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Full Length Article

Response of Tillage, Nitrogen and Stubble Management on Phenology and Crop Establishment of Wheat

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Abstract

Field study was conducted at Cereal Crops Research Institute Pirsabak Nowshera, Khyber Pakhtunkhwa, Pakistan during 2009-2011 in a randomized complete block design with split plot arrangement having four replications. Three tillage systems (TS) [minimum, conventional and deep] were laid out in main plots, whereas the subplots were six maize stubble management (SM) practices such as removal, burning and incorporation with and without nitrogen (N; 120 kg ha^{-1}) application. The objective of the study was to examine the treatment effects on phenology, establishment and yield of succeeding wheat crop. Result showed that wheat phenology except days to emergence was not affected by different TS however; early emergence (10 days) was observed in minimum tillage rather than conventional and deep tillage system. Nitrogen fertilization (120 kg N ha^{-1}) enhanced days to phenological observations, while no significant variation in days to emergence and physiological maturity were recorded among SM practices, however; stubble incorporation delayed the booting and anthesis stage compared to burning and removing. Minimum tillage improved emergence, tillers and grain yield (3134 kg ha^{-1}) compared to deep tillage systems. Nitrogen fertilization at the rate of 120 kg ha^{-1} and maize stubble incorporation prior to wheat sowing also improved emergence, tillers, plant height and grain yield compared to control and stubble removal or burning. It is concluded from current study that maize stubble incorporation with recommended dose of fertilizer N (120 kg ha^{-1}) prior to wheat sowing delayed phenology, and improved wheat establishment and yield under minimum tillage in a continuous cereal based cropping system instead of stubble burning and removal.

Keywords: Tillage systems; Stubble management; Nitrogen fertilization; Phenology; Crop stand

Introduction

Wheat yield and quality is influenced by management of the previous crop but is highly dependent on current year management (Wiatrak *et al*., 2006). Stubble management practices are need of the time that can minimize fertility degrading factors responsible for crop productivity. The soils in Khyber Pakhtunkhwa, Pakistan due to continuous cropping have lesser organic matter (Amanullah *et al.,* 2012). Application of reduced source of N to the soil is considered good for building organic matter as well as for sustainability of soil. However, scare resources and environmental concerns do not allow the farmer boundless application of commercial fertilizers (Sepaskhah *et al*., 2006).

Farmers are always interested in getting higher yield which could not be possible without better crop management, good stand establishment and optimum utilization of resources. Crop production is influenced by its establishment and plant vigor representing the key factors towards crop development (Amanullah *et al.,* 2009). Tillage also play an important role in managing residue through incorporation, loosening the soil for planting and emergence and controlling weeds, and thus creating best ecological conditions for better and early seed establishment. Khan *et al.* (2008) are of the opinion that conservation farming systems can maintain optimum soil temperature for seed germination and improve soil water content for crop growth and land operations.

Fertilizer nitrogen plays an important role in the betterment of soil fertility and crop production (Habtegebrial *et al.,* 2007), thus optimum N availability is necessary to fulfill the crop N requirement and increase wheat biomass. The main reason farmers adopt conservation farming system is to conserve soil for optimum crop production. Moreover, it could improve proper sowing, soil moisture storage and minimize cost of production (Al-Kaisi and Yin, 2005). Maintaining crop residue with suitable tillage system is important from agronomic point of view, because it can lead to improve stability of soil structure and drainage (Blackwell, 2000), increased yield (Wilhelm *et al*., 2004) as well as conserving soil water in semiarid conditions (Campbell *et al*., 2001; Wilhelm *et al*., 2004). In mechanized farming system, machinery issues of tillage and

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stubble management have been intensively reviewed in recent past (Anderson, 2009). Therefore, the present study was conducted to underline the impact of different tillage systems and stubble incorporation as well as burning and removal with and without N application on growth, phenology and wheat crop stand.

