Pak. J. Bot., 42(3): 1651-1664, 2010.

EFFECT OF CROP SEQUENCE AND CROP RESIDUES ON SOIL C, SOIL N AND YIELD OF MAIZE

MOHAMMAD SHAFI[1*], JEHAN BAKHT[2], ATTAULLAH[1] AND MOHAMMAD AMAN KHAN[3].

[1]*Department of Agronomy, Agricultural University Peshawar KPK, Pakistan*
[2]*Institute of Biotechnology and Genetic Engineering, Agricultural University Peshawar KPK, Pakistan*
[3]*Department of Pathology LRH Peshawar, Pakistan,*
**Corresponding author E-mail: mshafi.aup@gmail.com;*

Abstract

Improved management of nitrogen (N) in low N soils is critical for increased soil productivity and crop sustainability. The objective of the present study was to evaluate the effects of residues incorporation, residues retention on soil surface as mulch, fertilizer N and legumes in crop rotation on soil fertility and yield of maize *(Zea may* L*.)*. Fertilizer N was applied to maize @ 160 kg ha^{-1}, and to wheat @ 120 kg ha^{-1} or no fertilizer N application. Crop rotation with the sequence of maize after wheat (*Triticum aestivum* L.), maize after lentil (*Lens culinaris Medic*) or wheat after mash bean (*Vigna mungo* L.) arranged in a split plot design was followed. Post-harvest incorporation of crop residues and residues retention on soil surface as mulch had significantly ($p \leq 0.05$) affected grain and stover yield during 2004 and 2005. Two years average data revealed that grain yield was increased by 3.31 and 6.72% due to mulch and residues incorporation. Similarly, stover yield was also enhanced by 5.39 and 10.27% due to the same treatment respectively. Mulch and residues incorporation also improved stover N uptake by 2.23 and 6.58%, respectively. Total soil N and organic matter was non significantly ($p \geq 0.05$) increased by 5.63 and 2.38% due to mulch and 4.13, 7.75% because of crop residues incorporation in the soil. Maize grain and stover yield responded significantly ($p \leq 0.05$) to the previous legume (lentil) crop when compared with the previous cereal crop (wheat). The treatment of lentil – maize(+N), on the average, increased grain yield of maize by 15.35%, stover yield by 16.84%, total soil N by 10.31% and organic matter by 10.17%. Similarly, fertilizer N applied to the previous wheat showed carry over effect on grain yield (6.82%) and stover yield (11.37%) of the following maize crop. The present study suggested that retention of residues on soil surface as mulch, incorporation of residues in soil and legume (lentil – maize) rotation improved the N economy of the cropping system and enhances crop productivity.

Introduction

Crop yield is stagnant in Pakistan in recent years. This situation can not coup to solve the food problem of our rising population. It is necessary to continuously increase crop production to meet the demands of the people. As both land and water are at the verge of their limit, increasing yield per unit is the only open strategy. Among the plant nutrients, nitrogen deficiency is one of the major limiting factors for cereals (McDonald, 1992; Shah *et al*., 2003), hence fertilizer nitrogen application is an essential input for crop productivity in most areas of the world (Amanullah *et al*., 2009). With continued cereal cropping, the N supplied from the breakdown of organic matter must be supplemented from other sources. In the developed world, N is supplied in sufficient amount as chemical fertilizer; however, in majority of the developing countries including Pakistan, this is not possible because of high cost of fertilizer, low per capita income and limited credit facilities available to most of the farmers. As a consequence, farmers either use the available organic sources or the crop remains unfertilized (Ahmad *et al*., 2009). To satisfy the nutrient requirement of the plant, farmers are indispensably inclined to use commercial fertilizer. But during the last few years, the prices of fertilizers have shown unprecedented hike and their availability at proper time has been a matter of serious concern in some developing countries including Pakistan. The result is failure to obtain the targeted production and hence the national average yield of major crops is thus below the demonstrated production potential. In such a system, the inclusion of legume in crop rotation can play an important role to maintain soil fertility and sustain crop productivity. The ability of legumes to fix atmospheric nitrogen, their nodulated roots and plant residues left after harvesting represent a valuable source of N. Legumes in cropping system maintain the soil fertility. Many workers have reported more soil moisture availability after a legume than after a non-legume crop (Aslam *et al*., 1998). Concern for the sustainability of yield and soil fertility has led to a renewed interest in cropping system and incorporation of crop residues. Farmers and researchers have shown increased interest in crop rotation and management of crop residues as valuable management tools. This interest has resulted because of increased costs of inorganic fertilizers and reduced yields in monoculture cropping systems.

Management of crop residues on soil surface as mulch improves soil quality in terms of organic carbon and biotic activity. An increase in infiltration of water into the soil has also been reported by Bruce *et al*., (1992). Research under laboratory and field condition have shown that the use of surface organic mulch (straw) can result in storing more precipitation water in soil by reducing runoff, increasing infiltration and decreasing evaporation. In addition to reduce runoff, soil surface mulching with crop residues also reduces direct evaporation from wet soil surface and thus increases water availability (Jalota & Prihar, 1990). Gajri *et al.*, (1994) concluded that proper combination of management practices like residues incorporation, mulching and manuring which increases depth and rooting density, can enhance the crop productivity of less water retentive coarse textured soil in arid and semi arid environment and alleviate water and nutrient stress.

