Research Article

Effect of Tillage, Residue and Fertilizer on Yields within a Wheat-Maize Cropping System

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Abstract | The field study was carried out to determine the effect of tillage with and without residues and organic and inorganic fertilizers on yield of wheat-maize cropping systems in the erosion-vulnerable sub-humid area. Treatments included tillage levels *i.e.* ST (shallow tillage), ST_R (shallow tillage with residues), DT (deep tillage) and DT_R (deep tillage with residues). Sub plots had three fertilizer's levels viz. F1 (control), F2 (inorganic fertilizers) and F3 (farm yard manure; FYM+ inorganic fertilizers). Deep tillage increased wheat yield by 60%, 37% and 29% over ST, ST_R and DT_R, respectively. F2 and F3 increased grain and straw yield compare to F1. In the case of maize, DT increased grain yield by 53%, 20% and 15%, over ST, ST_R and DT_R, respectively. Deep tillage showed statistically higher water use efficiency (WUE) of 4.56 kg ha^{-1} mm^{-1} and 4.02 kg ha^{-1} mm^{-1} for both wheat and maize, respectively. However, similar WUE of wheat and maize was recorded for F2 and F3. Soil nitrogen, phosphorus and potassium after wheat-maize cropping rotations significantly responded to tillage, residues and organic and inorganic fertilizers. These results suggest that deep tillage has the potential to increase crop yield and WUE of wheat-maize cropping system in mountainous and sub-humid conditions.

Received | July 12, 2016; **Accepted** | February 17, 2017; **Published** | March 09, 2017
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Citation | Shaheen, A. and N. Sabir. 2017. Effect of tillage, residue and fertilizer on yields within a wheat-maize cropping system. Sarhad Journal of Agriculture. 33(1): 127-138.
DOI | http://dx.doi.org/10.17582/journal.sja/2017.33.1.127.138
Keywords | Farm yard manure, Residues incorporation, Tillage practices, Wheat-maize

Introduction

Eroded areas have lower yield due to climatic factors, land configuration and faulty conventional soil and crop management practices. The erratic and higher intensity rain, gentle to steep slopes and the lower addition of organic amendments cause less productivity. The mountainous topographic features in humid and sub-humid conditions result in higher runoff losses and low infiltration. Water erosion causes soil losses and nutrients removal with both runoff and sediments. It ultimately declines soil fertility, productivity, causes economic losses and environmental pollution (Lal, 1998; Lal, 2001). The total amount, intensity and duration of rainfall, soil properties, land configuration, crops, soil and crop management practices determine the rate of erosion from agriculture farm lands (Lu et al., 2007; Jiao et al., 2009; Ezemonye and Emeribe, 2012). The rate of erosion gets increase with low infiltration, crusting and compaction, less addition of crop residues (Bruce et al., 2006).

The adoption of soil management practices which improves soil physical conditions and build up soil organic matter (SOM) may increase crop yield in eroded areas (Wright et al., 2008).

Among soil management practices crop residues in-

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corporation has improved soil properties viz. biological, physical and chemical and conserved soil moisture and increased crop production (Hejazi et al., 2010). Residues retention protects top soil and reduces soil nutrient losses (Mandal et al., 2004). Numerous studies (Lal, 1974, 1978, 1995; Unger, 1986; Wicks et al., 1994; Sadeghi and Bahrani, 2009) have shown higher maize yield with crop residues maintenance in soil. Crop residues incorporation increase SOM, soil N, P and K (Mandal et al., 2004). However, the effects of tillage vary according to different soil type and properties, cropping sequence, residue addition and climate. Few studies (Paustian et al., 2000; Six et al., 2000) illustrated that tillage causes SOM decomposition and accelerates OM degradation which results less OM build up in soil. The additions of crop residues in soil at the sowing time mostly immobilize the inorganic nitrogen (Mandal et al., 2004). However, this can be reduced with incorporation of nitrogen as starter dose along with straw incorporation (Mandal et al., 2004). Tillage also affects soil water content by affecting surface runoff, infiltration rate and evaporation (Zhai et al., 1990).

The water use efficiency (WUE) of eroded areas also increases with available water contents and nutrients. The use of organic amendments (including farmyard manure (FYM) not only supply nutrients but also improves soil properties and conserves soil water (Schjonning et al., 1994; Tran-Thuc-Son et al.1995; EI- Shakweer et al., 1998; Belay et al., 2001). The integrated application of FYM with inorganic fertilizers has increased wheat and maize yield (Ma et al., 1999; Yadav, 2001). Similarly, straw incorporation with organic manure has improved soil physical properties and increased wheat yield (Kang and Balasubramanian, 1990; Mandal et al., 2004). Studies (Murwira and Kirchman, 1993; Makinde et al., 2001 and Adeniyan and Ojeniyi, 2005) have shown higher crop productivity with the integrated addition of organic and inorganic amendments.

Due to global change in rainfall pattern, the humid areas having uncertain conditions of rainfall and winter rains are becoming less during the wheat germination period. For efficient utilization of rain water focus on more infiltration and less runoff is required. Research on tillage system is necessary to lessen land degradation and to get potential crop yields as average yield production of wheat-maize in mountainous, erosion-vulnerable areas region of Rawalakot (Latitude 33° 51' to 33° 85' N and longitude 73° 48' to 73° 80' E) Azad Kashmir-Pakistan is 1 Mg ha^{-1} to 1.5 Mg ha^{-1}.

Wheat and maize are major cereal crops of the state of Azad Jammu and Kashmir-Pakistan and studies have not been conducted so far on tillage practices of wheat-maize cropping system. Due to the importance of wheat and maize crop for nation's economy, lack of research on soil management and conservation practices, a study was conducted to determine (i) whether higher grain yield and water use efficiency due to deep tillage with and without residue incorporation is greater than shallow tillage with and without crop residues incorporation (ii) Response of crop yield and WUE to organic and inorganic fertilizers.

Materials and Methods

Study site

The field experiment of wheat-maize cropping system was carried out in 2009 and 2010 on clay loam soil at experimental research fields, Faculty of Agriculture, Univeristy of Poonch, Azad Jammu and Kashmir-Pakistan. The average annual precipitation of study area (Latitude 33° 51' to 33° 85' N and longitude 73° 48' to 73° 80' E) is 1481 mm; 33% rainfall is received in winter (Dec. to March), and parent material is residuium-colluvium from shales. Mean winter soil temperature is 15°C. The monthly rainfall and temperature (minimum and maximum) during wheat and maize growing period is given in Figure 1.

