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PHENOLOGY AND CROP STAND OF WHEAT AS AFFECTED BY NITROGEN SOURCES AND TILLAGE SYSTEMS

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Abstract

Phenology and crop stand are the important determinant which fix crop growth cycle and directly or indirectly affect crop productivity. In Pakistan, the conventional tillage practices are used for the production of wheat since long ago. The present concern about the environmental pollution due to the intensive tillage practices and high inorganic fertilization is an important issue. Field experiments were conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar Pakistan during winter 2005-07 in Randomized Complete Block (RCB) design with split plot arrangement having three replications. Twelve treatments of N, farmyard manure (FYM) and soybean residue (SR) management were arranged in subplots and three tillage practices [deep tillage (DT), conventional tillage (CT) and minimum tillage (MT)] in main plots. The objective of this study was to investigate the effects of N sources under different tillage systems on wheat. The MT plots took less days to emergence, boot, anthesis, milk and maturity stages than CT and DT. Both MT and CT proved superior in terms of plant height as well as crop stand i.e. emergence m^{-2} and tiller m^{-2} as compared to DT and were statistically at par with each other. Likewise, among the N sources, FYM application @ of 20 tons ha^{-1} combined with 60 kg N ha^{-1} delayed phenology, but improved crop stand and plant height compared to all other treatments followed by 20 tons FYM ha^{-1} combined with 30 kg N ha^{-1}. It is concluded that FYM application in combination with minimum N (30 or 60 kg N ha^{-1}) is an alternative and sustainable practice for improving crop growth and stand.

Introduction

Wheat (*Trticum aestivum* L.) is a chief source of food for a great deal of population in the world. In Pakistan it ranks first among the cereal crops and occupies about 66% of the annual food cropped area (Anon., 2006). It is the staple food for the people of Pakistan and meets the major dietary requirements, supplies about 60% of the calories and protein of the average diet (Khalil & Jan, 2002). In the recent years, 5-10% of the total wheat harvest has been utilized as feed because wheat is cheaper than all other alternate feed grain substitutes (Mustafa *et al*., 2004). Wheat per capita consumption (125 kg year $^{-1}$) is the highest in the world (Mustafa *et al*., 2004). Its straw is used as animal feed and also for manufacturing papers (Iqtidar *et al*., 2006). Actual farm yield of the wheat in Pakistan is about 30-35 % of the total potential yield, whereas 50% mean yield is realized in wheat as compared to leading nations like China and Mexico (Anon., 1997).

Farming based on the use of off-farm organic residues (David *et al*., 2005), N management, conservation tillage systems and using the disruptive organic resources in combination with N fertilizer (Ouédraogo *et al.,* 2006), are the best options to improve agricultural sustainability in arid and semi arid areas. Conservation and supplementation of organic residue/manure strategies conserved soil productivity (Ortega *et al.,* 2002). These practices were considered as a primary substrate for replenishment of soil organic matter (Wong *et al.,* 1999; Celik *et al.,* 2004; Blair *et al.,* 2006; Rasool *et al.,* 2007) and can be regarded as an alternative way of adding fertilizer to increase soil fertility and crop productivity in organic farming (Wong *et al*., 1999).

Tillage is considered the most effective farm activity for developing a desired soil structure (Bahadar *et al*., 2007). Tillage methods that incorporate residues into soil could improve productivity and retard organic matter decline. However, there is not enough information on influence of residue management, particularly in silt clay loam soil like in Pakistan. The objective of this research was to determine the influence of FYM and soybean residue in combination with inorganic N under various tillage management practices on phenology and crop stand of wheat.

Materials and Methods

Field experiments were conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar Pakistan during winter 2005-07. The soil was a silt clay loam, well drained, fine textured, derived from piedmont alluvium, deep well developed and belong to Great Group Haplustalfs. The experimental site has a warm to hot, semi-arid subtropical continental climate with a mean annual rainfall of about 360 mm. The soil is deficient in mineral nitrogen (<0.08 g kg^{-1} soil) and phosphorus (<20 g kg^{-1} soil), but has adequate potassium (>120 g kg^{-1} soil) with a pH of 8.2 and organic matter content less than 1%.

