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THE IMPACT OF BARLEY RESIDUE MANAGEMENT AND TILLAGE ON FORAGE MAIZE

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ABSTRACT

In order to determine the influence of tillage and residue management on yield, protein and nitrate of maize (cv. SC 704) in climatic condition of Esfahan, Iran, an experiment was conducted at research farm, faculty of agriculture, Islamic Azad University, Esfahan (Khorasgan) branch in 2009 and 2010. Three factors randomized complete block design with Split-split plot combined over years was used to determine the influence of plant density and nitrogen on forage and seed yield of maize. The main plots were years, 2009 and 2010. The subplots were different kinds of tillage system, namely disk harrow, tooth harrow and moldboard, and Split-subplots were consist of 100% burning of barely residues, 50% burning of barley residues, 100% residue retention and 50% residue retention. The experimental field was under cultivation of barley. In this experiment the highest final plant height, stem diameter, LAI, total fresh yield, leaf dry weight, stem dry weight, ear dry weight, and total dry yield were recorded in 2009, while the maximum protein percentage was achieved in 2010. The higher values of total fresh yield, ear dry weight and total dry weight was recorded with disk harrow, as compared to those of other treatments; however, the maximum protein percentage was achieved by using of moldboard. The highest final plant height, LAI, total fresh yield, leaf dry weight, stem dry weight and total dry yield were obtained by 100% burning, however, the maximum protein percentage was related to 50% residue retention. Moreover, the values of fresh forage yield and dry forage yield were appropriate in 50% reside retention. Retaining crop residues can warrant improvements in the sustainability in crop productivity. Using tooth harrow followed by residue retention in maize cropping after barley, was recommended to farmers in climatic condition of Isfahan.

Key words: Conservation agriculture, barley residue management, tillage, forage maize.

INTRODUCTION

Tillage, post-harvest residue burning and crop rotation are traditional agriculture management practices affecting the soil environment, nutrient cycling, microbial community composition and soil structure (Wang et al., 2010; Munkholm et al., 2013). Maize (*Zea mays*) is widely cultivated for both forage and grain throughout the world, being one of the most important crops that plays a great role in human nutrition (Khayatnezhad et al., 2011; Panhwar et al., 2011; Ali et al., 2012; Cui et al., 2012). Goncalves et al. (2007) reported that the different residue management treatments resulted in pronounced effects on growth of crops. The intensive tillage practices employing inversion implements such as mould board plough result in loss of surface crop residue and subsequent loss of soil organic carbon (SOC) from soil aggregates. The adoption of conservation tillage systems has been encouraged to preserve soil and water and of course crop response of cereal production (Blanco-Moure et al., 2012). Long-term biomass removal resulted in reduced total biomass yields over time due to nutrient depletion, as reflected by increased nitrogen stress days on subsequent crops (Meki et al., 2013). Erenstein (2011) illustrated that retention of crop residues is generally considered advantageous because it recycles both organic matter and nutrients back to the soil. Burning residues facilitates seeding, reduces crop disease infestation and improves weed control (Wang et al., 2010). Residue burning, however, causes considerable loss of organic C, N and other nutrients by volatilization (Malhi and Kutcher, 2007), which may detrimentally affect soil microorganisms (Razafimbelo et al., 2006).

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Unlike European regions, the USA, Canada and Australia, the influence of different tillage systems and crop residue management under semi-arid region in center of Iran have been scarcely studied. It is necessary to quantify the widespread impacts of tillage and burning, to encourage well-informed management decisions that will guide the future of sustainable agriculture and crop production in semi-arid regions.

MATERIAL AND METHODS

In order to determine the influence of tillage and residue management on yield, protein and nitrate of maize (cv. SC 704) in climatic condition of Esfahan, Iran, an experiment was conducted at research farm, faculty of agriculture, Islamic Azad University, Khorasgan branch in 2009 and 2010 (Latitude 32° 40′ N, longitude 51° 58′ E, and 1570 m elevation). Long term average precipitation was 150 mm and this area is semi arid. Soil analysis was done before beginning of study at two depths in 2009 (0-30 cm and 30-60 cm). Electrical conductivity of soil at 0-30 and 30-60 cm was 1.7 and 1.6 ds m^{-1}, respectively (Table 1).

Three factors randomized complete block design with split-split plot combined over years was used to determine the influence of tillage and residue management on forage yield, protein and nitrate of maize. The main plots were years, 2009 and 2010. The subplots were different kinds of tillage system, namely disk harrow, tooth harrow and moldboard, and split-subplots consisted of 100% burning of barely residues, 50% burning of barley residues, 100% residue retention and 50% residue retention.

