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Full Length Article

Carryover Response of Tillage Depth, Legume Residue and Nitrogen-rates on Maize Yield and Yield Contributing Traits

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Abstract

Maize (*Zea mays* L.) after wheat (*Triticum aestivum* L.) is successfully grown in tropics and sub-topics where cereals grains contribute in staple food and their by-products as fodder. This study evaluated the carryover response of tillage depth (TD), crop residue (R) and fertilizer nitrogen rates (N) on maize in wheat-maize cropping system during summer 2010 and 2011. On dry matter (DM) basis, 5 tones ha^{-1} legume residue (LR) of cowpea and cereal residue (CR) from maize vs. no-residue (NR) were incorporated into the soil as main plot treatments. The soil was immediately plowed with moldboard for deep tillage (DT) and with cultivator for shallow tillage (ST) as main plot treatments. Different N-rates (0, 40, 80, 120 and 160 kg ha^{-1}) were applied as subplot treatments. Results showed that DT increased grains yield by 2.27% than ST and ear number by 6%, grain number by 2.79% and thousand grains weight (1.02%). When compared with NR, the grain yield increased by 8.09% with incorporation of LR and 1.37% with CR with higher fractional contributions of ear and grain number than grain weight. Similarly, maize grain yield also increased by 44.91, 42.40, 29.81 and 6.64% by application of 160, 120, 80 and 40 kg N ha^{-1}. Canopy radiation use efficiency (RUE) also increased in similar trend as for grain yield under given treatments. Interaction was significant ($p<0.05$) for grain yield in 2011 and for two years average. Two years average data also showed markedly higher ($p<0.05$) grain yield under LR than CR or NR treatments. Similarly, as compared to control and N-rate 40 kg ha^{-1}, the 80 and 120 kg N ha^{-1} showed significantly marked changes in yield with highest in LR, followed by CR and lowest by NR. For interaction, the yield difference with treatments was mainly associated with ear number and to some extent in 1000 grain weight. The study suggests that 5 t ha^{-1} residue (legume > cereals > No residue) with 120 kg N ha^{-1} when incorporated deeply in soil has long lasting favorably positive response on crop yield and soil fertility in regularly cultivated cereal based rotation.

Keywords: Tillage depth; Crop residue; N-rates; Maize yield; Radiation use efficiency

Introduction

Maize, a high yielding cereal in the world, has significant importance in production systems of countries where grain is consumed as food and straw/stalks as fodder (Akmal *et al*., 2010). Countries where population expansion has already out-stripped resources, crops are generally treated with insufficient or inappropriate nutrients application due to resource limitation and/or its availability meeting growers demand in time. The growing trend of world's population is not only threat for deterioration of the existing natural resources but also a question for sustainable farming where density has approaching the saturation index. Issue is becoming acute in densely populated, under developed and ecologically fragile areas of Hindu Kush Himalayan (HKH) region (Rasul and Karki, 2007; Tiwari *et al*., 2008). To meet increasing demand of the growing population, subsistence agriculture has been intensified in the HKH region. Nonetheless, intensification has been applied without suitable management practices that might lead to organic matter (OM) loss, soil fertility depletion, accelerated deforestation, soil erosion and environmental degradation (Tiwari *et al*., 2008; Tanveer *et al*., 2014).

Maize is successfully grown after wheat in summer, fertilized mainly with nitrogen, phosphorus and occasionally with potassium. It is relatively short duration warm season cereal with potential to utilize solar energy more efficiently for production (Grassini and Cassman, 2012; Liu *et al*., 2012). Cold weather retards pollen shedding and hot dry conditions tend to hasten it (Muui *et al*., 2007). However, maize yield remained stagnant but might has adverse effects in long term due to nutrient deficiency that may be essential for sustainable production (Long and Sun, 2012; Shumway *et al*., 2012). Tillage had a significant impact on crop production. Deep tillage and erosion has shown a reduction in soil OM and loss in production (Ibrahim *et al*., 2011; Ngwira *et al*., 2012). The adverse effects are largely overcome by reduced or no tillage practices for cereals production (Kihara *et al*., 2012) but improvement in soil OM though addition of residue or manuring have been observed with positive effects on sustainable crop production (Aulakh *et al*., 2001; Abbasi and Khizar, 2012). Short-duration legumes (e.g., mungbean and cowpea) can be grown in fallow period after the wheat harvest, which has increased rice yield with reducing N-fertilizer in proceeding (Laik *et al*., 2014). Green manures or residue are valuable sources of improving soil N and OM (Habib *et al*., 2011). After 45 to 60 days green manure crop can generally accumulate about N 100 kg ha^{-1}, which corresponds to the amount of mineral fertilizer N applied to crop. Integrated use of residue and chemical fertilizer could save 50–75% of N fertilizers for cereals besides its significant effect on soil chemical, physical and biological properties (Imaz *et al*., 2010). Organic matter amendment as residue in the soil is a technique through which one can improve production (Biederman and Whisenant, 2009) and soil physical condition (Peterson *et al*., 2004) through mineralization and immobilization of existing microbial community (Blumenthal *et al*., 2003). Instead of destroying residue, farm yard manure and other organic by-products abundantly exists that can effectively be utilized for production and improvement of soil physical, chemical, and biological characteristics for sustainable production (Goyal *et al*., 1999). Organic matter is essential for sustainable production in tropics and sub-tropics, where soil is generally poor (Kumar and Goh, 2003) and energy from the residue provides nutrients for soil microbial growth and activity that serves as source of soil mineralization–immobilization process (Jansson and Persson, 1982). Conservation of soil OM near the surface by reduced tillage is equal to greater soil microbial biomass production in topsoil layers (Carter and Rennie, 1987). It is reported that addition of cereal residue has increased N and C but legume improved OM (Janzen *et al*., 1990; Mbah and Nneji, 2011).

