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Response of Wheat to Farm Yard Manure, Potassium and Zinc under Rainfed Cropping Patterns

[1]Khalid Nawab, [2]Amanullah and [2]Asad Ali

[1]Departemt of Extension Education and Communication, [2]Departemt of Agronomy,
NWFP, Agriculture University, Peshawar, Pakistan

Abstract: Little work has been done on Potassium and Zinc in combination with Farm Yard Manure under rainfed conditions in NWFP. Thus this study was designed to examine the effects of un-irrigated cropping patterns and organic and in-organic fertilizers on wheat crop. The experiment was conducted under un-irrigated conditions at Agricultural Research Station, Serai Naurang Bannu for two years during 2001-2002 and 2002-2003. The experiment was designed in RCB design with split arrangements. Two factors in were studied in the experiment. Effects of five cropping patterns i.e., fallow-wheat, groundnut-wheat, mungbean-wheat, sorghum-wheat and pigeonpea-wheat and three organic and in-organic fertilizers on subsequent wheat crop were observed. Data were recorded on yield and yield components of wheat during both the years. Grains per spike data were non significant at un-irrigated site, while leaf area/tiller (cm^2), productive tillers m^{-2}, thousand grains weight, harvest index, biological, gain yields were statistically significant. More leaf area and harvest index were produced by wheat following fallow. Heavier grains were produced by wheat fallowing pigeon pea. Highest biological (9433 kg ha^{-1}) and grain yields (3193 kg ha^{-1}) were produced by wheat fallowing mungbean. Based on two years average, it is concluded from this study that, wheat following mungbean produced more yield and wheat following groundnut produced less yield under rainfed conditions.

Key words: Wheat % FYM % potassium % zinc % rainfed condition % grain yield

INTRODUCTION

Of the total area of around 80 m ha. 20.5 ha are cultivated with 15.6 m ha irrigated and 5 m ha barani. A breakdown of cultivated areas for each of the four provinces is presented. The Punjab accounts for almost 70% of the cropped areas with the remainder essentially spread between the NWFP and the Sindh. A breakdown of barani areas by province shows that>80% of the area is in the Punjab and NWFP. Together, the two provinces account for around 3.5 m ha and involve an estimated 1.0 m farmers. The majority of farms range between 1 and 10 ha in size. Water management is perhaps the greatest challenge facing farmers. Difficulties arise because the pattern of rainfall does not necessarily coincide with crop requirements, because of variability of rainfall and because of the large losses of precipitation through run-off. Therefore, it is critical that soil water should be used efficiently by crops. This can only happen if conditions for crop growth are optimized. It has been widely observed in rain-fed environments similar to the barani areas of Pakistan (e.g. Australia, Middle East, North Africa), that WUE of wheat will respond to treatments such as applied fertilizer N and previous legume crop, increasing yields by as much as 100%. Thus, in these water limited conditions, factors such as available N, rather than water, may be responsible for low yield.

In barani cropping patterns in Pakistan, low soil fertility has now been recognized as one of the most, if not the most, important problems causing low yields [1]. In one study involving around 8,000 soil samples, 95% were deficient in N. The soils of these areas no longer have the capacity to supply adequate amounts of N in a plant available from because the organic bank has been depleted through deforestation, many years (and in large areas of the country, centuries) of cropping, overgrazing and the removal of animal wastes and crop residues. Even the stubble is grazed and the crop system is nutrient exhausting because of the wide-scale dominance of cereals crop. Thus, the challenge is to redress this problem.

Corresponding Author: Dr. Amanullah, Departemt of Agronomy, NWFP, Agriculture University, Peshawar, Pakistan

Pakistan is a wheat growing nation. The country produces around 15 m tones annually from almost 8 m ha. Almost 40% of the total cropped area and 60% of the area sown to cereals and legumes is used for wheat production. An additional 4.0 m ha is used for other cereals, leaving just 1.5 m ha for legume cropping. Thus, the overall ratio in Pakistan of cereal: legume for both irrigated and barani agriculture is 8:1.

For the barani areas, the relative importance of cereals and legumes changes dramatically. Wheat remains the major crop, accounting for around 30% of the total area, even though around 80% of the national wheat crop is irrigated. Upland rice is not grown in Pakistan, so the other cereal category is of less importance. Grain legumes, on the other hand, come into their own and represent around 25% of the cropped area (pulses only) and 30% of the area if guar (legume crop grown for industrial purposes) is included. Chickpea is the principal legume grown, both in the barani areas and in Pakistan as a whole. Virtually the entire legume crop is grown under rainfed conditions as well as the majority of the millet, sorghum and barley crops. Breakdown of the major cereal and legume crops grown in the barani areas of Pakistan. Included also are the values for the percentage of each crop areas, i.e. irrigated plus barani, in Pakistan that is rain-fed.