Keeping in view the long term sustainability and productivity of soils through cereal -legume cropping system and management of residues, the present study was initiated to investigate the effects of the management of crop residues, fertilizer N and crop rotation on the yield of maize and soil fertility.

Materials and Methods

Trial description: The experiment was carried out at the Research Farms of Agricultural University Peshawar KPK, Pakistan (longitude 71^0 50'E, latitude 34^0 01'N). Soil at the experimental site was silty clay to silty clay loam (fine mixed, hypothermic, acidic Astochrepths placed in the Pirsabak series), none-saline (EC < 2.00 mmhos/cm), alkaline in reaction (pH 8.0), and low in organic matter (< 1.0%), total N (< 0.07%) and available P (<3.0 µg P g^{-1}). The altitude of the site is 400 m above sea level in Peshawar Valley of NWFP, Pakistan. Mean annual rainfall ranged from 380-550 mm.

Experimental design and sowing: Experiments were replicated four times using a split plot design with three residues management treatments as main plot factors (i.e. residues incorporation, residues retention on soil as mulch and residues removal. The sub plot factors were eight crop rotation with or without fertilizer N. Sub-plot size was 8m x 5m. The experiment was commenced in May 2004 with maize *(Zea may* L.) and mash bean (*Vigna mungo* L.) in the summer followed by wheat (*Triticum aestivum* L.) and lentil (*Lens culinaris* Medic.) in the winter, 2004-05. Fertilizer N rate were 120 kg ha^{-1} for wheat and 160 kg ha^{-1} for maize. This sequence of crop rotation was completed with summer, 2005 after the harvest of summer crops (maize and mash bean). This paper, however, presents only the results of maize yield and soil fertility for two years as influenced by residues retention on soil surface as mulch, residues incorporation, residues removal and N fertilizer treatments. All seeds were sown by hand-drill to 5 cm depth. Row spacing was 30 cm (wheat, mash bean and lentil) or 65 cm (maize). Cereals were either unfertilized (0N) or fertilized (+N) with 120 kg N ha^{-1} (wheat) or 160 kg N ha^{-1} (maize) as urea, half at sowing and half at second/third irrigation. Mash bean and lentil received 25 kg N ha^{-1} as starter dose at each sowing. The rates and timings of fertilizers application were according to the local recommendations. Wheat and lentil were grown in the first week of November and harvested in the middle of May. Maize and mash bean were grown in the first week of June and harvested in first week of September. Canal water was used for irrigation when needed. Wheat cultivar Saleem-2000, maize cultivar Azam, Lentil cultivar Masoor-93 and Mash bean cultivar Mash-I were used through out the study. The crops were harvested at maturity and data on biomass and grain yields were recorded. Crop residues samples were taken for N analysis. Immediately after grain harvest, above-ground residues of all crops were either completely removed (-residues), returned (+residues) or incorporated by disc harrow and rotavator to 20 cm depth or maintained on soil surface as mulch. All treatment plots were sampled to a depth of 30 cm after each harvest and analyzed for total soil N and organic matter.

Laboratory analysis: All plant samples were oven dried at 80°C to a constant mass, weighed, then finely ground (<0.1mm) and analyzed for plant N (Bremner & Mulvaney, 1982). The soil samples were air dried for one day, ground, sieved (< 2mm) and analyzed for total soil N (Keeney & Nelson, 1982) and organic matter (Nelson & Sommers, 1982).

Statistical analysis: All data are presented as mean values of four replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by Gomez & Gomez (1984). MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983). The significance of differences among means was compared by using Least Significant Difference (LSD) test (Steel & Torrie, 1997).

Results and Discussion

Total soil N: Statistical analysis of the data showed that total soil N in all combinations of crop rotation was non significantly ($p \geq 0.05$) increased. However, crop rotation of wheat +N–maize 0N enhanced the soil total N by 2.70 and 2.63% when compared with wheat 0N–maize 0N during 2004 and 2005 respectively (Table 1). The cropping sequence of lentil–maize 0N increased the soil total N by 5.41 and 11.76% compared to wheat 0N–maize 0N during 2004 and 2005, respectively. Similarly, rotation of wheat +N–maize +N did enhance the soil total N by 10 and 22.50% when compared with wheat 0N–maize +N during 2004 and 2005, respectively. Our results further showed that rotation of lentil–maize +N increased the soil total N by 13.33% and 16.67% when compared with cropping sequence of wheat 0N–maize +N during the growing seasons of 2004 and 2005. It was also observed that the sequence of wheat +N–mash bean when compared with wheat 0N–mash bean raised the soil total N status by 6.98 and 13.64% during 2004 and 2005, respectively. These results agree with those reported by Utomo *et al*., (1990) and Shah *et al*., (2003). Shafi *et al*., (2007) and Bakht *et al.,* (2009) also reported increase in total N of soil by inclusion of chick pea in crop rotation. Stevenson & Kessel, (1996) investigated that soil N availability throughout the growing season was greater in a pea-wheat rotation than in a wheat-wheat rotation.