Little information is available on residual effect of applied crop residue, tillage depths and N-rates on yield and yield traits of the following crop in a cereal based rotation system. We, therefore, intend to study the effect of N-rates and legume as well as cereal residue incorporated with tillage depth of deep and shallow on following crop in a wheat-maize cropping system.

Materials and Methods

Site Description

The soil of experimental location is heavy clay-loam of ecotype, namely Tarnab soil series. The location is about 1200 km North of Indian Oceans at an altitude of 350 m and latitude 34.01°N. Topography at the experimental site can be described as gently sloping from North to South. Mountains surround the valley on all sides and two rivers flow into provide water for irrigation. Soil is clay loam low in organic matter (1.15%) and alkaline with pH 7.85 total nitrogen of 0.089%. The climate is tropical, receiving 500–700 mm annual precipitation mostly in summer with daily mean temperatures varying from 45±4°C in summer to 10±3°C in winter. Supplemental irrigation to field is provided through canal water as per crop water demand.

Residue Preparation and Application

Cowpea (*Vigna unguiculata*), (cv. Ebony cowpea), a legume fodder crop was grown and harvested at full bloom stage. The biomass was sundried in field for two weeks and turned-over on diurnal basis. Maize (*Zea mays* L.) after ear removal, as a cereal residue was obtained from the harvested maize crop. The dried residues (23% moisture) were chopped on an electrical chopper (2 cm length). Dry matter (DM) was determined by oven drying of randomly selected samples in triplicate of a species at 80°C for about 46 h. Based on oven-dried materials, quantity of DM (5 t ha^{-1}) of each residue was applied to main plot by spreading uniformly over the fields.

Experimental Design and Treatments

To study the carryover effect of applied treatments on preceding wheat crop, all three treatments were applied to soil and spring wheat was planted as winter season crop in 2009–2010 and 2010–2011, respectively. After the wheat harvest, maize as test crop was planted with no further application of any additional inputs as autumn crop in 2010 and 2011, respectively. The experimental design was randomized complete block in split plot arrangement, replicated each treatment four times. The main-plots were allotted with crop residues (R) and tillage depths (TD) treatments and the subplots with fertilizer nitrogen rates (N). An experimental unit was four rows 3 m wide and 4 m long. Crop residue, TD and N-rates were applied subsequently in early October 5 tones ha^{-1} well chopped on DM basis of legume (LR) and cereal (CR) vs. fallow i.e. no-residue (NR) within respective demarcations of main-plots. The residue was initially manually incorporated in soil surface and subsequently plowed with two tillage systems: the one half plowed with cultivator as shallow tillage (ST) and other half with a MB-plow as deep tillage (DT). The fallow plots (NR) were also plowed accordingly with ST and DT systems. Field was flood irrigated, and about a month after the residue incorporation, phosphorus (P_2O_5 80 kg ha^{-1}) and potassium (K_2O 40 kg ha^{-1}) were uniformly broadcasted using single super phosphate (SSP) and murate of potash (MOP) sources, respectively. Each main-plot was sub-divided for subplot treatments fertilizer N-rates (i.e. 0, 40. 80, 120, and 160 kg ha^{-1}). Nitrogen was applied in two splits: half at sowing and half about 45 days after sowing the wheat crop. Right after wheat harvest, maize (cv. Jalal) was planted using seed drill, four rows per subplot spaced 0.75 m on July 01, 2010 and July 04, 2011, respectively. No additional nutrient was applied to maize. Maize crop was harvested on October 15, 2010 and October 14, 2011. Two weeding in vegetative stages and three irrigations in addition to seasonal rainfall were given to maize each year. Grain yield was measured by harvesting two central rows and adjusted at 15% grain moisture content. The yield traits were measured on ten representative plants at crop harvest.