The beneficial effects that specific crops have on the yields of subsequent crops were known even to the ancient omans. With the development of agricultural chemicals following World War-II, interest in crop rotating diminished. Chemical pesticides and fertilizers seemed to replace the benefits of rotating crops. Changes in the economics of crop production and recognition of the potential environmentally damaging effects of agricultural chemicals have led to renewed interest in sustainable production systems. These systems replace some purchased inputs, especially pesticides and fertilizers, with cultural practices, timeliness and labor and usually involve rotating crops. Although more research is under way on why crop rotation influences yield of subsequent crops, producers can receive maximum benefit from rotating crops if they know the conditions that influence rotation effects. For example, knowledge of how precipitation influences the rotation effect, when combined with weather predictions and economic analysis, will enable producers to improve their crop selection decision.

Previous research has investigated the beneficial effects of legumes on subsequent crops. These effects are often separated into Nitrogen (N) effects from addition of symbiotically fixed N_2 and non-N effects, defined as the benefits of rotation besides the effects of added N. Non-N effects occur when crop yields of continuous monocultures do not attain the yields of crops in rotation, even with the addition of high fertilizer N rates. None N rotation effects are generally difficult to explain using only the measurements commonly recorded in field studies.

Precipitation often alters the effect of previous cropping history on subsequent crop yield. A greater effect of previous crop on corn yields has been observed in dry years than in wet Asghari and Hanson [2] used regression analysis to relate corn N response to precipitation and temperature after two previous crops. They proposed a model of grain yield based on precipitation, heat unit accumulation during June and July and grain N.

Rotation studies are long term since the effects of rotation must be documented over the range of possible weather conditions. The amount of precipitation in the growing season is important, particularly at the regional limits of crops adaptation, such as the western edge of the Corn Belt. The experiment reported here was initiated to determine the effects of previous crop on crop yield under varying rainfall conditions.

The component of Integrated Nutrient Management (INM) consists of the soil resource, organic matter, bio nutrient resources, mineral fertilizers and cropping systems. Proper management of INM components in dry lands can be difficult because of poor economic conditions of the farmers and other associated problems. The present research work and the aim of the project is to inquire into all these matters and to produce a mid way between them to informed and enabled the farmers to use the integrated nutrient management to crops of wheat under dry land cropping systems. The project was designed to study:

- To test the performance of wheat under un-irrigated cropping patterns.
- To study the effects of FYM, K and Zn and their interactions on yield, agronomic and physiologic parameters of wheat under un-irrigated cropping patterns.
- To find out the proper combination of FYM, K and Zn for wheat under un-irrigated cropping patterns.

Experimental details: The experiment titled "Response of wheat to FYM, Potassium and Zinc under Unirrigated Cropping Patterns" was conducted at Agricultural

Research Station, Serai Naurang, Bannu for 2 years. The station is located in the southern unirrigated belt of the NWFP. Five cropping patterns, FYM, K and Zn each at two levels were studied in the experiment as detailed below:

A. Cropping patterns

- C_1 = Fallow-Wheat
- C_2 = Groundnut-Wheat
- C_3 = Mungbean-Wheat
- C_4 = Sorghum-Wheat
- C_5 = Pigeonpea-Wheat

B. Manures/Fertilizers

- FYM @ 0 and 25 t ha^{-1} (F1 = No FYM applied, F2 = 25 t ha^{-1} FYM applied)
- Zn @ 0 and 7 kg ha^{-1} (Z1 = No Zn applied, Z2 = 7 kg ha^{-1} Zn applied)
- K @ 0 and 150 kg ha^{-1} (K1 = No K applied, K2 = 150 kg ha^{-1} K applied)

Sub-plot combinations

Treatment #	FYM (t ha^{-1})	Zn (kg ha^{-1})	K (kg ha^{-1})
1	0	0	0
2	25	0	0
3	0	7	0
4	25	7	0
5	0	0	150
6	25	0	150
7	0	7	150
8	25	7	150

The experiment was conducted using RCB design with split plot arrangements and four replications with net plot size of 12 m^2 (2.4×5 m). Wheat variety Marwat-J-1 was sown at the un-irrigated site. Five cropping patterns were allotted to main plots and the eight combinations of FYM, K and Zn to the sub-plots. Same plots were used for next year sowing. The following recommended doses were applied to the summer crops in the four cropping patterns. Fallow plots were kept weeds free.