The experiment was conducted in Randomized Complete Block (RCB) design with split plot arrangement having three replications. Twelve treatments of N, farmyard manure (FYM) and soybean residue (SR) management were arranged in subplots and three tillage practices [deep tillage (DT), conventional tillage (CT) and minimum tillage (MT)] in main plots. The organic and inorganic N treatments were 0kg N ha^{-1} (N0), 60kg N ha^{-1} (N1), 120kg N ha^{-1} (N2), 10 tons FYM ha^{-1} (FYM1), 20 tons FYM ha^{-1} (FYM2), 30kg N and 10 tons FYM ha^{-1} (FYM1 + ½ N1), 60 kg N and 10 tons FYM ha^{-1} (FYM1 + ½ N2), 30 kg N and 20 tons FYM ha^{-1} (FYM2 + ½ N1), 60 kg N and 20 tons FYM ha^{-1} (FYM2 + ½ N2), 10 tons SR ha^{-1}, 30 kg N and 10 tons SR ha^{-1} (SR + ½ N1), 60 kg N and 10 tons SR ha^{-1} (SR + ½ N2).

Deep tillage practices were carried out by chisel plough which tilled the soil upto 45cm followed by a common cultivator. Common cultivator was used for CT which tilled the soil upto 30cm. In both DT and CT, the soil was ploughed two times horizontally as well as vertically and planking was done to break the clods and level the field. Minimum tillage practice was done by the use of rotivators to bury only the FYM/soybean residue for 4-6cm depth. FYM was obtained from the dairy farm of NWFP Agricultural University Peshawar Pakistan and was well decomposed. Soybean was used as residue crop, harvested last year and was partially decomposed. The chemical composition of FYM and SR is shown in Table 1. Urea (46 % N) was used as inorganic N source. FYM/residue incorporation was made 45 days before the sowing in specific plots of 5 x 3m. Urea was applied in split application, half at sowing and the other half just after 1st irrigation (27 days after sowing).

Planting was done on 29th October, 2005 for first wheat crop and on 16th October, 2006 for second wheat crop. The fertilizer broadcasted at sowing time consisted of 120 kg ha^{-1} sulphate of potash (60% K) and 200 kg ha^{-1} single super phosphate (18% P_2O_5) to supply recommended 60 and 90 kg ha^{-1} K and P, respectively. Plots were irrigated fortnightly as flood irrigation. Weeds were controlled manually as well as through herbicide application.

Table 1. Composition of farm yard manure and soybean residue.

Quality parameters	FYM		Soybean residue	
	(%)	(Kg ton^{-1})	(%)	(Kg ton^{-1})
Total N	1.11	11.1	3.12	31.2
Mineral N	0.12	1.12	0.15	1.5
EC (dS m^{-1})	4.92	-	5.21	-
pH	7.80	-	7.20	-
Organic C	16.2	162.0	18.7	187.0

Days to emergence were recorded by counting the days taken from the date of sowing to the date when 70 – 80% emergence was completed. Emergence m^{-2} was recorded by counting the number of seedling emerged in two central rows (when almost all the seedling emerged in each subplot) and were converted into square meter accordingly. Days to boot, anthesis, milk and physiological maturity stages were recorded by counting days from date of sowing to the date when plants in each subplot attained boot, anthesis, milk and physiological stage, respectively. Complete loss of the green color of the glumes was used as indication of physiological maturity. Plant height data were recoded on randomly selected 10 plants in each sub plot and was averaged. Tillers m^{-2} were recorded by counting the numbers of tillers in central three rows of each subplot, and then converted into numbers of tillers m^{-2}, accordingly. Lodging score was determined by the procedure outlined by Oplinger *et al*., (1995) with help of following formula:

$$\text{Lodging score} = S \times I \times 0.02$$

where
S= Surface area of lodged crop i.e. 1 mean none, while 9 mean totally lodged
I = Intensity of lodging i.e., 1= no lodged, and 9 = completely lodged
Lodging score range is 0.2 - 9

