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Influence of different tillage practices and earthworm on selected soil physio-chemical parameters and yield of maize

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Abstract

A study was conducted to evaluate the effect of different tillage practices and earthworm (Peretima hawayana) on soil water content, bulk density and organic carbon contents, and yield and yield parameters of maize. The experiment was conducted at Koont Research Farm, PMAS Arid Agriculture University Rawalpindi, during 2010. The treatments were No-till (NT), No-till + earthworms (NTE), Reduced tillage (RT) and Conventional tillage (CT) with three replication in RCBD. NTE had the highest bulk density (1.42 g cm^{-3}) and maximum soil organic carbon (11.61Mg C ha^{-1}) followed by NT, reduced tillage and conventional tillage. The CT had 32% less nitrate nitrogen than NT at 0-15 cm soil depth. Similar result was noted in case of 15-30 cm depth.NTE had more available phosphorus than CT and RT at 0-15 cm depth. Number of grains cob^{-1} (336) and grain yield (3.6 tha^{-1}) were the highest in CT while the lowest number of grains cob^{-1} (259) and grain yield (2.57 t ha^{-1}) were recorded in NT. Likewise CT had more1000 grain weight (33%), biological (28%) and economical yield (23%) as compared to NT. The higher grain yield (3.6 t ha^{-1}) was obtained in CT and RT (3.35 t ha^{-1}), than NTE (2.92 t ha^{-1}) and NT (2.57 t ha^{-1}). The cost benefit ratio was more in CT (3.57) than NT (2.85). NTE had positive effects on soil and crop, however long term studies are needed to evaluate the effects of tillage on soil quality and crop production.

Keywords: *Conventional tillage, no-till, earthworm, soil properties*

Introduction

Conventional tillage (CT) can lead to unfavorable effects like soil compaction, reduction of soil organic matter, degradation of soil aggregates, disruption of soil microbes including mycorrhiza, arthropods, earthworms and soil deterioration processes (Lal, 1993; Arif *et al*., 2007; Curaqueo *et al*., 2010). So, for sustainable agro-ecosystem disproportionate and needless tillage practices should be replaced with conservation tillage in order to mitigate its detrimental effects on soil and environment (Iqbal *et al.,* 2005). Ogle *et al*. (2003) found that CT practices have detrimental impact on soil organic carbon (SOC) and could cause 20-50 percent loss of soil organic carbon (SOC) through continuous tillage for long time.

No-till an emergent agricultural technology has positive relationship with soil reserves including total organic carbon because of its ability to protect soil from external damages like erosion (Kasper *et al*., 2009). Likewise, Rhoton (2000) reported that except pH and magnesium, almost all other soil chemical properties under NT were higher than CT and resulted in better soil nutrients availability, less soil degradation and more productivity. Long term conservation tillage resulted in a considerable increase in SOC (Aase *et al*., 1995; Tarkalson *et al*., 2006; Curaqueo *et al*., 2010). NT had significantly higher SOC fraction near the soil surface (0-20 cm) than reduced tillage and CT. However, in deeper soil layers, SOC fraction remained similar (Ogle *et al*., 2003). So, No-Till had more SOC sequestration near the soil surface due to presence of more residue cover as compared to CT which had no residue left after ploughing (Alvaro Fuentes *et al*., 2008). Curaqueo *et al*. (2010) found that NT had 24.8 g kg^{-1} whereas CT treatment had only 17.1 g kg^{-1} SOC at the time of harvest and NT proved to be a better pool for SOC storage as compared to CT.

Jin *et al*. (2011) reported 29.6% increase in available P, 31% available N and 16.1% in organic matter under NT as compared to CT in soil layer of 0-10 cm depth in two cropping sequence of wheat and maize. He *et al*. (2009) performed an experiment to study the response of 10 years of conservation tillage on soil properties and farm production in Mongolia, China and found that NT had more SOC, total nitrogen (TN) and available phosphorus than traditional tillage. Available P was 34.5% more in NT at upper soil depth than conventional tillage. Crop yields were 14% greater in NT than tradition tillage (TT) due to better

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water use efficiency (WUE) and improvement in soil conditions.

Earthworms are perhaps the most important soil organisms in terms of their influence on organic matter breakdown, soil structural development and nutrient cycling, especially in productive ecosystems. In most of the cases, earthworms had positive effect on soil properties and yield of crops except some which show negative effects (Edwards *et al.,* 1996). Beneficial effects of earthworms on plant growth may be due to increased nutrient and water availability, improved soil structure, stimulation of microorganisms or formation of microbial products that enhance plant growth, or possibly through direct production of plant growth promoting substances.