Wheat	=	70:45:00 NPK kg ha^{-1}
Groundnut	=	20:80:40 NPK kgha^{-1}
Mungbean	=	25:64:00 NPK kg ha^{-1}
Sorghum	=	60:40:00 NPK kg ha^{-1}
Pigeonpea	=	20:60:00 NPK kg ha^{-1}

- Fallow plots to were kept weed free during kharif season by repeated disking/harrowing/cultivating followed immediately planking.
- FYM at 25/t ha in treatments were applied before the start of monsoon rains and turned in with mold-board plough.
- Fertilizer for wheat was applied into soil at least 15 day before drilling wheat in the same furrows.
- The experiments were conducted on the same sites as permanent plots for the year 2.
- The following data were collected from each trial site.

  - Physico-chemical status of the soil for site characterization.
  - Agronomic data.

The composite soil samples were taken before sowing and after the harvest of component kharif crops in the existing cropping system of the experiment and were analyzed for NPK and micronutrient statues.

Data were collected on the following parameters.

- Leaf area/tiller at anthesis.
- Productive tillers m^{-2}.
- Grains/spike.
- Thousand grain weight.
- Biological yield.
- Grain yield.
- Harvest index.

RESULTS AND DISCUSSIONS

Grain and biological yields of summer crops at un-irrigated site: The grain and biological yields of summer crops in the first experiment of the un-irrigated cropping patterns are re-ported in Tables 2 & 3 of the farm location at ARS, Serai Naurang, Bannu for both the years. In the year 2001 Pod yield of groundnut ranged from 600-700 kg ha^{-1} in different plots with a mean yield of 620 kg ha^{-1} under rainfed conditions at the station (Table 2). The pod yield of groundnut on comparative basis during 2002 ranged 500-600 kg ha^{-1} with 548 kg ha^{-1} average pod yield showing a reduction of 13.2%. Seed yield of mungbean was in the rang of for 850 kg ha^{-1} with an average of 715 kg ha^{-1} during 2001 which is the maximum in the whole experiment and as compared to 612 kg ha^{-1} of mungbean average seed yield during 2002 having an increase of about 15%. In the Kharif experiment of both the years gram yield of Sorghum ranged 1100-1500 kg ha^{-1} with 1100 kg ha^{-1} as average yield during 2001 and 1200-1500 kg ha^{-1} as ranged and averaged 1205 kg ha^{-1} during 2002. There was about 4% increase in the gram yield of

Table 1: Physico-chemical status of soils at ARS, Serai Naurang, Bannu

S. No.	Property	Unit	Value
1.	pH	-	7.9
2.	Electrical conductivity	Milli mhos/cm or ds/m	0.17
3.	Organic matter	%	0.495
4.	$CaCO_3$ eq	%	6.3
5.	Sand	%	24.0
6.	Silt	%	38.2
7.	Clay	%	37.8
8.	Textural class	-	Clay loam
9.	AB-DTPA extractable Zn	ppm	1 mg kg ha^{-1}

Table 2: Grain and biological yields (kg ha^{-1}) of kharif crops in Barani wheat based cropping patterns at agricultural research station Serai Naurang, Bannu during Kharif 2001

	Grain yield (kg ha^{-1})		Biological yield (kg ha^{-1})	
Crops	(Average)	(Range)	(Average)	(Range)
Fallow	-	-	-	-
Groundnut	620.0	(600-700)	6818.0	(4000-8200)
Mungbean	715.5	(700-850)	2519.0	(2300-2900)
Sorghum	G = 1160.0	(1100-1500)	D = 15000.0	(15000-16000)
Pigeon Pea	561.5	(560-670)	4773.0	(4100-5000)

Table 3: Grain and biological yields (kg ha^{-1}) of kharif crops in Barani wheat based cropping patterns at agricultural research station Serai Naurang, Bannu during kharif 2002

	Grain yield (kg ha^{-1})		Biological yield (kg ha^{-1})	
Crops	(Average)	(Range)	(Average)	(Range)
Fallow	-	-	-	-
Groundnut	548.0	(500-600)	6720.0	(6000-8000)
Mungbean	612.0	(600-650)	2300.0	(2300-2800)
Sorghum	G = 1205.0	(1000-2000)	D = 12015.0	(12000-13000)
Pigeon Pea	512.5	(500-600)	3812.0	(3000-4000)

Table 4: Leaf area per tiller (cm^2) at anthesis of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatment	Year 1	Year 2	Average
C1	Fallow-wheat	93.08	79.27	86.17
C2	Groundnut-wheat	77.99	71.72	74.86
C3	Mungbean-wheat	91.53	83.21	87.37
C4	Sorghum-wheat	79.98	66.11	73.04
C5	Pigeon pea-wheat	75.10	80.16	77.63
F0	No FYM	83.59	71.84	77.71
F1	FYM, 25 t ha^{-1}	83.79	80.05	81.92
K0	No potassium	82.83	75.26	79.05
K1	K, 150 kg ha^{-1}	84.24	76.93	80.59
Zn0	No zinc	81.48	75.89	76.69
Zn1	Zinc 7 kg ha^{-1}	85.59	76.30	80.95

Sorghum during the year 2002 over that in the year 2001 pigeon pea produce seed yield of 561.5 kg ha^{-1} during the year 2001 which was about 9% more than that produced during the following year.