Table 1. Soil analysis of agriculture research field in Esfahan (0-30 cm and 30-60 cm)

Depth (cm)	EC ds m^{-1}	pH	OC %	N %	P ppm available	K ppm available	T.N.V %	Soil texture
0-30	1.7	8.00	0.94	0.09	28	359	38	Si.Cl
30-60	1.6	8.00	0.98	0.10	29.3	362	38	Si.Cl

The experimental field was previously under cultivation of barley, and maize plantation was done just after harvesting of barley on 25th June with skillful workers. Four seeds per hill were sown and later thinned down one seedling per hill 2 weeks after sowing. For appropriate management of the amount of residue for each residue retention treatment, excess residues both flat and standing were removed. Row and plant spacing was 75 cm and 20 cm, respectively, and each plot had 6 rows. Rows number 1, 4 and 6 and also up to 50 cm, primer and edge lines were discarded from sampling. Lines number 2 and 3 were used for final sampling. The fertilizer broadcast consisted of 200 kg ha^{-1} urea (half of it at sowing time and half of it at six-leaf stage). According to soil analysis showing high amount of P and K, P and K fertilizers were not used. The first irrigation was applied immediately after sowing, second irrigation was done three days after the first one, after that plots were irrigated weekly. The pH and electrical conductivity of irrigation water were 7.3 and 2 ds m^{-1}, respectively. For weeds management, Atrazin (2.5 lit per ha) was used before seeds germination. Also, hand weeding was applied for eradication of weeds. Insect pests were controlled with recommended pesticides. Leaf area index was measured for 10 plants of each plot by leaf area meter (Delta T Device, UK) at dough seed stage. Plant height, stem diameter were taken from 10 plants in the field, and after determination of fresh forage yield, plants were dried at 60 centigrade for 96 hours in an aerated oven. The amount of nitrogen was calculated by Kjeldahl analysis from dry and ground samples (Bremner and Breitenbeck, 1983), and then nitrogen was multiplied by

6.25 to determine protein content. Analysis of variance (ANOVA) was used to determine the significant differences. Means were separated by Duncan,s Multiple Test at p≤5%. Correlation coefficients were calculated for the relationship between parameters. All statistics analysis was performed with MSTAT-C program.

RESULTS

The influence of years was significant on final plant height, stem diameter and fresh yield. Final plant height, stem diameter, leaf dry weight, stem dry weight, ear dry weight, total dry yield and protein percentage were significantly affected by tillage. Najafinezhad et al. (2007) also reported that tillage treatments had a significant effect on yield. All experimental characteristics were significantly influenced by residue management. Interaction between tillage and residue management had significant effect on final plant height, stem diameter, LAI, leaf dry weight and ear dry weight (Table 2). Najafinezhad et al. (2007) reported that tillage treatments effect on plant height was significant, but residue treatments had non significant effect on plant height. Bescansa et al. (2006) reported that barley yield was not affected by crop residue management. The highest final plant height of 232.25, which was significantly higher than in 2010, was obtained in 2009. Furthermore, the difference in stem diameter between 2009 and 2010 was significant, and the maximum stem diameter was recorded in 2009 (23.73 mm). Although the highest LAI, total fresh yield, leaf dry weight, stem dry weight, ear dry weight and total dry weight were obtained in 2009, all differences between 2009 and 2010 were not significant.

Table 2. Analysis of variance for final plant height, stem diameter, LAI, total fresh yield, leaf dry weight, stem dry weight, ear dry weight, total dry yield and protein percentage

S.O.V	Final plant height	Stem diameter	LAI	Total fresh yield	Leaf dry weight	Stem dry weight	Ear dry weight	Total dry yield	Protein percentage
Year (Y)	649.20**	58.68**	0.17	45.12*	0.0001	0.16	0.011	0.29	9.46
Replication (R)	181.58	3.22	2.00	53.36	0.015	0.46	0.081	1.30	3.25
Y×R	0.02	1.51	0.09	47.54	0.003	0.31	0.010	0.97	1.53
Tillage (A)	247.14**	58.34**	0.51	16.49	0.020*	0.38*	1.221**	0.62**	59.88*
Y×A	173.27**	17.38**	2.34**	40.29	0.193**	0.14	0.027*	0.87**	62.90*
Y×R×A	2.00	0.06	0.20	12.35	0.002	0.04	0.005	0.02	11.70
Residue management(B)	479.25**	66.84**	9.12**	103.68**	0.652**	2.19**	0.117**	4.41**	713.84**
Y×B	11.65*	5.27**	0.61*	16.49*	0.002	0.21	0.023*	0.34	0.28
Y×R×B	2.88	0.12	0.14	3.10	0.001	0.15	0.006	0.14	7.63
A×B	11.77*	3.63**	0.68*	10.71	0.021**	0.04	0.059**	0.16	12.58
Y×A×B	0.003	0.09	0.18	6.43	0.029**	0.07	0.013	0.12	2.80
Error	2.45	0.08	0.18	7.61	0.001	0.14	0.005	0.13	6.30