Description of field operations and treatments

The pre-sowing composite soil samples were collected for characterization of study area. The properties of experimental area are given in Table 1. The experimental plot was ploughed thoroughly twice by tractor and according to tillage depth field was tilled. The experiment lay out was split plot arranged in randomized complete block design with three replications. The treatments of main plots consists of: shallow tillage (0-15 cm; ST), shallow tillage with wheat straw incorporation @ 4 Mg ha^{-1} (ST_R), Deep tillage (0-30 cm; DT) and deep tillage with wheat straw incorporation @ 4 Mg ha^{-1} (DT_R). The sub-plots were having three fertilizers levels viz. F1: Control (no application of fertilizers), F2: Recommended rate of fertilizer application (120 kg N, 60 kg P_2O_5 and 90 kg K_2O per hectare) and F3: integrated application of inorganic and organic fertilizers (8 Mg farm yard manure (it provided 60 kg N, 60 kg P_2O_5 and 90 kg K_2O per hectare). The fertilizers urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were applied as source of nitrogen, phosphorus and potassium, respectively. All inorganic fertilizers were broadcasted at sowing and half nitrogen was applied at sowing and half after germination. The FYM was collected from neighboring house's pens and its analysis showed total nitrogen percent was 0.78%. FYM was mixed thoroughly and spread evenly and applied to the experimental plots at sowing. Wheat straw in specified treatments according to layout plan was incorporated and properly mixed up to 15 cm depth at the time of sowing.

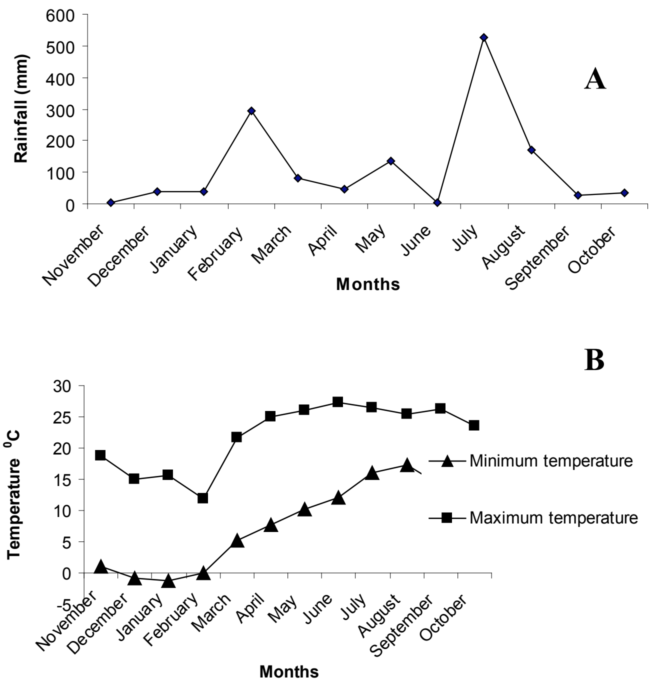

Figure 1: *Monthly rainfall during 2009-2010 (A); Monthly minimum and maximum temperature during 2009-2010 (B)*

Wheat and maize as test crops were sown in winter and summer, respectively in rotation. Wheat (*Triticum aestivum* L.) variety "Saher" was sown on October 25, 2009 and harvested on May 20, 2011. Maize (*Zea mays* L.) variety "Sarhad white" was sown on June 24, 2010 and harvested on October 18, 2010. All cultural practices were adopted during whole growing period of crop.

Measurements

Threshing was done manually and yield data was recorded at 12% water contents after harvesting middle rows of each plot. Leaf area (LA) measurements were taken at the flowering stage in wheat and at silking stage in maize.

Table 1: *Physico- chemical properties of pre- sowing soil samples*

Soil properties	Unit	0-15cm	15-30cm
Moisture	%	13	10
Bulk density	g cm^{-3}	1.15	1.3
Volumetric water contents	mm	22.43	33.9
Sand	%	24	52.5
Silt	%	39	15.3
Clay	%	36	32.2
Textural class	-	clay loam	sandy loam
pH(1:2)	-	7.81	7.9
Electrical Conductivity	dSm^{-1}	0.07	0.09
Organic matter	%	1.47	1.27
Calcium Carbonate	%	13.26	13.9
Nitrogen	%	0.072	0.06
Phosphorus (extractable)	mg kg^{-1}	10.8	8.9
Potassium (")	mg kg^{-1}	74	86
Copper (")	mg kg^{-1}	0.71	0.77
Iron (")	mg kg^{-1}	2.3	1.9
Manganese (")	mg kg^{-1}	3.571	4.616
Zinc (")	mg kg^{-1}	1.344	1.372

Water use efficiency was computes as:

$$\text{Grain yield} = \frac{\text{WUE (kg / ha / mm)}}{\text{Total water supplied}}$$

Where:
Total water supplied = water at sowing – water at harvesting + growing season precipitation

The harvest index was computed as:

$$\text{H.I (\%)} = \frac{\text{Grain Yield}}{\text{Biological yield}} \times 100$$

Soil analysis

The composite pre-sowing soil samples and post-harvest soil samples from every treatment were collected from 0-15 cm and 15–30 cm soil depth. Soil samples were air dried and processed by grinding in pestle and mortar and sieved with 2 mm sieve. The analyses for texture, $pH_{1:2}$, $EC_{1:10}$, OM, $CaCO_3$, total N, P, K, Cu, Fe, Mn and Zn were done. Soil texture was determined by Bouyoucos hydrometer method (Gee and Bauder, 1986). Soil pH was measured saturated 1:2 of soil water suspension using pH meter (McLean, 1982). Electrical conductivity was measured by preparing 1:10

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Table 2: *Effect of tillage practices and fertilizers levels on yield, harvest index, leaf area and water use efficiency of wheat- maize cropping system*

Treatments	Grain yield ($Mg\ ha^{-1}$)		Straw / Stover yield ($Mg\ ha^{-1}$)		Harvest index (%)		Leaf area (cm^2)		Water use efficiency ($kg\ ha^{-1}\ mm^{-1}$)	
	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize
Tillage practices (T)										
ST	1.79 c	2.0 b	3.99 ns	4.75 ns	0.33 ns	28.20 ns	26 c	5386.7 b	2.79 b	2.55 b
ST_R	2.08 bc	2.55 ab	3.76	5.36	0.37	32.40	29 bc	5619 b	3.31 b	3.35 ab
DT	2.86 a	3.06 a	5.10	5.59	0.34	35.96	34 ab	6093 a	4.56 a	4.02 a
DT_R	2.21 b	2.67 a	4.23	6.22	0.34	29.41	36 a	6064 a	3.45 b	3.51 a
Fertilizers levels (F)										
F1	1.64 b	1.22 b	2.68 b	3.92 b	0.37 ns	24.97 b	27 b	4717 c	2.57 b	1.60 b
F2	2.39 a	3.30 a	4.88 a	6.38 a	0.33	34.46 a	32 a	6521 a	3.78 a	4.33 a
F3	2.68 a	3.15 a	5.28 a	6.15 a	0.33	35.05 a	34 a	6134.8b	4.24 a	4.14 a
LSD										
T	0.41	0.656	4.23	NS	NS	NS	5.47	407.19	NS	0.856
F	0.53	0.362	0.79	0.769	NS	5.543	3.76	347.44	0.84	0.476
T×F	ns	ns	ns	1.539	ns	ns	ns	694.87	ns	ns