Statistical analysis: The experimental data were subjected to the analysis of variance appropriate for RCB design with split plot arrangement using statistical software GenState 8.1 (GenState, 2005). Upon significant F-value, the means were separated by least significant test at $p \leq 5\%$ using the procedure outlined by Gomez & Gomez (1983).

Results

The mean values of temperature and rainfall during the crop season are shown in Fig. 1. Mean air temperature was 9 to 31°C, whereas total rainfall per month varied between 0.20 and 79.00 mm during the growing season. Average rainfall was different between 2 years. Thus, in order to avoid water stress, in the second year, the field was irrigated from the beginning of April. As a consequence, the crop received an optimum water supply during grain filling in both years. Weeds emergence in second year were greater than first year which was the consequence of farmyard manure (FYM) and soybean residue (SR) application so, manual weeding as well as herbicide were carried out for weed controls. We interpreted only main factors data as all the interactions except (Tillage x N source for plant height) were not significant.

Table 2. Phonological data of wheat as affected by N source and tillage practices.

Treatments	Days to									
	Emergence		Boot		Anthesis		Milk		Maturity	
Tillage practices										
Minimum	11.3	b	79	b	100	b	114	b	171	b
Conventional	11.7	b	83	a	104	ab	119	ab	175	ab
Deep	12.1	a	85	a	109	a	124	a	179	a
$LSD_{0.05}$	**0.436**		**3.35**		**4.755**		**5.24**		**4.89**	
N sources										
Control	12.7	a	76	f	97	f	114	d	170	d
Nitrogen-60	12.4	ab	78	cd	98	f	115	d	170	d
Nitrogen-120	12.4	ab	85	abc	106	a-d	122	ab	177	ab
FYM-10	11.8	a-d	82	a-d	105	cde	119	bc	175	bc
FYM-20	11.2	cde	85	abc	106	bcd	120	abc	177	abc
FYM-10 + N-30	11.8	bcd	82	bcd	103	de	117	cd	177	ab
FYM-10 + N-60	11.3	cde	85	abc	108	abc	122	ab	178	ab
FYM-20 + N-30	11.0	de	86	ab	108	ab	122	ab	179	ab
FYM-20 + N-60	10.8	e	87	a	109	a	123	a	179	a
S-Residue-10	11.9	abc	80	de	102	e	117	cd	173	cd
S-Residue-10 + N-30	11.7	bcd	80	de	104	de	119	bc	173	cd
S-Residue-10 + N-60	11.2	cde	83	bcd	106	bcd	119	abc	175	abc
$LSD_{0.05}$	**0.85**		**3.38**		**3.34**		**3.54**		**3.91**	
Interactions	$P_{0.05}$ value		$P_{0.05}$ value		$P_{0.05}$ value		$P_{0.05}$ value		$P_{0.05}$ value	
Y x T	0.184	NS	0.965	NS	0.926	NS	0.780	NS	0.563	NS
Y x NS	0.425	NS	0.996	NS	0.868	NS	0.593	NS	0.932	NS
T x NS	0.324	NS	0.906	NS	0.349	NS	0.764	NS	0.887	NS
Y x T x NS	0.077	NS	0.827	NS	0.897	NS	0.819	NS	0.883	NS

NS Not significant

Mean followed by same letter(s) with in the same category are not different statistically using least significant difference (LSD) test at 5% level of probability.

