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PHENOLOGY, LEAF AREA INDEX AND GRAIN YIELD OF RAINFED WHEAT INFLUENCED BY ORGANIC AND INORGANIC FERTILIZER

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Abstract

Phenology, leaf area index and grain yield are the most important traits affected by fertilizer under rainfed condition. The objective of this study was to evaluate the effect of various levels of inorganic fertilizers (NPK) in combination with organic fertilizer in the form of farmyard manure (FYM) on phenology, leaf area index and grain yield of wheat under rainfed condition. Wheat variety Haider-2000 was planted during 2003-2004 and 2004-05 under rainfed condition at Cereal Crops Research Institute Pirsabak, KPK in randomized complete block (RCB) design with split plot arrangement replicated four times. Four levels of FYM (0, 15, 30 and 45 t ha^{-1}) were allotted to main plots, while nine combinations of NPK (0, 40-30-30, 40-30-60, 40-60-30, 40-60-60, 80-30-30, 80-30-60, 80-60-30 and 80-60-60 kg NPK ha^{-1}) were allotted to sub plots. Different levels of NPK and FYM alone or in combination had significant effect on tillers m^{-2}, days to 50% heading, days to maturity, leaf area index, plant height and grain yield. Maximum tillers m^{-2} (330), days to 50 % heading (117), days to maturity (151.1), plant height (82.4) and grain yield (2505 kg ha^{-1}) were recorded at 80-60-60 kg NPK ha^{-1}. Maximum leaf area index (2.50) was recorded at 80-60-30 kg ha^{-1}, while minimum leaf area index (2.23) was found at low level of 40-30-30 kg NPK ha^{-1}. Farmyard manure at 45 t ha^{-1} produced maximum tillers m^{-2} (318), while maximum grain yield (2470 kg ha^{-1}) was recorded at 30 t FYM ha^{-1}. It is concluded that both inorganic and organic fertilizers alone or in combination increased grain yield and other parameters of wheat, however maximum grain yield was recorded at 80-60-60 kg NPK ha^{-1} and 30t FYM ha^{-1}.

Introduction

Crop growth and yield depend on proper supply of fertilizer and water (Midmore *et al*., 1984; Reyonlds *et al*., 1998). Fertilizer may improve water use efficiency (WUE) of rainfed wheat (Deng *et al*., 2004). Nitrogen (N) is important in improving WUE and soil water use (SWU), while phosphorus plays an important role in increasing total SWU and water extraction from deep soil layer (Dang, 1999). Potassium supply increase root growth, maintains cell turgor, reduces water loss and wilting in plants and improves drought resistance (Tiwari, 2002). The favorable effects of inorganic fertilizers (NPK) under rainfed and irrigated conditions on crop development, yield and yield components of wheat have been reported by various scientists from different parts of the world.

Increase in N levels combined with phosphorus (P) and potassium (K) have increased number of tillers m^{-2} (Mossedaq & Smith 1994; Iqtidar *et al*., 2006). Days to 50% heading and days to maturity delayed with the increase in N levels in combination with P and K (Ayoub *et al*., 1994). Plant height of wheat crop increased with the increase in NPK combination (Lloveras *et al*., 2001; Hossain *et al*., 2002). Similarly yield and yield components of wheat increased with the use of NPK (Lloveras *et al*., 2001; Brown & Petrie 2006; Alvarez *et al*., 2004). Increase in leaf area index was reported with the use of NPK (Zhang *et al*., 1998; Mossedaq & Smith 1994).

Application of farmyard manure (FYM) to soil have been practiced for many centuries and its application to soil have increased crop yield, improved soil fertility, increased soil organic matter, increased microbiological activities and improved soil structure for sustainable agriculture (Blair *et al*., 2006; Kundu *et al*., 2007). Combination of both organic and inorganic fertilizers increased tillers m^{-2}, days to 50% heading, plant height, yield and yield components and leaf area index of wheat compared with sole organic or inorganic fertilizer (Badaruddin *et al*., 1999; Hossain *et al*., 2002; Manna *et al*., 2005). Limited work has been reported on application of both organic and inorganic fertilizer on crop productivity in the rainfed areas of North West Frontier Province (NWFP). The present study was therefore designed to evaluate the effect of various levels of NPK and FYM on phenology, leaf area index and grain yield of rainfed wheat.

Materials and Methods

Experimental site: Field experiments were conducted at Cereal Crops Research Institute, Pirsabak, Nowshera, Pakistan during the years 2003-04 and 2004-05. Pirsabak is located about 1600 km north of Indian Ocean at 34° N latitude, 72° E longitude and at an altitude of 288 m above sea level and has a continental climate. Temperature and rainfall data were collected from the meteorological station located about 500 m from the experimental site (Fig. 1).

Land preparation and experimental procedure: The land was ploughed with rotavator to open the soil by cutting and pulverizing the soil and inverting it to destroy weeds, uproot stubbles of the previous crop and buried them in the soil, increase infiltration of water and reduction of runoff. Before sowing the experimental field was ploughed with cultivator 3-4 times to prepare fine seed bed for wheat sowing. The crop was sown with hand hoe. Four levels of FYM (0, 15, 30, 45 tons ha^{-1}) and 9 combinations of NPK (0-0-0, 40-30-30, 40-30-60, 40-60-30, 40-60-60, 80-30-30, 80-30-60, 80-60-30 and 80-60-60 kg ha^{-1}) were applied in randomized complete block design with split plots arrangement replicated four times. Farmyard manure (FYM) was allotted to main plots, while combinations of NPK were applied to sub-plots. Sources of NPK were urea, single super phosphate (SSP) and murate of potash, respectively. Seed of improved wheat variety Haider-2000, recommended for rainfed areas in NWFP was planted on November 18, 2003 and November 20, 2004. A uniform seed rate of 100 kg ha^{-1} was used for the whole experiment. The size of sub plot was 5 m by 1.8 m having 6 rows 5 m long and 0.3 m apart. The entire N, phosphorous, potassium and FYM were applied one day before sowing and mixed with soil. Weeds were controlled manually. The crops were harvested on May 19, 2004 and May 20, 2005 during both years of experiments.