Light Measurement in Canopy

Radiation use efficiency (RUE) of the crop canopy was estimated in 2nd year by procedure in Akmal and Janssens (2004). Light interception by crop canopy was measured periodically using set of three light measuring sensors (LI-190 and LI-191, LI-COR, USA). The LI-190 was used to record irradiance on top of canopy and a pair of LI-191, the reflectance and transmittance by the crop canopy, simultaneously recoding 5 min averages in a data logger (LI-1400, LI-COR, USA) for 5 reading per experimental unit. All measurements were taken on a clear sunny day between 11-13 h of the day at 15 days interval from emergence to crop physiological maturity. Fraction of intercepted radiation by the canopy for an experimental unit was calculated from field measurements and multiplied with corresponding cumulative PAR obtained from a local weather station, located about 13 km from the experiment site. Photo-synthetically active radiation was estimated from solar radiation by multiplying with 0.47 (PAR fraction in solar light). The index of total biomass of 0.5 m and cumulative PAR absorbed for the period from emergence to maturity were regressed and slope of regression was termed as RUE for the treatment.

Statistical Analysis

All data were analyzed by ANOVA, using appropriate statistical design, and least significance differences between means were compared using LSD ($p \leq 0.05$) probability.

Results

Yield Traits

During 2011, maize crop showed higher ear number than 2010. When compared across years, LR showed significantly higher ear number than CR and/or NR (Table 1) and effect was similar in both years of the experiment. Between tillage methods, TD showed significant effect with higher ($p \leq 0.05$) ear number than ST. Among N-rates, compared to control, each N-level showed a significant difference in ear number with maximum at N 160 kg ha^{-1}, followed by N 120, 80, 40 kg ha^{-1} with minimum for control. Of two years averages, treatments interaction was significant ($p \leq 0.05$) for ear number (Fig. 1). Between TD, interactions RxTD were distinctly higher ($p \leq 0.05$) in ear number for DT than ST with LR, CR and NR treatments (Fig. 1a). Similarly, the interaction RxN showed moderate to noticeable increases in ear number with increasing N-rates from control to N 120 kg ha^{-1} with LR and CR than NR (Fig. 1b). Treatment NR was uncompetitive with either residue at any given N-rate. Difference in ear number at N 120 and 160 kg ha^{-1} were similar within residue treatments i.e. LR, CR and NR. Interaction TDxRxN showed moderate to visible increases ($p < 0.05$) in ear number under DT from N-rate 40 and 120 kg ha^{-1} with a non-significant difference between N 120 and 160 kg ha^{-1} (Fig. 1c). Treatment ST was lower ($p \leq 0.05$) in ear number at any given N-rate than DT. Interaction TDxRxN was significant ($p \leq 0.05$) with obvious changes in ear number for any residues at any applied N-rate (Fig. 1d). Compared to control, moderate (N- 40-80 kg ha^{-1}) to noticeable (N- 120-160 kg ha^{-1}) increase ($p \leq 0.05$) was observed for ear number at any given residue with higher in DT than ST.

As compared to 2010, 2011 crop showed higher grain number (Table 2). Across years, LR had the highest grain number, followed by CR. Treatment NR showed lowest grain number that did not differ statistically ($p \leq 0.05$) from CR. This effect was of similar fashion in both seasons. Tillage depth showed strong differences ($p \leq 0.05$) in grain number with higher in DT as compared to ST treatment. Grain number did not vary by tillage depth in 2010 but were higher under DT in 2011. Similarly, maximum grain number was observed at 120 kg N ha^{-1}, followed by N 40 kg ha^{-1}. Treatment 160 kg ha^{-1} did not differ ($p \leq 0.05$) than 120 kg N ha^{-1} for grain number. Control treatment showed the lowest grain number and interaction TDxR revealed that DT differs ($p \leq 0.05$) form ST in grain number with minor ($p \leq 0.05$) changes between LR and CR to greater ($p \leq 0.01$) form NR (Fig. 2a). Interaction RxN showed that residues of either kind differed ($p \leq 0.05$) from control treatment for grain number at 0, 40 and 120 kg N ha^{-1} (Fig. 2b). However, LR showed greater change ($p \leq 0.05$) in grain number at 120 kg N ha^{-1} when compared with CR treatment. Interaction TDxN showed obviously higher ($p \leq 0.05$) grain number in control for DT than ST (Fig. 2c). Treatment DT showed higher grain number than ST at 160 kg N ha^{-1} when compared with other N-rates. Interactive response of TDxRxN showed diversified relationship for grain number with maximum grain number at N 120 kg ha^{-1} for LR incorporated with deep tillage system and similarly in N 40 and 80 kg ha^{-1} incorporated with ST system (Fig. 2d).

Thousand grains weight (g) in 2011 were obviously heavier ($p \leq 0.05$) form 2010 (Table 3). While comparing across years, the LR showed heavier ($p \leq 0.05$) grains weight than CR and/or NR. However, 1000 grains weight did not change between CR and NR in 2011 and in two years average data. Similarly, tillage depth showed a significant ($p \leq 0.05$) change in 1000 grains weight with heavier for DT than ST in 2011 and two years average basis. Grains weight was significantly ($p \leq 0.05$) different by N-rates with maximum for N 160 and 120 kg ha^{-1}, followed by decreases ($p \leq 0.05$) for 80 and 40 kg N ha^{-1} with lowest in control. On two years average, interaction of TDxR

Table 1: Ear number (m^{-2}) under carryover effect of treatments crop residue (R), tillage depth (TD) and N-rates (N) in a wheat-maize cropping system

