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IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND GRAIN YIELD OF WHEAT UNDER IRRIGATED CROPPING SYSTEM

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Abstract

Field study was conducted during 2001-02 and 2002-03 to investigate the effect of cropping patterns and farm yard manure, potassium and zinc on the grain yield of wheat. Trials were conducted at Agricultural Research Farm, KPK Agricultural University Peshawar, Pakistan. Two factors cropping patterns and manures/fertilizers were studied in the experiment. Randomized complete block design was used with split plot arrangements and four replications having net plot size of 12 m^2. Wheat variety Ghaznavi-98 was sown in November soon after ploughing the soil at proper moisture level suitable for wheat seed germination. 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. Effects of five cropping patterns i.e., rice-wheat, maize-wheat, sunflower-wheat, sorghum-wheat and pigeon pea-wheat and three organic and in-organic fertilizers (Farmyard Manure, Potassium and Zinc) on subsequent wheat crop were observed. Highest grain yield was obtained when wheat was planted after pigeon pea. Manures/fertilizer application (Farmyard Manure, Potassium and Zinc) produced significantly higher grain yield than the control plots. The findings of the present study revealed that leguminous crops can significantly increase the yield of succeeding crops. Thus use of Farmyard Manure, Potassium and Zinc should be included in integrated crop management approaches for sustainable agriculture.

Introduction

Wheat is the most important cereal and staple food crop of Pakistan sharing 13.7% to the value added in agriculture and 3% to GDP. It is cultivated over an area of 8303 thousand hectares (Anon., 2005). Over the past three decades, increased agricultural productivity occurred largely due to the deployment of high-yielding cultivars and increased fertilizer use. With the introduction of semi-dwarf wheat cultivars, wheat productivity has been increased in all the major cropping systems representing the diverse and varying agro-ecological conditions. In Pakistan, wheat is grown in different cropping systems, such as cotton-wheat, rice-wheat, sugarcane-wheat, maize-wheat, fallow-wheat. Of these, cotton-wheat and rice-wheat systems together account about 60% of the total wheat area whereas rain-fed wheat covers more than 1.50 m ha area. Rotations with Maize-Sugarcane, Pulses and fallow are also important.

Improved semi-dwarf wheat cultivars available in Pakistan have genetic yield potential of 6-8 t ha^{-1} whereas our national average yields are about 2.5 t ha^{-1}. A large number of experiments and on-farm demonstrations have repeatedly shown high yield potential of the varieties. There are progressive farmers of irrigated area who are harvesting 6 to 7 tonnes yield ha^{-1}. However, farmers yield ranges between 0.5 to 1.3 tons ha^{-1} depending on the amount of rainfall. The yield in irrigated area ranges from 2.5 to 2.8 tons ha^{-1} depending upon the amount of water available and other factors (http://www.parc. gov.pk/ 1subdivisions/narccsi/csi/wheat.html).

Due to food crises all over the world and increasing population pressure there is an urgent need to increase the quantity and improve the quality of grains. To increase the yield per unit area a variety of factors can contribute like proper and balanced dose of fertilization, irrigation, time of sowing, use of quality seed etc. Apart from macronutrients, lack of micro nutrients is also the major concern in Pakistan. Micronutrient deficiency is widespread in plants, animals, and humans, especially in many Asian countries, due to the calcareous nature of soils, high pH, low organic matter, salt stress, continual drought, high bicarbonate content in irrigation water and imbalanced application of fertilizers (Malakouti, 2008; Khan *et al.*, 2010); Sillanpaa (1990) conducted broad study in several countries and revealed that crop yield, or soil and plant analytical data, or a combination of both indicated some degree of micronutrient deficiency, especially Zn, at all Iraqi and Pakistani study sites.

In Pakistan, NPK are generally considered as the only nutrients required for plant growth and development. As farmers are poor and illiterate therefore micronutrients are neglected. Many researchers have shown that micro-nutrients have a promising effect on the growth and development of the crop plants. Use of micronutrients improves the quality and quantity of the agricultural produce. Rafique & Rashid (2006) reported that in Pakistan Zn requirement for wheat is low (i.e., 2.0 kg Zn ha^{-1}) and Zn use enhances wheat productivity in a highly cost-effective manner. They further added that contrary to the general belief, Zn content in mature wheat grain is a good indicator of soil Zn availability status. Wheat critical Zn concentration in young whole shoots ranges from 16 to 20 mg kg^{-1}, flag leaves 12 to 16 mg kg^{-1} and mature grains 20 to 24 mg kg^{-1}. Zinc deficiency is a common micronutrient disorder in arid and semiarid regions of Pakistan (Rashid, 1996) because of low-Zn solubility and high-Zn fixation under such soil conditions (Lindsay, 1979).