Soil and farmyard manure analysis: Soil and farmyard manure (FYM) samples were taken and analyzed before planting the experiment. Composite soil samples at 0-30 cm depths were collected from the experimental field. Seven to ten random samples were taken and bulked. Similarly composite samples of about 1 kg were collected from fully matured well mixed heap of FYM and analyzed. The soil of the experimental field was sandy loam, moderately calcareous, alkaline in reaction (pH 7.7), low in organic matter (0.7 %), mineral N (NH_4-N + NO_3-N) (20 mg kg^{-1} soil), AB-DTPA extractable P (5.0 mg P_2O_5 kg^{-1} soil) and AB-DTPA extractable K (100 mg K_2O kg^{-1} soil). The FYM used in this study had (0.65 % N), (0.19 % P) and (0.63 % K).

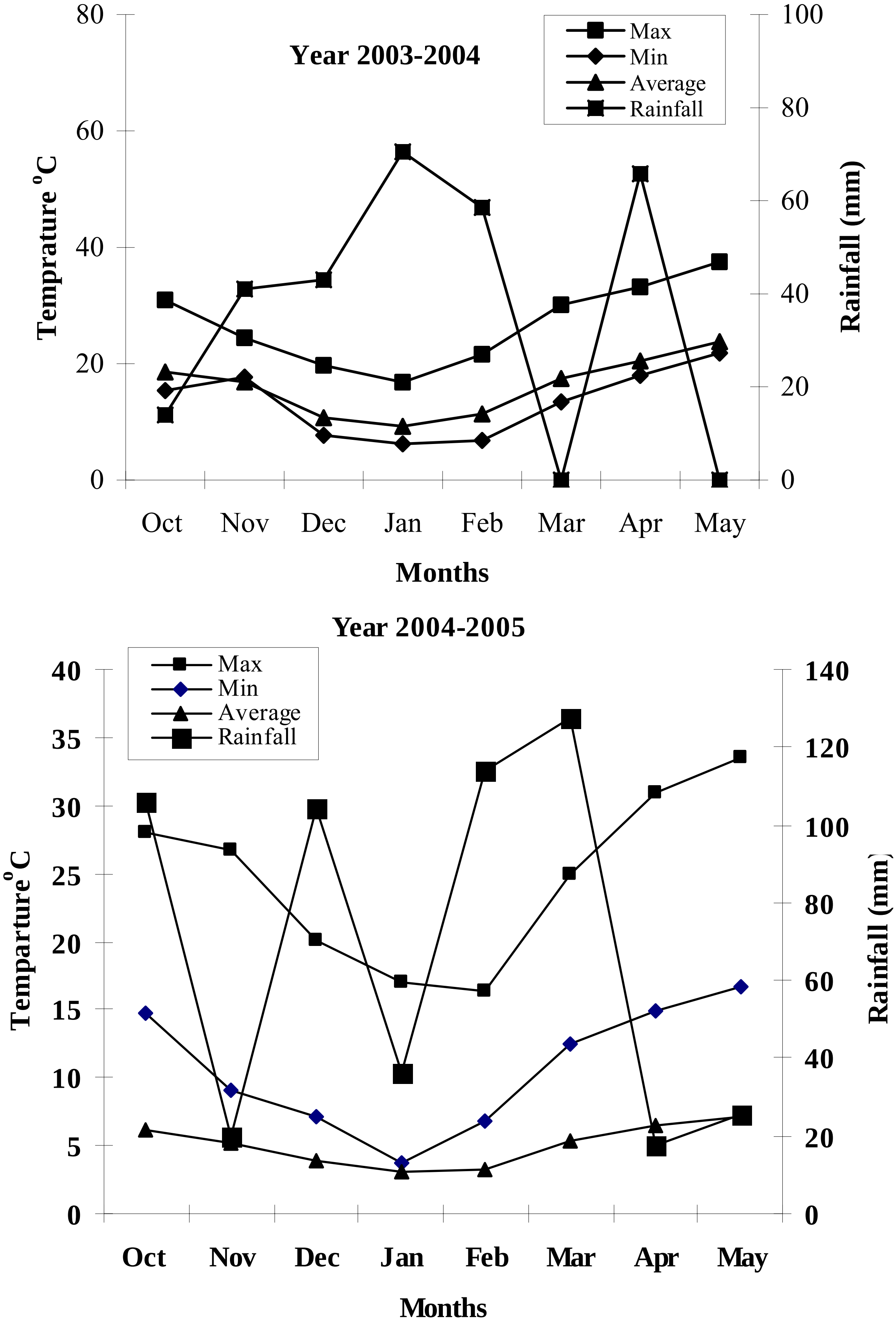

Fig. 1. Average air temperature and rainfall at Cereal Crops Research Institute Pirsabak, Nowshera during the 2003-04 and 2004-05 crop growing seasons.

Total N in soil and FYM samples was determined by the Kjeldhal method as described in (Bremner & Mulvaney, 1982). For determination of total P and K in FYM, the sample was first digested using wet-digestion method (nitric acid and perchloric acid) as described by Kue (1996). Phosphorus in the digest was measured by spectrophotometer and potash by flame photometer. Mineral N in soil sample was determined following the method of Keeney & Nelson (1982). The extractable P and K in soil sample were determined by the AB-DTPA extractable method (Soltanpour, 1985). Total organic matter in the soil was determined by the Walkely-Black procedure (Nelson & Sommers, 1982). Soil pH was determined in soil-water suspension (1:5) with the help of pH meter (McLean, 1982).

Experimental data procedure: Number of tillers in one meter long row at four different places were counted in four central rows in each subplot after anthesis and converted into number of tillers m^{-2}. Days to heading were calculated from the date of sowing and the date, when 50 % plants produced their heads (spikes) in four central rows in each subplot. Days to maturity were counted from date of sowing till wheat crop reached physiological maturity in four central rows of each subplot. Complete loss of green color from the glumes was used as criterion for physiological maturity. Plant height was recorded by measuring the height of ten randomly selected plants in each treatment in four central rows at physiological maturity from ground surface up to the tip of spikes excluding awn and their average was calculated.

Leaf area tiller^{-1} was measured by collecting leaves from five tillers in each sub-plot in four central rows at anthesis stage and their leaf area was calculated by multiplying leaf length (excluding leaf sheath) x width x factor. The factor used was 0.75 (Khalil *et al*., 2002) and averaged as leaf area tiller^{-1}. Leaf area index was calculated by multiplying leaf area tiller^{-1} over tillers m^{-2} and divided by 10,000. In order to determine grain yield, four central rows in each subplot were harvested, air dried, weighed and converted into kg ha^{-1}. Harvest index (%) was calculated by dividing the grain yield over total biological yield and multiplied by 100.

