Research Article

Impact of Tillage Tools and Weeding Regimes on Nutritive Values of Maize Grains

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Abstract | Two field trials were conducted at the Agronomy Research Farm of the University of Agriculture, Peshawar during the summer seasons of 2016 and 2017. The maize variety 'Azam' was sown in a layout of RCB design with split-plot arrangement, replicated four times. Data were recorded on the nutritive status of maize grains including crude protein content, fat content, ash content and dry matter content of the maize grains. The results showed 13% protein content, 5.8 % fat content, 0.93 % ash content and 89.6 % dry matter content in the maize grains, which were the higher values achieved in plots treated with mouldboard plough, while in the weeding regimes the crude protein content, fat content, ash content and dry matter contents were highest (13.8, 6.7, 1.0 and 92.5%, respectively) in the full season weeded treatments, followed by weeding for 12 weeks and so on. Similarly, lowest crude protein content, fat content, ash content and dry matter content (12.3, 4.6, 0.85 and 87.1%, respectively) were found in the full season weedy treatments, followed by weedy for 12 weeks, and so forth. For the interaction between tillage and weeding regimes, the maximum crude protein content, fat content, ash content and dry matter content were found in the treatments of mouldboard plough under full season weeding regime. Further, the nutritive status of maize grains gradually declined with increasing the weedy-ness duration of the crop.

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Introduction

Pakistan, an agricultural country, is blessed with all the seasons annually existing worldwide. The diverse environments of this country suit to the growth of many globally cultivated crops including maize crop, the third most important cereal crop in the country after wheat and rice crops and second after wheat crop in the province of Khyber Pakhtunkhwa (Arif *et al*., 2011). Globally, maize ranks 3rd among the most grown crops and is cultivated on an area of more than 1.3 million hectares having yield of about 4636.4 kg ha^{-1} (FAO, 2017). Maize contributes 2.7% to the value added in agriculture and 0.5% to GDP of Pakistan; Khyber Pakhtunkhwa contributes the highest production of maize among the provinces of Pakistan (GOP, 2017).

The interaction of weeds with maize has always been a core issue in Pakistan, particularly the local maize varieties are poor competitors against weeds infestation. Further, the use of hybrid varieties is quite detrimental to the native biodiversity. Therefore, the native varieties must be best competitors against the infesting weeds. Maize can however withstand weed competition for the initial three to four weeks after germination, and the associated weeds that emerge six to nine weeks after maize seeds germination do not cause significant maize yield losses. Consequently, managing the weeds after the critical period of competition may result in even up to 83% grain yield losses (Usman *et al*., 2001). Maize yield losses can be higher if the infesting weeds biomass, density and species diversity are increased (Blackshaw *et al*., 2002). In case of excessive weed infestation maize crop yield reduction may even be up to 80 % (Adigun, 2001; Ford and Pleasant, 1994).

Weeds are managed in various ways; however, the environmentally safe practices of weed management are the cry of the day. In this connection, tillage (an eco-friendly weed management tool) and weeding regimes have been collectively studied for their effect on the nutritive status of the maize grains. Tillage practices can vary from zero tillage (no soil disturbance) to deep tillage (conducted through MB plough for soil inversion). The use of cultivator and rotavator for seed bed operation is the most common conventional tillage practice in Pakistan (Ahmad *et al*., 2018). The study was conducted with the objective to investigate the effect of tillage tools and weeding regimes on the nutritional status of maize grains.

Materials and Methods

The two year experiments were carried out at the Agronomy Research Farm of the University of Agriculture, Peshawar during the summer seasons of 2016 and 2017. The maize variety 'Azam' was sown in a layout RCB design with split-plot arrangement, replicated four times.

The tillage tools consisted of the cultivator and the mouldboard plough assigned to the main plots of the experiments in each replication. The weeding regimes comprised of seven weed free and seven weed infested plots for certain uniform periods making a total of 14 combined levels. In the weed free plots, the weeds were uprooted and removed for the first two weeks in W_1 and then left infested for the rest of the season, followed by W_2 where weeding was done for the first four weeks after sowing and then left without any weeding till crop harvesting, W_3 was weeded out for the first six weeks, and so on. The plot of W_7 was used as control which was kept weed free throughout the crop season during both the years of the research. Similarly, in weed infested periods the weeds were left undisturbed for certain periods reciprocal and parallel to the weed free plots. Thus, the weeds were left to grow freely for first two weeks in W_8 plots and then weeded out for the rest of the season; the weeds were left undisturbed for the first four weeks in W_9 and then removed for the rest of the season. In the same way, the weeds were removed after the first six weeks of infestation in W_{10}, and so on. The weeds were left undisturbed for the whole maize crop season in the W_{14} plots of the experiments, which was considered as the control treatment for the weedy plots.