Materials and Methods

Experimental Site

The impact of different tillage systems and maize stubble management on phenology and wheat stand was examined for 2-year (2009-2010 and 2010-2011) field experiment on spring wheat (cv. Pirsabak-2005) with a continuous crop rotation of wheat-maize-wheat (with Maize, cv. Iqbal 2010) at Cereal Crops Research Institute Pirsabak (34ºN latitude, 72ºE longitude and 288m altitude) Nowshera under irrigated conditions. According to physico-chemical analysis; the soil type of the farm was silt clay loam, moderately drained as well as calcareous, having total N 0.6 g kg^{-1} soil, 0.0002% P, 0.021% K, 1.280 g cm^{-3} bulk density and 11.21 g kg^{-1} soil organic carbon with a pH of 7.85. The environmental conditions of the area were warm to hot, semi-arid subtropical continental climate with average annual rainfall of about 380 mm. Apart from rainfall during the growth season, the crop water requirement at critical growth stages was met through basin irrigation system as and when required.

Treatments Structure and Methodology

Three tillage systems (TS) (i) minimum (rotavator=10 cm) (ii) conventional (cultivator=20 cm) and, (iii) deep (mouldboard=30 cm) were allotted to the main plots whereas six maize stubble management practices with and without nitrogen (i) physical removal (ii) burning (iii) incorporation (iv) physical removal + 120 kg N ha^{-1} (v) burnt + 120 kg N ha^{-1} and (vi) incorporation + 120 kg N ha^{-1} were laid out in the subplots.

Plotting was done in the field having maize stubbles after harvesting the crop and field surface was tilled by a common cultivator to ease the stubble management practices two months prior to wheat sowing. Stubbles were removed physically from the control plots and sun-dried to have an idea of how much stubbles were burnt/ incorporated, which was recorded 2.5 ton ha^{-1}. In the burnt treated plots, sun-dry stubbles were collected and burnt by setting fire and ash were mixed in the soil immediately to control ash loss through wind whereas in case of soil incorporation, the residue was soil incorporated with the help of hoe.

Fertilizer urea (46% N) as an inorganic nitrogen source was applied at the rate of 120 kg ha^{-1} in split i.e. half at sowing and half at 2nd irrigation in designated plots. Three tillage implements were randomly operated twice by adjusting it to the required depth accordingly in the main plots and sowing of wheat was ensured in lines.

The subplot was of 5 m x 3 m having 10 rows 30 cm apart with 5 meter length, while a distance of 50 cm between tow subplots, one meter between the main plots and 2 meters between replications were maintained in the experimental field. Fertilizer phosphorus and potash was applied to the field at the rate of 90 and 60 kg ha^{-1} each as single super phosphate (18% P_2O_5) and murate of potash (52% K) respectively as a basal dose. The agronomic and cultural practices including irrigation, weeds control through weedicide and hoeing etc. were carried out uniformly for all the treatments in each replication.

Wheat was planted on 9th and 16th Nov. of 2009 and 2010 respectively and the left over maize stubble after harvesting in June, 2009 and 2010 were used as a source of residues for the succeeding wheat crop. In all cases, a tractor mounted planter equipped with row cleaner wheels was used. After wheat harvesting, maize was planted in rotation with recommended agronomic practices and waited till harvest maturity. After harvesting of maize crop the same demarcated plots having maize stubbles were used to repeat the experiment in the following year. The same tillage implements operated in the same fashion and six stubble management practices were conceded to examine its effect on wheat phenology and stand establishment in the subsequent year. Data were recorded on days to emergence, booting stage, anthesis and physiological maturity and, emergence (m^{-2}), tillers (m^{-2}), plant height and lodging score and grain yield.

Days to emergence were recorded by counting the days from the date of planting to when 70–80% emergence was completed while for the booting and anthesis stages days were recorded by counting the days when 50% plants attain boot stage and 50% plants extruded anthers respectively. Days to physiological maturity were recorded by counting the days from date of planting when 50% plants lost green colour from their glumes or peduncle and became physiologically mature. Emergence (m^{-2}) was recorded by counting the seedling numbers in a meter square area after 100% completion of germination. Tillers (m^{-2}) were recorded by counting tillers in a meter square area in each subplot. Plant height (cm) was measured up to spike tip of five randomly selected plants in each plot at maturity and then average plant height was worked out. Grain yield was recorded by weighting grains after threshing pack of central 6 rows of each sub plot and then converted to kg ha^{-1}. Oplinger *et al.* (1995) procedure was used to determine lodging score according to the formulae:

Lodging score= = $S \times I \times 0.02$

Where,

S= Surface area 1 mean none, while 9 mean totally

I = Intensity of lodging 1 mean none, while 9 mean totally

Lodging score range is 0.2 – 9.

