Wheat performance under different tillage practices and crop sequences with and with-out added N in calcareous soils

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Abstract:

Continuous cereal based cropping system and use of in-organic nitrogen (N) degrades soil fertility and productivity. The present study was designed with the objective in mind to sought out proper combination of both tillage practices (shallow, medium and deep plough) and nitrogen (With and without 120 kg N ha^{-1}) applications in different crop sequences (CS). Yield and yield components of wheat were studied in the field for two consecutive years. All the studied parameters of wheat crop were significantly ($p<0.05$) affected by tillage practices, crop sequence with and without added N and year as source of variation. When averaged across crop sequence with and without added N, shallow tillage practice was comparatively superior to medium and deep tillage. Likewise, by averaged across different tillage practices, cropping sequence having sesbania as summer legume with added N (CS6) was better in performance when compared with other cropping sequences with no additional in-organic N. Similarly, significant differences ($p<0.05$) were found in 2016-17 for almost all the studied parameters of wheat crop compared to 2015-16. Therefore, inclusion of summer legumes (Sesbania) in cereal based cropping system under shallow tillage practices and optimum N addition could be the best management strategy for sustainability in term of soil fertility and crop productivity.

Keywords: Crop sequence; grain yield; nitrogen application; tillage practices; Wheat

INTRODUCTION

Organic matter (OM) is an integral part of soil fertility and productivity (Khan *et al.,* 2017). Due to continuous cereal-based cropping system, imbalanced use of chemical fertilizers and intensive tillage practices, OM of the soils is declining rapidly (Shah *et al.*, 2003; Mohammad *et al.*, 2008). To reduce this rapid rate, more sustainable agricultural practices needs to be adapted (Arif*et al.,* 2007; Ramesh *et al.,* 2014). According to Timsina *et al.*, (2006), insertion of summer and/or winter legumes in a continuous cereal based cropping system are more sustainable in the form of soil fertility and crop productivity. Therefore, to pull-off this sustainability; tillage practice and cropping sequence can be exploited in our continuous cereal based cropping system. In Pakistan, both soil fertility and crop productivity are the key problems in cereal based cropping system (Ahmad *et al.,* 2013; Khan *et al.,* 2017) because soil OM is less than 1% (Rashid, 1994). OM decomposition and mineralization of organic nutrients are important for sustainability of agriculture system (Khan *et al.,* 2011). Different tillage depth have different rate of decomposition and can influence this decomposition and mineralization in favorable soil environment (Torbet *et al.,* 2001; Malhi *et al.,* 2006). According to Chen (2007), shallow tillage (15 cm) provides higher decomposition of organic matter than deep tillage (45 cm). Similarly, Kustermann *et al.,* (2013), observed that increasing organic matter decomposition and improved soil fertility in minimum tillage (8 cm) when comparing with conventional tillage (30 cm). Calado *et al.* (2010) concluded that soil environment i.e. temperature, moisture and pH play a vital role in decomposition of organic residues. Synergistic effects of OM with the addition of in-organic N build up more soil total nitrogen. According to Ali *et al.,* (2014) insertion of legume and in-organic N in a exhaustive cropping pattern, could increase the nitrogen economy of cropping system as well as improves crop production. Khan *et al.,* (2017) reported that nearly 40% of exogenously applied nutrients like N are utilized by crop plants and the remaining is lost from the system (soil) either through volatilization and de-nitrification to the atmosphere or through leaching beyond the root zone deep into the soil (Shah *et al.,* 2003) that's why decline soil fertility is at peak in a continuous cereal based cropping system in Pakistan. The use of in-organic N combined with organic sources play a significant role in improving soil health through retention of nutrients within the root zone (Malhi *et al.,* 2006). To low-down the losses of nutrients (N) added to the system (soil) from in-organic source is therefore one of the main bottleneck for improving soil fertilty and crop yield on sustainable basis (Mohammad *et al.,* 2006). Thus, this research was designed to find out suitable cropping sequence and tillage practice(s) along with proper added N as an integrated approach for improving soil health and crop yield.