Statistical analysis: The data across two years was statistically analyzed according to randomized complete block design with split plot treatment arrangement using SAS the PROC GLM procedure in SAS (Anon., 2000). When the F values were significant for main and interaction effects, means were compared using LSD test ($p \leq 0.05$). Single degree of freedom contrasts were also used for comparison among different combinations of the treatments.

Results and Discussion

Precipitation and temperature data: Total seasonal precipitation for the crop growing season was 293 mm in 2003-04, and 551 mm in 2004-05 (Fig. 1) Total rainfall in the second growing season was almost twice that of the first growing season. Rainfall received in year 2004-05 was 106 mm in October, 104 mm in December, 114 mm in February and 128 mm in March while in 2003-04 it was only 14, 43, 58 and 0 mm in the corresponding months, which was 2 times less than the 2004-05. However, the distribution of rainfalls during the growing seasons was enough for seed germination and good stand establishment. No rainfall was received during the month of March and May in the first growing season (2003-04). Average temperature during first growing season was higher than the second growing season. The favorable moisture and temperature during 2004-05 season resulted in higher yield than in 2003-04.

Table 1. Mean squares for tillers m^2 of wheat as affected by FYM and NPK levels combined over two years.

	Tiller m^{-2}	
S.O.V	**DF**	**MS**
Year (Y)	1	84357.78**
Rep (y*)	6	290.90
FYM	3	1952.43**
FYM linear	(1)	4434.53**
FYM quadratic	(1)	1148.00 NS
FYM cubic	(1)	274.75 NS
YXFYM	3	607.18 NS
Error1	18	355.41 **
NPK	8	5927.07 **
Control vs rest	(1)	20628.14 **
N	(1)	19321.00 *
P	(1)	5476.00 *
K	(1)	1225.00 **
N x P	(1)	500.64 **
N x K	(1)	141.02 NS
P x K	(1)	123.77 NS
N x P x K	(1)	1.00 NS
Y x NPK	8	53.55 NS
FYM x NPK	24	26.68 NS
Y x FYM x NPK	24	12.37 NS
Error 2	192	38.81
Total	**287**	

C.V% = 7.44
NS = Non significant
* = Significant at 5% level of probability
** = Significant at 1 % level of probability
y* = Represent replication over yea

Tillers m^{-2}: Tillers m^{-2} was significantly affected by years, FYM and NPK (Table 1). Maximum number of tillers m^{-2} (331) was recorded in 2004-05 while minimum tillers m^{-2} (297) was recorded in 2003-04 (Table 2). Significantly lower tillers m^{-2} in the first year compared with the second year may be due to the fact that total rainfall in the second year was almost twice of the first year (Fig. 1). The distribution of rainfall is more critical than total rainfall received during growing season. Rainfall received during December, the most critical time for tiller production was about 3 times more in second year compared with first year. This favorable environment in the second season led to the production of more tillers m^{-2} in second year. Minimum tillers m^{-2} (290) were recorded from the control. Tillers m^{-2} increased linearly with the increase in NPK levels and maximum tillers m^{-2} (330) were noted at 80-60-60 kg NPK ha^{-1}. The increased tillers m^{-2} at higher levels of NPK may be due to vigorous growth and development of wheat because more nutrients were supplied and available. The supply of more nutrients such as N improved WUE and SWU of wheat in rainfed (Deng *et al*., 2004). Phosphorus increased total SWU and extraction from deep soil layer (Dang, 1999), while potassium supply increased root growth, maintain cell turgor, reduce water loss and wilting in plants, improve drought resistance, increased shoot survival by staying green till maturity. These favorable effects of NPK led to the production of more tillers m^{-2} at higher levels of NPK (Tiwari, 2002; Ayoub *et al*., 1994; Iqtidar *et al*., 2006). Applications of FYM significantly increased tillers m^{-2} than control however; there was no significant difference among 15, 30 and 45 t FYM ha^{-1}. Maximum tillers m^{-2} (318) were recorded from plots that received highest level of 45 t FYM ha^{-1}, while minimum tillers m^{-2} (306) were recorded from control (Fig. 2). Application of FYM to the soil may have increased tillers m^{-2} due to improved soil fertility, increased soil organic matter, enhanced microbial activities and improved soil structure (Blair *et al*., 2006, Kundu *et al*., 2007). Both organic and inorganic fertilizer in combination improved early establishment of wheat through increased tillers m^{-2} which may be attributed to the increased availability of NPK, improvement of soil water holding capacity and reduction of volatilization of nitrogenous fertilizer to NH_3 gas (Badaruddin *et al*., 1999; Hossain *et al*., 2002; Sattar & Gaur, 1989; Gill & Meelu 1982; Tran-Thuc-Son *et al*., 1995).

Table 2. Tillers m^{-2} of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
			Average*		
0-0-0	283	291	296	294	290 h
40-30-30	290	302	301	301	299 g
40-30-60	301	307	307	309	306 f
40-60-30	302	314	316	316	312 e
40-60-60	310	316	319	326	316. d
80-30-30	314	319	322	326	320 c
80-30-60	315	325	328	329	324 b
80-60-30	310	329	331	332	328 a
80-60-60	322	335	332	330	329 a
Mean	**306 b**	**316 a**	**316 a**	**318 a**	

*=Average of 2 years
Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
Year 2003-2004 = 297b
Year 2004-2005 = 331a

Control vs rest		N		P		K	
Control	**Rest**	**40 kg ha^{-1}**	**80 kg ha^{-1}**	**30 kg ha^{-1}**	**60 kg ha^{-1}**	**30 kg ha^{-1}**	**60 kg ha^{-1}**
290.0 b	316.9 a	308.2 b	325.6 a	312.3 b	321.5 a	314.7 b	319.1 a

CV % = 7.44
LSD value for FYM at $p \leq 0.05$ (Average for years) = 6.601
LSD value for NPK at $p \leq 0.05$ (Average for years) = 3.072

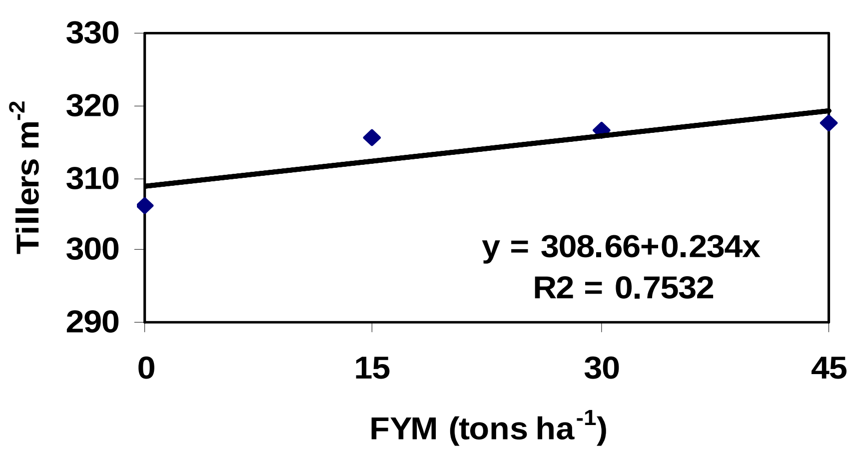

Fig. 2. Tillers m^{-2} of wheat as affected by different levels of FYM. Means represent average across years and NPK levels. LSD value for FYM at $p \leq 0.05$ (average for years) = 6.601.