Experimental Design and Statistical Analysis

A total of 18 treatments were tested in randomized complete block design with a split plot arrangement having 4 replications in each year. Analysis of variance (ANOVA) was used to perceive the significance of treatment effects on the different variables measured. Combined statistical analysis of the two years data was done according to the procedure relevant to RCBD and mean square values for the dependent variables were reported in Table 3 and Table 4. For existing significant differences among the treatments, least significance difference (LSD) test (Jan *et al.*, 2009) was used to separate the means.

Results

Phenological Observations

Different tillage systems significantly affected days to emergence (DE), while stubble management and their interaction with TS had non-significant effect for DE. Early emergence was observed in minimum tilled plots as compared to conventional and deep tilled plots (Table 1).

Nitrogen fertilization (120 kg N ha^{-1}) in sole or along with stubble management had non-significant effect on DE. Similarly non-significant difference was found for days to booting, anthesis and physiological maturity stages among different tillage systems (Table 1) however; all these stages were comparatively delayed in minimum tilled plots compared to conventional and deep tillage. In case of N fertilization (120 kg ha^{-1}), days to booting, anthesis and maturity were also delayed than where no N was applied (Table 1). Similarly, stubble incorporated plots took statistically more days to booting as compared to stubble burnt or removed plots (Table 1) having equal days to these stages. Similarly, stubble incorporated plots delayed anthesis and maturity stages compared to stubble burnt and removed treatments. However; interaction was non-significant for all phenological observations (Table 1).

Wheat Establishment and Production

Over the years, statistically greater number of emerged seedlings was observed in minimum tillage followed by conventional and deep tillage systems statistically with similar seedling count (Table 2). Similarly, N fertilization (120 kg ha^{-1}) significantly enhanced emergence (m^{-2}) as compared to unfertilized plots. On the other hand, statistically similar results were obtained for stubble management practices. Tillers statistically improved in the minimum tillage, however; statistically same number of tillers was recorded in conventional and deep tillage systems. Fertilization (120 kg N ha^{-1}) improved number of tillers over unfertilized plots. Likewise, stubble incorporated plots improved tillers as compared to stubble burnt and stubble removed plots. Number of tillers also responded significantly to the interactions N × SM, TS × N, and TS × SM. Statistically higher tillers were observed over two years in fertilized (120 kg N ha^{-1}) stubble incorporated plots (N × SM) as compared to burnt and stubble removed plots (Fig. 1). The two N rates showed that tillers were linearly increased in the order stubble incorporated > stubble burnt > stubble removed; however, it was significantly higher when stubble were managed along with fertilizer N (120 kg ha^{-1}). Higher wheat tillers were found (Fig. 2) in N fertilized (120 kg ha^{-1}) minimally tilled plots (TS × N) as compared to conventional and deep tilled plots. Wheat tillers also responded significantly to TS × SM interaction and higher wheat tillers per unit area was observed in minimally plowed stubble incorporated plots as compared to conventional and deep tillage plots (Fig. 3). Stubble removed deep plowed plots had minimum tillers as compared to burnt and incorporated plots.

Plant height was not affected by different tillage system, however; taller plants were observed in minimum tillage as compared to conventional and deep tillage system (Table 2). Unlike tillage system, N (120 kg ha^{-1}) added plots improved plant height as compared to control plots. Similarly, stubble incorporated plots statistically had taller plants followed by stubble burnt and stubble removed plots. Neither tillage nor stubble management practices with or without N had affected lodging score and therefore, statistically similar lodging score was observed among all treatments. Significantly, higher grain yield was recorded in minimum tilled plots followed by conventional and deep tillage (Table 2). Nitrogen fertilization (120 kg N ha^{-1}) over two years statistically also increased grain yield as compared to unfertilized plots. Similarly, stubble incorporated plots significantly had higher grain yield against burnt and stubble removed plots over two years. The trend in response to N × SM interaction (Fig. 4) showed higher grain yield, where stubbles were incorporated along with application of fertilizer N (120 kg ha^{-1}) followed by burnt and stubble removed plots. Control plots also shown a linear trend of grain yield in order of stubble removed < burnt < incorporated plots. Regarding grain yield response to TS × N interaction, statistically maximum grain yield were noted in fertilized (120 kg N ha^{-1}) and minimally tilled plots followed by conventional and deep tillage (Fig 5).