ST: *Shallow tillage 0-15 cm;* **ST_R**: *Shallow tillage with wheat straw residues @ 4 Mgha^{-1};* **DT**: *Deep tillage 1-30 cm;* **DT_R**: *Deep tillage with wheat straw residues @ 8 Mgha^{-1};* **F1**: *No fertilizers application;* **F2**: *120:90:60kg ha^{-1} $NP_2O_5K_2O$;***F3**: *60:90:60 kg ha^{-1} $NP_2O_5K_2O$ + FYM @ 8 Mgha^{-1}; NS/ns = non significant at $P \leq 0.05$; Columns / rows sharing same letters are non-significant at $P \leq 0.05$*

soil suspension (soil and water) (Rhoades, 1982). Soil OM was determined by a modified Mebius method (Nelson and Sommers, 1982). Percent $CaCO_3$ was determined by titration (Drouineau, 1942). Total nitrogen in the soil was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Available P by Olsen (1954) method using spectrophotometer and extractable K by Richard (1954) method using flame photometer. Micronutrients (Zn, Cu, Fe and Mn) soil extract was measured using atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Soil water contents and bulk density were measured at sowing and after harvest by gravimetric (Page et al., 1982) and core method (Blake and Hartage, 1986) respectively, up to depth of 30 cm. The water contents were expressed as volumetric water contents by multiplying with bulk density.

Statistical analyses

The statistical analyses were done by MSTAT C software, treatment differences were calculated at the 5% probability by least significant difference (LSD) test.

Results and discussions

Yield, harvest index and leaf area of wheat

Tillage practices and fertilizers levels (Table 2) showed statistically ($p \leq 0.05$) significant effect on grain yield. Among tillage treatments; DT gave higher yield (2.86 Mg ha^{-1}) while the lowest yield of 1.79 Mg ha^{-1} was found in ST. Deep tillage increases grain yield by 60%, 37% and 29% over ST, ST_R and DT_R, respectively. Among fertilizers levels, F2 and F3 showed statistically ($p \leq 0.05$) similar grain yield relative to the control (F1). The maximum higher straw yield was observed under DT that is statistically at par with DT_R, ST_R and ST. However, percent increase of straw yield in DT over ST, ST_R and DT_R was 28%, 36% and 21%, respectively. Among fertilizers levels, the trend of increase was similar as recorded for grain yield. Interactive effect of TxF was non-significant. Both tillage practices and fertilizers levels and their interactions showed statistically ($p \leq 0.05$) similar harvest index (HI) values.

Leaf area response for both tillage and fertilizers practices (Table 2) is statistically significant. Treatments DT and DT_R showed significantly ($p \leq 0.05$) higher LA than ST and ST_R. Both F2 and F3 showed significantly ($p \le 0.05$) higher LA than F1. Interaction of TxF was non-significant.

Yield, harvest index and leaf area of maize

Tillage and Integrated nutrient application practices significantly affected the grain yield of maize (Table 2). The significantly ($p \le 0.05$) higher grain yield (3.06 Mg ha^{-1}) was found in DT and DT$_R$ (2.67 Mg ha^{-1}) and the lowest of 2 Mg ha^{-1} in ST. DT showed 53%, 20% and 15% increase of grain yield over ST, ST$_R$ and DT$_R$, respectively. Integrated nutrient application practices also had statistically ($p \le 0.05$) significant impact on maize grain yield. The highest grain yield of 3.30 Mg ha^{-1} was recorded in F2 whereas in F3 it was 3.15 Mg ha^{-1} as compared to F1 (1.22 Mg ha^{-1}) where no fertilizer was applied. The T×F interaction was non-significant ($p \le 0.05$). The effect of tillage treatments (Table 2) on maize stover yield was non-significant. However, maximum yield of 6.22 Mg ha^{-1} was recorded in DT$_R$ and the lowest (4.75 Mg ha^{-1}) in ST. Among fertilizers level inorganic nutrient alone or in integrated application with organic nutrients had significantly ($p \le 0.05$) higher stover yield than control. Higher stover yield of 6.38 Mg ha^{-1} and 6.15 Mg ha^{-1} was obtained in F2 and F3 treatments, respectively. The interaction of T×F was significant ($p \le 0.05$).

The tillage practices and integrated nutrient application had non-significant ($p \le 0.05$) effect on HI of maize (Table 2). The HI was 28.20% and 35.96% for ST and DT, respectively. Integrated nutrient application showed highly significant differences in HI. Maximum HI was recorded in F3 that was statistically at par with F2 while F1 gave a minimum HI. Interaction of tillage and fertilizers non-significantly ($p \le 0.05$) affected the HI.

The higher LA (Table 2) was recorded in DT and DT$_R$ and minimum was in shallow tilled plots. Application of inorganic fertilizer and FYM in integration and separate had a statistically significant ($p \le 0.05$) effect on maize LA. The higher LA was recorded in F2 treatments followed by F3.

Water use efficiency of wheat and maize

Table 2 shows that statistically higher ($p \le 0.05$) WUE of wheat was recorded for DT (4.56 kg ha^{-1} mm^{-1}) and lower with ST (2.79 kg ha^{-1} mm^{-1}). Deep tillage showed 63, 38 and 32% increase of WUE over ST, ST$_R$ and DT$_R$, respectively. Among fertilizers levels, F3 gave 4.24 kg ha^{-1} mm^{-1} WUE which is statistically higher than F1 (2.57 kg ha^{-1} mm^{-1}) and similar to ($p \le 0.05$) F2 (3.78 kg ha^{-1} mm^{-1}). Interaction of T×F WUE was statistically non-significant.