Crop phenology: Emergence was significantly delayed (12.1d) in deep ploughed (DT) plots when compared to minimum ploughed (MT) plots (11.3 d) (Table 2). However, there were no statistical differences in days to emergence between MT and CT-plots (11.7d). Control plots took longer to emerge (12.7d) compared to plots incorporated with either sole FYM and/or N enriched. Emergence was earlier in plots with organic N incorporated than in those plots which received inorganic N. More specifically, faster emergence (10.8d) was recorded in plots with 20 tons FYM ha^{-1} added with 60 kg N ha^{-1} incorporated than those with urea N applied. Plots received sole FYM and soybean residue (SR) took longer to emerge compared to those receiving mixed organic and inorganic N. Emergence took 11.8 and 11.2 days in plots received 10 and 20 tons FYM ha^{-1}, respectively. Within those receiving 10 tons FYM ha^{-1}, emergence was faster in plots also receiving 60 kg N ha^{-1} than in those which received 30 kg N ha^{-1}. Soybean residue with the addition of 60 kg N ha^{-1} led to faster emergence than either soybean on its own or with 30 kg N ha^{-1}.

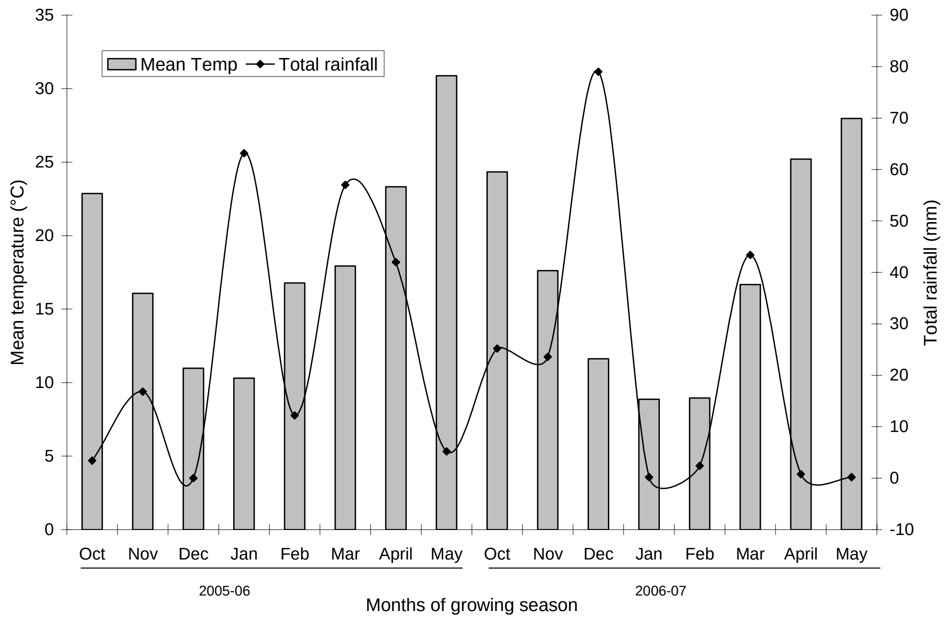

Fig. 1. Total precipitation (mm) and mean air temperature (°C) at the experimental site Peshawar during 2005 and 2007.

Days to boot stage were significantly affected by tillage and N sources (Table 2). Deep tilled plots took more days to boot stage (85d) compared to MT plots (79d), but were not different from plots subjected to CT (83d). Average over two years data showed that N sources significantly increased days to boot stage than control. Plots incorporated with FYM either sole or combined with N, took 82 to 87 days to boot stage compared to those incorporated with SR alone or reinforced with N, whose range was 80 to 83d. Similarly the plots having urea N had a range of 78-85d up to boot stage. Generally, plots incorporated with mixed FYM and N took longer to emerge than other treatments. More specifically delayed boot stage was observed in plots incorporated with 20 tons FYM ha^{-1} added with 60 kg N ha^{-1}, whereas early boot stage were observed in plots having 60 kg N ha^{-1}.