Table 3. Mean square of various traits of wheat as affected by different FYM and NPK levels combined over two years.

S.O.V	Mean square			
	DF	Leaf area index	Days to 50% heading	Days to maturity
Years (Y)		14.906**	288.00**	1780.06**
Rep (y.)	6	0.117	2.54 NS	2.53
FYM	3	0.363 NS	3.67 NS	53.99 NS
Y X FYM	3	0.043 NS	0.06 NS	111.44NS
Error1	18	2.181	1.40	216.14
NPK	8	0.390**	32.24**	148.69**
Control vs Rest	(1)	1.471**	93.85**	364.17 **
N	(1)	0.887**	106.35**	656.64**
P	(1)	0.266**	39.85**	147.02**
K	(1)	0.093 NS	14.54**	20.25*
NxP	(1)	0.126 *	0.19 NS	0.25 NS
NxK	(1)	0.111 *	0.32 NS	0.14 NS
PxK	(1)	0.130 *	1.13 NS	0.77 NS
NxPxK	(1)	0.037 NS	1.72 *	0.25 NS
Y X NPK	8	0.011 NS	0.05 NS	25.85**
FYM x NPK	24	0.021 NS	0.38 NS	5.25 NS
Y X FYM X NPK	24	0.006 NS	0.05 NS	3.03 NS
Error 2	192	0.025	0.30	4.55
Total	**287**			

NS = Non significant
* = Significant at 5% level of probability
** = Significant at 1 % level of probability
y" = Represent replication over yea

Leaf area index: Years and NPK combination significantly affected leaf area index (Table 3). Average of the two years revealed that maximum leaf area index (2.62) was recorded in 2004-05, while minimum leaf area index (2.17) was recorded in 2003-04 (Table 4). Precipitation in the second year was almost twice of the first growing year (Fig. 1). Limited precipitation in first year created moisture deficit environment that resulted in reduced growth, leaf traits, yield and yield components (Garcia Del Moral *et al*., 2003, Mihailescu *et al*., 1993, Guttieri *et al*., 2001). Minimum leaf area index (2.19) was recorded from control. Leaf area index increased with the application of NPK and maximum leaf area index (2.50) was recorded at the highest level of NPK ha^{-1} 80-60-30 kg. Leaf area index increased with the application of NPK as compared to control. Fertilizer application to wheat particularly N during early stages of development greatly increased leaf area by delaying leaf senescence, sustained leaf photosynthesis and extended leaf area duration which ultimately resulted in maximum LAI compared with control (Zhang *et al*., 1998; Frederick & Camberato (1995). FYM showed no increase in leaf area index however, maximum leaf area index (2.46) was recorded at highest level of 45t FYM ha^{-1} while minimum harvest index (2.30) was recoded in the control. FYM may have increased availability of plant nutrients, improved soil water holding capacity and reduced volatilization of N fertilizer to NH_3 gas. These impacts may have increased yield and yield components but it did not increase LAI in our study.

Table 4. Leaf area index of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (Kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
	Average*				
0-0-0	2.184	2.177	2.185	2.230	2.194 d
40-30-30	2.167	2.327	2.262	2.179	2.234 d
40-30-60	2.285	2.380	2.424	2.441	2.383 c
40-60-30	2.299	2.417	2.450	2.481	2.412 bc
40-60-60	2.312	2.379	2.440	2.558	2.422 bc
80-30-30	2.327	2.465	2.440	2.614	2.462 ab
80-30-60	2.341	2.522	2.469	2.585	2.479 ab
80-60-30	2.381	2.513	2.559	2.557	2.503 a
80-60-60	2.362	2.536	2.499	2.516	2.478 ab
Mean	**2.295**	**2.413**	**2.414**	**2.462**	

Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
*=Average of 2 years
Year 2003-2004 = 2.169b
Year 2004-2005 = 2.624a

Control vs rest		N		P		K	
Control	Rest	40 kg ha^{-1}	80 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}
2.194 b	2.421 a	2.362 b	2.479 a	2.389 b	2.452 a	2.402 b	2.439 a

CV % = 7.44
LSD value for NPK at $p \leq 0.05$ (Average for years) = 0.077

Days to 50% heading: Earlier heading (115 days) was taken by the crop grown in 2003-04 as compared to delayed heading (117) in 2004-05 (Tables 3 and 5). Earlier heading in first growing year may be due to high mean air temperature from sowing till heading which was almost 2^{o}C higher in first year compared with second year. Moreover precipitation in February was 50% less and no rainfall occurred in March in first year, while the crop received 128 mm rainfall in March in second year (Fig. 1). This low precipitation coupled with high mean air temperature in first year enhanced days to heading. Average of the two years showed that NPK combinations significantly increased days to 50% heading over control. Significant difference among different NPK levels was also recorded for days to 50% heading. Minimum days to 50% heading (114) were recorded in control. Linear increase in days to 50% heading was observed with increase in NPK levels and maximum days to 50% heading (117) were recorded at 80-60-60 kg NPK ha^{-1}. Increase in days to 50% heading may be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency with the use of fertilizer particularly N (Frederick & Camberato 1995; Deldon, 2001; Ayoub *et al*., 1994; Badaruddin *et al*., 1999). FYM did not increase days to 50% heading significantly however, increase in days to 50% heading (116) was noted in plots where 15 t FYM ha^{-1} was applied thereafter, further no increase in days to 50% heading was observed. These results are in line with Badaruddin *et al*., (1999) who reported no significant increase in days to 50% heading of wheat at 10t FYM compared with control.