Earthworm's presence had positive effect on crop yield due to efficient decomposition of organic litter by the earthworms (Angel *et al.,* 2007). Earthworm biology and ecology is not fully known at the present time and research is needed for their complete regulation (Edwards *et al.,* 1996). Maize crop is one of the most important cereals and is valuable for both food and industrial purposes. The present study was designed to evaluate the impact of different tillage practices and earthworm (*Peretima hawayana*) on selected soil physico-chemical parameters and yield of maize.

Materials and Methods

Study area

An experiment was conducted at Koont Research Farm, PMAS Arid Agriculture University Rawalpindi during 2010. Tillage practices were started in 2008 and soil sample were taken and analyzed. Mung bean, wheat and sunflower crops were sown and only the economic parts were harvested and the remaining (residues) were left over at surface of No-till and No-till with earthworms treatment and mixed in case of reduced tillage and conventional tillage treatments prior to cultivation of maize in same field. Soil sample were collected after harvesting of maize and analyzed in 2010. Actual plot size per treatment was 500 square meters, however, the data was collected according to the plot size (sample area) mentioned below. Machinery cost was calculated according to the actual plot size.

The experimental treatments were No-till (NT), No-Till +earthworms (NTE), Reduced tillage (RT) and Conventional tillage (CT) with three replications in RCBD and plot size was 6 m × 4 m with 100 cm buffer among the plots. Recommended cultural practices were done according to crop requirement. Maize was planted in first week of August 2010 after the rain fall and harvested in third week of November. Earthworms were added at the rate of 300 (number) in NTE treatment only where the residues of previous crop were buried and protected by making raised bands/barrier around plot. Fertilizer was applied at the rate of 120 kg nitrogen and 50 kg phosphorus by nitro phosphate and urea. All crop parameters were recorded at mentioned crop development stages and soil samples were collected from two depths (0-15 and 15-30 cm) before sowing and after harvesting, and statically analyzed to draw results.

Soil parameters

The soil samples were analyzed for water content (Gardner, 1986), bulk density (Blake and Hartage, 1986), pH (McLean, 1982), NO_3-N (Vendrell and Zupanic, 1990) and available P (Olsen and Sommers, 1982). Soil organic C was determined according to the method described by Schepers *et al.* (1989) and expressed as Mg C ha^{-1}.

Crop parameters

Twenty cobs selected at random from each plot were threshed manually, seeds were counted and average numbers of seeds were determined. Thousand grain weights of mature grains were recorded from each replication with digital weighing balance. Grain yield was recorded by removing the grain from cobs for each plot, weighing them on digital weighing balance and then converting to tons ha^{-1}. Biological yield was taken by weighing above ground part of all plants per plot at harvest and biological yield in kg ha^{-1} was computed. Harvest index value was obtained by dividing economic with biological yield and expressed in percentage (Tollenaar *et al.,* 2006). The cost benefit ratio (CBR) was calculated by the following formula (Gittenger, 1982).

$$CBR = \text{Gross income} / \text{Total expenditure}$$

Results and Discussion

Soil parameters

Soil water content (%)

Soil water contents were not significantly affected by tillage practices and earthworm application at 0-15 cm depth. Highest soil water contents (15%) were recorded in pre-sowing soil samples as compared to all other treatments. Contrarily, Lopez-Fando *et al*. (2007) found that different tillage practices had significant effect on soil water content up to 15 cm soil depth. However, soil moisture contents at 15-30 cm soil depth were significantly affected by tillage practices and earthworm application (Table 1). The greater soil water contents (17.63%) were found in pre-sowing soil sample than rest of treatments while conventional tillage had lowest soil water contents

(10.68%). Husnjak *et al*. (2002) and Lyon *et al*. (1998) also found more soil water contents under No-till as compared to tilled treatments. No-till with earthworm had significant greater soil water content than conventional tillage. These results were in line with Fonte *et al*. (2010).

and conventional tillage had similar bulk density values in the deeper soil layers (20-30 cm).

Soil pH

Tillage practices and earthworm did not affect soil pH (Table 2). Similar results were reported by Adeyemo and Agele (2010) and Bisht *et al*. (2006). In contrary, Tarkalson *et al*. (2006) found that tillage practices had significant increasing effect on soil pH.