Anthesis (Table 2) was significantly enhanced in plots subjected to MT (100d) than DT practiced plots (109d), but not varied significantly than plots subjected to CT (104d). Control plots took least days to anthesis (97d) than in the plots incorporated with either FYM and/or SR. Generally, plots having higher levels of FYM and N took longer to anthesis than lower level of FYM and N. More specifically, application of 20 tons FYM ha^{-1} along with 60 kg N ha^{-1} took more days to anthesis (109) than in those receiving 10 tons FYM ha^{-1} and 30 kg N ha^{-1} (103d). Similarly mixed application of SR took more days to anthesis than sole application of SR.

Both tillage and N source significantly affected days to milk stage in wheat (Table 2). Plots practiced with DT had delayed milk stage in wheat up to 124 days compared to MT (114d), but were not different than CT practiced plots (119d). Control plots and those receiving 60 kg N ha^{-1} attained milk stage in 114 and 115 days, respectively. Application of N either in the form of organic or inorganic N (except 60 kg N ha^{-1}) delayed milk stage compared to control. Generally mixed and high level of FYM and N application took more days to milk stage than sole and lower levels. More specifically, application of 20 tons FYM ha^{-1} added with 60 kg N ha^{-1} took maximum days to milk stage (123d) compared to all other treatments. Within those plots receiving SR, no variation in days to milk stage were observed for either sole or mixed application.

Minimum tilled plots matured in 171 days (Table 2) compared to CT (175d) and DT (179d). Plant maturity was significantly delayed in DT plots compared to MT plots. Plots incorporated with FYM delayed maturity compared to control, SR and N applied plots. Control plots and plots which received 60 kg N ha^{-1} took 170 days to maturity each. Maximum days to maturity were recorded in plots incorporated with 20 tons FYM ha^{-1} along with 60 kg N ha^{-1} compared to other lower levels of mixed application. Plots which received 10 tons SR ha^{-1}added with 60 kg N ha^{-1} delayed maturity (175 d), whereas other SR treatment took 173 days to maturity.

Crop stand: Tillage practices had significant effect on emergence m^{-2} (Table 3). Emergence m^{-2} was significantly higher in the MT (86) plots as compared to the DT plots (83). There were no significant differences for emergence m^{-2} between MT and CT practices. Various organic and inorganic N treatments had significant effects on emergence m^{-2} (Table 3). Generally, FYM applied plots had more emergence than control plots. Plots which received SR in combination with N fertilizer or sole FYM resulted in similar emergence m^{-2}. The highest emergence m^{-2} was recorded in plots, in which 20 tons FYM ha^{-1} was incorporated as sole or mixed with either 30 or 60 kg N ha^{-1}, but it was not significantly different from emergence observed in plots, applied with lower amount of FYM whether alone or combined with N.

Tillers m^{-2} were significantly affected by tillage and N sources (Table 3). Maximum tillers m^{-2} (291) were recorded in plots subjected to CT than DT plots (268). Tillers m^{-2} were significantly lower (260) in plots having no inputs (control) compared to plots fertilized regardless of N sources. There were no substantial differences in tillers m^{-2} production among the N fertilization, however mixed and higher level of FYM and N produced more tillers than either sole or lower levels. Similarly, plots received FYM have more tillers than in those having SR.

Lodging score was neither affected by tillage practices nor by N sources, and thus have about similar lodging in all plots (Table 3). Lodging varied from 0.04 to 0.05 for tillage practices, and from 0.03 to 0.06 for different N sources treatments.

Plant height: Tillage practice, N sources and its interaction have significantly affected plant height (Table 3). The tallest plants were noted in MT (103.7cm) or CT (103.0 cm) plots as compared to DT (99.2) plots. Plants in MT or CT practiced plots were not significantly different from each other. Incorporation of FYM resulted in taller plants than sole N, and SR applied plots, with the exception to higher level of sole N application (Table 3). Generally, higher levels of combined FYM and N attained more height than lower levels. Specifically, taller plants were recorded in plots incorporated with 20 tons FYM ha^{-1} amended with 60 kg N ha^{-1}, as compared to lower level of N or SR either sole or amended with N. Within those plots receiving SR, mixed application attained more height than sole application.