Materials and methods

Experimental Site

The experimental site is located at 34°N, 71°E and at altitude of 450 m above sea level at the Research Farm of the University of Agriculture, Peshawar. The soil of experimental field is clay loam (inceptisols and/or oxisols type soil series), deficient in mineral N (< 8.2 mg kg^{-1} soil) and P (< 20 mg kg^{-1} soil), but has adequate K (> 120 g kg^{-1} soil) with a pH of having pH = 8.04 and organic matter (0.842 g kg^{-1}). The physicochemical analysis of the experimental site before the initiation of the experiments is presented in Table 2. Climate is warm to hot, semi-arid subtropical receiving <500mm annual precipitation with daily mean temperatures varying from 45±4oC in summer to 10±3oC in winter. Rainfall and temperature data were collected and are summarized in Fig.1. In addition to rainfall the crop water requirement was provided through canal water when ever needed throughout crop life.

Experimental protocol

A field study was laid out in two factorial (split plot) randomized complete block (RCB) design having four replications during 2015-16 and 2016-17. Tillage practices [shallow tillage (cultivator, 0-10cm), medium tillage (mould board plough, 0-30cm) and deep tillage (chiesel plough, 0-60cm)] were assigned to the main plots while, cropping sequence along-with and with-out added N were allotted to subplots having net size 5x4m^2 (Table 1). Two splits of 120 kg N ha^{-1} were supplemented from in-organic fertilizer (Urea, 46%N) to field during sowing and after 15-20 days of sowing (after emergence) with 1st irrigation only to the plots where needed according to the treatments. Basal dose of 90 and 60 kg P_2O_5 and K_2O per hectare were added to all the plots uniformly as TSP and SOP, respectively. Spring wheat variety (hexaploid, 42 chromosomes) developed with a name (Seran-2010) by Institute of Biotechnology & Genetic Engineering (IBGE), Peshawar was planted @ 100 kg seed ha^{-1}. Wheat crop was irrigated thrice during crop life through flood irrigation system i.e. after 25 days of sowing, at boot stage and during milk stage. Stander cultural practices relevant to field experiment were adopted for the whole growing season.

Parameters studied

Data on plants emerged m^{-2} was taken by averaging the number of seedlings emerged in one meter long row in each sub-plot in triplicates. Days to anthesis and physiological maturity were counted from the sowing date till 80% spikes intruded their anthers and plant attained pale yellow color, respectively. Measuring tape was used for calculating plant height from the soil surface to the tip of a plant. Spikes per m^2 in each sub-plot was calculated by quadrant (1x1 ft^2) in triplicates randomly in each experimental unit and then averaged. The grains $spike^{-1}$ was counted by averaging the grains obtained from ten randomly selected spikes. Thousand cleaned seeds were randomly counted and weighed via electronic balance for measuring 1000 grains weight. Biomass and grain yield in kg ha^{-1} were measured by weighing the biomass and grain obtained from three central rows.

Statistical procedure

The replicated data were processed for analysis of variance (ANOVA) according to two factorial split plot RCBD design via statistical package Statistix 8.1. Means were further compared ($P<0.05$) using least significant difference test (LSD) according to the procedure used by Jan *et al.*, (2009).

Results

Tillage practices and crop sequence with and with-out added N significantly ($p<0.05$) affected both emergence $m^{-2}$and plant height in both years (table 3). By averaged across crop sequence with and with-out added N, shallow tillage practice has optimum (118 plants) emergence m^{-2} followed by medium tillage practice (115 plants) while poor (108 plants) emergence m^{-2} was recorded in deep tillage practice. When averaged across different tillage practices, it was also observed that, N addition significantly enhanced emergence m^{-2}. However, crop sequence (CS6) showed significant higher emergence m^{-2} (117). The emergence was significantly higher in 2016-17 (115 plants) compared to year 2015-16 (112). Similarly, optimum plant height (96cm) was recorded in plots treated with shallow tillage followed by medium tillage practice (95cm). Deep tillage practice has minimum (93cm) plant height when average across crop sequence with and without added N. By averaged across different tillage practices, plant height was also significantly ($p<0.05$) increased with application of N in different cropping sequence. However, maximum plant height (96cm) was recorded in crop sequence (CS6) followed by CS4. The minimum plant height (93cm) was noted in crop sequence (CS1). There was no significant ($p<0.05$) differences in plant height of wheat during 2015-16 and 2016-17.