Treatments		2010	2011	Mean
Residue (R)	Cereal (CR)	4.39 b	4.56 b	4.47 b
	Legume (LR)	4.55 a	4.74 a	4.64 a
	No residue (NR)	4.18 c	4.36 c	4.27 c
Tillage depth (TD)	Mold-board (DT)	4.50 a	4.68 a	4.59 a
	Cultivator (ST)	4.24 b	4.42 b	4.33 b
N-rate (kg ha^{-1})	0	4.02 e	4.16 e	4.09 e
	40	4.26 d	4.42 d	4.34 d
	80	4.46 c	4.65 c	4.55 c
	120	4.51 b	4.71 b	4.61 b
	160	4.61 a	4.81 a	4.71 a
Year's mean		4.37 b	4.55 a	4.46
Treatments interaction and significance level (p<0.05)				
Interaction	RxTD	NS	NS	*
	RxN	NS	NS	**
	TDxN	NS	NS	**
	RxTDxN	NS	NS	**

Different letters indicate significant differences among the category of treatments with LSD (p≤0.05)

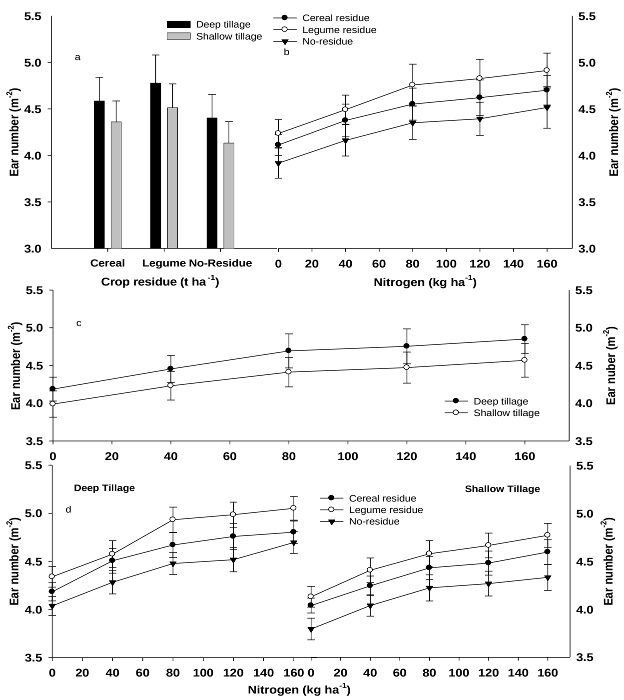

Fig. 1: Ear number (m^2) in maize influenced by carry-over effect of treatment interaction (a) RxTD (n = 40), (b) RxN (n = 80), (c) TDxN (n = 120) and (d) RxTD x N (n = 40) shown in different windows with vertical bars ±SD of mean

Table 2: Grain number per ear of maize as influenced by carryover effect of treatments crop residue (R), tillage depth (TD) and nitrogen rates (N) in wheat-maize cropping system

Treatments		2010	2011	Average
Residue (R)	Cereal (CR)	383.82 b	396.32 b	390.07 b
	Legume (LR)	406.91 a	413.41 a	410.16 a
	No residue (NR)	381.53 b	397.53 b	389.53 b
Tillage depth (TD)	Mold-board (DT)	395.20 a	408.87 a	402.04 a
	Cultivator (ST)	383.30 a	395.97 b	391.13 b
N-rate (kg ha^{-1})	00	377.28 b	388.94 b	383.11 c
	40	396.26 a	407.93 a	402.09 ab
	80	385.03 ab	396.70 ab	390.86 bc
	120	399.59 a	411.26 a	405.42 a
	160	395.60 ab	407.27 ab	401.44 ab
Year's mean		390.75 b	402.42 a	396.59
Treatments interactions and significance level (p<0.05)				
Interaction	RxTD	*	*	**
	RxN	*	*	**
	TDxN	*	*	**
	RxTDxN	NS	NS	**

Different letters indicate significant differences among the category of treatments by LSD test (p≤0.05)

Table 3: Thousand grains weight (g) of maize as influenced by carryover effect of treatments crop residue (R), tillage depth (TD) and nitrogen rates (N) in wheat-maize cropping system

Treatments		2010	2011	Average
Residue (R)	Cereal (CR)	311.23 c	321.40 b	316.31 b
	Legume (LR)	319.28 a	328.13 a	323.70 a
	No residue (NR)	315.12 b	320.30 b	317.71 b
Tillage depth (TD)	Mold-board (DT)	315.00 a	326.05 a	320.89 a
	Cultivator (ST)	314.00 a	320.50 b	317.65 b
N-rate (kg ha^{-1})	0	304.21 d	313.38 d	308.79 d
	40	310.24 c	319.54 c	314.89 c
	80	317.47 b	324.33 bc	320.90 b
	120	321.57 a	327.38 ab	324.47 a
	160	322.54 a	331.75 a	327.15 a
Year's mean		315.21 b	323.28 a	319.24
Treatments interaction and significance level (p<0.05)				
Interaction	RxTD	**	**	**
	RxN	**	*	**
	TDxN	NS	NS	**
	RxTDxN	NS	NS	**