Table 1. Effect of crop rotation and residues management on total soil N (%) in the surface layer (0-30 cm) after harvest of maize/mash bean crop.

Crop rotation	Soil total N (%)		
	2004	**2005**	**Average**
Maize 0N following			
Wheat +N	0.038	0.039	0.039
Wheat 0N	0.037	0.038	0.038
% increase	2.70	2.63	2.67
Maize 0N following			
Lentil	0.039	0.038	0.039
Wheat 0N	0.037	0.034	0.036
% increase	5.41	11.76	8.59
Maize +N following			
Wheat +N	0.033	0.049	0.041
Wheat 0N	0.030	0.040	0.035
% increase	10.00	22.50	16.25
Maize +N following			
Lentil	0.034	0.042	0.038
Wheat 0N	0.03	0.036	0.033
% increase	13.33	16.67	15.00
Mash bean following			
Wheat +N	0.046	0.050	0.048
Wheat 0N	0.043	0.044	0.044
% increase	6.98	13.64	10.31
Significance ($p \leq 0.05$)	**NS**	**NS**	
Crop residues management			
Residues on surface(mulch)	0.037	0.038	0.038
Residues removed	0.035	0.036	0.036
% increase	5.71	5.56	5.63
Residues incorporated	0.034	0.040	0.037
Residues removed	0.035	0.036	0.036
% increase	-2.86	11.11	4.13
Significance ($p \leq 0.05$)	**NS**	**NS**	

NS = Non significant

Our data also suggested that crop residues incorporation and retention of crop residues on soil surface as mulch increased non-significantly ($p \geq 0.05$) the total soil N content of soil during both years (Table 1). Crop residues management reduced soil total N by 2.86% during 2004 but during 2005, the same treatment non-significantly ($p \geq 0.05$) increased soil total N by 11.11%. The results obtained during 2005 are consistent with the findings of Kumar & Goh (2002), Shah *et al.*, (2003), Shafi *et al.,* (2007) and Bakht *et al.,* (2009) where retention of crop residues also improved N content of the soil. The reason for the reduction in total soil N due to residues incorporation during 2004 might be due to the immobilization of nitrogen after incorporation of stover in the soil and also to their high C: N ratio. Residues retention as mulch improved the soil total N by 5.71 and 5.56% during 2004 and 2005, respectively. Applied fertilizer is directly exposed to air and sunlight which may result in the rapid loss of N. Fertilizer N is more effective when the straw is retained on the soil surface rather than removed (Malhi & Nyborg, 1990). Mulching may protect the loss of fertilizer, especially the volatilization loss of N fertilizer and thereby increasing N use efficiency. Uptake of N was significantly higher under mulching when compared with non mulching conditions.

Soil organic matter: The results obtained on soil organic matter as affected by management of crop residues, cropping sequence and N application are shown in Table 2. Significant ($p \leq 0.05$) effect of crop rotation on soil organic matter during the second year (2005) was observed. Crop rotation during the first year (2004) and residues management during both years did not significantly ($p \geq 0.05$) affect soil organic matter.

The sequence of wheat +N–maize 0N when compared with wheat 0N–maize 0N resulted in an improvement of 0.53 and 0.92% in organic matter during 2004 and 2005 respectively. Our results also suggested that crop rotation of lentil–maize 0N showed an increase of 1.84% and 2.75% in organic matter when compared with wheat (0N)–maize (0N) cropping sequence during 2004 and 2005 respectively. Similarly, the wheat +N–maize +N crop rotation enhanced the soil organic matter by 1.41 and 4.42% when compared with the treatment of wheat 0N – maize +N in 2004 and 2005, respectively. Shah *et al*., (2003), Shafi *et al.,* (2007) and Bakht *et al.,* (2009) reported that soil organic matter was increased by N inputs from both fertilizer N and by retention of residues and N_2 fixation. The organic matter content was increased after preceding or succeeding legume crops than after proceeding or succeeding cereal crops. The average data showed an increase of 2.45 and 0.15% due to crop rotation of lentil–maize +N compared with the treatment of wheat 0N–maize +N during 2004 and 2005 respectively. The data further showed that cropping sequence of wheat +N–mash bean when compared with wheat 0N–mash bean increased the soil organic matter by 4.78% during 2004 and 15.57% in 2005. These results thus suggested that inclusion of legumes in crop rotation could improve soil organic fertility.

Analysis of the data revealed that crop residues incorporation did not significantly ($p \geq 0.05$) increase the soil organic matter (Table 2). On the average, soil organic matter was enhanced by 1.18 and 3.59% due to residues retention on soil surface as mulch than residues removed treatment during 2004 and 2005 respectively. Improvement in soil organic matter due to residues incorporation was 4.45 and 11.05% during 2004 and 2005 respectively. The non significant ($p \geq 0.05$) effect of crop residues on soil organic matter may be due to the fact that cereal crops residues have high C:N or lignin ratio, which can make them resistant to microbial attack. Shafi *et al*., (2007) and Bakht *et al.,* (2009) reported that crop residues incorporation increased the organic C of the soil over control treatment. Our results demonstrated only small and statistically non significant ($p \geq 0.05$) improvement in soil organic matter content both by bringing legume in crop rotation and residues incorporation and retaining residues on soil surface as mulch during two years period. It is however, evident that the improvement was gradual, so it is likely that the effect of both crop residues management and involvement of legumes in crop rotation on soil organic matter will be more evident in long term experiments. We are aware of the facts that organic matter in soil is typically slow to respond to management changes and treatment effects and may not be easily measured within a short period of time as suggested by Power *et al*., (1998).