The WUE of maize significantly responded to tillage and fertilizers levels (Table 2). The higher WUE was recorded in DT (4.02 kg ha^{-1} mm^{-1}) and DT$_R$ (3.51 kg ha^{-1} mm^{-1}) and it was statistically similar with ST$_R$ (3.35 kg ha^{-1} mm^{-1}) and higher than ($p \le 0.05$) ST (2.55 kg ha^{-1} mm^{-1}). The increase of WUE of DT over ST, ST$_R$ and DT$_R$ was 58%, 20%, 15%, respectively. Application of inorganic and integrated nutrients has significant effect on the WUE and higher WUE was found in F2 (4.33 kg ha^{-1} mm^{-1}) and it was followed by F3 (4.14 kg ha^{-1} mm^{-1}). Interaction of T×F non-significantly affected WUE.

Soil characteristics after wheat-maize cropping system

Tillage system showed a significant impact on soil bulk density (BD) (Table 3). The higher BD was found in ST than other tillage systems. The lowest BD was found in DT$_R$. Integrated nutrient application showed highly significant effect on the bulk density. The higher BD was in F1 and the lowest in F3 treatment. The TxF interaction significantly affected the BD at 15-30 cm depth but non-significantly at 0-15 cm depth at maize harvest.

Data of volumetric water contents is presented in Table 3. Tillage and fertilizer levels had statistically non-significant impact ($p \le 0.05$) on soil water at 0-15 and 15-30 cm depths. However, maximum water contents were found in DT and DT$_R$ than ST and ST$_R$. In integrated nutrient application the higher water contents were in F3 treatments. Interaction of TxF had non-significant effect on soil water contents at both depths.

Data pertaining to soil pH at 0-15 and 15-30 cm is given in Table 3. Statistically non-significant effect of tillage practices as well as fertilizers levels were found on soil pH at 0-15 and 15-30 cm soil depth. Interactive effect of TxF was statistically significant on soil pH.

Electrical conductivity of soil at depths 0-15 cm and 15-30 cm was statistically non-significant by tillage practices (Table 3). Integrated nutrient application effect on soil EC in surface plow layer was non-significant but had a significant effect on sub soil layer.

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Table 3: *Effect of tillage practices and fertilizers levels on soil properties after harvest of wheat-maize cropping system*

	Bulk Density ($g\ cm^{-3}$)		Volumetric water Contents (mm)		Soil pH		Electrical Conductivity (dSm^{-1})		Calcium carbonate (%)		Organic matter (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage practices (T)												
ST	1.48 a	1.54 a	17.27 ns	17.22 ns	7.77 ns	7.86 ns	0.08 ns	0.08 ns	9.0 ns	8.92 ns	0.97 b	0.66 ns
ST_R	1.44 ab	1.51 bc	17.37	17.316	7.89	7.95	0.08	0.08	9.25	9.25	1.23 a	0.73
DT	1.46 a	1.53 ab	17.63	18.05	7.91	7.89	0.08	0.08	10.2	10.21	1.21 a	0.68
DT_R	1.39 b	1.49 c	18.29	17.37	7.80	7.99	0.07	0.07	10.61	10.61	1.00 b	0.70
Fertilizers levels (F)												
F1	1.49 a	1.57 a	16.96 ns	17.58 ns	7.80 ns	7.93 ns	0.07 ns	0.07 b	9.37 b	8.92 b	0.99 b	0.60b
F2	1.44 b	1.51 b	17.37	17.33	7.83	7.92	0.08	0.08 ab	10.82 a	10.33 a	1.12 ab	0.69ab
F3	1.39 c	1.47 c	18.59	17.56	7.90	7.92	0.08	0.09 a	10.73 a	9.98 ab	1.20 a	0.78a
LSD												
T	0.05	0.03	NS	NS	NS	NS	NS	NS	NS	NS	0.18	NS
F	0.03	0.03	NS	NS	NS	NS	NS	0.013	1.269	1.139	0.16	0.15
T×F	ns	0.05	ns	ns	Ns	ns	ns	ns	2.538	2.227	ns	ns

ST: *Shallow tillage 0-15 cm;* **ST_R**: *Shallow tillage with wheat straw residues @ 4 $Mgha^{-1}$;* **DT**: *Deep tillage 1-30 cm;* **DT_R**: *Deep tillage with wheat straw residues @ 8 $Mgha^{-1}$;* **F1**: *no fertilizers application;* **F2**: *120:90:60kg ha^{-1} $NP_2O_5K_2O$;* **F3**: *60:90:60 kg ha^{-1} $NP_2O_5K_2O$ + FYM @ 8 $Mgha^{-1}$; NS/ns = non significant at $P \le 0.05$; Columns / rows sharing same letters are non-significant at $P \le 0.05$*

The maximum EC was recorded in F3 which was statistically at par to F2. The small difference in EC of both soil depths was found and soil was free from salinity problem. Interaction of TxF was non-significant.

Data regarding $CaCO_3$ are given in Table 3 at both 0-15 and 15-30 cm depth. The $CaCO_3$ did not show any statistical difference at both depths 0-15 and 15-30 cm to tillage types. Integrated nutrient application had statistically significant ($p \le 0.05$) impact on $CaCO_3$ at both 0-15 and 15-30 cm depth. The higher $CaCO_3$ contents were found in F2 at 0-15 cm and 15-30 cm depth. Interaction of TxF showed significant effect.

The tillage practices had a significant effect on OM in surface plow layer but had a non-significant effect on sub soil layer (Table 3). The highest OM (1.23%) was recorded for ST_R at surface plow layer and the same was at sub soil layer. Integrated nutrient application practices had a significant impact on OM at both 0-15 and 15-30 cm depth. The highest OM (1.20%) was found in F3 and it was statistically ($p \le 0.05$) at par with F2 at surface plow layer. Same trend was at sub soil layer. Interaction of TxF non-significantly affected the organic matter at both depths.

Soil Concentration of nutrients after wheat-maize harvest

Tillage systems did not have significant effect on soil N concentration (Table 4). However, the integrated nutrient application significantly ($p \le 0.05$) affected soil N concentration. The higher N was observed in F2 (0.07 %) at 0-15 cm depth and in F3 (0.06 %) at 15-30 cm soil depth. The TxF interaction had non-significant effect on N contents.

Soil phosphorous contents of different tillage practices were found statistically non-significant at both 0-15 and 15-30 cm depths. More soil P concentration (5.54 mg kg^{-1}) was found at surface plow layer compared to sub soil layer. Integrated nutrient application showed significant ($p \le 0.05$) effect at both depths (0-15 and 15-30 cm) and maximum soil P concentration (5.88 mg kg^{-1}) was found in F3 at 0-15 cm depth and F2 (4.91 mg kg^{-1}) at sub soil layer (15-30 cm) as compared to F1. TxF interaction showed significant effect at both depths 0-15 and 15-30 cm.