Analysis of variance exhibited that different tillage practices and crop sequence with and without added N significantly ($p<0.05$) influenced both days to anthesis and physiological maturity of wheat crop in both years (table 4). When average across crop sequence with and without added N, optimum days (135) to anthesis were observed for deep tillage practices followed by medium tillage while shallow tillage practice took minimum days (132) to anthesis. By average across different tillage practice, non-significant ($p<0.05$) differences were observed for cropping sequence CS1, CS2 and CS3. Days to anthesis were significantly higher (134 days) during year 2015-16 than the year 2016-17 (133 days). Contrary to anthesis, day to physiological maturity were significantly higher (167 days) in shallow tillage practice when average across crop sequence with and without added N while deep tillage practice has minimum (164) days to physiological maturity. When average across different tillage practice, there were no significant ($p<0.05$) differences found in crop sequence with and without added N. Likewise anthesis, days to physiological maturity were significantly higher (166 days) during year 2015-16 than year 2016-17 (165) days.

Tillage practices, crop sequence with and without added N as well as year as source of variation significantly ($p<0.05$) affected both spikes m^{-2} and grains $spike^{-1}$ of wheat crop (table 5). Maximum spikes m^{-2} (358) and grains $spike^{-1}$ (51) were recorded in shallow tillage while minimum were observed in deep tillage plots. Similarly, N addition improved both spikes m^{-2} and grains $spike^{-1}$in different cropping sequence compared to without N plots. Briefly, crop sequence (CS6) showed significantly higher spikes m^{-2} (389) and grains $spike^{-1}$ (55) than the rest while poor performance for these parameter were observed in CS1. Year 2016-17 was better than 2015-16 in term of improvement in both spikes m^{-2} and grains $spike^{-1}$.

Different tillage practices, crop sequence with and without added N and year as source of variation significantly ($p<0.05$) affected 1000 grains weight and biomass of wheat (table 6). Similar trend was observed in both traits when average across cropping sequence with and without added N or by average across different tillage practice. higher 1000 grains weight (46.9g) and biomass (8938 kg ha^{-1}) was observed at shallow tillage while, minimum were recorded in deep tillage practice. Similarly, both 1000 grains weight and biological yield have significantly ($p<0.05$) higher in crop sequence with added N when compared crop sequence without added N. Briefly, maximum 1000 grains weight (50.7g) and biological yield (10577 kg ha^{-1}) was observed for crop sequence (CS6) while CS1 produced lighter 1000 grains (36.7g) and biomass (5647 kg ha^{-1}). Both thousand grains weight (44.3g) and biomass (9126 kg ha^{-1}) were significantly higher during year 2016-17 compared to the year 2015-16.

Tillage practices, crop sequence with and without added N as well as year significantly ($p<0.05$) influenced both grain yield and harvest index (HI) of wheat crop (table 7). Among the tillage practices, shallow tillage was found better with respect to grain yield (2974 kg ha^{-1}) and HI (33.0%). Similarly, among the cropping sequence, CS6 produced significantly higher grain yield (3491 kg ha^{-1}) and HI (33.0%) while CS1 and CS3 produced minimum grain yield (1850 kg ha^{-1}) and HI (32.9%). HI (34.2%) and grain yield (3105 kg ha^{-1}) were considerably higher in year 2016-17 compared to the year 2015-16.