Different letters indicate significant differences among the category of treatments by LSD test (p≤0.05)

showed marked (p≤0.05) changes in 1000 grains weight between LR than CR and NR under DT only (Fig. 3a). Similarly, interaction RxN was significantly (p≤0.05) differed for grain weight in control, N 40 and 80 kg ha^{-1} when compared with N 120 and 160 kg ha^{-1} (Fig. 3b). Nonetheless, both residues did not differ for grain weight than NR at higher rates of 120 and 160 kg N ha^{-1}. Interaction TDxN expressed slightly higher grain weight for DT at any given N-rates over ST (Fig. 3c). Similarly, interactions TDxRxN showed a diversified relationship for 1000 grain weight with higher for LR than CR or NR at any applied N-rates under either DT or ST (Fig. 3d).

Grains Yield

During 2011, crop exhibited higher (p<0.05) grain yield than 2010 (Table 4). Comparing across years, the LR yielded highest yield, followed by CR and lowest for NR.

Table 4: Grain yield (kg ha^{-1}) of maize as influenced by carryover effect of treatments crop residue (R), tillage depth (TD) and nitrogen rates (N) in wheat-maize cropping system

Treatments		2010	2011	Average
Residue (R)	Cereal (C)	1929.88 b	2142.75 b	2036.31 b
	Legume (L)	2040.75 a	2301.88 a	2171.31 a
	No-residue (NR)	1909.68 c	2107.88 c	2008.78 c
Tillage depth (TD)	Deep (MB)	2006.7 a	2277.25 a	2095.38 a
	Shallow (CL)	1913.5 b	2091.08 b	2048.89 b
N-rate (kg ha^{-1})	00	1598.25 e	1723.75 d	1661.00 e
	40	1737.96 d	1804.58 c	1771.27 d
	80	1949.88 c	2362.50 b	2156.19 c
	120	2229.96 b	2500.42 a	2365.19 b
	160	2284.46 a	2529.58 a	2407.02 a
Years mean		1960.10 b	2184.17 a	2072.13
Treatments interactions and significance level (P<0.05)				
Interaction	RxTD	NS	**	**
	RxN	NS	**	**
	TDxN	NS	**	**
	RxTDxN	NS	**	**

Different letters indicate significant differences among the category of treatments by LSD test (p≤0.05)

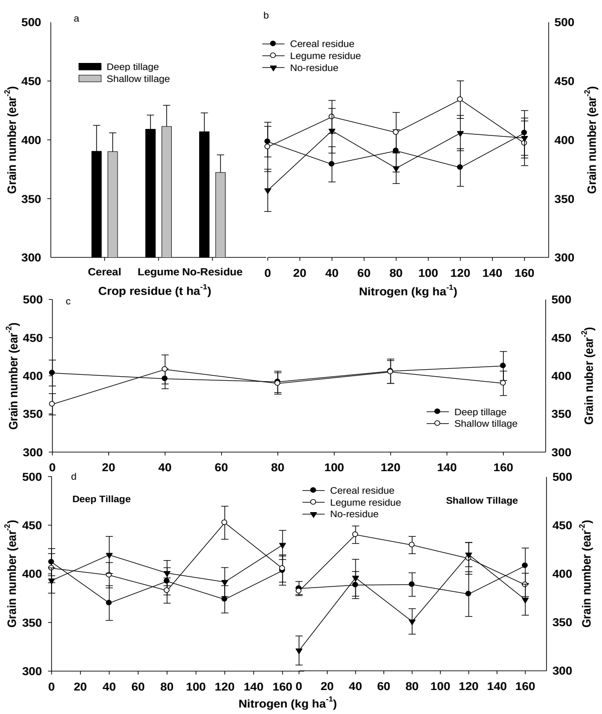

Fig. 2: Grain number (Ear-[1]) in maize influenced by carry-over effect of treatment interaction (a) RxTD (n = 40), (b) RxN (n = 80), (c) TDxN (n = 120) and (d) RxTDxN (n = 40) shown in different windows with vertical bars ±SD of mean

By comparing tillage depths, DT obviously showed higher (p<0.05) yield and grains yield did vary (p<0.05) by N-rate with the highest for 160 and 120 kg N ha^{-1}, followed by 120, 80 and 40 kg N ha^{-1} in 2011. Control treatment had the lowest yield during both years. Grain yield in 2010 was only significantly (p≤0.05) differed by 120 and 160 kg N ha^{-1},