Discussion

Wheat productivity depends on optimum nutrient availability and soil moisture content as well. The fast emergence in reduced tillage was due to the minimum soil manipulation, that economize the soil water loss through less evaporation (Licht and Al-Kaisi, 2005) and the soften seedbed helped in fast emergence by early softening of the seed coat. Booting, anthesis and physiological maturity growth stages were delayed in fertilized stubble incorporated plots due to increase in duration of leaf area, vegetative growth and light use efficiency with higher use of nitrogen (Frederick and Camberato, 1995; Deldon, 2001),

Table 1: Phenological observations as affected by various tillage systems, nitrogen (N) and stubble management practices over two years

Tillage Systems (TS)	Days to emergence		Days to boot stage		Days to anthesis		Days to physiological maturity	
Minimum Tillage	10.42	b	120.83	a	129.58	a	160.65	a
Conventional Tillage	11.06	ab	120.54	a	128.73	a	159.83	a
Deep Tillage	11.65	a	120.21	a	128.17	a	159.21	a
$LSD_{(0.05)}$	0.78		ns		ns		ns	
Fertilizer-N (kg N ha^{-1})								
0	11.10	a	118.39	b	126.97	b	155.68	b
120	10.99	a	122.67	a	130.68	a	164.11	a
$LSD_{(0.05)}$	ns		1.67		1.77		3.82	
Stubble Management (SM)								
Removed	11.10	a	119.63	b	127.83	b	157.42	b
Burnt	11.10	a	119.92	b	128.21	b	159.44	ab
Incorporated	10.92	a	122.04	a	130.44	a	162.83	a
$LSD_{(0.05)}$	ns		2.05		2.17		4.68	
Interactions								
N × SM	ns		ns		ns		ns	
TS × N	ns		ns		ns		ns	
TS × SM	ns		ns		ns		ns	
TS × N x SM	ns		ns		ns		ns	

ns= non-significant
Mean followed by different letter(s) in each group are statistically different at $P \leq 0.05$ using $LSD_{(0.05)}$ test

Table 2: Wheat establishment and grain yield as affected by various tillage systems, N and stubble management practices over two years

Tillage Systems (TS)	Emergence (m^{-2})		Tillers (m^{-2})		Plant Height (cm)		Lodging Score		Grain Yield (kg ha^{-1})	
Minimum Tillage	91.08	a	298.13	a	104.00	a	0.70	a	3134.14	a
Conventional Tillage	88.33	ab	283.48	b	103.71	a	0.70	a	2804.52	b
Deep Tillage	86.58	b	278.02	b	103.43	a	0.68	a	2628.16	b
$LSD_{(0.05)}$	3.04		8.83		ns		ns		205.61	
Fertilizer-N (kg N ha^{-1})										
0	87.28	b	275.03	b	102.04	b	0.68	a	2555.00	b
120	90.06	a	298.06	a	105.39	a	0.71	a	3156.21	a
$LSD_{(0.05)}$	1.94		4.60		1.05		ns		104.63	
Stubble Management (SM)										
Removed	88.00	a	277.06	c	102.59	b	0.71	a	2645.59	c
Burnt	88.50	a	285.73	b	103.88	ab	0.69	a	2830.03	b
Incorporated	89.50	a	296.83	a	104.67	a	0.68	a	3091.19	a
$LSD_{(0.05)}$	ns		5.83		1.29		ns		128.14	
Interactions										
N × SM	ns		*		ns		ns		*	
TS × N	ns		**		ns		ns		*	
TS × SM	ns		**		ns		ns		ns	
TS × N × SM	ns		ns		ns		ns		ns	

ns= non-significant, *=significant at $P \leq 0.05$ **= significant at $P \leq 0.01$
Mean followed by different letter(s) in each group are statistically different at $P \leq 0.05$ using $LSD_{(0.05)}$ test

soil organic carbon (Dolan *et al.*, 2006), and active carbon and N fraction (Sainju *et al.*, 2007); hence improved phenology and plant productivity.