Soil potassium contents were significantly affected by tillage practices at 0-15 and15-30 cm (Table 4). Maximum K contents (82.56 mg $kg^{-1}$and 73.11 mg kg^{-1}) were in ST than other tillage system at both depths (0-15 and 15-30 cm). The higher soil K concentration was found at 0-15 cm depth compared to that at subsoil (15-30 cm). Integrated nutrient application sig nificantly ($p \le 0.05$) affected K concentration at both depths (0-15 and 15-30 cm) and the maximum soil K contents (83.83 mg kg^{-1} and 76 mg kg^{-1}) were found in F2 treatments at both depths (0-15 and 15-30 cm)

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Table 4: *Effect of tillage practices and fertilizers levels on soil nitrogen, phosphorus and potassium after harvest of wheat-maize cropping system*

	Total N (%)		Phosphorus (mg kg^{-1})		Potassium (mg kg^{-1})	
Treatments	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage practices (T)						
ST	0.05 ns	0.05 ns	5.31 ns	4.12 ns	82.56 a	73.11 a
ST_R	0.06	0.06	5.39	4.40	78.56 b	72.78 a
DT	0.06	0.06	5.48	4.60	73.67 c	68.78 b
DT_R	0.06	0.05	5.54	4.67	76.33 bc	72.00 a
Fertilizers levels (F)						
F1	0.04 b	0.05 b	4.60 b	3.62 b	73.75 b	66.42 c
F2	0.07 a	0.05 b	5.81 a	4.91 a	83.83 a	76.00 a
F3	0.06 a	0.06 a	5.88 a	4.81 a	75.75 b	72.58 b
LSD						
T	NS	NS	NS	0.634	1.228	1.884
F	0.0114	0.01	0.816	0.670	3.254	2.748
T×F	ns	ns	1.633	1.339	6.508	5.496

ST: *Shallow tillage 0-15 cm;* **ST_R**: *Shallow tillage with wheat straw residues @ 4 Mgha^{-1};* **DT**: *Deep tillage 1-30 cm;* **DT_R**: *Deep tillage with wheat straw residues @ 8 Mgha^{-1};* **F1**: *no fertilizers application;* **F2**: *120:90:60kg ha^{-1} $NP_2O_5K_2O$;* **F3**: *60:90:60 kg ha^{-1} $NP_2O_5K_2O$ + FYM @ 8 Mgha^{-1}; NS/ns = Non significant at P ≤ 0.05; Columns / rows sharing same letters are non-significant at P ≤ 0.05*

and lower in F1. Interaction of TxF also significantly affected K concentration at both depths (0-15 and 15-30 cm).

Wheat yield

Residue incorporation with ST and DT did not show significant effect on crop yield that may be due to application of residues at the time of sowing *i.e.* residues had less time for decomposition altogether and nutrients of residues have not been into freely available form. Few studies had shown decreased grain yield of wheat due to crop residues incorporation because of poor seed germination (Hejazi et al., 2010). Higher yield under DT compare to ST (Table 2) could be due to less runoff and higher infiltration. Data of grain yield (Table 2) suggests that integrated nutrient application was about as efficient as inorganic source of fertilizer. The combined use of FYM with inorganic fertilizers improve soil permeability, soil aggregates stability, checks N losses by organic mineral complexes and uptake of nutrients which in turn increase plant yield (Satyanarayana et al., 2002). In long-term studies (Bayu et al., 2006; Yadav, 2001) FYM @ 5 Mg ha^{-1} with 50% of the recommended rate of inorganic fertilizer has increased grain yield equivalent to 100% of the inorganic recommend rate of fertilizer. The results propose that integrated nutrient management can reduce 50 % usage of inorganic fertilizers. Earlier it was reported by Abbasi and Tahir (2012) that urea nitrogen + FYM in 75:25 ratios saved ≈25% (30 kg) of N fertilizer for wheat production.

Maize yield

In DT and DT_R, the highest grain yield was obtained as compared to ST. It is attributed to the less soil compaction (Abu-Hamdeh, 2003) and uniform distribution of soil nutrients (Mahboubi et al., 1993). Zorita (2000) and Astier et al. (2006) reported higher maize grain yield in deep tilled and conventional tillage practices than no tillage. The interaction of organic and inorganic sources and alone had higher grain yield than control. These results were in line with Negassa et al. (2003) who demonstrated that the integrated application of FYM with NP fertilizers had similar maize grain as with recommended rate of inorganic fertilizers.

However, stover yield was statistically non-significant at all tillage treatments. Same results were found by Iqbal et al. (2005). The higher stover yield with integrated management practices (Table 2) might be due to availability of more nutrients that gave higher plant biomass and stover yield (Saeed et al., 2001).

Harvest index and leaf area of wheat and maize

Tillage practices had non-significant effect on wheat and maize harvest index (HI). Ijaz and Ali (2007) reported significant effect of tillage on harvest index. Higher HI in application of inorganic source of nutrients and integrated organic and inorganic fertilizers application may be attributed to abundant root growth and higher water and nutrients uptake. It results in higher HI of maize crop (Saeed et al., 2001).

Plant LA had direct impact on carbohydrate manufacturing and transpiration process. The increase in LA in DT and F2 and F3 treatments is attributed to the readily available form of inorganic N and due to higher root proliferation and utilization of nutrients during growing season.

Wheat and maize water use efficiency

Higher WUE under DT may be due to disruption of hard layers or disruption of naturally occurring dense pans, which develops due to ploughing at same for long time (Campbell et al., 1994). Similarly, DT_R had statistically similar WUE of maize as DT. Crop residue management, especially in sub-humid and semiarid regions, is to improve soil water conservation (Steiner, 1994) due to reduced runoff due to improved soil structure that allows more infiltration. The more availability of water and nutrients in the root zone had a positive impact on WUE (Hatfield et al., 2001). In our study lower WUE in ST might be due to less conservation of soil water and lower grain yield.

Soil characteristics after wheat-maize cropping system

Tillage and residue application affected soil water contents and BD variably. The non-significant water contents under tillage and fertilizers treatments may results because of irregular dry days and/or because of low residue rates under rain-fed conditions. The tillage practices affect soil water contents by affecting infiltration rate, surface runoff, evaporation losses and reducing the rain-drop impact (Zhai et al., 1990). Some studies however, showed a non-significant variance in soil water content of conservation and conventional tillage practices (Hill et al., 1985). The study indicated the effect of tillage-residue practices on soil bulk density is variable as some scientists showed no effect (Hill, 1990), whereas others reported lower soil bulk density (Edwards et al., 1992) and residue incorporation (Sidhu and Sur, 1993). In F1 higher bulk density may be due to higher re-settling of soil separates due to less growth and less canopy to cover surface from impact of rain drop. Soil pH and EC were unaffected by the treatments, however, EC is below 4 dSm^{-1} which shows no salinity problem in these soils. Lower $CaCO_3$ in post- harvest compare to pre-sowing may be attributed to redistribution of $CaCO_3$ in soil profile. Post-harvest organic matter was less compare to pre-sowing and this reduction is due to exhaustive effect of wheat-maize cropping system. Interactive effect of tillage practices with N fertilization (organic and inorganic) had higher SOC and both active carbon and nitrogen fraction (Dolan et al., 2006; Sainju et al., 2007). The highest OM (1.23%) at surface plow layer and lowest (0.66%) at sub soil layer might be due to wheat residue incorporation on upper surface which showed higher OM at 0-15 cm depth (Kashif et al., 2006).