Discussions

We observed better crop performance at shallow tillage followed by medium while the poor performance was observed at deep tillage operation. Different tillage operations have varying impact over soil residual N (Sainju*et al.*, 2007), NO_3 leaching, NUE and C content (Bossche*et al.*, 2009; Dolan *et al.*, 2006) and water holding capacity (Al-Kaisi, 2005). Thus, improved crop productivity at shallow tillage could be attributed to adequate soil moisture content, enhanced mineralization rate (Usman *et al.*, 2013), higher microbial activity (Ali *et al.*, 2000), reduce N losses through leaching (Yang *et al.*, 2001), increase organic carbon (Halepyati. 2001), maximum N utilization (Imran *et al.*, 2013). Similarly, N addition (Soon *et al.*, 2001) and inclusion of winter and summer legumes (Thomas *et al.*, 2007) in a cereal based cropping system (Bossche*et al.*, 2009) improved crop yield and soil health (Khan *et al.,* 2017). Ali e*t al.* (2016) considered tillage as a best plough method for higher yield production in wheat-maize cropping system.

Nitrogen promotes vegetative (Otteson *et al.,* 2007) as well as reproductive growth (Subedi *et al.,* 2007) of wheat crop. However, excess amount of added N delayed physiological maturity (Alam et al., 2014). Nitrogen application significantly increased 15% (Matusso and Mateus, 2016) and 11% (Usman *et al.,* 2013) grains yield in wheat crop. According to Pandiaraj *et al.,* (2015) N application at stem extension could increase sink size which ultimately increases grain yield (Seadh*et al.*2009). It could also be due to increased dry matter accumulation in seed under N application (Waraich*et al.* 2007).

Fertilized plots gave 25% higher wheat grain yield than unfertilized plots (Thomas *et al.* 2007). Ercoliet, (2008) obtained improved wheat under N application. Asif Iqbal *et al.* (2010) observed improved plant height, leaf area, leaf area index and grain yield. These results confirms Jan *et al.,* (2016) findings who also reported 3% increase in harvest index of wheat crop in response to N application. It could be ascribed to mobilization of the stored assimilates from vegetative tissues to the reproductive parts like grain (Hossain *et al.* 2006). In contrast, Iqbal *et al.* (2013) observed higher HI in wheat under deep tillage at higher N addition. Khan *et al.* (2011) and Pandiaraj*et al.* (2015) reported that applied N delay days to anthesis stage and substantially improve biological yield of wheat due to improvement in vegetative growth. Our results are in support to Bakht *et al.* (2010) who observed more days to anthesis at 120 kg N ha^{-1}. As N play a key role in vegetative growth thus N addition delayed leaf senescence, maintained leaf photosynthesis throughout grain filling stage and sustained the grain filling duration (Frederick and Camberato, 1995). Excellent emergence of wheat due to N application under reduce tillage practices was reported by Memon *et al.* (2013).

Poor wheat emergence under shallow tillage system may be due to decrease soil temperature and maximum water availability. According to Massawe *et al*. (2016) traditional soil management practices such as removal of soil residues and nutrients may decrease plant emergence. Govaerts *et al*. (2005) obtained taller plants under zero tillage practice due to resides and nutrients retention. In our case, N application improved plant height by 26% compared to without added N. This could be ascribed to sufficient N availability in fertilized plots at early growth stages. According to Akmal *et* *al*.(2015), N application improve plant photosynthetic activity due to which taller plants and higher biomass are obtained under N addition (Ali *et al*., 2016 ; Huang *et al.*, 2015)

Conclusions

Shallow tillage performed better over medium and deep tillage. Similarly, soil fertility was enhanced due to inclusion of legumes in cereal based cropping system and hence addition of proper N application to the cropping system showed additional beneficial effect in natural and conservative crop production where soils are poor in nutrient. Our results provide a sound underpinning for crop growth and showed an augmentation in all the studied characters related to intensification of wheat crop. The strategies of using appropriate type of tillage with suitable cropping pattern and nitrogen application might be a valuable substitute to the conventional approach in the cereal growing areas. Therefore, integration of summer legumes in a cereal based cropping system under shallow tillage practice and optimum added N is the best practice for improved wheat productivity.

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Novelty Statement:

Lack of suitable integrated approach influences the soil fertility, so tillage practice and cropping sequence with and without added N can be explored in the cereal based cropping system of Pakistan. In this study we observed that Shallow tillage performed better compared with medium and deep tillage practices.