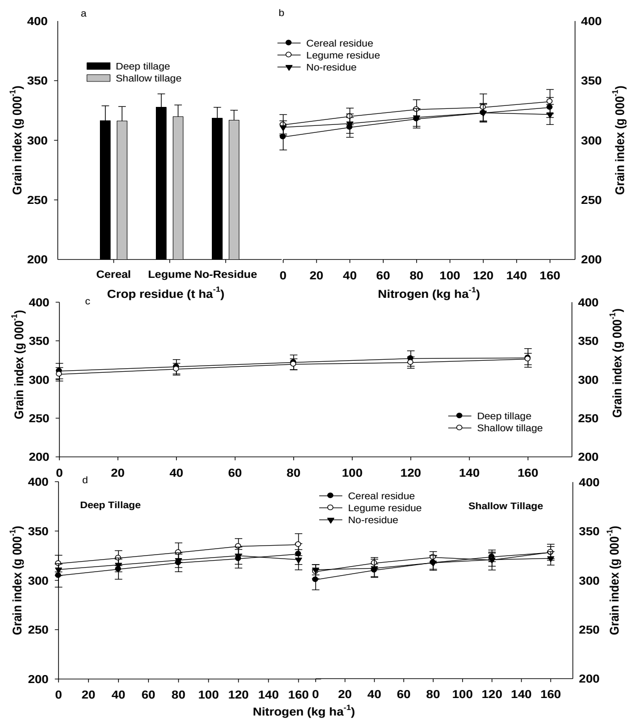

Fig. 3: Thousand grains weight (g) in maize influenced by carry-over effect of treatment interaction (a) RxTD (n = 40), (b) RxN (n = 80), (c) TDxN (n = 120) and (d) RxTDxN (n = 40) shown in different windows with vertical bars ±SD of mean

resulting in significant (p≤0.05) change in yield during both years. Interaction of treatments was significant (p≤0.05) for yield in 2011 and/or two years average. For both years average, interactions TDxR showed distinctly higher (p≤0.05) yield for CR and NR with almost alike grain yield in LR under DT and ST (Fig. 4a). Interactive effect of RxN was also significant (p<0.05) with highest yield for LR, followed by CR and lowest for NR. However, these increases in yield with increased N-rates were increases from 0 to 40 and 40 to 120 kg N ha^{-1} (Fig. 4b). Grain yield between 120 and 160 kg N ha^{-1} was non-significant (p≤0.05) for any residue treatment. Interaction TDxN exhibited slightly higher yield at 80 and 120 kg N ha^{-1} by DT than ST (Fig. 4c). Treatments interaction TDxRxN showed higher (p≤0.05) grain yield with DT than ST for any residue and N-rates (Fig. 4d). Grain yield showed increasing trends with highest for LR, followed by CR and NR with slight to strong increments between 0 to 40 kg N ha^{-1} and 40 to 120 kg N ha^{-1}, respectively at either DT or ST treatments. When comparing yield for 120 and 160 kg N ha^{-1}, it was non-significantly different for residue or tillage depth.

Yield and Traits Relationship

Yield is product of traits (e.g. plant stand, grain per cob and

Table 5: Radiation use efficiency (g MJ^{-1} $PAR_{absorbed}$) of maize as influenced by carryover effects of treatment crop residue, tillage depth and N-rates in wheat-maize cropping system

Treatments		Nitrogen rate (kg ha^{-1})					
Residue	Tillage	0	40	80	120	160	Means
Cereal (CR)	DT	1.26	1.25	1.60	1.66	1.65	1.48 b
	ST	1.17	1.22	1.49	1.52	1.53	1.39 c
Legume (LR)	DT	1.28	1.27	1.62	1.68	1.69	1.51 a
	ST	1.26	1.22	1.54	1.63	1.67	1.46 b
No residue (NR)	DT	1.25	1.23	1.58	1.66	1.61	1.47 b
	ST	1.14	1.24	1.50	1.53	1.53	1.39 c
Cereal (CR)		1.22	1.24	1.55	1.59	1.59	1.44 b
Legume (LR)		1.27	1.24	1.58	1.66	1.68	1.49 a
No-residue (NR)		1.19	1.23	1.54	1.60	1.57	1.43 b
Mold-board (DT)		1.26	1.25	1.60	1.67	1.65	1.49 a
Cultivator (ST)		1.19	1.22	1.51	1.56	1.57	1.41 b
Means		1.23 c	1.24 c	1.56 b	1.61 a	1.61 a	

Different letters indicate significant differences among the category of treatments by LSD test ($p \leq 0.05$)