Table 5. Days to 50 % heading of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (Kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
Average*					
0-0-0	115	114	113	114	114 h
40-30-30	115	115	115	115	115 g
40-30-60	115	115	115	115	115 f
40-60-30	116	116	116	115	115 e
40-60-60	116	116	116	116	116 d
80-30-30	116	116	116	116	116 cd
80-30-60	116	117	116	116	116 bc
80-60-30	117	117	117	116	116 b
80-60-60	118	118	117	117	117 a
Mean	116	116	116	115	

Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
*=Average of 2 years
Year 2003-2004 = 115b
Year 2004-2005 = 1174a

Control vs rest		N		P		K	
Control	Rest	40 kg ha^{-1}	80 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}
114 b	116 a	115 b	117 a	116 b	116 a	116 b	116 a

CV % = 1.32
LSD value for NPK at $p \leq 0.05$ (Average for years) = 0.077

Table 6. Day to maturity of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (Kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
Average*					
0-0-0	143	147	146	143	145 g
40-30-30	146	147	146	145	146 fg
40-30-60	146	148	147	145	146 ef
40-60-30	148	148	147	146	147 de
40-60-60	147	149	147	147	148 d
80-30-30	149	1450	148	149	149 c
80-30-60	150	151	148	149	150 bc
80-60-30	151	150	151	150	151 ab
80-60-60	151	152	151	150	151 a
Mean	148	149	148	147	

Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
*=Average of 2 years
Year 2003-2004 = 146b
Year 2004-2005 = 151a

Control vs rest		N		P		K	
Control	Rest	40 kg ha^{-1}	80 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}
144.8 b	148.4 a	146.8 b	150.0 a	147.6 b	149.2 a	148.1 b	148.7 a

CV % = 3.71
LSD value for NPK at $p \leq 0.05$ (Average for years) = 1.052

Table 7. Analysis of variance for plant height (cm) and grain yield (kg ha^{-1}) of wheat as affected by different FYM and NPK levels combined over two years.

S OV	df	Plant height	S OV	df	Grain yield (kg ha^{-1})
Years (Y)	1	7260.13 **	Years (Y)	1	226184 **
Rep (y*)	6	33.51	Rep (y*)	6	1136
FYM	3	39.00 NS	FYM	3	12047 **
Y X FYM	3	2.90 NS	FYM linear	(1)	6592 *
Error1	18	18.67	FYM Quadratic	(1)	24809 **
NPK	8	102.69 **	FYM cubic	(1)	4741*
Control vs rest	(1)	337.64 **	Y X FYM	3	12368 **
N	(1)	236.39 **	Error1	18	830
P	(1)	66.02 **	NPK	8	155342 **
K	(1)	102.52 **	cont vs rest R	(1)	1108721
N x P	(1)	58.14 **	N	(1)	88209 **
N x K	(1)	1.27 NS	P	(1)	17956 **
P x K	(1)	9.77 NS	K	(1)	14072 **
N x P x K	(1)	9.77 NS	N x P	(1)	5948 **
Y X NPK	8	1.22 NS	N x K	(1)	1073
FYM x NPK	24	20.19 **	P x K	(1)	1444*
FYM L x cont vs R	(1)	34.89 *	N x P x K	(1)	5311**
FYM Q x cont vs R	(1)	27.13 *	Y X NPK	8	716 *
FYM C x cont vs R	(1)	5.78 NS	FYM x NPK	24	6846**
FYM L x N	(1)	0.53 NS	FYM L x cont vs R	(1)	85609 **
FYM Q x N	(1)	5.64 NS	FYM Q x cont vs R	(1)	20199 **
FYM C x N	(1)	10.88 NS	FYM C x cont vs	(1)	36508 **
FYM L x P	(1)	73.15 **	FYM L x N	(1)	597 NS
FYM Q x P	(1)	1.27 NS	FYM Q x N	(1)	8603 *
FYMC x P	(1)	0.00 NS	FYM C x N	(1)	279 NS
FYM L x K	(1)	4.75 NS	FYM L x P	(1)	416 NS
FYM Q x K	(1)	26.27 *	FYM Q x P	(1)	18 NS
FYM C x K	(1)	58.65 **	FYMC x P	(1)	41 NS
FYM Lx (N x P)	(1)	1.95 NS	FYM L x K	(1)	12 NS
FYM Q x (N x P)	(1)	0.02 NS	FYM Q x K	(1)	40 NS
FYM C x (N x P)	(1)	6.33 NS	FYM C x K	(1)	32 NS
FYM Lx (N x K)	(1)	0.53 NS	FYM Lx (N x P)	(1)	365 NS
FYM Q x (N x K)	(1)	28.89 *	FYM Q x (N x P)	(1)	159 NS
FYM C x (N x K)	(1)	0.00 NS	FYM C x (N x P)	(1)	567NS
FYM Lx (P x K)	(1)	83.03 **	FYM Lx (N x K)	(1)	425 NS
FYM Q x (P x K)	(1)	28.89 *	FYM Q x (N x K)	(1)	915 NS
FYM C x (P x K)	(1)	52.00 **	FYM C x (N x K)	(1)	0.53 NS
FYM Lx (N x P x K)	(1)	9.45 NS	FYM Lx (P x K)	(1)	5636 **
FYM Q x (N x P x K)	(1)	15.02 NS	FYM Q x (P x K)	(1)	1980 *
FYM C x (N x P x K)	(1)	9.45 NS	FYM C x (P x K)	(1)	264 NS
Y X FYM X NPK	24	1.50 NS	FYM Lx (N x P x K)	24	17 NS
Error 2	192	6.02	FYM Q x (N x P x K)	192	877 NS
			FYM C x (N x P x K)	(1)	744 NS
			Y x FYM x NPK	24	326 NS
			Error 2	192	319
Total	**287**				

C.V % = 7.49

NS = Non-significant

y* = represent replication over year

Days to maturity: Maturity was delayed to 151 days in 2004-05 as compared to 146 days in 2003-04 (Tables 3 and 6). Delay in maturity in the second year may be due to the fact that mean air temperature was 3^{o}C higher from sowing till maturity and precipitation was 50% less in year 1 than year 2 (Fig. 1). This high temperature coupled with low precipitation enhanced maturity of wheat crop in season 1 compared with season 2. Minimum days to maturity (145) were observed in the control. Days to maturity increased linearly with each increment of NPK and maximum days to maturity (151) were recorded at highest level of 80-60-60 kg NPK ha^{-1}. Increase in days to maturity like days to heading may be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency (Deldon, 2001). Higher N levels delayed leaf senescence, sustained leaf photosynthesis during grain filling period and extended grain filling duration (Frederick & Camberato, 1995; Ayoub *et al*., 1994. FYM showed no significant effect on days to maturity however, minimum days to maturity (147) were recorded at 45 t FYM ha^{-1} while, delayed maturity (149 days) was observed at15 t FYM ha^{-1}. It may be due to the fact that phonological traits such as days to heading or maturity may be insensitive to FYM levels used in this experiment Badaruddin *et al*., (1999).