The data were statistically analyzed using the software Statistix 8.1 version for the ANOVA of Randomized Complete Block Design. The significance letters were generated using the LSD test after achieving significant F-test results.

Results and Discussion

Crude protein content (%)

Statistical analysis of the data revealed that tillage tools and weeding regimes significantly ($P<0.05$) affected the crude protein content (Table 1), and their interaction was also significant. The average tillage values indicated that average crude protein content was higher (13.0 %) in the plots of mouldboard plough and lower (12.9 %) in the cultivator plots. The mean values for weeding regimes indicated that the highest crude protein content (13.8 %) was noted in the full season weeded treatments, followed by plots where weeding was carried out for 12 weeks (13.6 %), 10, 8 and 6 weeks (13.3 %), respectively. The higher crude protein content in full season weed free plots was probably due to the least competition for nutrients and other resources (Berardo *et al*., 2009). Similarly, lower crude protein content of 12.3 % was recorded in full season weedy plots, followed by plots infested for 12 weeks, 10 and 8 weeks (12.3, 12.5 and 12.6 %, respectively). The lower crude protein content recorded in the infested plots is due to the severe infestation of weeds. As far as the interaction of tillage tools and weeding regimes is concerned, the crude protein content was highest in mouldboard plough plots under the longest weeding intervals (full season weed free). Comparatively, the mouldboard plough operations resulted in more crude protein content (%) than the cultivator tillage practice (Figure 1).

Crude fat content (%)

There was a significant ($P<0.05$) effect of the tillage tools and weeding regimes on crude fat content (Table 2), however their interaction was non-significant. The crude fat content noted in mouldboard plough treatments was higher (5.8 %) than the cultivator plots (5.4 %). The highest crude fat content in treatments of mouldboard plough could be due to the increased soil porosity and ease of the nutrients availability for maize plants. The highest crude fat content (6.7 %) was achieved in full season weed-free plots, followed by 12, 10, 8 and 6 weeks, respectively. The increase in crude fat content (%) in maize grains under weed free plots might be due to the absence of weed competition (Ullah *et al*., 2010). On the other hand, the lowest crude fat content was obtained from the full season infested plots (4.6 %), followed by plots infested for 12 (4.7 %), 10 (4.8 %), 8 (5.0 %) and 6 weeks (5.1 %). The reason for the lowest crude fat content in the full season infested plots may be the higher competition of weeds with the crop plants that reduced the overall biomass of the crop plants. Consequently, the crop plants gained fewer nutrients which adversely affected the crude fat content of maize grains. The interactions between tillage tools and weeding regimes revealed that increasing the weeding period increased the crude fat content (%) under both the tillage tools; the increase was more prominent in mouldboard plough (Figure 2). Further, the crude fat content (%) was decreased with the gradual increase in the weeds infestation periods, regardless of the tillage tools.

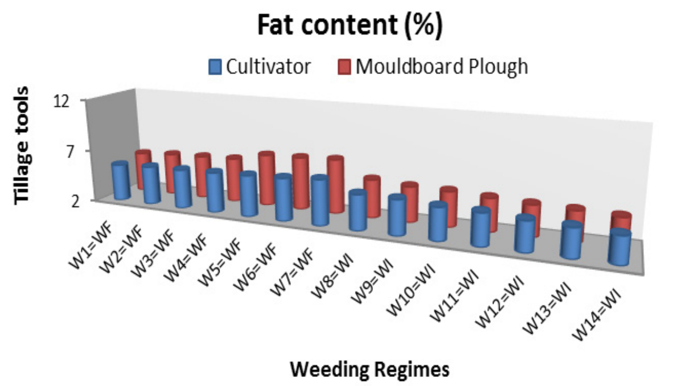

Figure 1: *Interaction of tillage tools and weeding intervals on protein content (%) in 2016 and 17.*