Like micronutrients, farm yard manure (FYM) is also considered as an important source of macro and micronutrients that increase crop yield. Due to higher prices of inorganic fertilizers, farmers in Pakistan could easily manage to prepare FYM in their farms and to apply in fields. Herbert (1998) reported that animal manures are an excellent source of plant nutrients. Approximately 70-80 % of the nitrogen, 60-85% of the phosphorus and 80-90 % of the potassium in feeds are excreted in the manure. He further added that manure contains all the plant nutrients needed for crop growth including trace elements. The availability or efficiency of manure utilization by a crop is determined by the method of application, time to incorporation and the rate of manure decomposition by microorganisms in soil.

Considering the importance of wheat for national economy and the effect of macro and micronutrients like Zn and FYM, the present study was conducted with the objectives to evaluate the performance of wheat in different cropping patterns under irrigated conditions of Peshawar and to investigate the effect of FYM, K and Zn and their interaction on yield and yield related traits of wheat.

Materials and Methods

Study was conducted to investigate the response of wheat to farm yard manure, potassium and Zinc under irrigated cropping patterns during 2001-2002 and 2002-2003 at Agricultural Research Farm, NWFP Agricultural University, Peshawar for 2 years. Five cropping patterns and FYM, K and Zn each at two levels were studied in the experiment as described below:

Cropping patterns included; C_1 = Rice-Wheat, C_2 = Maize-Wheat, C_3 = Sunflower-Wheat, C_4 = Sorghum-Wheat and C_5=Pigeonpea-Wheat. While manures/fertilizers were 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).

Randomized complete block design was used with split plot arrangements and four replications having net plot size of 12 m^2. Wheat variety Ghaznavi-98 was sown in November soon after ploughing the soil at proper moisture level suitable for wheat seed germination. 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 wheat and summer crops in the five cropping patterns.

Wheat	=	135:55:00	NPK kg ha^{-1}
Rice	=	100:67:62	NPK kg ha^{-1}
Maize	=	120:50:00	NPK kg ha
Sunflower	=	45:35:15	NPK kg ha
Sorghum	=	100:50:00	NPK kg ha
Pigeon pea	=	25:64:00	NPK kg ha

FYM at 25 t ha^{-1} in treatments were applied before the start of monsoon rains and turned in with mold-board plough. Fertilizer for wheat was applied into soil a day before drilling wheat in the same furrows. The experiments were conducted on the same sites as permanent plots for the year 2. The physico-chemical analysis of the soil samples taken from the experimental fields is presented in Table 1. Data were recorded on productive tillers m^{-2} , grain yield, mean crop growth rate up to anthesis and maturity. Productive tillers in 1 m long row were counted and finally converted into tillers m^{-2}. Three central rows were harvested and the grain yield was recorded and subsequently converted into kg ha^{-1}.

Statistical analysis: Data obtained were statistically analyzed by using the analysis of variance techniques and using plain comparisons at 5% probability to compare the differences among the different cropping patterns and manures/fertilizers treatments mean (Steel & Torrie, 1980).

Results and Discussion

Productive tillers: Analysis of the data exhibited that tillers m^{-2} of wheat were significantly affected by cropping patterns. Means of the two year's cropping patterns data showed that more (296) tillers m^{-2} were observed in plots where wheat was sown after sunflower, while similar number of tillers m^{-2} were produced by wheat following rice, maize and pigeon pea i.e., 282, 274 and 272, respectively. Less (252) tillers m^{-2} of wheat was recorded where wheat was planted after sorghum (Table 2). Farmyard manure, potassium and zinc increased the number of tillers m^{-2} as compared to no application of these nutrients. Overall wheat crop sown during 2nd year (2002-03) produced more tillers m^{-2} than the crop sown during the first year (2001-02). The effects of manures/fertilizers on tillers m^{-2} of wheat under irrigated conditions were non-significant. Any how in years 2 more tillers were produced than in year 1. Interactions, fertilizer x potassium x zinc (FKZ), year x fertilizer (YF) and year x cropping patterns x fertilizer (YCF) had significant effect on tillers m^{-2} of wheat while all other interactions were non-significant. These findings are not in agreement with Yilmaz *et al.,* (1997) who reported that with foliar application spikes number m^{-2} was most affected by Zinc application. Patra *et al*., (1998) also reported that combination of NPK and FYM gave the highest number of spikes m^{-2}.