Table 8. Plant height (cm) of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (Kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
Average*					
0-0-0	77.0 jkl	76.3 kl	75.8 l	80.8 c – h	77.4 c
40-30-30	77.8 I - l	77.8 I – l	77.0 jkl	82.0 a – d	78.6 bc
40-30-60	79.3 f - j	79.5 e – i	78.8 g - j	79.5 e – i	79.3 b
40-60-30	81.3 b - f	81.8 b – e	78.0 I - l	78.3 ijk	79.8 b
40-60-60	83.0 abc	80.0 d – i	81.8 b - e	83.3 ab	82.0 a
80-30-30	81.5 b - f	79.3 f – j	81.0 b - g	83.3 ab	81.3 a
80-30-60	81.5 b - f	82.5 abc	83.0 abc	82.5 abc	82.4 a
80-60-30	82.8 abc	82.5 abc	78.5 h - k	81.5 b – f	81.3 a
80-60-60	82.3 a - d	81.3 b – f	84.3 a	82.0 a – d	82.4 a
Mean	**80.7**	**80.1**	**79.8**	**81.4**	

Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
*=Average of 2 years
Year 2003-2004 = 75.5b
Year 2004-2005 = 85.5a

Control vs rest		N		P		K	
Control	Rest	40 kg ha^{-1}	80 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}	30 kg ha^{-1}	60 kg ha^{-1}
77.5 b	80.9 a	80.0 b	81.9 a	80.4 b	81.4 a	80.3 b	81.5 a

CV % = 7.49
LSD value for NPK at $p \leq 0.05$ (Average for years) = 1.2010
LSD value for interactionat at $p \leq 0.05$ (Average for years) = 2.420

Plant height: Taller plants of 85.5 cm height were recorded in 2004-05 as compared to dwarf plants (75.5 cm) in 2003-04 (Tables 7 and 8). Significantly taller plants in the second year may be due to the fact that low mean air temperature (3^{o}C) and 50% higher precipitation in second year might have provided favorable environment for the growth, development and proper nourishment of the crop that led to the production of taller plants compared with first year. Shortest plants (77.4 cm) were recorded in the control. Plant height significantly increased with increase in NPK levels and maximum plant height (82.4 cm) was recorded at 80-60-60 kg NPK ha^{-1}. Increase in plant height is likely due to typical favorable effect of N and P on promoting vigorous plant growth through efficient photosynthesis and dry matter production as N is the main constituent of chlorophyll molecule and P is the major component of ATP and sugar phosphate needed for effective carbon fixation (Hossain *et al*., 2001; Iqtidar *et al*., 2006; Lloveras *et al*. 2001; Ayoub *et al*., 1994). Interaction between NPK and FYM levels showed that the highest plant height of 84.3 cm was recorded at 30 t FYM ha^{-1} and 80-60-60 kg NPK ha^{-1}, while shortest plants of 75.8 cm height were observed at no NPK and 30t FYM ha^{-1}. The favorable effects of FYM and NPK on plant height of wheat may be attributed to more availability of macro and micro nutrients and improvement in soil water holding capacity (Matsi *et al*., 2003; Hossain *et al*., 2002; Lloveras *et al*., 2001).

Grain yield: Highest grain yield (2481 kg ha^{-1}) was recorded in 2004-05, while lowest grain yield (2425 kg ha^{-1}) was recorded in 2003-04 (Tables 7 and 9). Low mean air temperature (3°C) and 50% higher and well distributed precipitation during second year particularly 3 times more rainfall during tillering stage (Fig. 1) might have produced favorable environment for the growth, production of tillers and proper nourishment of the crop which ultimately led to higher grain yield. Moreover, there is direct relationship between precipitation and yield (Gutlieri *et al*., 2001, Mihartescu *et al*., 1993). Minimum grain yield (2278 kg ha^{-1}) was recorded in the control. Grain yield increased with each increment of NPK and maximum grain yield (2505 kg ha^{-1}) was recorded at the highest combination of 80-60-60 kg NPK ha^{-1}. The increase in grain yield may be due to collective role of NPK such as N improve SWU of rainfed wheat (Deg *et al*., 2004), P might have increased SWU and extraction from deep layers of soil (Deng, 1999) and K increased root growth, reduced water loss and wilting and improved drought resistance (Twari, 2002). Increased wheat grain yield with NPK or NP may be attributed to increased tillers m^{-2}, spikes m^{-2} and heavier 1000 grain weight (Brown & Petrie, 2006, Vegra & Sveenjak, 2006, Bundy & Andraski, 2004, Bly & Woodward, 2003 Minimum grain yield (2439 kg ha^{-1}) was recorded in control. FYM significantly increased grain yield and maximum grain yield (2470 kg ha^{-1}) was recorded at 30 t FYM ha^{-1} (Fig. 3). NPK x FYM interaction showed that maximum grain yield (2512 kg ha^{-1}) was recorded from the interaction of 80-60-60 kg NPK ha^{-1} and 45 t FYM ha^{-1}, while minimum grain yield (2217 kg ha^{-1}) was recorded from plots where no NPK and 45 t FYM ha^{-1} were applied. These results suggest that sole application of either FYM or NPK is not advisable as none of them produced maximum grain. FYM and NPK used in combination improved grain yield by increasing tillers m^{-2}, early plant vigor, spikes m^{-2} and biomass yield (Rehman & Khalil, 2008; Hossain *et al*., 2002).

Conclusion

Improper inorganic and organic fertilizers application particularly with continued soil nutrient mining, fluctuation in rainfall and temperature are the major factors contributing to less leaf area index, plant height and grain yield of wheat under rainfed conditions of north-western Pakistan. A combination of 80-6-60 kg NPK ha^{-1} and 30 t FYM ha^{-1} gave maximum yield and yield components of wheat under rainfed conditions of NWFP.

Table 9. Grain yield (kg ha^{-1}) of wheat as affected by FYM and NPK levels during two growing seasons.

