak tasselling time and core tasselling time

In conditions where nitrogen is limited, plants of the legume family have the ability to perform atmospheric nitrogen fixation through Rhizobium bacteria in their roots, and this is of great importance in legume-based production systems. Although there are variations according to species, legumes have a nitrogen fixation potential of between 100 and 300 kg ha^{-1} from the atmosphere. (Sun et al., 2008; Dwivedi et al., 2015; Dhanushkodi et al., 2018). Large quantities of mineral N can be released when legume residues are converted largely by nitrification and denitrification (Sant'Anna et al., 2018). Thus, for plants grown subsequently legume plants, may provide more mineral N than cereal residues due to their relatively high N content. In addition, the nitrogen element becomes more immobilized during the decomposition of cereal plant residues compared to the decomposition of legume plant residues, thus decreasing its usefulness (Hayat et al., 2008).

The roots of legume plants provide a high percentage of organic matter to the soil (Miheguli et al., 2018). Increasing organic matter improves many properties of the soil and facilitates the intake of nutrients. Another advantage of legume residues is that they have a lower C:N ratio than cereal residues (Palm et al., 2001; Lynch et al., 2016). In the C:N ratio, cellulose and lignin content are among the most important factors affecting mineralization of plant residues. A high C:N ratio usually leads to immobilization. In cases where the C: N ratio is high (> 25), nitrogen is immobilized by microorganisms during the decomposition of organic matter or is mineralized into the soil as ammoniacal nitrogen (Talgre et al., 2017). Decomposition is very slow in plant residues with high C:N, Lignin: N and polyphenol: N ratios (Lupwayi et al., 2011).

Plants grown after legumes can use 10% to 20% of the N amount in legume residues, and this ratio decreases to less than 10% in non-legume plant residues (Fillery, 2001). This contributes to the good nutrition of the plants grown after the pre-plant, especially during the seedling period, the formation of healthy seedlings and ultimately the increase in yield. In a study by Adeleke and Haruna (2012) the nitrogen content in the upper part of the soil was determined to increase by 250% in the lablab area, 200% in the peanut area, 170% in the feed pea field and 107% in the soybean area before maize planting. Arif et al. (2011), reported that chickpea cultivation, before maize, provided significant increases in maize yield compared to wheat cultivation. A similar result was found by Rajkumara et al. (2014) who stated that the application of 5 t ha^{-1} chickpea crop residue in no-tillage farming condition resulted in an increased maize yield. Amusan et al. (2011) reported that soybean residues found in the maize production area increased the maize yield by 7%. Singh et al. (2011) reported that legume residues in legume-wheat production systems caused an increase of 156% in the amount of soil microbial biomass carbon compared to the areas without residue. Gul et al. (2008) reported that legumes pre-planting is very good for maize, both increasing the dry matter yield of maize and reducing the nitrogen need of maize. Videnovic et al. (2013) determined that soybean, grown as a pre-plant, had a greater positive effect on maize grain yield compared to winter wheat.

In that study, when the legume plants were evaluated, while higher green herbage yield, dry matter ratio and dry matter yield values were obtained from common vetch, narbon vetch and without pre-plant application, lower values were recorded in fodder pea. Ozyazici and Manga (2000) used some legume plants, including common vetch, narbon vetch and fodder pea, as green manure plants, and when these three plants were compared in terms of maize green herbage yield, the highest yield was determined in the common vetch and narbon vetch plant treatments, and the lowest yield value was recorded in fodder pea treatment. In the same study, the dry matter yield from large to small was recorded in narbon vetch, common vetch and fodder pea, respectively. In another study, Kavut and Geren (2015) reported that the use of common vetch as a pre-plant in maize cultivation provided higher green herbage yield compared to fodder peas. Kalkan and Avci (2020) used narbon vetch, Hungarian vetch and fodder pea plants as pre-plants in maize cultivation and determined that the maize green herbage yield was higher in the narbon vetch applications compared to the fodder peas. Idikut and Kara (2011) used vetch and wheat plants as pre-plants in maize cultivation and reported that higher protein ratio and grain yields were obtained in maize grown after the vetch plant pre-planting. The findings of the current study are similar to these literature results.

Generally, the nitrogen contribution is expected to be higher in vetch species than in fodder peas. This is because in fodder peas, some of the nitrogen accumulates in the grains and leaves the system, but in the small grain vetches, nitrogen is added to the soil by remaining in the plant residues (Enrico et al., 2020). Sidaris et al. (1999) grew common vetch using different tillage methods and found that the nitrogen accumulation of the above-ground organs varied between 54.3 and 109.0 kg ha^{-1}, and that the same values varied between 73.3 and 173.3 kg ha^{-1} in the root. Ntatsi et al. (2019) reported biological nitrogen fixation of 45-125 kg ha^{-1} in peas, and also Cuttle et al. (2003) reported that although nitrogen fixation in peas ranged from 215 to 246 kg ha^{-1}, most of this was lost with the grain and the net gain of nitrogen was 106 kg ha^{-1}. These data show that vetch species provide more nitrogen to the soil for the next plant than peas.

When the cereals were evaluated, it was seen that the application without pre-planting positively affected the maize yield compared to the treatment where cereals were grown. Due to their high C:N ratio, cereals can inhibit the mobility of soil N, reduce the availability of N, and adversely affect the growth and yield of subsequent crops (Schomberg et al., 2004). Loomis et al. (2020) reported that the C:N ratio of barley varies between 54:1 and 80:1 depending on the growing conditions and location. Since the plants not included in the legume family have low N content and high C:N ratios, they have little or no positive effect on the crops grown after them, and may sometimes even have negative effects (Kramberger et al., 2009). This explains the yield decreases in the parcel where the cereal plants were used as pre-planting in the current study.

CONCLUSION

The results of this study demonstrated that pre-plant applications in maize cultivation under no-tillage conditions are effective on yield and some other agronomic characteristics. Especially when legume plants were used as pre-plants, higher yields were obtained compared to cereal pre-planting. In the evaluation of forage legumes, higher values were determined especially in terms of yield in the plots where common vetch was used as the pre-plant. When the results obtained from cereals were evaluated, pre-plant applications caused a decrease in yields, and higher yields were recorded in plots without pre-planting. It was concluded from the findings of this study that forage legumes should be preferred as the pre-plant in maize cultivation, common vetch in particular provides a significant increase in yield and the use of cereals as pre-plants causes a decrease especially in green herbage yield and dry matter yield. However, barley gave better results compared to triticale and annual ryegrass. Therefore, in regions where legumes cannot be cultivated it would be appropriate to use barley as a pre-plant.

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