Table 3. Plant height and crop stand of wheat as affected by various N source and tillage practices.

Treatments	Plant height		Emergence m^{-2}		Tillers m^{-2}		Lodging score	
Tillage practices								
Minimum	103.7	a	86	a	284	a	0.05	a
Conventional	103.0	a	86	a	291	a	0.04	a
Deep	99.2	b	83	b	268	b	0.05	a
$LSD_{0.05}$	**2.509**		**2.13**		**10.66**		**NS**	
N sources								
Control	97.5	f	81	b	260	c	0.06	a
Nitrogen-60	98.4	f	84	ab	265	ba	0.04	a
Nitrogen-120	101.8	cde	84	ab	286	a	0.06	a
FYM-10	100.3	def	84	ab	286	a	0.04	a
FYM-20	104.1	abc	87	a	285	a	0.04	a
FYM-10 + N-30	102.5	b-e	85	a	289	a	0.03	a
FYM-10 + N-60	103.1	a-d	86	a	289	a	0.06	a
FYM-20 + N-30	105.1	ab	87	a	290	a	0.04	a
FYM-20 + N-60	106.0	a	87	a	293	a	0.06	a
S-Residue-10	99.4	ef	85	a	263	bc	0.05	a
S-Residue-10 + N-30	102.2	b-e	85	a	278	ab	0.04	a
S-Residue-10 + N-60	103.0	a-d	86	a	289	a	0.05	a
$LSD_{0.05}$	**3.21**		**3.34**		**15.02**		**NS**	
Interactions	$P_{0.05}$ value		$P_{0.05}$ value		$P_{0.05}$ value		$P_{0.05}$ value	
Y x T	0.145	NS	0.890	NS	0.931	NS	0.976	NS
Y x NS	0.978	NS	0.098	NS	1.000	NS	0.999	NS
T x NS	0.015	*	0.214	NS	1.000	NS	0.319	NS
Y x T x NS	0.285	NS	0.079	NS	1.000	NS	0.936	NS

NS Not significant; * Significant at $p \leq 0.05$

Mean followed by same letter(s) with in the same category are not different statistically using least significant difference (LSD) test at 5% level of probability.

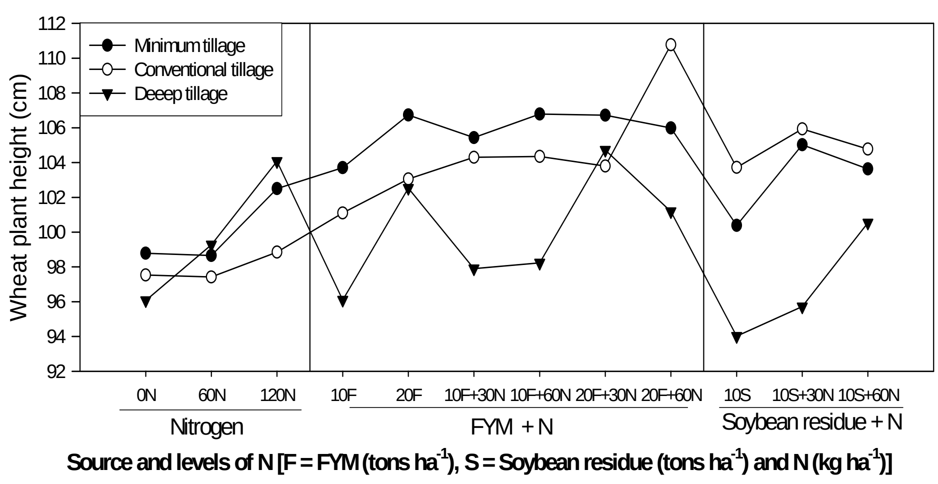

Fig. 2. Plant height of wheat (cm) as affected by tillage x N sources interaction over years.