Concentration of nitrogen, phosphorus and potassium in soil after wheat-maize harvest

The N contents were statistically non-significant among tillage practices, however, lower N was found in ST. The initial crop growth was significantly reduced by reducing the tillage intensity (Zorita, 2000). The non-significant difference in total N contents in soil at maize harvest was also reported by Iqbal et al. (2005). Overall negative balance of total nitrogen when compared with pre-sowing total nitrogen is attributed to exhaustive cropping system and fates of nitrogen losses. Higher N contents in F2 and F3 at 0-15 cm depth is due to higher application rate of N compare to F1. However, statistically similar N contents in F2 and F3 may be due to slow mineralization and less leaching of N in F3. The synergistic effect of N and organic fertilizers maintain higher soil total N (Huang et al., 2007). The nitrogen fertilizers contribute 18-34 % soil residual N (Yang et al., 2007) and 4-9.4% further mineralization from soil total N (Li et al., 2003).

Tillage system showed no effect on P contents however, P concentration was higher in surface plow layer than sub soil layer (Duiker and Beegle, 2006; Najafinezhad et al., 2007). The response of organic and inorganic sources alone and in combination showed the same response of higher P at 0-15 cm depth. The higher P content in F2 and F3 due to application of P compare to F1. The organic manures slowly releases nutrients and had higher residual effect than inorganic fertilizers (Sharma and Mittra, 1991). Ewulo et al. (2008) reported a higher P availability due to increase in soil OM contents. However, overall soil phosphorous was low at maize harvest; this again might be due to exhaustive crops or P fixation.

Combination of FYM and NPK (a mineral fertilizer) had higher soil nutrient (N, P, K) contents (Adeyemo and Agele, 2010). The K contents were higher in up-

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per 0-15 cm soil as than 15-30 cm depth. Duiker and Beegle (2006) and Thomas et al. (2006) after long experimentation of different tillage systems reported higher K concentrations in the surface layer than subsoil.

Conclusions

The higher yield was obtained with deep tillage than shallow tillage. Crop residues incorporation with shallow and deep tillage practices did not give higher yield as deep tillage without residues incorporation but showed higher yield than shallow tillage. Farm yard manure application as integrated approach with inorganic fertilizers gave comparable yield and of both wheat and maize as inorganic fertilizers application. Continuous plouging at same depth and removal of all crop residues reduces the yield of major cereals wheat and maize in wheat-maize cropping system.

Author's Contribution

Aqila Shaheen designed the research, did the statistical analysis and wrote the manuscript. Nadia Sabir continued maize study, analysed the soil and plant samples and recorded the yield.

References

Abbasi, M.K. and M.M. Tahir. 2012. Economizing nitrogen fertilizer in wheat through combinations with organic manures in Kashmir-Pakistan. Agron. J. 104 (1): 169-177. https://doi.org/10.2134/agronj2011.0264

Abu-Hamdeh, N.H. 2003. Effect of compaction and deep tillage on soil hydraulic and aeration properties and wheat yield. Commun. Soil Sci. Plant Anal. 34: 2277-2290. https://doi.org/10.1081/CSS-120024063

Adeniyan, O.N. and S.O. Ojeniyi. 2005. Effect of poultry manure, NPK 15-15-15 and combination of their reduced levels on maize growth and soil chemical properties. Nigerian J. Soil Sci. 15: 34-41.

Adeyemo, A.J and S.O. Agele. 2010. Effects of tillage and manure application on soil physicochemical properties and yield of maize grown on a degraded intensively tilled alfisol in southwestern Nigeria. J. Soil Sci. Environ. Manage. 8(1): 205-216.

Astier, M., J.M. Mass, J.D. Etchevers-Barra, J.J. Pena and F.D. Gonzalez. 2006. Short term green manure and tillage management effects on maize yield and soil quality in an Andisol. Soil Tillage Res. 88: 153-159. https://doi.org/10.1016/j.still.2005.05.003

Bayu, W., N.F.G. Rethman, P.S. Hammes and G. Alemu. 2006. Effect of farmyard manure and inorganic fertilizers on sorghum growth, yield and nitrogen use in semi-arid area of, Ethiop. J. Plant Nutr. 29: 391-407. https://doi.org/10.1080/01904160500320962

Belay, A., A.S. Claassens, F.C Wehner and J.M. DeBeer. 2001. Influence of residual manure on selected nutrient elements and microbial composition of soil under long-term crop rotation. S. Afr. J. Plant Soil. 18: 1-6. https://doi.org/10.1080/02571862.2001.10634392

Blake, G.R and K.H. Hartge. 1986. Bulk density. In: Klute A (ed) Methods of soil analysis. Physical and mineralogical methods, part 1, 2nd ed., ASA-SSSA, Madison, WI. pp. 363–375.

Bremner, J.M and C.S. Mulvaney. 1982. Nitrogen total. p. 595-624. In A. L. Page (ed.), Methods of soil analysis. Argon. No. 9, Part 2: Chemical and microbiological properties, 2nd ed., American Society of Argonomy, Madison, WI, USA.

Bruce, A.L., S.M. Brouder and J.E. Hill. 2006. Winter straw and water management effects on soil nitrogen dynamics in California rice systems. Agron. J. 98: 1050-1059. https://doi.org/10.2134/agronj2005.0350

Campbell, J.A., M.E. Akhtar and G.W. Robertson. 1994. Water balance and deep tillage in rainfed agriculture of the potowar plateau of Pakistan. In: Proc. Efficient Use of Plant Nutrients. 4th National Congress of Soil Science. May 24–26, 1992 at Islamabad. pp. 439–50.

Drouineau, G. 1942. Dosage rapid du calcire actif du sol. Nouvelles donnes sur in reportation de la nature des fractions calcaries. Ann. Agron. 12: 411-450.