The biological yields of summer crops under un-irrigated cropping patterns at ARS, Sarai Naurang are reported in Table 2 and 3 for both the years. It is evident that the biological yields during 2001 were significantly higher than those obtained in the following year due to some adverse growth and weather condition in consonance with the production of gram yield. The higher average biological yield of 1500 kg ha^{-1} was produced by Sorghum ranged 15000-16000 kg followed by groundnut with on average biological yield of 6818 kg during 2001as compared to 12015 kg by Sorghum and 6720 kg by groundnut in the following year. Mungbean yielded 2300 kg ha^{-1} with a range of 2300-2800 2519.0 kg ha^{-1} in the proceeding year showing an increase of 8.7%. Similarly pigeon pea had higher yield during the year 2001 with an average of 477.0 kg ha^{-1} as compared to 3812.0 kg in 2002 with 20% increase in the year 2001.

Base crop (Wheat):

Leaf area per tiller at anthesis: Leaf area per tiller of wheat under rainfed conditions was significantly affected by cropping patterns (Table 4). The highest (87-37 cm^2) area tiller was produced by wheat following mungbean closely followed by wheat following follow (86.17 cm^2). Wheat following sorghum produced the lowest (73.04 cm^2) leaf area/tiller. Farm yard application @ 25 ha^{-2} increased l3eaf area/tiller of wheat under rainfed conditions as compared to no FYM and this effect was much more significant in year 2. Potash and zinc had no significant effect on leaf area/tiller of wheat. These findings are in agreement with cook *et al*. [3] who reported that potassium chloride applied in field and green house significantly reduced percentage leaf area of wheat. These years and interaction effects were non-significant, only four interactions CZK, YF, YFK and YCFK had significant effect on leaf area/tiller.

The highest leaf area/tiller of wheat following mungbean and follow may be due to more nitrogen in plots of mungbean and summer season accumulation of nitrogen from moon soon rains in fallow plots. The increase in leaf area/tiller in plots of FYM may be due to balanced nutrient status of the crop as well as it may be due to more favorable moisture in the soil as organic matter increases water holding capacity of soil.

Productive tillers m^{-2}: Tillers m^{-2} of wheat crop as affected by cropping patterns and manures/fertilizers

Table 5: Productive tillers m^{-2} (No) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatment	Year 1	Year 2	Average
C1	Fallow-wheat	353.13	441.50	397.31
C2	Groundnut-wheat	298.25	396.13	347.19
C3	Mungbean-wheat	339.63	423.13	381.38
C4	Sorghum-wheat	303.63	331.25	317.44
C5	Pigeon pea-wheat	281.63	440.38	361.00
F0	No FYM	310.00	393.70	351.85
F1	FYM, 25 t ha^{-1}	320.50	419.25	369.88
K0	No potassium	323.30	400.65	361.98
K1	K, 150 kg ha^{-1}	327.20	412.30	369.75
Zn0	No zinc	315.25	405.45	360.35
Zn1	Zinc 7 kg ha^{-1}	315.25	407.50	361.38

Table 6: Grains per spike (No) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatment	Year 1	Year 2	Average
C1	Fallow-wheat	37.09	49.53	43.31
C2	Groundnut-wheat	35.20	45.68	40.44
C3	Mungbean-wheat	34.40	47.53	40.97
C4	Sorghum-wheat	34.75	49.10	41.92
C5	Pigeon pea-wheat	36.10	48.39	42.25
F1	FYM, 25 t ha^{-1}	36.05	48.76	42.40
K0	No potassium	35.30	47.92	41.71
K1	K, 150 kg ha^{-1}	35.72	48.17	41.84

under un-irrigated conditions (Table 5) showed that litters m^{-2} were significantly affected by cropping patterns. While manures and fertilizers affect was statistically non-significant. It is evident from the planned comparisons that maximum (397.31) tillers m^{-2} were produced by fallow wheat followed by mungbean-wheat which produced (381.38) tillers m^{-2}. While the minimum (317.44) tillers m^{-2} produced by wheat following sorghum.