Similarly, the T x N interaction (Fig. 2), revealed that MT practices attained more plant length when FYM either alone or N enriched were soil incorporated, DT only at 120 kg N ha^{-1}, whereas CT at higher levels of mixed FYM + N and also due to SR incorporation.

Discussion

Crop productivity basically depends on the available nutrients status of the soil. Integration of tillage practices with N fertilization in organic or inorganic form would result in more amount of soil water (Al-Kaisi & Yan, 2005), soil organic carbon (Dolan *et al.,* 2006), and active C and N fraction (Sainju *et al.,* 2007) and hence plant productivity. Wheat productivity respond positively to organic and inorganic N-treatments, would be probably due to carry-over effects of organic and inorganic N for optimum growth of the crop from the previous crop. The lower N level in the soil results in lower yield due to less available N for the optimum plant growth (Sidhu & Sur 1993; Lemcoff & Loomis, 1994).

Days to emergence was not affected by tillage and N sources in the first years, but enhanced emergence in the following year would be a consequence of more availability of water for seed coat softening, and might be due to soften seed bed. Delayed boot, milk, anthesis and maturity stage in fertilized plots would be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency with increase in use of N (Frederick & Camberato 1995; Deldon, 2001). The more availability of nutrients and good soil conditions due to organic source of N which resulted in vigorous crop growth might have elongated growing period (Li, 2003), and thus have delayed phenology. Nitrogen application delayed leaf senescence, sustained leaf photosynthesis during the grain filling period and extended the duration of grain fill (Frederick & Camberato, 1995) and had direct effects on phenology. Slow release of nutrients from FYM (Matsi *et al.,* 2003) might be another possible explanation for delayed phenology in fertilized plots.

Crop establishment in the form of emergence m^{-2}, tillering m^{-2} and lodging score, are some of the important parameters of any crop and substantially contributes to final yield. More seedlings and tillering in MT and mixed organic and inorganic N plots would be due to proper and adequate water availability being stored by organic N source (Chiroma *et al.,* 2006) for proper germination, increased availability of nutrient, improvement of soil water holding capacity and reduction of volatilization of nitrogenous fertilizer to NH_3 gas (Sattar & Gaur 1989; Tran-Thuc-Son *et al*., 1995), and increased shoot survival by staying green longer and large number of tillers survived till maturity at higher N levels (Ayoub *et al*., 1994; Iqtidar *et al*., 2006), which may have resulted in proper, uniform and improved early crop establishment through increased seedling germination and tillering. Another possible explanation for improved crop stand would be incorporation of residue in soil, which is thought to reduce the evaporation demand, thus have adequate water for plant roots to develop or perhaps due to the softness of soil caused by manure in which the roots may expand rapidly enough into wet soil to meet plant water requirements (Jama & Ottman, 1993).

Plant stature affects crop in several ways and have a direct positive effect on biological yield. Increase in plant height may be due to favorable effect of N on promoting vigorous plant growth (Arnon, 1972; Lloveras *et al*., 2001; Ayoub *et al*., 1994; Iqtidar *et al*., 2006), more availability of macro and micro nutrients and improvement in soil water holding capacity (Lloveras *et al*., 2001; Hossain *et al*., 2002; Matsi *et al*., 2003), thus fertilized plots had more taller plants than either control or low fertilized plots.

The lack of superiority of higher FYM application over low FYM application does not imply the inefficacy of the FYM, but plants in higher and lower FYM incorporated plots utilized the water and nutrients in a better way, resulted in optimum plant growth which can be attributed to deeper and denser rooting (Gajri *et al.,* 1994; Sow *et al.,* 1997). It is evident from these results that FYM incorporation in conjunction with a minimum N is an alternative and sustainable practice of soil management for crop production, improved early growth and seedling establishment. In addition to these, our results showed superiority of MT over CT and DT in terms of cost applied on CT and DT, environmental problems, and other soil degrading factors.

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