Authors Contributions:

M.Z performed the experiment; M.Z wrote the first draft of the manuscripts. M.S. and J.B designed the experimentation and H.K & I.K supervised M.Z during data collection and experiment maintenance. All authors read and approved the final manuscript.

Conflict of Interest:

"The author(s) declare(s) that there is no conflict of interests regarding the publication of this article".

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FIGURES

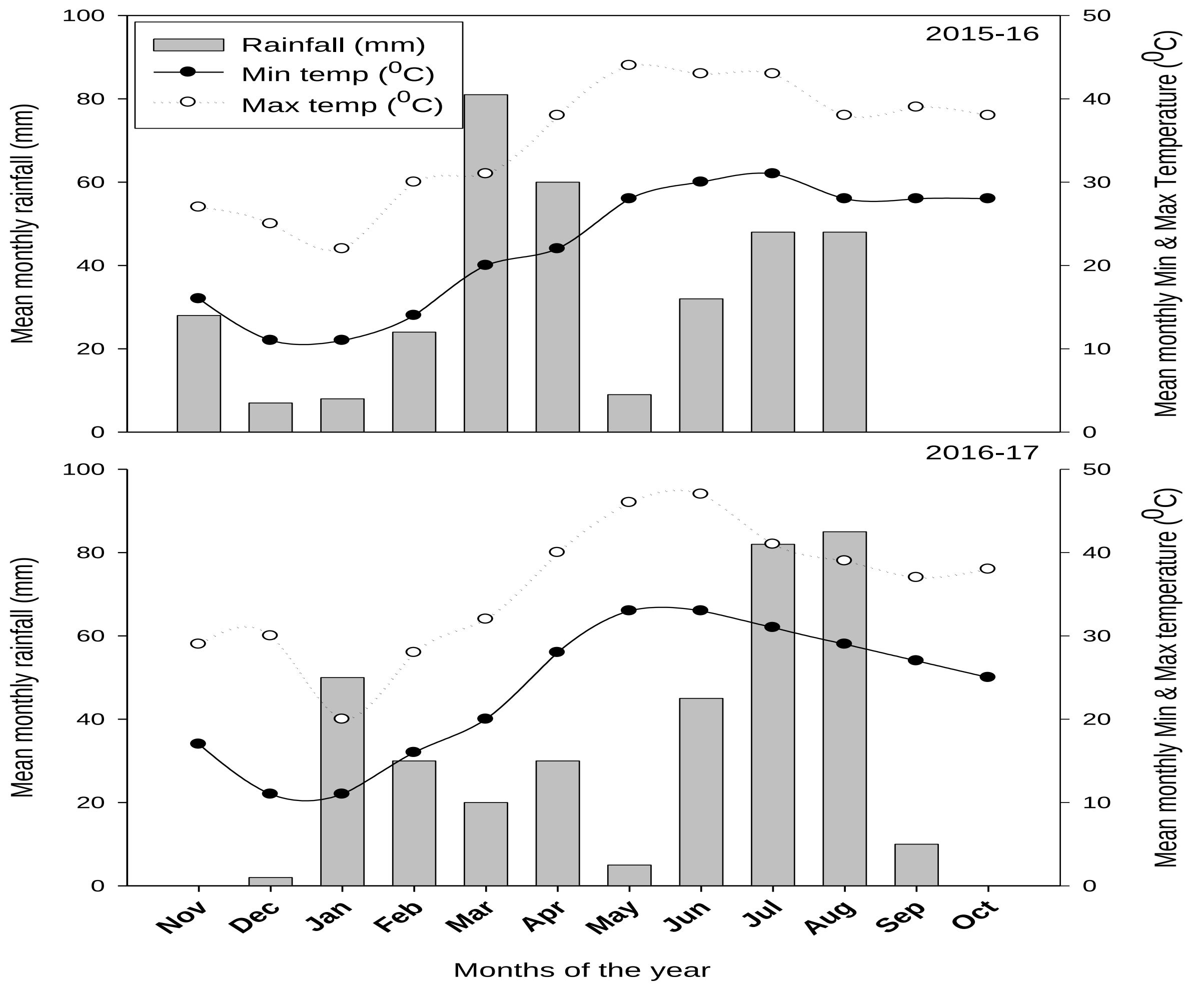

Fig.1. Mean monthly rainfall (mm) and temperature (max. & min., ^{0}C) for the year 2015-16 and 2016-17.