Ash content (%)

According to statistical analysis of the data, the ash content (%) was significantly (P<0.05) affected by different tillage tools and weeding regimes (Table 3). According to the combined analysis ash content (0.93 %) was recorded greater in mouldboard plough treatments while lower (0.88 %) in cultivator plots. The inversion of the soil and burying of weeds in the soil with the mouldboard plough operations produced better results (Demejanova *et al*., 2009). Average values for the weeding regimes described that highest ash content (1.0 %) was obtained in treatments of weed free for whole growing season, followed by 0.96 % in 12 weeks weeding, 10 (0.95 %), 8(0.94 %) and 6 weeks (0.93 %). This is due to the continuous hand weeding in the weed free plots during the whole crop growth season (Naveed *et al*., 2008; Egesel and Kalriman, 2012; Nutli *et al*., 2013). In contrary, lowest ash content (0.85 %) was observed in treatments of full season infested plots, followed by 12 weeks infested (0.86%), 10, 8 and 6 weeks (0.88%). Figure 3 showed interaction between tillage tools and weeding regimes. The highest ash content (%) was noted in mouldboard plough where full season weeding was conducted.

Table 1: *Impact of tillage tools and weeding intervals on crude protein content (%) in maize seeds during 2016 and 2017.*

Tillage depths	Year		Mean
	2016	2017	
Cultivator	12.8	13.0	12.9 a
Mouldboard plough	12.9	13.0	13.0 a
$LSD_{(0.05)}$ for TD			NS
Weeding regimes (WR)			
W_1 = Weeding for 2 weeks	12.5	13.1	12.8 cd
W_2 = Weeding for 4 weeks	12.6	13.2	12.9 c
W_3 = Weeding for 6 weeks	13.2	13.4	13.3 b
W_4 = Weeding for 8 weeks	13.3	13.5	13.4 b
W_5 = Weeding for 10 weeks	13.4	13.6	13.5 ab
W_6 = Weeding for 12 weeks	13.5	13.7	13.6 ab
W_7 = Weeding for full season	13.6	13.9	13.8 a
W_8 = Infested for 2 weeks	12.8	12.8	12.8 cd
W_9 = Infested for 4 weeks	12.7	12.7	12.7 cd
W_{10} = Infested for 6 weeks	12.6	12.6	12.6 cde
W_{11} = Infested for 8 weeks	12.6	12.6	12.6 cde
W_{12} = Infested for 10 weeks	12.5	12.5	12.5 def
W_{13} = Infested for 12 weeks	12.3	12.4	12.3 ef
W_{14} = Infested for full season	12.2	12.3	12.3 f
$LSD_{(0.05)}$ for WR			0.3
Year means	12.9	13.0	*
Interactions	Signif-icance	Interactions	Signifi-cance
Y x TD	NS	Y x WR	NS
TD x WR	0.4	YxTDxWR	NS

Means in same column followed by same letters are statistically similar at 5 % level of significance, NS: Non Significant.

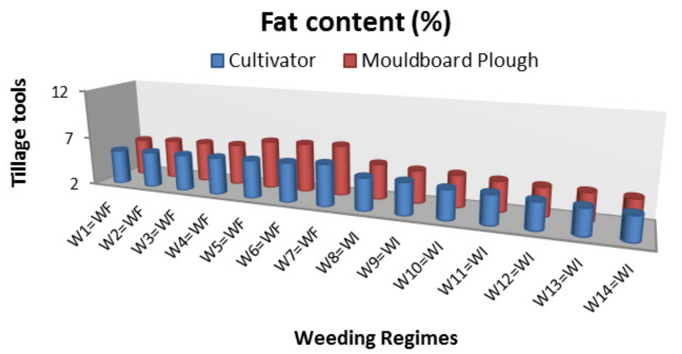

Figure 2: *Interaction of tillage tools and weeding intervals on fat content (%) in 2016 and 17.*