NPK (Kg ha^{-1})	FYM (tons ha^{-1})				Mean
	0	15	30	45	
	Average*				
0-0-0	2367 o	2235 q	2292 p	2217 r	2278 f
40-30-30	2417 n	2433 lmn	2442 klm	2417 n	2427 e
40-30-60	2417 n	2482 d-g	2485 def	2455 ijk	2460 d
40-60-30	2425 mn	2482 efg	2496 a-f	2467 ghi	2467 cd
40-60-60	2447 jkl	2480 fgh	2499 a-e	2464 hij	2472 c
80-30-30	2467 ghi	2490 c-f	2500 a-d	2492 b- f	2487 b
80-30-60	2467 ghi	2491 b-f	2508 ab	2507 abc	2493 b
80-60-30	2456 ijk	2492 b-f	2504 abc	2507 abc	2490 b
80-60-60	2491 b-f	2511 a	2506 abc	2512 a	2505 a
Mean	2439 c	2455 b	2470 a	2449 bc	

Means of the same category followed by similar letters are non significant at ($p \leq 0.05$) using LSD.
*=Average of 2 years
Year 2003-2004 = 2425b
Year 2004-2005 = 2481a

Control vs rest		N		P		K	
Control	**Rest**	**40 kg ha^{-1}**	**80 kg ha^{-1}**	**30 kg ha^{-1}**	**60 kg ha^{-1}**	**30 kg ha^{-1}**	**60 kg ha^{-1}**
2278 b	2475 a	2457 b	2494 a	2467 b	2484 a	2468 b	2483 a

CV % = 3.23
LSD value for FYM at $p \leq 0.05$(Average for years) = 10.09
LSD value for interaction at $p \leq 0.05$ (Average for years) = 17.61
LSD value for NPK at $p \leq 0.05$ (Average for years) = 8.807

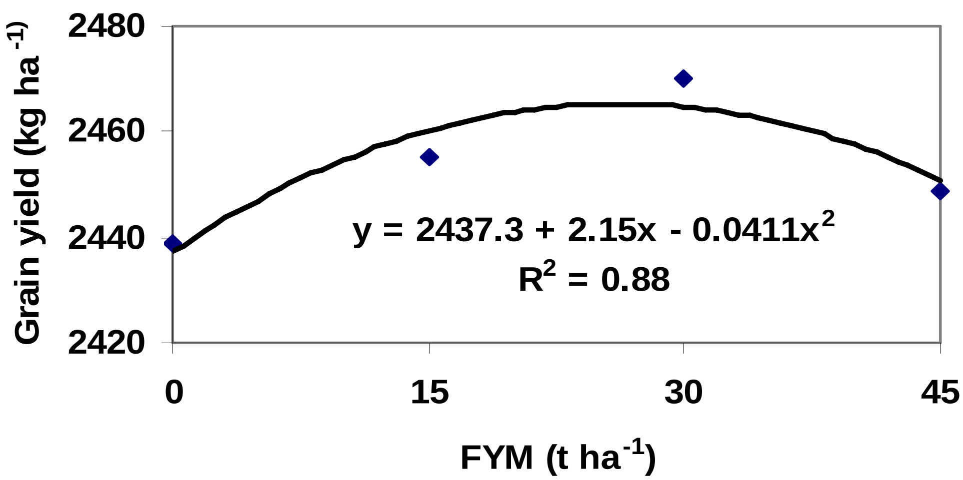

Fig. 3. Grain yield (kg ha^{-1}) of wheat as affected by different levels of FYM. Means represent average across years and NPK levels. LSD value for FYM at $p \leq 0.05$ (average for years) =10.09.

Reference

Alvarez, R.H., S. Steinbach, S.M. Grigera, E. Cartier, G. Obregon, S. Torri and R. Garcia. 2004. The balance sheet method as a conceptual framework for nitrogen fertilization of wheat in Pampean agroecosystem. *Agron. J.*, 96: 1050-1 057.

Arnon, I. 1972. Plant population and distribution patterns in crop production in dry regions. Vol.1 National Book Foundation, Islamabad, Pakistan 443-456.

Ayoub, M., S. Guertin, S. Lussier and D.L. Smith. 1994. Timing and level of nitrogen fertilizer effects on spring wheat yield in eastern Canada. *Crop Sci*., 34: 748-756.

Badruddin, M., M.P. Reynolds and O.A.A. Ageeb. 1999. Wheat management in warm nvironments: Effect of organic and inorganic fertilizers, irrigation frequency and mulching. *Agron. J*., 91: 975-983.

Blair, N.R., D. Faulkner, A.R. Till and P.R. Poulton. 2006. Long-term management impacts on soil C, N and physical fertility. *Soil and Tillage Res*., 91: 30-38.

Bly, A.G. and H.J. Woodward. 2003. Foliar nitrogen application timing influence on grain yield and protein concentration of hard red winter and spring wheat. *Agron. J*., 95:335-338.

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

Brown, B.D. and S. Petrie. 2006. Irrigated hard winter wheat response to fall, spring, and late season applied nitrogen. *Field Crops Res*., 96: 260-268.

Bundy, L.G. and T.W. Andraski. 2004. Diagnostic tests for site-specific nitrogen recommendation for winter wheat. *Agron. J*., 96: 608-614.

Dang, T.H. 1999. Effect of fertilization on water use efficiency of winter wheat in arid highland. *Eco-Agri. Res*., 7: 28-31.

Delden, A.V. 2001. Yield and growth components of potato and wheat under organic nitrogen management. *Agron. J*., 93: 1370-1385.

Deng, X.P., L. Shan, H. Zhang and N.C. Turner. 2004. New directions for a diverse planet. In: *Proceeding of the 4th International Crop Science Congress*, Sep. 26–1st Oct., 2004, Brisbane, Australia

Frederick, J.R. and J.J. Camberato. 1995. Water and nitrogen effects on winter wheat in the southeasten coastal plain: II. Physiological response. *Agron. J*., 87: 527-532.

Gill, H.S. and O.P. Meelu. 1982. Studies on the substitution of inorganic fertilizers with organic manure and their effect on soil fertility in rice-wheat rotation. *Fert. Res*., 3: 303-314.

Hossain, S.M.A., A.M.A. Kamal, M.R. Islam and M.A. Mannan. 2002. Effects of different levels of chemical and organic fertilizers on growth, yield and protein content of wheat. *J. BioI. Sci*., 2: 304-306.

Iqtidar, H., K.M. Ayyaz and K.E. Ahmad. 2006. Bread wheat varieties as influenced by different nitrogen levels. *J Zhejiang Univ. Sci*., 7: 70-78.