TABLES

Table 1. Cropping sequence as subplot treatment showing cereal based crop rotation with inclusion of legume crops in the sequence with and with-out added N from 2015 to 2017.

Treatments	**Cropping Sequence with and with-out N fertilization**				
	2015-16	**2016**	**2016-17**	**2017**	**Sequence**
CS $_1$	Wheat (-N)	Maize (-N)	Wheat (-N)	Maize (-N)	Cereal(-)Cereal(-)
CS $_2$	Wheat (-N)	Maize (+N)	Wheat (-N)	Maize (+N)	Cereal(-)Cereal(+)
CS $_3$	Wheat (-N)	Sasbenia	Wheat (-N)	Sasbenia	Cereal (-)Legume
CS $_4$	Wheat (+N)	Sasbenia	Wheat (+N)	Sasbenia	Cereal (+)Legume
CS $_5$	Wheat (+N)	Maize (-N)	Wheat (+N)	Maize (-N)	Cereal(+)Cereal(-)
CS $_6$	Wheat (+N)	Maize (+N)	Wheat (+N)	Maize (+N)	Cereal(+)Cereal(+)

Table 2. Soil physicochemical analysis of the experimental site before experiment

Property	Values
Sand (g kg^{-1})	140
Silt (g kg^{-1})	600
Clay (g kg^{-1})	316
Soil Texture	Silty clay loam
Organic C (%)	0.55
Mineral N (%)	0.18
Total N (mg kg^{-1})	370
Soil EC (dSm^{-1})	0.55
Soil pH (%)	7.3

Table 3. Emergence^{-2} and plant height (cm) of wheat crop under different tillage practices and crop sequence with and with-out added N during 2015-16 and 2016-17.

Treatments	Emergence m^{-2}			Plant height (cm)		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Shallow	118	119	118 a	95.9	96.3	96.1 a
Medium	113	116	115 b	94.5	95.0	94.8 b
Deep	106	109	108 c	92.9	93.3	93.1 c
CS $_1$ Cereal(0)Cereal(0)	111	113	112 c	93.3	92.7	93.0 f
CS $_2$ Cereal(0)Cereal(N)	111	114	112 c	93.3	94.8	94.1 d
CS $_3$ Cereal (0)Legume	111	113	112 c	93.3	93.8	93.5 e
CS $_4$ Cereal (N)Legume	114	116	115 b	95.5	96.0	95.8 b
CS $_5$ Cereal(N)Cereal(0)	114	115	114 b	95.5	94.8	95.2 c
CS $_6$ Cereal(N)Cereal(N)	114	120	117 a	95.5	96.9	96.2 a
Mean	112 b	115 a		94.4 a	94.8 a	

Mean values of the same category followed by different letters are significantly different at 5% level of significance.
ns = non significant at 5% level of probability.

Table 4. Days to anthesis and physiological maturity of wheat crop under different tillage practices and crop sequence with and with-out added N during 2015-16 and 2016-17.

Treatments	Days to anthesis			Days to maturity		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Shallow	132	132	132 c	168	166	167 a
Medium	134	133	133 b	166	165	165 b
Deep	136	134	135 a	165	164	164 c
CS $_1$ Cereal(0)Cereal(0)	135	135	135 a	167	163	165 bc
CS $_2$ Cereal(0)Cereal(N)	135	133	134 ab	167	165	166 a
CS $_3$ Cereal (0)Legume	135	134	135 a	167	164	166 ab
CS $_4$ Cereal (N)Legume	132	131	132 c	165	166	165 a-c
CS $_5$ Cereal(N)Cereal(0)	132	132	132 cd	165	165	165 c
CS $_6$ Cereal(N)Cereal(N)	132	130	131 d	165	167	166 ab
Mean	134 a	133 b		166 a	165 b	

Mean values of the same category followed by different letters are significantly different at 5% level of significance.
ns = non significant at 5% level of probability.