Table 2. Effect of crop rotation and residues management on soil organic matter (%) in the surface layer (0-30 cm) after harvest of maize/mash bean crop.

Crop rotation	Organic matter (%)		
	2004	**2005**	**Average**
Maize 0N following			
Wheat +N	0.765	0.771A	0.768
Wheat 0N	0.761	0.764BC	0.763
% increase	0.53	0.92	0.72
Maize 0N following			
Lentil	0.775	0.785A	0.780
Wheat 0N	0.761	0.764A	0.763
% increase	1.84	2.75	2.29
Maize +N following			
Wheat +N	0.790	0.804A	0.797
Wheat 0N	0.779	0.770B	0.775
% increase	1.41	4.42	2.91
Maize +N following			
Lentil	0.712	0.671BC	0.692
Wheat 0N	0.695	0.67A	0.683
% increase	2.45	0.15	1.30
Mash bean following			
Wheat +N	0.746	0.757BC	0.752
Wheat 0N	0.712	0.655C	0.684
% increase	4.78	15.57	10.17
Significance (p≤0.05)	**NS**	**S**	
Crop residues management			
Residues on surface(mulch)	0.773	0.750	0.762
Residues removed	0.764	0.724	0.744
% increase	1.18	3.59	2.38
Residues incorporated	0.798	0.804	0.801
Residues removed	0.764	0.724	0.744
% increase	4.45	11.05	7.75
Significance (p≤0.05)	**NS**	**NS**	

NS = Non significant
S = Significant
Means followed by different letters are statistically significant at p≤0.05.

N uptake by maize stover: Crop residues management and crop rotation did not significantly (p≥0.05) increase the stover N uptake by maize crop during 2004. Crop rotation during the second year (2005) did significantly (p≤0.05) enhance the N uptake of maize crop (Table 3). The N uptake in stover of maize in cropping sequence of wheat +N–maize 0N was increased by 6.05% during 2004 and 10.94% in 2005 when compared with the treatment of wheat 0N–maize 0N. Similarly, the N uptake in cropping sequence

Table 3. Effect of crop rotation and residues management on stover N uptake (%) after harvest of maize/mash bean crop.

Crop rotation	**Stover N uptake (%)**		
	2004	**2005**	**Average**
Maize 0N following			
Wheat +N	0.298	0.365B	0.332
Wheat 0N	0.281	0.277C	0.305
% increase	6.05	10.94	8.50
Maize 0N following			
Lentil	0.301	0.335B	0.318
Wheat 0N	0.281	0.277C	0.279
% increase	7.12	20.94	14.03
Maize +N following			
Wheat +N	0.318	0.432A	0.325
Wheat 0N	0.279	0.291C	0.285
% increase	13.98	14.09	14.03
Maize +N following			
Lentil	0.321	0.456A	0.339
Wheat 0N	0.279	0.291C	0.285
% increase	15.05	22.34	18.70
Significance ($p \leq 0.05$)	**NS**	**S**	
Crop residues management			
Residues on surface(mulch)	0.374	0.356	0.365
Residues removed	0.364	0.35	0.357
% increase	2.75	1.71	2.23
Residues incorporated	0.389	0.372	0.381
Residues removed	0.364	0.35	0.357
% increase	6.87	6.29	6.58
Significance ($p \leq 0.05$)	**NS**	**NS**	

NS = Non-significant
S = Significant
Means followed by different letters are statistically significant at $p \leq 0.05$.

of lentil–maize 0N was improved non significantly ($p \geq 0.05$) by 7.12% in 2004 and significantly by 20.94% during 2005 when compared with the rotation of wheat 0N–maize 0N. Crop rotation of wheat +N - maize +N increased the maize stover N uptake by an average of 13.98 and 14.09% during 2004 and 2005 respectively. Our data further revealed that the treatment of lentil–maize +N non-significantly ($p \geq 0.05$) increased the stover N uptake by 15.05% during 2004 and significantly by 22.34% in 2005 when compared with wheat 0N–maize +N during the same years. These results agree with those reported by Staggenborg *et al*., (2003). Similarly, Stevenson & Van Kessel (1996) found that total N accumulated in cereal (wheat) was 27 kg ha^{-1} greater in a pea-wheat rotation than in the wheat-wheat rotation. The premium for high protein wheat seed is yet another reason why producers should consider crop rotation that includes legume crops. The carry over effect of fertilizer N applied to wheat was evident in the following maize (Table 3). The effect was, however, more evident in the N fertilized than in the N-unfertilized wheat. Shah *et al*., (2003) found similar responses of fertilizer N applied to maize on the following wheat in a rain-fed environment. Shafi *et al*., (2007) observed carry over effect of fertilizer N applied to the wheat on the following maize crop. Fertilizer N applied to current wheat crop increased the N uptake in maize stover. There are however, reports where fertilizer N to the previous wheat exerted carry over effects on the following 0N wheat (Shah *et al*., 2003). These results also agree with Feigenbaum *et al.*, (1984) who reported recovery of 8-10% of fertilizer N by the second cereal crop of wheat. Contrary to our results, Corbeels *et al*., (1998) found no increase in N uptake in the seed of sunflower following N fertilized wheat. Staggenborg *et al*., (2003) reported that grain N content increased as applied N increased.