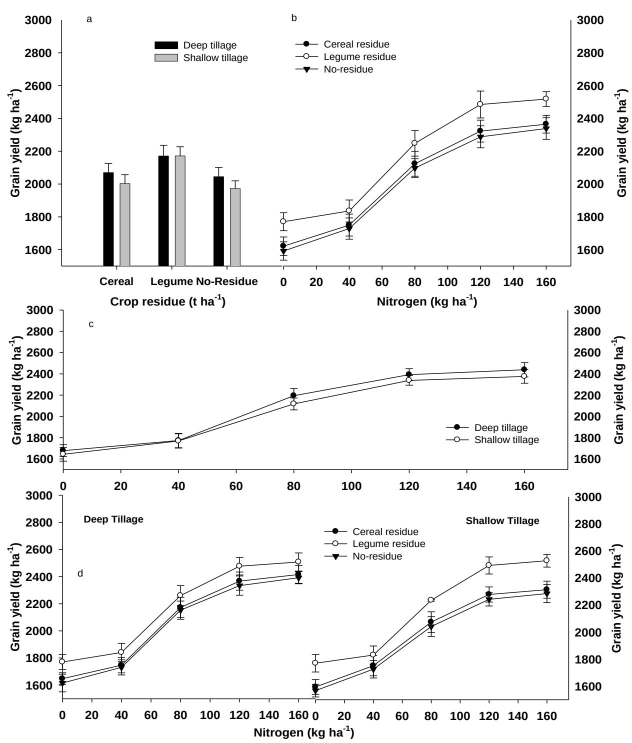

Fig. 4: Grain yield (kg ha^{-1}) in maize as influenced by carry-over effect of treatment interaction (a) RxTD (n = 40), (b) RxN (n = 80), (c) TDxN (n = 120) and (d) RxTDxN (n = 40) shown in different windows with vertical bars ±SD of mean

grain weight) at a uniform density. Therefore, grain number and thousand grain weight were major contributors of grains yield. The relationship of grain number (ear number m^{-2} x grain per ear) and grains weight (g) with grain yield (g m^{-2}) under the treatments (R, TD and N) is shown in Fig. 5. The treatment LR exceeds in grain yield than CR and/or NR treatment due to almost equal contribution with increases in grain number and/or grains weight (Fig. 5a). Likewise, treatments DT over ST showed a noticeable ($p<0.05$) difference with contribution in grain number which and grain weight in total grains yield (Fig. 5b). Among N-rates, as compared to 160 and 120 kg N ha^{-1}, all other N-rates showed lower ($p<0.05$) grain yield (Fig. 5c). Increased in yield was due to significant increments in grain number with partly in grain weight resulted in significant changes in yield.

Radiation Use Efficiency

Radiation use efficiency (RUE) showed profound differences by DT and ST (Table 5). The LR resulted in higher RUE as compared to CR or NR treatments and CR and NR did not differ statistically in RUE from each other. The high N-rate (160 kg ha^{-1}) revealed higher RUE that was significantly ($p<0.05$) similar to 120 kg N ha^{-1}. Likewise, RUE for 80 kg N ha^{-1} was lower ($p<0.05$) than 120 kg N ha^{-1} but reported higher ($p<0.05$) for 40 kg N ha^{-1}. Both 40 kg N ha^{-1} and control treatments were non-significant ($p<0.05$) in RUE. Interactive effect was significant ($p<0.05$) for RUE (Fig. 6). Interaction TDxN exhibited higher RUE for DT than ST system at any given N-rates (Fig. 6a). When compared for DT with ST, differences in RUE were smaller at 40 kg N ha^{-1} to greater at 80 kg N ha^{-1}. Interaction RxN showed smaller variations in RUE with higher to relatively stable increments in and residue treatments from 80 kg N ha^{-1} onwards (Fig. 6b). Nonetheless, RUE for CR and NR was similar ($p<0.05$) between 80 and 160 kg N ha^{-1} but much higher for LR. The RUE for DT was higher than ST for all residues at any N-rates (Fig. 6c-d). The RUE under DT was similar for control and 40 kg N ha^{-1} but showed nominal increments under ST for all R treatments. Thereafter, RUE rose sharply between 40 and 80 kg N ha^{-1} in all residues for DT and ST but thereafter increased at smooth rates between 80 and 120 kg N ha^{-1}. The LR showed higher RUE at 80 kg N ha^{-1} onwards from CR and NR under both DT and ST with higher in ST system.

Discussion

Relatively higher grains yield were found during 2011 than 2010. This increase was also observed in all yield contributing traits. Residue decomposition in soil is a natural but slow process and takes time to be available for plants and/or soil microbes (Blumenthal *et al*., 2003). Residue decomposition in soil is subjected to the nitrogen availability. Decomposition continues with liberation of CO_2 and H_2O into organic combinations and formation of new compounds. Organisms which decomposed residue, besides other essential elements may need nitrogen and carbon. At lower soil nitrogen, the process of decomposition might slow-down (Md Alamgir *et al*., 2012). The C to N ratio of the residue incorporated in soil, therefore, is essential

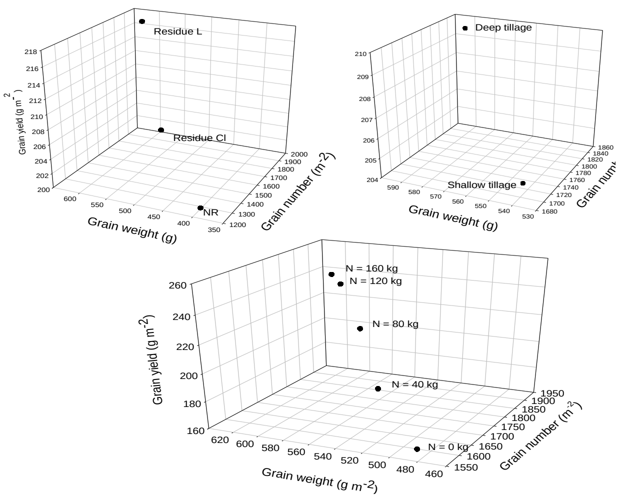

Fig. 5: Yield traits (grain number and grains weight vs. grains yield) in relationship with the treatments crop residue (R), tillage depth (TD), and N-rates (N) sown in different boxes