More tillers were produced in 2nd year as compare to Ist year in all the five cropping patterns. While manures and fertilizers effect was statistically non-significant. These findings are in contrast with Grewal *et al*. [4], Patra *et al*. [5], Jiang *et al*. [6] who said that foliar Zn application increased spike number. Ravindra *et al*. [7] also concluded that 15 and 30 kg Z_nSO_4 ha^{-1} increased total number of tillers. Though comparatively more tillers were produced in year 2 than year 1, the F-value for years is not significant in the ANOVA, which may be mainly due to the fact that based on expected mean square reps (years) were used as denominator to calculate F value for years and the replications (years) was highly significant. Highest number of tillers were noted in wheat after fallow, which may be due to better tillering as a result of more nutrients and water availability due to no summer crop in the fallow plots. Wheat after pigeon pea had better emergence than wheat after fallow and mung bean but the lower tillers m^{-2} in wheat after pigeon pea show that tillers per plant were lower than the other two plots. The lowest number of tiller m^{-2} in wheat following sorghum may be the result of reduced tillering due to more nutrient extraction by sorghum in summer.

Grains per spike: Data referring grains/spike of wheat as affected by cropping patterns and manures/fertilizers under rainfed conditions are showed in Table 6. Statistical analysis of the data revealed that grains/spike of wheat was non-significantly affected both by cropping patterns and manures/fertilizers. It is evident from the results that wheat produced more grains/spike in the 2nd year as compared to Ist year.

Based on the planned comparison of cropping patterns, wheat grown after fallow produced more grains (43.31) per spike comparatively. All the interactions except FKZ and YFKZ and non-significant effect on grains/spike of wheat crop. These findings are in contrast with Patra *et al*. [5], Zhang *et al*. [8] and Yang *et al*. [9] who concluded that grains/spike increased with increase in potassium levels.

Effect of cropping patterns, FYM, Potassium, Zinc and many of the interactions are not significant. This may be due the fact that none of the factors affected spikelet initiation and grains/spikelet in both the years. The reason for greater grains/spike in year 2 may be early planting and better rainfall in year 2 as compared to year 1.

Thousand grains weight (g): Grains weight of wheat as affected by cropping patterns and manures/fertilizers is given in Table 7. Statistical analysis of the data showed that effects of FYM and Zinc were significant on 1000 grain weight of wheat. Cropping patterns and effect of years and potassium were not significant on 1000 grains weight of wheat. Among the interactions, only CZ interaction was significant. The difference between grain weight of wheat in year 1 and year 2 was not significant, showing that grain weight has higher heretability or no significant difference in grain weight of both the years may be due to compensatory effect of yield components. FYM application increased grains weight as well. Both 25t ha^{-1} of FYM and 7 kg ha^{-1} of Zinc increased grains weight by about 1 mg as compared to no FYM and no Zinc. These results are in contrast with

Table 7: 1000 grains weight (g) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatments	Year 1	Year 2	Average
C1	Fallow-wheat	29.86	30.06	29.96
C2	Groundnut-wheat	28.91	31.36	30.13
C3	Mungbean-wheat	28.71	29.48	29.09
C4	Sorghum-wheat	28.10	30.22	29.16
C5	Pigeon pea-wheat	29.56	33.12	31.34
F1	FYM, 25 t ha^{-1}	29.89	31.24	30.57
K0	No potassium	28.82	30.48	29.65
K1	K, 150 kg ha^{-1}	29.24	31.21	30.22
Zn1	Zinc 7 kg ha^{-1}	29.99	31.66	30.83

Z	C1	C2	C3	C4	C5
1	29.68	29.00	29.08	31.63	28.88
2	30.23	31.27	29.11	31.06	29.44

Table 8: Biological yield (kg ha^{-1}) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatments	Year 1	Year 2	Average
C1	Fallow-wheat	7144	11407	9276
C2	Groundnut-wheat	5892	10186	8039
C3	Mungbean-wheat	7459	11407	9433
C4	Sorghum-wheat	5832	8808	7320
C5	Pigeon pea-wheat	5368	11553	8461
F0	No FYM	6077	10700	8389
F1	FYM, 25 t ha^{-1}	6601	10645	8623
K0	No potassium	6328	10550	8439
K1	K, 150 kg ha^{-1}	6350	10795	8573
Zn0	No zinc	6245	10654	8449
Zn1	Zinc 7 kg ha^{-1}	6433	10692	8562

Relative

Symbol	Treatment	Year 1	Year 2	% Difference
C1	Fallow-wheat	112.70	106.88	-5.82
C2	Groundnut-wheat	92.95	95.45	2.50
C3	Mungbean-wheat	117.67	106.88	-10.78
C4	Sorghum-wheat	92.00	82.53	-9.47
C5	Pigeon pea-wheat	84.69	108.25	23.57
F0	No FYM	95.87	100.26	4.39
F1	FYM, 25 t ha^{-1}	104.13	99.74	-4.39
K0	No potassium	100.18	101.15	0.97
K1	K, 150 kg ha^{-1}	99.82	98.85	-0.97
Zn0	No zinc	98.52	99.82	1.30
Zn1	Zinc 7 kg ha^{-1}	101.48	100.18	-1.30

Yang *et al*. [9] and Shen *et al*. [10] who concluded that heavier grains were produced by optimal potassium application. Kinaci [11] indicated that 1000 grains weight was significantly increased by Zinc application.