Our results further demonstrated that crop residues management (residues incorporation or residues retention on soil surface as mulch) did not significantly ($p \geq 0.05$) increase the N uptake of maize during 2004 and 2005. However, residues retention as mulch increased N uptake in stover by 2.75 and 1.71% when compared with the treatment of residues removed in 2004 and 2005 respectively. The treatment of residues incorporation increased the stover N uptake by 6.87 and 6.29% than residues removed treatment during 2004 and 2005, respectively. These results indicate that residues return to soil is likely to have long term impact on N uptake. Stevenson & Van Kessel (1996) and Shafi *et al*., (2007) concluded that residues incorporation resulted in extra accumulation of N by maize. Similar findings were also reported by Acharya & Sharma (1994) who observed that retaining residues on soil surface as mulch generally showed an increase in total uptake of N, P and K than corresponding residues removed treatments.

Stover yield: The results presented in Table 4 indicated that the effect of crop residues incorporation, fertilizer N applications and involvement lentil in cropping system was significant ($p \leq 0.05$) on stover production of maize during 2004 and 2005.

The cropping sequence of wheat 0N–maize 0N improved the stover production by 2.50 and 20.25% than wheat 0N–maize 0N during 2004 and 2005, respectively. Similarly, crop rotation of wheat +N–maize +N increased stover yield by 3.53% during 2004 and 6.20% in 2005 when compared with crop rotation of wheat 0N–maize +N. Previous legume crop (lentil) had a significant ($p \leq 0.05$) effect on the stover yield of the succeeding maize during both 2004 and 2005. The corresponding increases in stover yield were 7.71 and 13.75% in 2004 and 2005, respectively for the treatments of maize (0N) following lentil than following wheat 0N. The effect of lentil–maize +N increased the stover yield by 12.49% in 2004 and 21.18% during 2005 when compared with the treatment of wheat 0N–maize +N. Our results also revealed that fertilizer N applied to the previous wheat crop had a carry over effect on the stover yield of the following maize crop during 2004 and 2005. Statistical analysis of the data also revealed that incorporation of crop residues on the average resulted in 15.13 and 5.42% increase in stover yield compared with the residues removed treatments during 2004 and 2005, respectively. Similarly, retention of residues on soil surface as mulch increased the stover yield by 7.51% in 2004 and 3.28% in 2005 when compared with the residues removed treatments. Shah *et al*., (2003), Shafi *et al*., (2007) and Bakht *et al.,* (2009) reported that shoot biomass was increased with residues retention. Similar findings were also reported by Bhagat, (1990) who used different tillage, mulch and farm manure combination and found maximum dry biomass in wheat in conventional tillage and mulch compared with other treatment combination. This might be due to the modifying effect of mulch on hydrothermal regime of the soil (Bhagat & Acharya, 1987) which favorably affects the root growth (Wilhelm *et al*., 1982; Chudhary & Chopra, 1983). Mulching increased the dry matter yield of maize. Increasing soil moisture content by reducing evaporative losses

Table 4. Effect of crop rotation and residues management on stover yield (kg ha^{-1}) of maize crop.

Crop rotation	Stover yield (kg ha^{-1})		
	2004	2005	Average
Maize 0N following			
Wheat +N	1888B	4757BC	3323
Wheat 0N	1842B	3956C	2899
% increase	2.50	20.25	11.37
Maize 0N following			
Lentil	1984B	4500BC	3242
Wheat 0N	1842B	3956BC	2899
% increase	7.71	13.75	10.73
Maize +N following			
Wheat +N	3899A	5245AB	4572
Wheat 0N	3766A	4939BC	4353
% increase	3.53	6.20	4.86
Maize +N following			
Lentil	3674A	5985A	4830
Wheat 0N	3266AB	4939BC	4103
% increase	12.49	21.18	16.84
Significance ($p \leq 0.05$)	**S**	**S**	
Crop residues management			
Residues on surface(mulch)	3006A	4882A	3944
Residues removed	2796B	4727B	3762
% increase	7.51	3.28	5.39
Residues incorporated	3219A	4983A	4101
Residues removed	2796B	4727B	3762
% increase	15.13	5.42	10.27
Significance ($p \leq 0.05$)	**S**	**S**	

S = Significant

Means followed by different letters are statistically significant at $p \leq 0.05$.

using crop residues as mulch is reported to increase the dry matter of wheat. Gill *et al*., (1996) while performing experiments on corn observed that dry matter was affected by mulching. Mulching resulted in greater dry matter production.