Dolan M.S., C.E. Clapp, R.R. Allmaras, J.M. Baker and J.A.E. Molina. 2006. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. Soil Tillage Res. 89: 221–231. https://doi.org/10.1016/j.still.2005.07.015

Duiker, S.W. and D.B. Beegle. 2005. Soil fertility distribution in long-term, no-till, chisel/disk and moldboard plow/disk systems. Soil Tillage Res. 88: 30-41. https://doi.org/10.1016/j.

still.2005.04.004

Edwards, J.H., C.W. Wood, D.L. Thurlow and M.E. Ruf. 1992. Tillage and crop rotation effects on fertility status of a Hapludult soil. Soil Sci. Soc. Am. J. 56: 1577-1582. https://doi.org/10.2136/sssaj1992.03615995005600050040x

EI-Shakweer, M.H.A., E.A. EI-Sayad and M.S.A. Ewees. 1998. Soil and plant analysis as a guide for interpretation of the improvement efficiency of organic conditioners added to different soils in Egypt. Commun. Soil Sci. Plant Anal. 29: 2067-2088. https://doi.org/10.1080/00103629809370094

Ewulo, B.S., O.S. Ojeniyi and D.A. Akkani. 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. Afr. *J.* Agric. Res. 3: 612–616.

Ezemonye, M.N. and Emeribe C.N. 2012. Rainfall erosivity in southeastern Nigeria. Ethiop. J. Environ. Stud. Manage. **5**: 112–122. https://doi.org/10.4314/ejesm.v5i2.1

Gee, G.W. and J.W. Bauder. 1986. Particle size Analysis. In: Klute, A. (ed). Methods of Soil Analysis. Part 1. Am. Soc. Agron. No. 9. Madison, Wisconsin.pp. 383-411.

Ijaz, S.S. and S. Ali. 2007. Tillage and mulch effects on profile moisture dynamics, fallow efficiency and rain fed wheat yields in Potowar. J. Agric. Sci. 44: 90-95.

Iqbal, M.M., J. Akthar, W. Muhammad, S.M. Shah, H. Nawaz and K. Mahmood. 2005. Effect of tillage and fertilizer levels on wheat yield, nitrogen uptake and their correlation with carbon isotope determination under rain fed conditions in north-west Pakistan. Soil Tillage Res. 80: 47-57. https://doi.org/10.1016/j.still.2004.02.016

Hatfield, J.L., J.S. Thomas and J.H. Prueger. 2001. Managing soils to achieve greater water use efficiency. Agron. J. 93: 271-280. https://doi.org/10.2134/agronj2001.932271x

Hejazi, A., M.J. Bahrani and S.A. Kazemeini. 2010. Yield and yield components of irrigated rapeseed-wheat rotation as influenced by crop residues and nitrogen levels in a reduced tillage method. Amer-Eurasian J. Agric. Environ. Sci. 8: 502-507.

Hill, R.L., R. Horton and R.M. Cruse. 1985. Tillage effects on soil water retention and pore size distribution of two mollisols. Soil Sci. Soc. Am. J. 49: 1264-1270. https://doi.org/10.2136/sssaj1985.03615995004900050039x

Hill, R.L. 1990. Long-term conventional and no-till effects on selected soil physical properties. Soil Sci. Soc. Am. J. 54: 161-166. https://doi.org/10.2136/sssaj1990.03615995005400010025x

Huang, B, W.Z. Sun, Y.Z. Hao, J. Hu, R. Yang, Z. Zou, F. Ding and J. Su. 2007. Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural Ecosystem as affected by farming practices. Geoderma. 139: 336-345. https://doi.org/10.1016/j.geoderma.2007.02.012

Jiao, J., Zou H., Jia Y. and N. Wang. 2009. Research progress on the effect of soil erosion on vegetation. Acta Ecol. Sinica. 29: 85–91. https://doi.org/10.1016/j.chnaes.2009.05.001

Kang, B.T and V. Balasubramanian. 1990. Long term fertilizer trials on alfisols in West Africa. In: Transactions 14th Int. Cong. Soil Sci., Kyoto, Japan. Aug. 5: 20-25.

Kashif, K., M. Iqbal, M.S Arif and A. Nawaz. 2006. Effect of tillage and mulch on soil physical properties and growth of maize. Int. J. Agric. Biol. 5: 593-596.

Lal, R. 1974. Soil temperature, soil moisture and maize yield from mulched and unmulched tropical soils. Plant Soil. 40: 129–43. https://doi.org/10.1007/BF00011415

Lal, R. 1978. Influence of within and between row mulching on soil temperature, soil moisture, root development and yield of maize (*Zea mays*) in a tropical soils. Field Crops Res. 1: 127–39. https://doi.org/10.1016/0378-4290(78)90016-3

Lal, R. 1995. Tillage and mulching effects on maize yield for seventeen consecutive seasons on a tropical alfisol. J. Sustain. Agric. 5: 79–93. https://doi.org/10.1300/J064v05n04_07

Lal, R. 1998. Soil quality changes under continuous cropping for seventeen seasons of an alfisol in western Nigeria. Land Degrad. Dev. 9: 259-274. https://doi.org/10.1002/(SICI)1099-145X(199805/06)9:3<259::AID-LDR290>3.0.CO;2-V

Lal, R. 2001. Soil degradation by erosion. Land Degrad. Dev. 12: 519 – 539. https://doi.org/10.1002/ldr.472

Li, H., Y. Han and Z. Cai. 2003. Nitrogen mineralization in paddy soils of the Taihu Region of China under anaerobic conditions, dynamics and model fitting. Geoderma. 115: 161-175. https://doi.org/10.1016/S0016-7061(02)00358-0

Lindsay, W.L. and W.A. Norvell. 1979. Chemical equilibria in soils. New York: John Wiley and Sons.

Lu, Y., B. Fu, L. Chen, G. Liu and W. Wei. 2007. Nutrient transport associated with water erosion: progress and prospect. Progress in Physical Geography. 31: 607–620. https://doi.org/10.1177/0309133307087085

Ma, B.L., L.M. Dwyer and G.E. Gregorich. 1999. Soil nitrogen amendment effects on nitrogen uptake and grain yield of maize. Agron. J. 9: 650-656. https://doi.org/10.2134/agronj1999.914650x

Mahboubi, A.A., R. Lal and N.R. Faussey. 1993. Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J. 57: 06–512.

Makinde, E.A., A.A. Agboola and F.I. Oluwatoyinbo. 2001. The effects of organic and inorganic fertilizers on the growth and yield of maize in a maize/melon intercrop. Moor J. Agric. Res. 2: 15-20.

Mandal, K.G., A.K. Misra, K.M. Hati, K.K. Bandyopadhyay, P.K. Ghosh and M. Mohanty. 2004. Rice residue- management options and effects on soil properties and crop productivity. J. Food Agric. Environ. 2: 224-231.