The cropping patterns produced grains of about the same weight, may be due to compensatory effects of yield components on each other. Wheat in year 2 produced slightly heavier grains than year 1, but the difference did not reach to the significance level. There were much greater variations in grain weight of wheat after summer fallow and different crops in year 2 than in year 1, with wheat after pigeon pea producing heavier grains than wheat in other plots.

Biological yield (kg ha^{-1}): Statistical analysis of data revealed (Table 8) that differences between the mean biological yield of wheat of the two years were significant, with year 2 producing on the average about 10,463 kg ha^{-1} biological yield which was significantly higher than the mean biological yield of year 1. The difference of 4147 kg ha^{-1} is highly significant. Differences among biological yields of the five cropping patterns were significant. The higher biological yield of 9433 kg ha^{-1} was produced by mungbean pea-wheat cropping pattern, while the lowest (7320 kg ha^{-1}) biological yield was produced by sorghum-wheat cropping patters. The planned comparisons show that legums vs sorghum and fallow vs other comparisons were highly significant. Effect of FYM was non-significant with 25 t ha^{-1} of FYM producing higher yield than plots to which no FYM had been applied. Only one interaction YCZ had significant effect. Main effects of FYM, Potassium and Zinc and interactions other than the above were non-significant. These results are in agreement with Rajput *et al*. [12] who observed that FYM 10 t ha^{-1} + 20 kg N ha^{-1} gave the highest returns. The results of zinc are in contrast with Rajput *et al*. [12] and Agarwal *et al*. [13] as they stated that a doze of 5kg ha^{-1} Z_n $S0_4$ gave higher yields and net returns.

Reason for higher yields in year 2 is the favorable weather conditions and high well distributed rainfall in year 2 than in year 1. The highest biological yields of wheat following mung bean may be due to the in fixation by mung bean. The higher biological yield of wheat following pigeon pea may be due to the beneficial effect of infixation by pigeon pea as well as much greater residue in the form of leaves by the pigeon pea crop. Overall greater biological yield of wheat following legumes as compared to wheat

Grain yield (kg ha^{-1}): Grain yield of wheat under rainfed conditions as affected by cropping patterns and manures/fertilizers are reported in Table 9. Analysis of the data showed that effects of years and FYM levels were significant. The F value for cropping patters in ANOVA

Table 9: Grain yield (Kg ha^{-1}) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatments	Year 1	Year 2	Average
C1	Fallow-wheat	2425	3748	3086
C2	Groundnut-wheat	2087	3459	2773
C3	Mungbean-wheat	2556	3833	3194
C4	Sorghum-wheat	2268	3340	2804
C5	Pigeon pea-wheat	1970	3861	2915
F0	No FYM	2182	3586	2884
F1	FYM, 25 t ha^{-1}	2341	3710	3025
K0	No potassium	2318	3535	2926
K1	K, 150 kg ha^{-1}	2205	3761	2983
Zn0	No zinc 2220	3632	2926	
Zn1	Zinc 7 kg ha^{-1}	2302	3664	2983

Relative grain yield

Symbol	Treatments	Year 1	Year 2	Average
C1	Fallow-wheat	107.2	102.7	-4.5
C2	Groundnut-wheat	92.3	94.8	2.5
C3	Mungbean-wheat	113.0	105.1	-8.0
C4	Sorghum-wheat	100.3	91.6	-8.7
C5	Pigeon pea-wheat	87.1	105.8	18.7
F0	No FYM	103.5	101.7	-1.8
F1	FYM, 25 t ha^{-1}	96.5	98.3	1.8
K0	No potassium	102.5	96.9	-5.6
K1	K, 150 kg ha^{-1}	97.5	103.1	5.6
Zn0	No zinc	101.8	99.6	-2.2
Zn1	Zinc 7 kg ha^{-1}	98.2	100.4	2.2

for grain yield was significant ($p<0.05$). YK and CFKZ interactions were significant. Main effects of zinc, potassium and other interactions were not significant. Based on the average of two years the highest grain yield (3194 kg ha^{-1}) was produced by wheat following mungbean among the five cropping patterns. Among the pre planned meaningful comparisons only one groundnut vs mungbean and pigeon pea was significant. The lowest grain yield (2773 kg ha^{-1}) was produced by wheat grown in plots of groundnut.