Grain yield of maize: The effect of crop residues management, cropping sequence and fertilizer N application was significant ($p \leq 0.05$) on grain yield of maize during 2004 and 2005 as presented in Table 5. Crop rotation of wheat +N–maize 0N resulted in grain yield increase of 3.07 and 10.58% during 2004 and 2005 respectively when compared with wheat 0N–maize 0N. The same treatments also improved 100 grains weight by 3.56 and 12.02% during 2004 and 2005 respectively (Table 7). Similarly, grains cob^{-1} was also increased by 5.07 and 7.93% during 2004 and 2005 respectively by the same treatments (Table 6). The data also suggested that the treatment of lentil–maize 0N improved the grain yield of maize by 16.07 and 6.09% when compared with wheat 0N–maize 0N during 2004 and 2005, respectively. This could be due to more number of grains cob^{-1} and more 100 grains weight (Tables 6 and 7). The treatments of lentil– maize +N when compared with wheat 0N–maize +N enhanced the grain yield by 6.29 and 24.40% during 2004 and 2005, respectively. Again, the probable reason for more grain yield could be

Table 5. Effect of crop rotation and residues management on grains yield ($kg\ ha^{-1}$) of maize crop.

Crop rotation	Grains yield ($kg\ ha^{-1}$)		
	2004	**2005**	**Average**
Maize 0N following			
Wheat +N	1244C	1724C	1484
Wheat 0N	1207C	1559C	1383
% increase	3.07	10.58	6.82
Maize 0N following			
Lentil	1601B	1654C	1528
Wheat 0N	1207C	1559C	1383
% increase	16.07	6.09	11.08
Maize +N following			
Wheat +N	2394A	2605AB	2500
Wheat 0N	2097A	2344B	2221
% increase	14.16	11.13	12.65
Maize +N following			
Lentil	2398A	2916A	2657
Wheat 0N	2056A	2344B	2300
% increase	6.29	24.40	15.35
Significance ($p \leq 0.05$)	**S**	**S**	
Crop residues management			
Residues on surface(mulch)	1878B	2170A	2024
Residues removed	1820B	2098B	1959
% increase	3.19	3.43	3.31
Residues incorporated	2002A	2220A	2061
Residues removed	1820B	2038B	1929
% increase	4.51	8.93	6.72
Significance ($p \leq 0.05$)	**S**	**S**	

S = Significant
Means followed by different letters are statistically significant at $p \leq 0.05$.

heavier grains and more number of grains cob^{-1} as shown in Table 6 and 7. Similarly, many studies (Chalk *et al*., 1993) verified that N is a key factor in the response of cereals following legumes compared with cereals following non-legumes. Stevenson & Van Kessel (1996) and Chalk (1998) reported that cereals derive both yield and N benefits from crop rotation with grain legume compared with cereal monoculture. Crop rotation of wheat +N–maize +N when compared with wheat 0N–maize +N produced 14.16 and 11.13% higher grain yield during 2004 and 2005 respectively (Table 5). The same treatments also improved 100 grains weight by 10.42 and 15.39% in 2004 and 2005, respectively (Table 7). Similar is the case with grain cob^{-1} which were increased by the same treatments (14.79 and 15.18% during 2004 and 2005, respectively) (Table 6). There are reports where fertilizer N applied to the previous maize exerted carry over effect on the following 0N wheat (Shah *et al*., 2003; Shafi *et al*., 2007; Bakht *et al.,* 2009). The effects of fertilizer N on wheat yields are consistent with the low organic matter fertility of the soil of this site. Similarly, Rasmussen *et al*., (1997) also found that increasing N fertilizer rate increased the number of grains $spike^{-1}$ which resulted in more grain yield compared with their control (0N) treatment. A yield advantage for

Table 6. Effect of crop rotation and residues management on grains cob^{-1} of maize crop.

Crop rotation	Grains cob^{-1}		
	2004	2005	Average
Maize 0N following			
Wheat +N	171.39BC	180.33CD	175.86
Wheat 0N	163.12BC	167.08D	165.10
% increase	5.07	7.93	6.50
Maize 0N following			
Lentil	177.03B	179.25CD	178.14
Wheat 0N	163.82BC	167.08D	165.45
% increase	8.06	7.28	7.67
Maize +N following			
Wheat +N	230.73A	252.25B	241.49
Wheat 0N	201.00B	219.00BC	210.00
% increase	14.79	15.18	14.99
Maize +N following			
Lentil	234.36A	296.00A	265.18
Wheat 0N	201.00	219.00BC	210.00
% increase	16.60	35.16	25.88
Significance ($p \leq 0.05$)	**S**	**S**	
Crop residues management			
Residues on surface(mulch)	205.94	212.37	209.16
Residues removed	197.81	206.51	202.16
% increase	4.11	2.84	3.47
Residues incorporated	214.16	228.04	221.1
Residues removed	197.81	206.51	202.16
% increase	8.27	10.43	9.35
Significance ($p \leq 0.05$)	**NS**	**NS**	

NS = Non-significant
S = Significant
Means followed by different letters are statistically significant at $p \leq 0.05$

wheat following legumes crop of lentil may be attributed to various factors, such as lower nutrient export from the soil by legumes than by cereal, fixation of atmospheric N, better establishment and growth of cereal after legume than in cereal monoculture and other rotation effects.