Table 5. Spikes m^{-2} and grains $spike^{-1}$ of wheat crop under different tillage practices and crop sequence with and with-out added N during 2015-16 and 2016-17.

Treatments	Spikes m^{-2}			Grains $spike^{-1}$		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Shallow	355	362	358 a	51	51	51 a
Medium	328	341	335 b	47	49	48 b
Deep	314	321	317 c	45	46	45 c
CS $_1$ Cereal(0)Cereal(0)	281	257	269 e	40	36	38 e
CS $_2$ Cereal(0)Cereal(N)	281	354	317 c	40	51	45 c
CS $_3$ Cereal (0)Legume	281	286	283 d	40	41	40 d
CS $_4$ Cereal (N)Legume	284	389	386 a	55	55	55 a
CS $_5$ Cereal(N)Cereal(0)	284	369	376 b	55	53	54 b
CS $_6$ Cereal(N)Cereal(N)	284	395	389 a	55	56	55 a
Mean	332 b	341 a		47 b	49 a	

Mean values of the same category followed by different letters are significantly different at 5% level of significance.
ns = non significant at 5% level of probability.

Table 6. Thousand grains weight (g) and biological yield (kg ha^{-1}) of wheat crop under different tillage practices and crop sequence with and with-out added N during 2015-16 and 2016-17.

Treatments	Thousand grains weight (g)			Biological yield (kg ha^{-1})		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Shallow	46.2	47.5	46.9 a	8200	9676	8938 a
Medium	43.1	44.1	43.6 b	7898	9070	8484 b
Deep	40.9	41.4	41.1 c	7589	8633	8111 c
CS $_1$ Cereal(0)Cereal(0)	37.9	35.6	36.7 e	5691	5603	5647 f
CS $_2$ Cereal(0)Cereal(N)	37.9	45.2	41.5 d	5691	9669	7680 e
CS $_3$ Cereal (0)Legume	37.9	36.4	37.1 e	5691	7805	6748 d
CS $_4$ Cereal (N)Legume	48.9	49.5	49.2 b	10100	10582	10341 c
CS $_5$ Cereal(N)Cereal(0)	48.9	46.9	47.9 c	10100	10045	10073 b
CS $_6$ Cereal(N)Cereal(N)	48.9	52.5	50.7 a	10100	11054	10577 a
Mean	43.4 b	44.3 a		7895 b	9126 a	

Mean values of the same category followed by different letters are significantly different at 5% level of significance.
ns = non significant at 5% level of probability.

Table 7. Grain yield (kg ha^{-1}) and harvest index (%) of wheat crop under different tillage practices and crop sequence with and with-out added N during 2015-16 and 2016-17.

Treatments	Grain yield (kg ha^{-1})			Harvest index (%)		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Shallow	2650	3298	2974 a	31.7	34.2	33.0 a
Medium	2550	3087	2818 b	31.6	34.3	32.9 b
Deep	2448	2932	2690 c	31.6	34.2	32.9 b
CS_1 Cereal(0)Cereal(0)	1900	1800	1850 f	31.6	34.3	33.0 bc
CS_2 Cereal(0)Cereal(N)	1900	3313	2606 d	31.6	34.3	32.9 bc
CS_3 Cereal (0)Legume	1900	2670	2285 e	31.6	34.2	32.9 c
CS_4 Cereal (N)Legume	3198	3628	3413 b	31.7	34.3	33.0 a
CS_5 Cereal(N)Cereal(0)	3198	3438	3318 c	31.7	34.2	33.0 bc
CS_6 Cereal(N)Cereal(N)	3198	3783	3491 a	31.7	34.2	33.0 ab
Mean	2549 b	3105 a		31.7 b	34.2 a	

Mean values of the same category followed by different letters are significantly different at 5% level of significance.
ns = non significant at 5% level of probability.