Based on the average of two years, year 2 produced more grain yield than year 1. Application of 25 t ha^{-1} FYM increased yield by 141kg ha^{-1}. The year x potassium interaction is significant because there was slight increase in grain yield of wheat with application of potassium in year 1 but in year 2 application of potassium decreased grain yield of wheat. Application of zinc had non-significant effect on grain yield of wheat under rainfed conditions. These results are in contrast with Thakur *et al.* [14] who concluded that 10 kg zinc ha^{-1} increased in grain yield of wheat 4-9%. De Long *et al*. [15] concluded that K fertilizer did not have a significant impact on grain yields of wheat. Negi and Gulshan [16] reported that 10 t FYM ha^{-1} caused a significant increase in grain yield of wheat.

The increase in wheat yield after mung bean may be due to nitrogen fixation by the previous legume crop. Though ground nut is also a legume and can fix nitrogen but the yields of wheat following ground nut is lower, which may be due to the greater quantity of Ca absorbed by groundnut or due to allelopathic effect of ground nut on wheat. Though the yield of wheat after pigeon pea is lower in Ist year, which may be due to typing of nitrogen by the decomposing leaves of pigeon pea, yet the yield of wheat following pigeon pea was the highest in the 2nd year. The highest yield of wheat after pigeon pea in the 2nd year may be due to the residual effect of the last year's leaves and stubble decomposition releasing nitrogen and other nutrients for wheat crop. The relative yield was calculated to put the two years yield of cropping patterns and manures/fertilizers on one basis (% age of mean) for comparing effects in both years.

The differences between relative yields of two years was calculated and used as a criterion for sustainability of cropping patters. The differences in relative yields of the two years show that there was much improvement in relative yields of wheat following pigeon pea in year 2 which shows that pigeon pea wheat cropping pattern is more sustainable. The negative values for mung bean-wheat, sorghum-wheat and fallow-wheat shows that continuous use of these cropping patterns may reduce wheat yield. The higher grain yield of wheat following mung bean may be partly due to more spikes m^{-2}, greater leaf area per tiller and higher leaf area index.

Harvest index (%): Data concerning harvest under (%) of wheat crop as affected by cropping pattern and manures/fertilizers under rainfed conditions are presented in Table 10. Statistical analysis of both the individual year and combined analysis of two years data exhibited that cropping patterns had significantly affected harvest index of wheat crop while the manures and fertilizers' effect was non-significant. All the interactions except YK and YFKZ had non-significant effect on harvest index of wheat crop. Based on the average of two years, the plots where wheat was sown following pigeon pea had showed the highest (39.54%) harvest index. Parallel harvest indices were observed for wheat following groundnut and sorghum while the lowest harvest index (34.30%) was observed in the plots where wheat was

Table 10: Harvest index (%) of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at agricultural research station, Serai Naurang, Bannu

Symbol	Treatments	Year 1	Year 2	Average
C1	Fallow-wheat	36.51	34.58	35.55
C2	Groundnut-wheat	35.49	33.11	34.30
C3	Mungbean-wheat	35.62	33.96	34.79
C4	Sorghum-wheat	37.20	33.71	35.45
C5	Pigeon pea-wheat	39.90	39.19	39.54
F0	No FYM	36.54	34.12	35.33
F1	FYM, 25 t haG^{1}	37.35	35.71	36.53
K0	No potassium	35.93	34.59	35.26
K1	K, 150 kg haG^{1}	37.96	35.24	36.60
Zn0	No zinc	36.09	34.25	35.17
Zn1	Zinc 7 kg haG^{1}	37.80	35.58	36.69

sown after fallow. These results are in not agreement with Ravindra *et al*. [7] who said that harvest Index increased with increase in Zinc levels. Zhang *et al*. [8] also concluded that harvest index increased with increase in potassium levels.

Significant differences among the different cropping patterns are due to variation mainly in grain yield as variation in biological yield was comparatively lower. The higher harvest index of wheat following pigeon pea denote that comparatively greater proportion of biomas was partitioned to grains, may be due to better plant nutrition and higher rate of photosynthesis and more availability of assimilates during seed fill duration. Assimilates partitioning to grains in both years was the same. So harvest index was not affected by years as a source of variation in ANOVA. Similarly the main effects of FYM, potassium and zinc were not significant, showing that partitioning of assimilates to the reproductive parts in wheat was not much affected by the manures and fertilizer treatments in this experiment.

CONCLUSIONS

C Wheat in mung bean-wheat cropping pattern produced more yield and wheat in groundnut-wheat produced less yield under rainfed conditions.