^{ns} non significant, *significant at 0.05 significance in F-tests, **significant at 0.001 significance in F-tests.

The highest and the lowest final plant heights, which were significantly different from each other, were recorded under moldboard and disk harrow treatments, respectively. The maximum stem diameter was obtained with moldboard. Even though its difference from tooth harrow was not significant, the difference from disk harrow treatment was significant. The maximum and the minimum LAI was related to moldboard (6.12) and disk harrow (5.97), respectively. There were no significant differences among treatments in total fresh yield. The highest leaf dry weight (3.60 t ha^{-1}) and stem dry weight

(5.40 t ha^{-1}) were obtained for tooth harrow and moldboard, respectively. Disk harrow and tooth harrow produced the highest and the lowest ear dry weight, which had significant difference with each other. Moreover, both of these treatments had significant difference as compared with moldboard. The highest total dry yield was obtained for disk harrow, followed by moldboard and tooth harrow. Tooth harrow was significantly different from both moldboard and disk harrow. Raoufat and Mahmoodieh (2005) noted that the moldboard plough resulted in better plant establishment and more uniform plant spacing. Optimum tillage combined with weed and fertilizer would be essential not only to enhance crop productivity, but also to maintain soil health and sustainability (Nema et al., 2008). Even though the lowest protein percentage was related to disk harrow, its difference from tooth harrow was not significant, but the difference from moldboard treatment, which obtained the maximum protein percentage (35.54%) was significant. The highest final plant height, as compared to other treatments, was obtained for 50% burning, which was significantly different from all other treatments, except 50% residue retention. The highest and the lowest stem diameter were obtained for 100% residue retention (24.62 mm), and 50% burning (21.15 mm). The maximum LAI and total fresh yield were 6.65 and 80.73 t ha^{-1} which were related to 100% burning; in both treatments, there were meaningful differences between 100% burning and other treatments. The highest leaf dry weight was obtained for 100% burning, followed by 50% burning, 50% residue retention, and 100% residue retention. The maximum and the minimum stem dry weight was achieved in 100% burning and 100% residue retention, which had significant difference with each other. However, the difference between 50% burning and 100% burning was not significant. The highest ear dry weight was recorded at 50% residue retention, followed by 100% residue retention. There was no significant difference between 50% burning and 100% burning of residues. 100% burning residues and 100% residue retention produced the highest and the lowest total dry yield, significantly different from each other. The highest protein percentage was achieved in 50% residue retention, as compared to other treatments. All differences among treatments were significant (Table 3).

Table 3. Mean comparison for final plant height (cm), stem diameter (mm), LAI, total fresh yield (t ha^{-1}), leaf dry weight (t ha^{-1}), stem dry weight (t ha^{-1}), ear dry weight (t ha^{-1}), total dry yield (t ha^{-1}) and protein percentage

S.O.V	Final plant height	Stem diameter	LAI	Total fresh yield	Leaf dry weight	Stem dry weight	Ear dry weight	Total dry yield	Protein percentage
Year (Y)	649.20**	58.68**	0.17	45.12*	0.0001	0.16	0.011	0.29	9.46
Replication (R)	181.58	3.22	2.00	53.36	0.015	0.46	0.081	1.30	3.25
Y×R	0.02	1.51	0.09	47.54	0.003	0.31	0.010	0.97	1.53
Tillage (A)	247.14**	58.34**	0.51	16.49	0.020*	0.38*	1.221**	0.62**	59.88*
Y×A	173.27**	17.38**	2.34**	40.29	0.193**	0.14	0.027*	0.87**	62.90*
Y×R×A	2.00	0.06	0.20	12.35	0.002	0.04	0.005	0.02	11.70
Residue management (B)	479.25**	66.84**	9.12**	103.68**	0.652**	2.19**	0.117**	4.41**	713.84**
Y×B	11.65*	5.27**	0.61*	16.49*	0.002	0.21	0.023*	0.34	0.28
Y×R×B	2.88	0.12	0.14	3.10	0.001	0.15	0.006	0.14	7.63
A×B	11.77*	3.63**	0.68*	10.71	0.021**	0.04	0.059**	0.16	12.58
Y×A×B	0.003	0.09	0.18	6.43	0.029**	0.07	0.013	0.12	2.80
Error	2.45	0.08	0.18	7.61	0.001	0.14	0.005	0.13	6.30