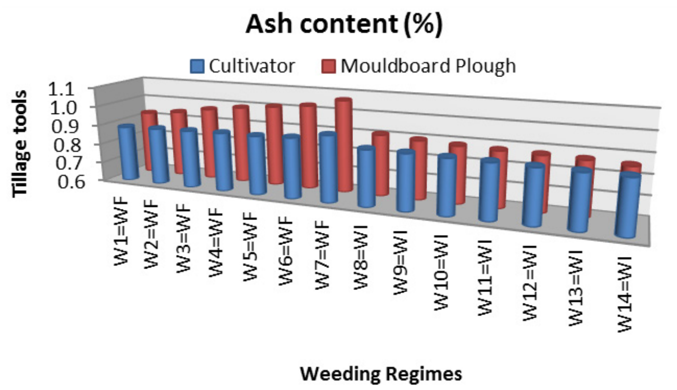

Figure 3: *Interaction of tillage tools and weeding intervals on ash content (%) in 2016 and 17.*

Table 2: *Impact of tillage tools and weeding intervals on crude fat content (%) in maize grains during 2016 and 2017.*

Tillage depths	Year		Mean
	2016	2017	
Cultivator	5.4	5.3	5.4 b
Mouldboard Plough	5.7	5.8	5.8 a
$LSD_{(0.05)}$ for TD			0.2
Weeding regimes (WR)			
W_1 = Weeding for 2 weeks	5.6	5.7	5.7 cd
W_2 = Weeding for 4 weeks	5.9	5.8	5.8 bc
W_3 = Weeding for 6 weeks	5.9	5.9	5.9 bc
W_4 = Weeding for 8 weeks	6.0	6.0	6.0 b
W_5 = Weeding for 10 weeks	6.3	6.4	6.4 b
W_6 = Weeding for 12 weeks	6.4	6.5	6.5 a
W_7 = Weeding for full season	6.6	6.7	6.7 a
W_8 = Infested for 2 weeks	5.4	5.4	5.4 de
W_9 = Infested for 4 weeks	5.3	5.3	5.3 ef
W_{10} = Infested for 6 weeks	5.1	5.1	5.1 ef
W_{11} = Infested for 8 weeks	5.1	5.0	5.0 fg
W_{12} = Infested for 10 weeks	4.8	4.8	4.8 gh
W_{13} = Infested for 12 weeks	4.7	4.8	4.7 gh
W_{14} = Infested for full season	4.6	4.5	4.6 h
$LSD_{(0.05)}$ for WR			0.3
Year means	5.6	5.6	NS
Interactions	Signif-icance	Interactions	Signifi-cance
Y x TD	NS	YxWR	NS
TD x WR	0.4	YxTDxWR	NS

Means in same column followed by same letters are statistically similar at 5 % level of significance, NS: Non significant.

Table 3: *Impact of tillage tools and weeding intervals on ash content (%) in maizegrains.*

Tillage depths	Year		Mean
	2016	2017	
Cultivator	0.9	0.9	0.88 b
Mouldboard Plough	0.9	1.0	0.93 a
$LSD_{(0.05)}$ for TD			0.03
Weeding regimes (WR)			
W_1 = Weeding for 2 weeks	0.9	0.9	0.90 defg
W_2 = Weeding for 4 weeks	0.9	0.9	0.91 cdef
W_3 = Weeding for 6 weeks	0.9	0.9	0.93 bcde
W_4 = Weeding for 8 weeks	0.9	1.0	0.94 bcd
W_5 = Weeding for 10 weeks	0.9	1.0	0.95 bc
W_6 = Weeding for 12 weeks	1.0	1.0	0.96 ab
W_7 = Weeding for full season	1.0	1.0	1.0 a
W_8 = Infested for 2 weeks	0.9	0.9	0.89 efgh
W_9 = Infested for 4 weeks	0.9	0.9	0.88 fgh
W_{10} = Infested for 6 weeks	0.9	0.9	0.88 fgh
W_{11} = Infested for 8 weeks	0.9	0.9	0.88 fgh
W_{12} = Infested for 10 weeks	0.9	0.9	0.87 gh
W_{13} = Infested for 12 weeks	0.9	0.9	0.86 gh
W_{14} = Infested for full season	0.9	0.9	0.85 h
$LSD_{(0.05)}$ for WR			0.04
Year means	0.9	0.9	NS
Interactions	Signifi-cance	Interac-tions	Signifi-cance
Y x TD	NS	YxWR	NS
TD x WR	0.06	YxTDx-WR	NS

Means in same column followed by same letters are statistically similar at 5 % level of significance, NS: Non Significant.