Plants respond to the prevailing warmer conditions by adjusting their phenology (Hovenden *et al.*, 2008). The added fertilizer-N delayed leaf senescence, sustained leaf photosynthesis during grain filling stage and thereby prolonged the grain filling duration (Frederick and Camberato, 1995), and thus had direct influence on phenology. Optimum nutrient availability and improved soil conditions due to carbon based source might have extended growing period as a result of vigorous and better crop growth (Li, 2003), and thus delayed phenology of wheat. Slow release of nutrients (Matsi *et al.*, 2003) might be another possible justification for delayed phenology in fertilized stubble incorporated plots. Ayoub *et al*. (1994) and Badaruddin *et al*. (1999) also observed delayed heading and physiological maturity in fertilized plots.

Emergence and tillering per unit area, plant height and lodging score, are important with respect to crop establishment, and therefore, play a significant role in the productivity of any crop. The better emergence and more tillers in minimum tillage would be attributed to appropriate and sufficient moisture availability being

Table 3: Mean squares for days to emergence (DE), days to boot stage (DBS), days to anthesis (DA) and days to physiological maturity (DPM) as affected by tillage systems, N and stubble management practices over two years

Source of Variation	df	DE		DBS		DA		DPM	
Years (Y)	1	12.250	ns	393.36	**	444.51	**	1813.34	**
Reps within Y	6	3.139		12.14		4.74		5.16	
Tillage System (TS)	2	18.146	*	4.69	ns	24.42	ns	24.94	ns
Y x TS	2	2.438	ns	9.53	ns	1.55	ns	3.80	ns
Error 1	12	3.069		14.02		45.94		75.16	
Management (M)	5	0.333	ns	176.68	**	142.99	**	656.98	**
Nitrogen (N)	1	0.444	ns	658.78	**	495.06	**	2558.67	**
Stubble Management (SM)	2	0.563	ns	83.53	*	95.13	*	359.65	ns
Removed (R) vs (B +I)	[1]	0.281	ns	58.68	ns	71.00	ns	442.53	ns
Burnt (B) vs Incorporated(I)	[1]	0.844	ns	108.38	*	119.26	*	276.76	ns
N x SM	2	0.049	ns	28.78	ns	14.81	ns	3.47	ns
(No-N vs N) × [R vs (B + I)]	[1]	0.003	ns	20.06	ns	2.53	ns	6.42	ns
(No-N vs N) × (B vs I)	[1]	0.094	ns	37.50	ns	27.09	ns	0.51	ns
Y × M	5	0.467	ns	11.09	ns	1.59	ns	16.82	ns
Y × N	1	0.111	ns	26.69	ns	2.01	ns	65.34	ns
Y × SM	[2]	1.021	ns	1.36	ns	1.88	ns	4.09	ns
Y × N × SM	[2]	0.090	ns	13.03	ns	1.09	ns	5.30	ns
TS × M	10	0.104	ns	2.79	ns	2.15	ns	0.65	ns
TS × N	[2]	0.007	ns	5.36	ns	5.40	ns	0.34	ns
TS × SM	[4]	0.115	ns	2.74	ns	1.78	ns	1.15	ns
TS × N × SM	[4]	0.142	ns	1.55	ns	0.90	ns	0.32	ns
Y × TS × M	10	0.579	ns	1.59	ns	0.71	ns	1.23	ns
Y × TS × N	[2]	0.632	ns	0.36	ns	0.55	ns	0.17	ns
Y × TS × SM	[4]	0.802	ns	2.72	ns	1.42	ns	1.55	ns
Y × TS × N × SM	[4]	2.031	ns	17.83	ns	3.76	ns	24.11	ns
Error II	90	1.576		25.74		28.81		133.84	
Main Plot CV%		15.87		3.11		5.26		5.42	
Subplot CV%		11.37		4.21		4.17		7.24	

* = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, ns = non-significant

Table 4: Mean squares for emergence m^{-2} (E. m^{-2}), Tillers m^{-2} (T. m^{-2}), Plant height (P. Height), Lodging score (L. Score) and grain yield as affected by tillage systems, N and stubble management practices over two years