Table 1: Impact of different tillage practices and earthworm on soil water content and soil bulk density

Treatment	Soil Water Content (%)		Soil Bulk Density (g cm^{-3})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Pre-sowing soil analysis (2008)(PS)	15.09 a	17.63 a	1.40 ab	1.43^{NS}
No-till (NT)	11.79 b	13.64 b	1.41 a	1.43
No-till + earthworm (NTE)	10.52 b	12.23 bc	1.42 a	1.42
Reduced tillage (RT)	9.14 b	12.97 bc	1.36 bc	1.39
Conventional tillage (CT)	9.64 b	10.68 c	1.34 c	1.38

Table 2: Impact of different tillage practices and earthworm on soil pH and soil nitrate nitrogen available phosphorus and soil organic carbon

Treatment	Soil pH		Soil nitrate nitrogen (mg kg^{-1})		Available phosphorus (mg kg^{-1})		Soil organic carbon (Mg C ha^{-1})	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
	cm							
Pre-sowing soil analysis (2008) (PS)	7.68^{NS}	7.8^{NS}	5.24 c	4.90 b	5.00 bc	4.20 a	4.26 c	4.87 d
No-till (NT)	7.63	7.76	8.34 a	6.40 a	5.43 ab	4.06 a	11.15 a	5.73 ab
No-till + earthworm (NTE)	7.7	7.73	8.87 a	7.00 a	6.39 a	4.58 a	11.61 a	5.96 a
Reduced tillage (RT)	7.7	7.8	7.64 ab	5.80 ab	4.43 bc	3.06 b	8.84 b	4.89 bc
Conventional tillage (CT)	7.63	7.76	6.70 bc	5.03 b	4.33 c	3.26 b	8.76 b	4.83 c

Any two means having different letter in column are significantly different at 5% probability level. PS = Pre-sowing soil analysis (2008)(PS), NT = No-till, NTE = No-till with earthworm, RT = Reduced tillage (Two ploughing with planking) and CT = conventional tillage (Three ploughing with planking)

Soil bulk density (g cm^{-3})

The different tillage practices and earthworm had significant effect on soil bulk density (SBD) at 0-15 cm depth (Table 1). The highest SBD (1.42 g cm^{-3}) was recorded in No-till with earthworm while the lowest bulk density (1.34) was observed in reduced tillage and conventional tillage (1.36 g cm^{-3}). However, tillage practices and earthworm had non- significant effect on SBD at 15-30 cm depth. Conservation tillage had more bulk density than conventional tillage in the upper (0-20 cm) layer of soil (Gomez *et al.,* 1999; Lampurlane´s and Cantero-Martınez, 2003; Singh and Malhi, 2006). Treatments inoculated with earthworm had less bulk density than non-inoculated treatments (Fonte *et al.,* 2010). In contrast, Basamba *et al*. (2006) reported that tillage treatment with reduced ploughing had more bulk density than No-till. These results (15-30 cm) are similar with the findings of Gomez *et al*. (1999) they reported that No-till

Soil nitrate nitrogen (mg kg^{-1})

Among tillage practices the concentration of soil NO_3–N was less in conventional tillage treatment as compared to No- till and No-till with earthworm (NTE) at both depths (Table 2) while earthworm had no effect on soil NO_3–N concentration. High concentration of soil NO_3–N under No-till was associated with increased mineralization by high organic matter content and lesser leaching (Stoddard *et al*., 2005). Similar results were reported by Wang *et al*. (2008) and Jin *et al*. (2011) but Grant and Lafond (1994) found that in most of soil profile layers NO_3–N did not differ for tillage treatments. Noguera *et al*. (2010) reported higher nitrate contents for earthworm inoculated treatments as compared to non-inoculated treatments.

Soil available phosphorus (mg kg^{-1})

The concentration of available soil phosphorus (P) was significantly affected by different tillage practices and earthworm at both soil depths (Table 2). At 0-15 cm, maximum P concentration was recorded in No-till with earthworm (6.39 mg kg^{-1}) while minimum soil P was found under conventional tillage (4.33 mg kg^{-1}) however, at 15-30 cm, the highest P (4.58 mg kg^{-1}) was recorded in No-till with earthworm. Available phosphorus for conservation tillage may be due to more residue cover (Agbede, 2006) and less soil disturbance that resulted in less nutrient leaching (Ali *et al*., 2006). Contrary results were found by Ishaq *et al*. (2002) they found high phosphorus content under conventional tillage than reduced tillage. Hussain *et al*. (1999) found no effect of different tillage practices on available phosphorus. Earthworm treatments had more available phosphorus content in the soil as compared to non-earthworm treatments (Wan *et al.,* 2004).

Soil organic carbon (Mg C ha^{-1})

Table 2 indicates a significant increase in SOC contents by tillage practices and earthworm at upper surface and lower soil layers. Maximum SOC of 11.61 Mg C ha^{-1} for soil surface was found in No-till with earthworm treatment. The lowest SOC (8.76 Mg C ha^{-1}) of surface soil was recorded under conventional tillage. The same trend was noted for lower soil depths. Like surface soil, deeper soils under No-till with earthworm had highest SOC (5.96 Mg C ha^{-1}) and lowest SOC value of 4.83 Mg C ha^{-1} was recorded for conventional tillage. The more organic carbon under No-till at upper soil surfaceas compared to conventional tillage may be due to less soil disturbance and more accumulation of residue under NT (Yaduvanshi and Sharma, 2008). Malik *et al*. (2000) recorded lower SOC in conventional tillage than zero tillage. Curaqueo *et al*. (2010) also found high organic carbon under un-tilled plots as compared to tilled plots. Joschko *et al*. (2009) reported mixed effects of earthworm addition on soil organic carbon.