Analysis of the data also suggested that incorporation of residues in soil and retention of residues on soil surface as mulch significantly ($p \leq 0.05$) affected the grain yield of wheat during 2004 and 2005 growing season (Table 5). The effect of residues retention on soil surface as mulch when compared with residues removed treatments increased grain yield by 3.19 and 3.43% during 2004 and 2005, respectively. This could be due to more 100 grains weight and number of grains cob^{-1} (Tables 6 and 7). Incorporation of residues in soil enhanced the grain yield by 4.51 and 8.93% when compared with the treatment of residues removal during 2004 and 2005, respectively.

Table 7. Effect of crop rotation and residues management on 100 grains weight (g) of maize crop.

Crop rotation	100 grains weight (g)		
	2004	**2005**	**Average**
Maize 0N following			
Wheat +N	20.05B	21.62A	20.84
Wheat 0N	19.36BC	19.30B	19.33
% increase	3.56	12.02	7.79
Maize 0N following			
Lentil	20.45B	19.62B	20.04
Wheat 0N	19.36BC	18.30B	18.83
% increase	5.63	7.21	6.42
Maize +N following			
Wheat +N	21.08B	22.86A	23.47
Wheat 0N	19.09BC	22.41A	20.75
% increase	10.42	15.39	12.91
Maize +N following			
Lentil	23.54A	21.82A	23.17
Wheat 0N	21.09B	21.41A	21.25
% increase	11.62	6.49	9.05
Significance ($p \leq 0.05$)	**S**	**S**	
Crop residues management			
Residues on surface(mulch)	21.13	21.28	21.21
Residues removed	20.09	21.23	20.66
% increase	5.18	0.24	2.71
Residues incorporated	22.03	21.30	22.67
Residues removed	20.09	21.23	20.66
% increase	9.66	9.75	9.70
Significance ($p \leq 0.05$)	**NS**	**NS**	

NS = Non-significant
S = Significant
Means followed by different letters are statistically significant at $p \leq 0.05$

The same treatments also increased number of grains cob^{-1} and 100 grains weight (Tables 6 and 7). Kouyate *et al*., (2000) also reported an increase in cereal grain and stover yields by 37 and 49% respectively, when crop residues were incorporated compared with control treatment (no residues incorporation). Shafi *et al*., (2007) and Bakht *et al.*, (2009) reported an increase in cereal grain yield when crop residues were incorporated compared with untreated controls (no residues incorporation).

References

Acharya, C.L. and P.D. Sharma. 1994. Tillage and mulch effects on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisol in north west India. *Soil Till. Res*., 32: 291-302.

Ahmad, K., M.T. Jan, K.B. Marwat and M. Arif. 2009. Organic and inorganic nitrogen treatments effects on plant and yield attributes of maize in a different tillage systems. *Pak. J. Bot.*, 41: 99-108.

Amanullah, K.B. Marwat, P. Shah, N. Maula and S. Arifullah. 2009. Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. *Pak. J. Bot*., 41: 761-768.

Aslam, M., I. Mahmood, S. Ahmad, M.B. Peoples and D.F. Herridge. 1998. Survey of chickpea N_2-fixation in the Potohar and Thal area of the Punjab, Pakistan. In: *Extending nitrogen fixation research to farmer fields. Proceedings of. Inter Workshop on Managing Legume Nitrogen Fixation in Cropping System of Asia. Asia Centre, India*. (Eds.): O.P. Rupala, C. Johansen, and D.F. Herridge, p. 353-360.

Bakht, J., M. Shafi, M.T. Jan and Z. Shah. 2009. Influence of crop residues management, cropping system and N fertilizer on soil N and C dynamics and sustainable wheat production. *Soil and Till. Res.,* 104: 233-240.

Bhagat, R.M. 1990. Effect of tillage and residues management on hydrothermal regime, nutrient uptake and yield of wheat in a river deposit. *Soil Till, Res*., 9: 315-326.

Bhagat, R.M. and C.L. Acharya. 1987. Effect of soil management on rainfed wheat in Northern India. 1. Hydrothermal regime and root growth. *Soil Tillage Res*., 9: 65-77.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-Total. In: *Methods of Soil Analysis*, (Eds.): A.L. Page, R.H. Miller, D.R. Keeney. Part II. Chemical and Microbiological Properties. Second Ed. *Am. Soc. Agron*, Madison, WI, USA, P. 595-624.

Bruce, R.R., G.W. Langdale, L.T. West and W.P. Miller. 1992. Soil surface modification by biomass inputs affecting rainfall infiltration. *Soil. Sci. Soc. Am. J*., 56: 1615-1620.

Chalk, P.M. 1998. Dynamics of biologically fixed N in legume-cereal rotations: A review *Aust. J. Agric. Res*., 49: 303-316.

Chalk, P.M., C.J. Smith, S.D. Hamilton and P. Hopmans. 1993. Characterization of the N benefit of a grain legume (*Lupinus angustifolius* L.) to a cereal (*Hordeum vulgare* L.) by an *in situ* ^{15}N isotope dilution technique. *Biol. Fertil. Soils*, 15: 39-44.