McLean, E.O. 1982. Soil pH and lime requirement. p. 199-224, In A.L. Page (ed.), Methods of Soil Analysis, part 2: Chemical and Microbiological Properties. Am. Soc. Agron. Madison, WI, USA.

Murwira, H.K. and H. Kirchmann. 1993. Carbon and nitrogen mineralization of cattle manures subjected to different treatments in Zimbabwean and 246 Swedish soils. In: Mulongoy K., R. Merckx (eds.) Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. 189-198.

Najafinezhad, H., M.A. Javaheri, M. Gheibi and M.A. Rostami. 2007. Influence of tillage practices on the grain yield of maize and some soil properties in maize – wheat cropping system of Iran. Iran. J. Agric. Soc. Sci. 3(3): 87-90.

Negassa, W., K. Negisho, D.K. Friesen, J. Ransom and A. Yadessa. 2002. Determination of optimum farmyard manure and np fertilizer for maize under the farmers' conditions. pp. 387-393. In: proceeding of 7th East and South African Regional Maize Conference, 11-15th February 2002, Nairobi, Kenya.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In: Page, A.L., R.H. Miller and D. R Keeney. (Eds.), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, 2nd Edition, Agronomy, 9. Am. Soc. Agron., Madison, WI: pp. 539–594.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, pp. 1–19.

Page, A.L., R.H. Miller and D.R. Keeney. 1982. Methods of soil analysis. Part II, 2nd ed. Am.erican Society of Agronomy, No.9. Madison, Wisconsin, USA.

Paustian, K., J. Six, E.T. Elliot and H.W. Hunt. 2000. Management options for reducing CO_2 emission from agricultural soils. Biogeochemistry. 48: 147-163. https://doi.org/10.1023/A:1006271331703

Rhoades, J.D. 1982. Soluble salts (Electrical conductivity). In: Page, A.L., R.H. Miller and D. R. Keeney. (eds). Methods of Soil Analysis Part 2. Amer. Soc. Agron., No. 9. Madison, Wisconsin, USA: 172-173.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkaline soils. USDA Agric. Handbook, 60. U. S. Gov. Print. Office, Washington, D. C., USA.

Sadeghi, H. and M.J. Bahrani. 2009. Effects of crop residue and nitrogen rates on yield and yield components of two dryland wheat (*Triticum aestivum* L.) cultivars. Plant Prod. Sci. 12: 497-502. https://doi.org/10.1626/pps.12.497

Saeed, I., M.K. Abbasi and M. Kazmi. 2001. Response of maize (*Zea mays* L.) to N and P fertilization under agro climatic conditions of Rawalakot Azad Jammu and Kashmir. Pak. J. Biol. Sci. 4: 949-952. https://doi.org/10.3923/pjbs.2001.949.952

Sainju U.M., T. Caesar-TonThat, A.W. Lenssen, R.G. Evans and R. Kolberg. 2007. Long-term tillage and cropping sequence effects on dryland residue and soil carbon fractions. Soil Sci. Soc. Am. J. 71: 1730–1739. https://doi.org/10.2136/sssaj2006.0433

Satyanarayana, V., V.V. Prasad, V.R.K. Murth and K.J. Boote. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. J. Plant Nutr. 25: 2081-2090. https://doi.org/10.1081/PLN-120014062

Schjonning, P., B.T. Christensen and B. Carstensen. 1994. Physical and chemical properties of a sandy loam receiving animal manure, mineral fertilizer or no fertilizer for 90 years. *Europ.* J. Soil Sci. 45: 257-268. https://doi.org/10.1111/j.1365-2389.1994.tb00508.x

Sharma, A.R and B.N. Mittra. 1991. Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. *J. Agric. Sci.* 117: 313-318. https://doi.org/10.1017/S002185960006704

Sidhu, A.S and H.S. Sur. 1993. Effect of incorporation of legume straw on soil properties and crop yield in a maize-wheat sequence. Trop. Agric. 70: 226-229.

Six, J., E.T. Elliott and K. Paustian. 2000. Soil macro aggregate turnover and micro aggregate formation: a mechanism for C sequestration under no-tillage agriculture. Soil Biol. Biochem. 32: 2013-2099. https://doi.org/10.1016/S0038-0717(00)00179-6

Steiner, J.L. 1994. Crop residue effects on water conservation. In. Unger P (ed), "Managing Agricultural Residues," CRC Press/Lewis Publishers, Boca Raton, FL: 41-76.

Thomas, G.A., R.C. Dalal and J. Standley. 2006. No-till effects on organic matter, pH, cation exchange capacity and nutrient distribution Luvisol in the semi-arid subtropics. Soil Tillage Res. 94: 295-304. https://doi.org/10.1016/j.still.2006.08.005

Tran-Thuc-Son, U. Sing, J.L. Padilla and R.J. Buresh. 1995. Management of urea and degraded soils of Red River Delta (Vietnam): Effect of growing season and cultural practice. P. 161-175. In G. L. Denning and Vo-Tong- Xuan (eds) Vietnam and IRRI, a partnership in rice research. Proc. Conf., Los Banos, Philippines. IRRI, Los Banos.

Unger, P.W. 1986. Wheat residue management effects on soil water storage and corn production. Soil Sci. Soc. Am. J. 50: 764–70. https://doi.org/10.2136/sssaj1986.03615995005000030040x

Wicks, G.A., D.A. Crutchfield and O.C. Burnside. 1994. Influence of wheat (*Triticum aestivum)* straw mulch and metolachlor on corn (Zea *mays*) growth and yield. Weed Sci. 42: 141–7.

Wright, D., J. Marois, J. Rich and R. Sprinkel. 2008. Field corn production guide-SS-AGR-85, univ. Florida.

Yadav, R.L. 2001. On-farm experiments on integrated nutrient management in rice-wheat cropping systems. Exp. Agric. 37: 99-113. https://doi.org/10.1017/S0014479701001077

Yang, J.Y., E.C. Huffman, R.D. Jong, V. Kirkwood, K.B. MacDonald and C.F. Drury. 2007. Residual soil nitrogen in soil landscapes of Canada as affected by land use practices and Agricultural policy scenarios. Land Use Policy. 24: 89-99. https://doi.org/10.1016/j.landusepol.2006.03.002

Zhai R, R.G. Kachanoski and R.P. Voroney. 1990. Tillage effects on the spatial and temporal variation of soil water. Soil Sci. Soc. Am. J. 54: 186-192. https://doi.org/10.2136/sssaj1990.03615995005400010029x

Zorita, M.D. 2000. Effect of deep tillage and nitrogen fertilization interactions on dry land corn productivity. Soil Tillage Res. 54: 11-19. https://doi.org/10.1016/S0167-1987(99)00100-2