Source of Variation	df	E. m^{-2}		T. m^{-2}		P. Height		L. Score		Grain Yield	
Years (Y)	1	272.25	**	12731.4	**	8.80	ns	0.034	ns	14145330	**
Reps within Y	6	17.07		347.1		2.86		0.063		165937	
Tillage System (TS)	2	247.00	*	5187.8	**	3.85	ns	0.005	ns	3166211	**
Y x TS	2	1.33	ns	333.8	ns	0.21	ns	0.054	ns	284625	ns
Error 1	12	46.61		393.7		22.83		0.036		213690	
Management (M)	5	70.80	*	6008.1	**	102.00	**	0.022	ns	3716274	**
Nitrogen (N)	1	277.78	**	19090.0	**	404.01	**	0.040	ns	13012520	**
Stubble Management (SM)	2	28.00	ns	4714.4	**	52.89	**	0.019	ns	2406173	**
Removed (R) vs (B +I)	[1]	32.00	ns	6469.5	**	90.90	**	0.029	ns	3175527	**
Burnt (B) vs Incorporated(I)	[1]	24.00	ns	2959.3	**	14.88	ns	0.008	ns	1636819	**
N x SM	2	10.11	ns	760.7	*	0.10	ns	0.017	ns	378251	*
(No-N vs N) × [R vs (B + I)]	[1]	3.56	ns	627.2	ns	0.10	ns	0.025	ns	327136	ns
(No-N vs N) × (B vs I)	[1]	16.67	ns	894.3	*	0.09	ns	0.008	ns	429367	*
Y × M	5	18.12	ns	65.8	ns	0.44	ns	0.008	ns	16868	ns
Y × N	1	66.69	ns	103.4	ns	1.14	ns	0.003	ns	2	ns
Y × SM	[2]	3.58	ns	81.1	ns	0.08	ns	0.007	ns	23585	ns
Y × N × SM	[2]	8.36	ns	31.8	ns	0.45	ns	0.013	ns	18583	ns
TS × M	10	7.38	ns	688.6	**	0.12	ns	0.041	ns	205752	*
TS × N	[2]	21.36	ns	1001.1	**	0.01	ns	0.106	ns	398263	*
TS × SM	[4]	3.25	ns	749.2	**	0.02	ns	0.029	ns	185769	ns
TS × N × SM	[4]	4.51	ns	471.7	ns	0.27	ns	0.021	ns	129481	ns
Y × TS × M	10	4.83	ns	49.3	ns	0.13	ns	0.017	ns	25775	ns
Y × TS × N	[2]	5.03	ns	77.6	ns	0.21	ns	0.023	ns	56881	ns
Y × TS × SM	[4]	3.60	ns	29.9	ns	0.10	ns	0.011	ns	23316	ns
Y × TS × N × SM	[4]	34.71	ns	205.6	ns	0.87	ns	0.052	ns	85522	ns
Error II	90	21.99		194.4		10.18		0.023		100521	
Main Plot CV%		7.70		6.92		4.61		27.46		16.19	
Subplot CV%		5.29		4.87		3.08		22.01		11.10	

* = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, ns = non-significant

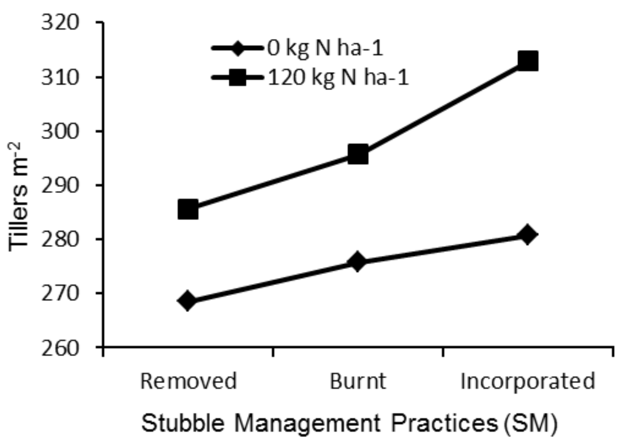

Fig. 1: Interactive effect of N and stubble management practices on tillers m^{-2} of wheat over two years

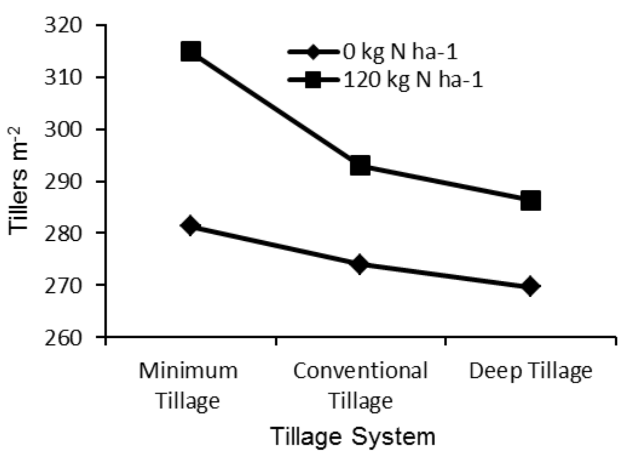

Fig. 2: Interactive effect of tillage systems and N on tillers m^{-2} of wheat over two years