Mean of each column followed by similar letters are not significantly different (Duncan 5%).

DISCUSSION

The rapidly increasing population and request for food and feed in the world had led to increased soil cultivation, so appropriate agronomical management of residues and soil tillage system is necessary for enhancing site productivity in maize plantations in rotation with barley. In this experiment the highest final plant height, stem diameter, LAI, total fresh yield, leaf dry weight, stem dry weight, ear dry weight, and total dry yield were recorded in 2009, while the maximum protein percentage was achieved in 2010. Higher values of total fresh yield, ear dry weight and total dry weight were recorded under disk harrow compared to those of other treatments; however, the maximum protein percentage was achieved in usage of moldboard. Appropriate tillage management for cereal production can conserve water and increase crop productivity (Imaz et al., 2010; Fan et al., 2013). Bescansa et al. (2006) noted that tillage has a greater impact on soil properties and on crop yield than crop residue management, which means that tillage operations play a major role in sustainable farming systems (Mohammadi et al., 2013). The highest final plant height, LAI, total fresh yield, leaf dry weight, stem dry weight and total dry yield were obtained by 100% burning, however, the maximum protein percentage was related to 50% residue retention. Furthermore, the values of fresh forage yield and dry forage yield were appropriate in 50% reside retention. Retaining instead of burning residues provides several potential benefits (Tutua et al., 2008), including reducing atmospheric pollution, sequestering C, improving various soil properties, and reducing fertilizer requirements through recycling nutrients in the residues, resulting in higher yields (Viator and Wang, 2011; Thorburn et al., 2012). Hulugalle and Cooper (1994), and Hoyle and Murphy (2006) also reported that retention of crop residues have greater beneficial effects on the soil physical properties and yield in the long term. The conservation agriculture principles, minimal soil disturbance, residues retention, along with profitability at the farm level are increasingly recognized as essential for sustainable agriculture (Berhe et al., 2012; Roozbeh et al., 2012). So, if residues are managed properly, then this can warrant improvements in the sustainability in crop productivity. On the basis of previous results, it can be concluded that complete 100% burning is to be avoided due to concerns for reduced soil organic matter levels, environmental and soil erosion problems. It is essential to adopt tillage and residue management techniques that reduce residue levels, improve seedbed condition and improve corn production. Advantages of not burning, especially the long-term increase in soil organic matter and its impact on aggregation, have been reported. Burning has agronomic advantages linked to crop protection, such as the reduction of pests and weeds that can be important when implementing no-tillage system. Moreover, soil management becomes easier when crop residues are burned after harvesting. Crop residue burning for summer planting is a usual practice in most parts Iran, which makes land preparation for the next crop easier and helps control pest. Since irrigated wheat and barley crop have high residues after harvesting and time of corn planting is short, farmers tend to include tillage operations in their system. Because of the lower cost of seedbed preparation and higher yield in conservative tillage and also the benefits of retained barley residue, appropriate tillage including retained barley residue is recommended. However, plant residue increase the risk of poor stand establishment for maize; this may results in reduced crop yield and may limit adoption of conservation tillage by farmers (Raoufat and Mahmoodieh, 2005).

CONCLUSIONS

Complete residue removal or burning should be avoided due to concerns for reduced soil organic matter levels, environmental and soil erosion problems. If maize production is to be successful following barley in a reduced tillage system, it is important to adopt tillage and residue management techniques that reduce residue levels in the row center and improve seedbed conditions. To conclude, returning crop residues to the soil improves the N economy of the cropping systems and enhances crop productivity through the additional N and other soil benefits. The farmers who traditionally remove residues for fodder and fuel will require demonstration of the relative benefits of residues return to soil for sustainable crop productivity. Using tooth harrow followed by residue retention in maize cropping after barley, was recommended to farmers in climatic condition of Isfahan.

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