Keeney, D.R. and D.W. Nelson. 1982. Nitrogen inorganic forms. In: *Methods of Soil Analysis*. (Eds.): A.L. Page, R.H. Miller and D.R. Keeney. Parts II: Chemical and microbiological properties, second ed. *Am. Soc Agron*., 9: 643-698.

Khalil, S.K., K. Zeb and A.Z. Khan. 2002. Changes in leaf area, assimilate accumulation and partitioning of wheat varieties planted on different dates. *Pak. J. Soil Sci*., 21: 15-19.

Kue, S. 1996. Phosphorous. In: *Methods of Soil Analysis*. Parts-3: Chemical methods (Ed.): D.L. Sparks, SSSA Books series NO.5., SSA inc., ASA Inc., Madison, Wisconin, USA.

Kundu, S., R. Bhattacharyya, V. Parkash, B.N. Ghosh and H.S. Gupta. 2007. Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the India Himalayas. *Soil and Tillage Res*., 92: 87-95.

Li, Y.X., Z.K. Xie and X.K. Van. 2004. Runoff characteristics of artificial catchments materials for rainwater harvesting in the semiarid regions of China. *Agric. Water Manag*., 65: 211-224.

Li, Y.X. and J.D. Gong. 2002. Effects of different ridge: furrow ratios and supplemental irrigation on crop production in ridge and furrow rainfall harvesting system with mulches. *Agric. Water Manag*., 54: 243-254.

Li, Y.X., J.D. Gong, O.Z. Gao and F.R. Li. 2001. Incorporation of ridge and furrow method of rainfall harvesting with mulching for crop production under semiarid conditions. *Agric. Water Manag*., 50: 173-183.

Lloveras, J., A. Lopez, J. Ferran, S. Espachs and J. Solsona. 2001. Breadmaking wheat and soil nitrate as affected by nitrogen fertilization in irrigated Mediterranean conditions. *Agron. J*., 93: 1183-1190.

Manna, M.C., A. Swarup, R.H. Wanjari, H.N. Ravankar, B. Mishra, M.N. Saha, Y.V. Singh, D.K. Sahi and P.A. Sarap. 2005. Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops Res*., 93: 264-280.

Matsi, T.A., S. Lithourgidis and A.A. Gagianas. 2003. Effect of injected liquid cattle manure on growth and yield of winter wheat and soil characteristics. *Agron. J*., 95: 592-596.

McLean, E.O. 1982. Soil pH and lime requirement. In: *Methods of soil analysis*. (Eds.): A.L. Page, R.H. Miller and D.R. Keeney. Part 2. 2nd (eds.). Am. Soc. Agron. Madison, WI ,USA, pp. 199-224.

Melaj, M.A., H.E. Echeverria, S.C. Lopez, G. Studdert, F. Andrade and N.O. Barbaro. 2003. Timing of nitrogen fertilization in wheat under conventional and no-tillage system. *Agron. J*., 95: 1525-1531.

Metho, L.A., P.S. Hammes, N.M.D. Beer and H.T. Groeneveld. 1997. Interaction between cultivar and soil fertility on grain yield, yield components and grain nitrogen content of wheat. *South Afr. J. Plant Soil*, 14: 158-164.

Midmore, D.J., P.M. Cartwright and R.A. Fisher. 1984. Wheat in tropical environment: II. Crop growth and grain yield. *Field Crops Res*., 8: 207-227.

Morgan, J.A. and D.R. Lecain. 1991. Leaf gas exchange and related leaf traits among 15 winter wheat genotypes. *Crop Sci*., 31: 443-448.

Mossedaq. F. and D.H. Smith. 1994. Timing nitrogen application to enhance spring wheat yields in a Mediterranean climates. *Agron. J*., 86: 221-226.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter. In: *Methods of soil analysis*. (Eds.): A.L. Page, R.H. Miller and D.R. Keeney. Part 2. 2nd (eds.). Am. Soc. Agron. Madison, WI ,USA, pp. 539-580.

Oweis, T., M. Pala and J. Ryan. 1998. Stabilizing rainfed wheat yield with supplemental irrigation and nitrogen in a Mediterranean climate. *Agron. J*., 90: 672-681.

Rehman, S. and S.K. Khalil. 2008. Organic and inorganic fertilizers increase wheat yield components and biomass under rainfed condition. *Sarhad J. Agric*., 24(1): 11-20.

Reynolds, M.P., R.P. Singh, A. Ibrahim, O.A.A. Ageeb, A.L. Saavedra and J.S. Quick. 1998. Evaluation physiological traits to compliment empirical selection for wheat in warm environments. *Euphytica*, 100: 8495.

Anonymous. 2000. The SAS system for windows. V.8.1. SAS Inst., Cary, NC.

Sattar, M.A. and A.C. Gaur. 1989. Effect of VA-mycorrhiza and phosphate dissolving microorganism on the yield and phosphorus uptake of wheat (*Triticum vulgare*) in Bangladesh. *Bangladesh J. Agric. Res*., 14: 233-239.

Soltanpour, P.N. 1985. Use of AB-DTPA to evaluate elements availability and toxicity. *Comm in Soil Science and Plant Analysis*, 16: 323-338.

Tiwari, K.N. 2002. Phosphorus and potassium fertilization reduces dry weather and late harvest risks. *Fertilizer Knowledge*, 2: 1-2.

Tran-Thuc-Son., U. Singh, J.L. Padilla and R.J. Buresh. 1995. Management of urea and degraded soils of Red River Delta (Vietnam): Effect of growing season and cultural practice. pp.161-175. In: Vietnam and IRRI, a partnership in rice research. (Eds.): G.L. Denning and Vo-Tong-Xuan. Proc. Conf., Los Baflos, Philippines. IRRI, Los Baflos

Zhang, H., T.Y. Oweis, S. Garabet and M. Pala. 1998. Water use efficiency and transpiration efficiency of wheat under rainfed conditions and supplemental irrigation in a Mediterranean type environment. *Plant Soil*, 20: 295-305.

Zhang, Z.H. and H.J. Cal. 2001. Effects of regulated deficit irrigation on plastic mulched cotton. *J. Northwest Sci-Tech. Univ. Agric. Forest*, 29: 9-12.

Zhu, Q. and Y.H. Li. 1998. On rainwater catchment and utilization. *Proceedings of the International Symposium and 2nd National Conference on rainwater utilization*, October 21-23, Xuzhou, China

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