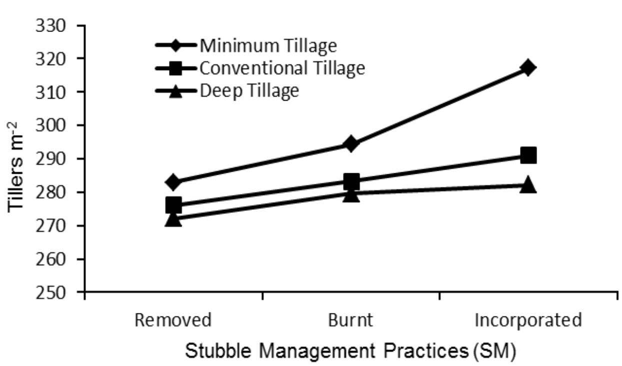

Fig. 3: Interactive effect of tillage systems and stubble management practices on tillers m^{-2} of wheat over two years

conserved in reduced tillage (Chiroma *et al.,* 2006; Thomas *et al*., 2007; Sławinski *et al.,* 2012) for proper sprouting and germination initiation of Phase II seedling stage. The more organic C (Al-Kaisi and Yan, 2005; Guzman *et al*., 2006; Nakamoto *et al*., 2006) and/or soil nitrogen (Soon *et al*., 2001) or slighter N leaching (Sainju *et al*., 2006) possibly have improved crop stand or establishment in term of shoots and tillers development.

The greater essential nutrient availability (Ortega *et al*., 2002), better water holding capacity of soil (Wong *et al*., 1999) and little volatilization of N fertilizer to ammonium gas form (Tran-Thuc-Son *et al*., 1995) might be the possible explanations for satisfactory crop stand in N mixed stubble incorporated plots compared to stubble burnt and removed plots. This improvement could also be linked to the highest shoot survival by remaining green longer and hence great number of tillers survived till reproductive stage (Ayoub *et al*., 1994; Iqtidar *et al*., 2006) at optimum N level through applications of organic and available N sources.

Reduction of soil evaporation (Ortega *et al*., 2002) in N mixed stubble incorporated plots made available sufficient water for root development (Hossain *et al*., 2002; Matsi *et al*., 2003) could also plead for higher seedling emergence and thus better tillering potential and improved crop stand. Badaruddin *et al*. (1999) and Hossain *et al*. (2002) also observed statistically higher tillers in plots having combined sources of organic and inorganic fertilizers.

The response of plant stature to different tillage systems was not significant however; minimum tilled soil had a bit taller plants than conventional and deep tilled plots and could be associated with optimum amount of soil moisture (Al-Kaisi and Yin, 2005), organic matter (Dolan *et al*., 2006), and residual soil nitrogen (Sainju *et al*., 2007) and improved crop growth. Pederson and Lauer (2003) recorded 2% higher plant height and kernel weight in minimum tillage compared to other tillage systems. Taller wheat plants in N added stubble incorporated plots are credited to the readily available N from reduced source of N. Increase in plant stature may be due to positive effect of nitrogen on plant growth (Ayoub *et al*., 1994; Loveras *et al*., 2001; Iqtidar *et al*., 2006). The higher availability of essential nutrients and better water holding capacity (Loveras *et al*., 2001; Hossain *et al*., 2002; Matsi *et al*., 2003) in fertilized stubble incorporated plots might have resulted in taller plants than control. The availability of optimum plant nutrients might have accelerated cell expansion, enlargement and division, and thus resulted into taller plants (Loveras *et al*. 2001; Iqtidar *et al*. 2006). The lodging score was not statistically different due to tillage systems and N or SM treatments. Since wheat variety Pisabak-2005 is drought resistant variety having a bit deep root system produced strong enough tillers in all plots, might have minimized lodging.