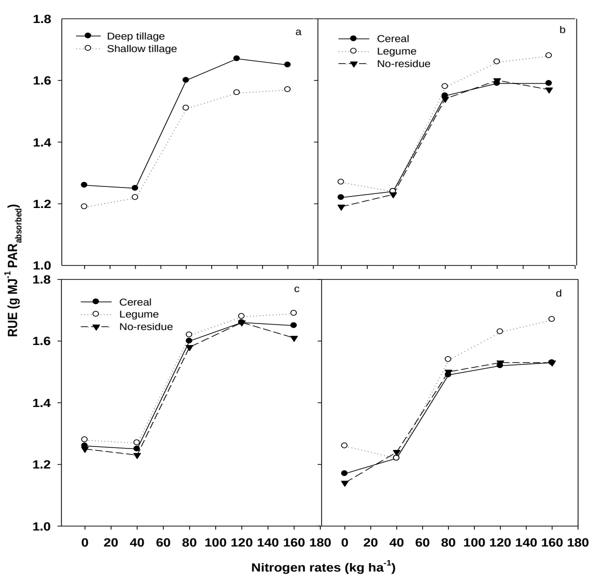

Fig. 6: Radiation use efficiency (g MJ^{-1} $PAR_{absorbed}$) in maize as influenced by carry-over effect of treatments interactions (a) TDxN (n = 60), RxN (n = 20) and RxTD x N (n = 20) shown in windows with vertical bars ± SD of mean

to be taken in consideration (Sierra and Motisi, 2012). Legume vs. cereal and residue vs. fallow has a higher C:N ratio (Mbah and Nneji, 2010), therefore, we observed greater grains yield and favorable response on yield traits for LR, followed by CR as compared with NR treatments. This favorable effect of treatments was observed for yield traits especially grain number and had relatively higher yield during 2011 season. With continuous cereals production, the soil is generally exhausted and/or imbalanced with essential nutrients for crop growth and might unable to express the potential yield with increase of sole nitrogen application (Youjun and Ming, 2011). Legume residue showed favorable significant effect on yield of following crop in rotation that may be due to changes in soil C:N ratio (Youjun and Ming, 2011). With uniform population, grains yield can therefore be better correlated with ear number, grains per cob and 1000 grains weight. The grains weight did not change ($p \leq 0.05$) with CR and NR may be due to poor grain development because few grains per cob generally showed heavier weights by relatively uncompetitive sink (Akmal *et al*., 2010).

The deep tillage system than shallow one is generally advantageous for soils under long cereal-based-rotation system (Hou *et al*., 2012; Kumar *et al*., 2012). Leaching of nutrients from surface soil is common for fields plowed with shallow tillage. Deep tillage under such conditions favor plants to provide pulverized seedbed for root development and recycling leached down nutrients with efficient microorganisms activities (Kihara *et al*., 2012). A number of microorganisms exists in soil and remains active as long as there is carbon for their energy source (Blumenthal *et al*., 2003). A large number of bacteria in soil exist but due to their small sizes have limited biomass. Soil is rich of fungus and bacteria responsible for residue decomposition. Soil OM composed of microorganisms, residues, and humus. Humus (35:65) is a long-term soil OM fraction, relatively older with resistant to quick decomposition. Deep tillage and legume residue provides more N and C as well as extended soft tilled soil, which enhanced healthy microbial activities of organisms (Atkins and Smith, 2007).

Nitrogen fertilizer application to crop increases productivity (Laik *et al*., 2014). Maize rotation with legumes (e.g. alfalfa, berseem) curtains the total N demand as compared to other crops (e.g. cereals). Nitrogen is, therefore, universally accepted a key component of grain crops. It is important for plant vegetative development and its alone application improved yield of cereals over the control (Gehl *et al*., 2005). The highest rate 160 kg N ha^{-1} might be advantageous to obtain the maximum production and to sustain soil fertility status in cereal based cropping system. As earlier discussion indicate that sufficient C and N are essential for growth of soil microorganisms to express yield potential from it (Wang *et al*., 2012). We observed a favorable response on yield traits by increasing N-rates, which enhanced yield as carryover effect (Youjun and Ming, 2011) by increasing ear number than grain number or thousand grains weight.

Conclusion

It can be concluded that crop residue improved yield traits that expressed yield increments of following crop indicating long-term response of LR and CR in a cereal based cropping system. Residues plowed deep have favorable effect over the shallow plowing system. The optimum rate of 120 kg N ha^{-1} along with legume residue deeply plowed improved biomass that resulted in better RUE and grains yield of the following maize in wheat-maize cropping system. Legumes than cereals residue can be of higher advantage to optimize N-rate for crops with sustainable production system.

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