Chudhary, T.N. and U.K. Chopra. 1983. Effect of soil covers on growth and yield of irrigated wheat planted at two dates. *Field Crops Res*., 6: 293-304.

Corbeels, M., G. Hofman and O.V. Cleemput. 1998. Residual effect of nitrogen fertilization in wheat-sunflower cropping sequence on Vertisol under semi-arid Mediterranean conditions. *Eur. J. Agron.*, 9: 109-116.

Feigenbaum, S., N.G. Seligman and R.W. Benjamin. 1984. Fate of nitrogen-15 applied to spring wheat grown for three consecutive years in a semi-arid region. *Soil Sci. Soc. Am. J*., 48: 838-843.

Gajri, P.R., V.K. Arora and M.R. Chaudhry. 1994. Maize growth responses to deep tillage straw mulching and farm yard manure in coarse textured soil of N.W. India. *Soil Use and Managmt.*, 10: 15-20.

Gill, K.S., P.R. Gajri, M.R. Chaudhary and B. Singh. 1996. Tillage, mulch and irrigation effects on corn (*Zea mays* L.) in relation to evaporative demand. *Soil Till. Res*., 39: 213-227.

Gomez, K.A. and A.A. Gomez. 1984. *Statistical procedures for agricultural research*. John Wiley and Sons, New York, USA.

Jalota, S.K. and S.S. Prihar. 1990. Effect of straw mulch on evaporation reduction in relation to rates of mulching and evaporability. *J. Indian Soc. Soil Sci.,* 38: 728-730.

Keeney, D.R. and D.W. Nelson. 1982. Nitrogen-inorganic forms In: *Methods of Soil Analysis*. *Parts II. Chemical and Microbiological Properties*. (Eds.): A.L. Page, R.H. Miller, D.R. Keeney. Agronomy No. 9, *American Society of Agronomy* Madison, WI, P. 643-698.

Kouyate, Z., K. Franzluebbers, A.S.R. Juo and L. Hossner. 2000. Tillage, crop residues, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. *Plant and Soil.*, 225: 141-151.

Kumar, K and K.M. Goh. 2002. Management practices of antecedent leguminous and non-leguminous crop residues in relation to winter wheat yield, nitrogen uptake, soil nitrogen mineralization and simple nitrogen balance. *Euro. J. Agron*., 16: 295-308.

Malhi, S.S. and M. Nyborg. 1990. Effect of tillage and straw on yield and N uptake of barley grown under different N fertility regions. *Soil Tillage Res*., 17: 115-124.

McDonald, G.K. 1992. Effects of nitrogenous fertilizer on the growth, grain yield and grain protein concentration of wheat. *Aust. J. Agric. Res*., 43: 949-967.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. In: *Methods of Soil Analysis Part II. Chemical and Microbiological Properties*. *Second ed*. (Eds.): A.L. Page, R.H. Miller, D.R. Keeney. *Am. Soc. Agron*. Madison, WI, USA, pp. 539-580.

Power, P.T., J.W. Koener and W.W. Wilhelm. 1998. Residual effect of crop residues on grain production and selected soil properties. *Soil Sci. Soc. Am. J*., 62: 1393-1397.

Rasmussen, P.A., R.W. Rickman and B.L. Klepper. 1997. Residues and fertility effects on yield of no tillage wheat. *Agron. J*., 89: 563-567.

Russel, D.F. and S.P. Eisensmith. 1983. MSTAT-C. Crop and Soil Science Michigan State University, East Lansing, MI. USA.

Shafi, M., J. Bakht, M.T. Jan and Z. Shah. 2007. Soil C and N dynamics and maize (*Zea mays* L.) yield as affected by cropping systems and residues management in North-western Pakistan. *Soil Till. Res*., 94: 520-529.

Shah, Z., S.H. Shah, M.B. Peoples, G.D. Schwenke and D.E. Herriedge. 2003. Crop residues and fertilizer N effects on nitrogen fixation and yields of legume-cereal rotations and soil organic fertility. *Field Crops Res*., 83: 1-11.

Staggenborg, D.A., D.L. Whitney and J.P. Shroyer. 2003. Seeding and nitrogen rates required to optimize winter wheat yields following grain sorghum and soybean. *Agron . J*., 95: 253-259.

Steel, R.G.D. and J.H. Torrie. 1997. *Principles and Procedures of Statistics*: A biometrical approach. 3rd Edition McGraw Hill Book Co. Inc. New York.

Stevenson, F.C. and C. Van Kessel. 1996. The nitrogen and non-nitrogen benefits of pea to succeeding crops. *Can. J. Plant Sci*., 76: 735-745.

Utomo, M., W.W. Frye and R.L. Blevins. 1990. Sustaining soil nitrogen for corn using hairy vetch clover crop. *Agron. J*., 82: 979-983.

Wilhelm, W.W., L.N. Nielke and C.R. Fenster. 1982. Root development of wheat as related to tillage practices in western Nebraska. *Agron. J*., 74: 85-88.

(Received for publication 14 February 2009)