Significantly greater wheat yield was obtained in minimum tilled plots compared to the rest of tillage systems. The greater conserved soil biota (Nakamoto *et al.,* 2006), greater water retention (Thomas *et al.,* 2007), improved fertility of soil (Papini *et al.,* 2007), less soil densification

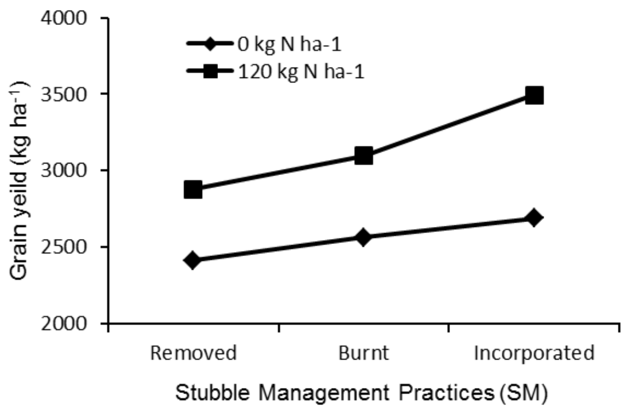

Fig. 4: Interactive effect of N and SM on grain yield (kg ha^{-1}) of wheat over two years

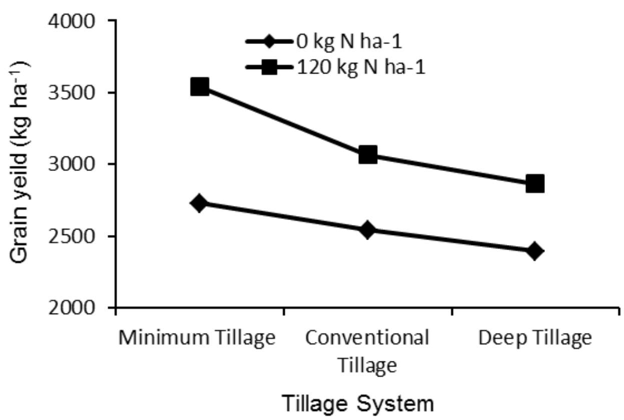

Fig. 51: Interactive effect of tillage systems and N on grain yield (kg ha^{-1}) of wheat over two years

(Weisskopf and Anken, 2006), optimum availability of nutrient (Xiao-Bin *et al.,* 2006), minimum nutrient losses (Sainju *et al.,* 2006) and optimum N availability met crop N requirement had increased individual plant performance in less ploughed plots, and thus might have increased grain yield. Moreover, decomposition of organic carbon played an important role in increasing soil fertility and minimizing soil erosion (Lopez-Bellido *et al.*, 2001; Lopez-Bellido, 2003; Sainju *et al.,* 2006) under minimum tillage and thus had positively influenced grain yield.

Greater grain yield was observed in fertilized and stubble incorporated plots compared to control or burnt plots. This is due to greater nutrient availability in fertilized stubble incorporated plots (Camara *et al.,* 2003; Malhi *et al.,* 2006). Retention of crop residues close to soil surface might had increased organic carbon and released nutrients (Singh *et al*., 2004), lowered evapotranspiration (Ortega *et al*., 2002), conserved greater soil water (Cantero-Martinez *et al*., 1995; Wilhelm *et al*., 2004), decreased soil temperature (Badaruddin *et al*., 1999), decreased soil pH (Heenan, 2005), greater aggregate stability and better resistant to soil erosion (Rasmussen, 1999) and thus excelled yield and yield component efficiency. The increased wheat yield in fertilized stubble incorporated plots can also be associated to increased tillers; productive tillers, number of kernels per spike and 1000-seed weight (Hossain *et al.,* 2002). The availability of mineral N as applied, and developed as a result of mineralization of organic N may have described the yield differences. The improved yield in stubble incorporated plots might be possible due to mineralization of stubbles, resultantly increased microbial carbon and N pools (Kristensen *et al*., 2003) and residual soil N (Habtegebrial *et al*., 2007). The satisfactory moisture content in the root zone of the subsurface managed stubble treatments or more efficient utilization of nutrients, released as a result of decomposition of the added crop residues (Chiroma *et al.,* 2006) might be the other possible reasons for more grain yield in fertilized stubble incorporated plots.

It can be concluded from results that stubble incorporation along with application of fertilizer N (120 kg ha^{-1}) under minimum tillage system is considered suitable practice for soil and residue management compared to the rest of management practices, delayed phenology, and improved stand establishment and crop yield.

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