Dry matter content (%)

Analysis of variance of the data showed that the tillage tools and weeding regimes significantly (P<0.05) influenced the dry matter content (Table 4). Combined data for tillage tools indicated that higher dry matter (89.6%) content was noted in plots of mouldboard plough than that in cultivator plots (89.0%). The increase in dry matter content under mouldboard plough was resulted from the lesser weed density which indirectly reduced the competition for resources between the crop plants and weeds (Arif *et al*., 2007). The mean data for weeding regimes resulted in maximum dry matter (92.5 %) in full season weed free plots, followed by weeding for 12 weeks (91.4%), 10 (90.9%), 8 (90.4%) and 6 weeks (90.0%). The dry matter was lowest in full season weedy-ness (87.1%). Decrease in the dry matter content in the weed infested treatments might be due to the increased weed-crop competitions for moisture, light and nutrients and other available resources. The interaction effect of tillage tools and weeding regimes was significant for the dry matter content which illustrated that highest weeding regimes had the highest dry matter content (%) which gradually decreased with decrease in the weeding intervals (Figure 4).

Table 4: *Impact of tillage tools and weeding intervals on dry matter (%) in maize grains.*

Tillage depths	Year		Mean
	2016	2017	
Cultivator	89.0	89.1	89.0 b
Mouldboard Plough	89.5	89.7	89.6 a
$LSD_{(0.05)}$ for TD			0.48
Weeding regimes (WR)			
W_1 = Weeding for 2 weeks	89.4	89.2	89.3 ef
W_2 = Weeding for 4 weeks	89.7	89.5	89.6 de
W_3 = Weeding for 6 weeks	90.3	89.8	90.0 cde
W_4 = Weeding for 8 weeks	90.2	90.6	90.4 bcd
W_5 = Weeding for 10 weeks	90.8	91.0	90.9 bc
W_6 = Weeding for 12 weeks	91.3	91.4	91.4 b
W_7 = Weeding for full season	92.3	92.7	92.5 a
W_8 = Infested for 2 weeks	89.1	89.0	89.1efg
W_9 = Infested for 4 weeks	88.2	88.8	88.5 fgh
W_{10} = Infested for 6 weeks	88.1	88.4	88.3 fgh
W_{11} = Infested for 8 weeks	87.8	88.2	88.0ghi
W_{12} = Infested for 10 weeks	87.7	87.9	87.8 hi
W_{13} = Infested for 12 weeks	87.5	87.7	87.6 hi
W_{14} = Infested for full season	87.2	87.1	87.1 i
$LSD_{(0.05)}$ for WR			1.1
Year means	89.3	89.4	NS
Interactions	Significance	Interactions	Significance
Y x TD	NS	YxWR	NS
TD x WR	1.5	YxTDx WR	NS

Means in same column followed by same letters are statistically similar at 5 % level of significance, NS: Non Significant.

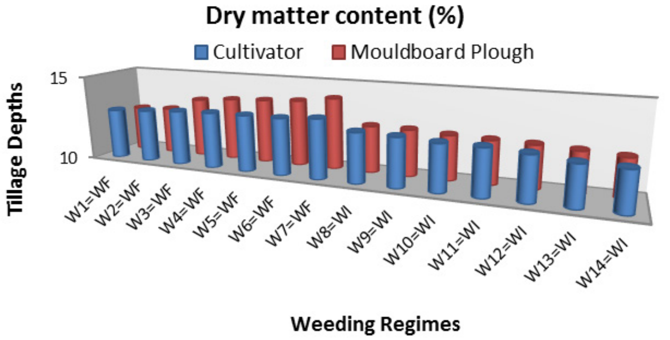

Figure 4: *Interaction of tillage tools and weeding intervals on dry matter content (%).*

Conclusions and Recommendations

The full season weeding regime has been the most successful in all the nutritive parameters of the maize grains. The tillage practice with mould-board plough in combination with full season weeding is recommended for having a desirable nutritional status of the maize grains.

Acknowledgment

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Novelty Statement

The novelty in the study is that the combination of different sowing depths with varying weeding regimes (durations or intervals) has never been tested for assessment of nutritional status of the 'Azam' variety of maize grains in the agro-ecological conditions of Peshawar, Pakistan.

Author's Contribution

Luqman: Planned the study, conducted the trials and wrote the manuscript.
Zahid Hussain: Supervised and managed the study, statistically analyzed the data and finalized the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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