C To explore the sustainability of cropping patterns, relative yields were calculated for the 2 years. The difference between relative yields of year 1 and year 2 reveals that pigeon pea-wheat cropping pattern seems to be more sustainable in terms of yield under rainfed conditions.

C As groundnut has allelopathic effect and also cause Ca deficiency, it is suggested that someone should work on the effect of gypsum applied to wheat following groundnut.

C FYM should be applied to wheat in both irrigated and rainfed cropping patterns.

REFERENCES

1. Khan, A.R., A. Qayyum and G.A. Chaudhary, 1989. A country paper on soil, water and crop management systems fordry land agriculture in Pakistan. In: Soil, Water and Crop/Livestock Management Systems for Raibfed Agriculture in the Near East Region, (Whitmar, C.E., J.F. Parr, R.I. Papendick and R.E. Meyer, Eds.). ICARDA, USAID, pp: 88-102.
2. Asghari, M. and R.G. Hanson, 1984. Nitrogen, climate and previous crop effect on corn yield and grain N. Agron. J., 76: 536-542.
3. Cook, J.W., P.S. Kettlewell and D.W. Parry, 1995. The effect of foliar applied potassium chloride on Erysiphe graminis infecting wheat. Integrated crop protection: towards sustainability? Proceedings of a Symposium, Edinburgh, Scotland, pp: 363-370.
4. Grewal, H.S., R.D. Graham and Z. Rengel, 1996. Genotypic variation in zinc efficiency and resistance to crown rot disease (Fusarium graminearum Schw. Group 1) in wheat. Plant and Soil, 2: 219-226.
5. Patra, A.P., D. Panda, B.C. Patra and A.J. Karmakar, 1998. Effect of FYM, zinc and NPK fertilizers on yield components and yield of wheat after winter rice in West Bengal. J. Interacademicia, 2: 1-6.
6. Jiang, R., Q. Zhang, R.F. Jiang and Q.G. Zhang, 1995. The effects of zinc on growth and nitrogen uptake in wheat. Acta Agriculturae Universitatis Pekinensis, 21: 77-80.
7. Ravindra, S., N.L. Meena, A.S. Godara and R. Singh, 1996. Growth and yield attributes of wheat (*Triticum aestivum* L.) as influenced by phosphorus, zinc sulphate and plant growth regulator. Annals Agric. Biol. Res., 1: 1-2.
8. Zhang, G., J. Chen, E.A. Tirore, G.P. Zhang and J.X. Chen, 1999. Genotypic variation for potassium uptake and utilization efficiency in wheat. Nutrient Cycling in Agroecosystems, 1: 41-48.
9. Yang, Y., Y. Yin, S. Lao, G. Wang, G. Liu, Y.C. Yang, Y.P. Yin, S.S. Lao, G.F. Wang and G.F. Liu, 1997. The effect of potassium fertilizer application on yield of wheat in potassium-deficient soils. Jiangsu Agric. Sci., 1: 47-48.

10. Shen, M., G. Wang, Y. Cai, X. Ji, M.X. Shen, G.W. Wang, Y.H. Cai and X.Y. Ji, 1998. The effectiveness of supplementary application of potassium, zinc and boron fertilizers to wheat in the Jiziahe district of Jiangsu Province. Jiangsu Agric. Sci., 2: 45-47.
11. Kinaci, G., 2000. Effect of zinc microelement on quality of some wheat cultivars grown in Central Anatolia. Turk. J. Agric. Fores., 5: 601-606.
12. Rajput, A.L., D.P. Singh and S.P. Singh, 1995. Effect of soil and foliar application of nitrogen and zinc with farmyard manure on late-sown wheat (*Triticum aestivum*). Ind. J. Agron., 4: 598-600.
13. Agarwal, S.K., B. Suraj and S. Bhan, 1997. Effect of levels of zinc sulphate application on the yield and net return in rice-wheat cropping sequence. Ind. J. Agric. Res., 3: 174-178.
14. Thakur, H.S., R.K.S. Raghuwanshi, R.A. Sharma and N.K. Sinha, 2001. Long term effects of sulphur and zinc fertilization in soybean (Glycine max)-wheat (Triticum aestivum) cropping system. Crop Research Hisar, 3: 283-286.
15. DeLong, R.E., W.F. Johnson, Jr. M.D. Correll and W.E. Sabbe, 2001. Agronomics of field-average or site-specific applications of phosphorus and potassium fertilizers on wheat. Research Series Arkansas Agricultural Experiment Station, 480: 27-33.
16. Negi, S.C. and M. Gulshan, 2000. Effect of FYM, planting methods and fertilizer levels on rainfed wheat. Crop Research Hisar, 3: 534-536.