Crop parameters

Number of grains cob^{-1}

The different tillage practices and earthworm had a significant effect on number of grain per cob of maize (Table 3). Maximum grains per cob (336) were recorded in conventional tillage while minimum grains per cob (259) were recorded in No-till. Halvorson *et al*. (2006) and Ahadiyat and Ranamukhaarachch (2008) also reported higher number of grains per cob in conventional and deep tillage as compared to No-till. Earthworm had non-significant effect on number of grains (Gilot-Villenave *et al*., 1996).

1000 grain weight (g)

Conventional tillage had significantly higher 1000 grain weight (290 g) than No-till (218 g)(Table 3). The heavier grains in conventional tillage as compared to No-till were recorded by Monneveux *et al.* (2005) and Khurshid *et al*. (2006).

Grain yield (tons ha^{-1})

The effect of tillage practices and earthworm was significant on economic yield (Table 3). There was an increasing trend in grain yield with the increase in tillage practices. Maximum grain yield of 3.6 t ha^{-1} was obtained under conventional tillage followed by reduced tillage (3.35 t ha^{-1}) and No-till with earthworm having grain yield of 2.92 t ha^{-1}. However, the lowest grain yield was recorded in No-till (2.57 tha^{-1}) which was 40 percent less than conventional tillage. Husnjak *et al*. (2002) reported the highest yield under conventional tillage as compared to other tillage treatments. Similarly, Sessiz *et al*. (2008) observed that grain yield was greatly reduced by No-till as compared to conventional tillage. In contrast, Najafinezhad *et al*. (2007) observed that the grain yield was same under No-till and conventional tillage.

Table 3: Impact of different tillage practices and earthworm on number of grains cob^{-1}, number of cobs plant^{-1}, 1000 grain weight, grain yield, biological yield, harvest index and cost benefit ratio

Treatment	No. of grains cob^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Cost benefit ratio
No-till (NT)	259 b	218 b	2.57 c	6.028 b	43^{NS}	2.85 b
No-till + earthworm (NTE)	276 ab	251 ab	2.92 bc	6.653ab	44	3.05 ab
Reduced tillage (RT)	295 ab	259 ab	3.35 ab	7.083 ab	47	3.39 ab
Conventional tillage (CT)	336 a	290 a	3.6 a	7.847 a	47	3.57 a

Any two means having different letter in column are significantly different at 5 % probability level. NT = No-till, NTE = No-till with earthworm, RT = Reduced tillage (Two ploughing with planking) and CT = conventional tillage (Three ploughing with planking)

Table 4: Cost of inputs and prices of produce for cost benefit ratio

	Description	Unit	Unit Cost(Rs.)
Inputs	Tractor rent	Hr^{-1}	900
	Weed Control	ha^{-1}	7000
	Maize seed	kg^{-1}	50
	Fertilizer DAP	Per 50 kg bag	3800
	Fertilizer Urea	Per 50 kg bag	880
	Harvesting & Threshing	Hr^{-1}	1450
	Post- harvest rent	ha^{-1}	5000-7000
	Misc. Expenditure	-	5000-7000
Output	Maize grain	Per 40 kg	1200
	Maize straw	Per 40 kg	200

Biological yield (tons ha^{-1})

A significant effect of different tillage practices and earthworm was recorded on biological yield (Table 3). Conventional tillage produced 28% more biological yield than no-till and 22% more than no-till with earthworm. Arif *et al*. (2007) and Gul *et al*. (2009) reported similar results.

Harvest index (HI)

A non-significant effect of different tillage practices and earthworm was found on harvest index (Table 3). Guy and Lauver (2007) observed that tillage treatments had no effects on harvest index. On contrary, Ahadiyat and Ranamukhaarachchi (2008) found increase in harvest index in conventional tillage as compared to No-till.

Cost benefit ratio

Economic analysis is the decisive factor in choosing certain agriculture practice for crop production (Table 4). Maximum CBR was recorded in conventional tillage (3.57) and minimum in no-till treatment plots (2.85).

Conclusion

No-till with earthworm had improved soil bulk density, water content, soil organic carbon, available phosphorus and nitrate nitrogen as compared to conventional tillage. Further, long term study is needed to evaluate the effect of tillage practices on soil quality and crop production.

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