More tillers in year 2 is mainly due to better emergence in year 2 as the average tillers production plant^{-1} in the field conditions was less in both years. Wheat produced comparatively more number of tillers when planted after pigeon pea might be due to the beneficial effect of nutrients released from decomposition of pigeon pea residues especially leaves. Pigeon pea being leguminous crop may have added nitrogen to the soil by nitrogen fixation. The minimum tillers population in wheat after sorghum may be due to the exhaustive effect of sorghum in terms of nutrient absorption. Sorghum plants have allelopathic effect and this might have released allelochemicals to the soil which subsequently affected the following crop. None of the main effects of manures/fertilizers nutrients were significant which indicates that sufficient nutrients were available for crop growth and tiller production. There was much greater effect of FYM in year 2 than in year 1, which may be the cause of significant interaction between years and FYM. The greater effect in year 2 may be due to favourable conditions for growth and tillering in year 2 as indicated by over all effect of year 2 on growth interval.

Table 1. Chemical status of soils at Agricultural Research Farm, KPK Agricultural University, Peshawar.

S. No.	Property	Unit	Value
1.	Textural class	-	Clay loam
2.	pH	-	8.3
3.	Ec x 10^6	ds m^{-1}	0.93
4.	CaCO3	(%)	5.15-15.60
5.	Organic matter	(%)	0.60-1.88
6.	Extractable potassium	(mg kg^{-1})	215
7.	Extractable phosphorus	(mg kg^{-1})	14.1
8.	Nitrogen	(%)	0.090-0.098
9.	Calcareousness	-	highly calcareous
10.	Total soluble salts	(TSS %)	0.060

Table 2. Productive tillers m^{-2}, grain yield and differences in RY of wheat after different summer crops as affected by FYM, K & Zn under irrigated conditions

Treatments	Productive Tillers m^{-2}	Grain yield (kg ha^{-1})	Difference in relative yield (%)
Rice-wheat	282 a	2735 b	3.62
Maize-wheat	274 ab	2546 c	0.88
Sunflower-wheat	296 a	2499 c	-23.63
Sorghum-wheat	252 b	2352 d	-2.23
Pigeon pea-wheat	272 ab	2856 a	21.36
$LSD_{0.05}$	27.63	93.52	-
No FYM	38.14	2553	-2.91
FYM, 25 t ha^{-1}	38.29	2642	2.91
Significance level	NS	NS	-
No Potassium	38.02	2545	-4.28
K, 150 kg ha^{-1}	38.42	2651	4.28
Significance level	NS	56.5	-
No Zinc	38.18	2545	-0.25
Zinc 7 kg ha^{-1}	38.26	2650	0.25
Significance level	*	*	

NS= Non-significant, * = Significant at $p \leq 0.05$

Table 3. Crop growth rate up to anthesis and maturity of wheat after different summer crops as affected by FYM, K & Zn under irrigated conditions

Treatments	Mean crop growth rate up to anthesis (g/m^2/day)	Mean crop growth rate up to maturity (g/m^2/day)
Rice-wheat	5.89 b	5.91
Maize-wheat	6.46 ab	6.58
Sunflower-wheat	6.54 ab	6.38
Sorghum-wheat	6.63 a	6.52
Pigeon pea-wheat	6.99 a	7.08
$LSD_{0.05}$	0.68	NS
No FYM	6.50	6.42
FYM, 25 t ha^{-1}	6.50	6.57
Significance level	NS	NS
No Potassium	6.42	6.44
K, 150 kg ha^{-1}	6.58	6.55
Significance level	NS	NS
No Zinc	6.48	6.45
Zinc 7 kg ha^{-1}	6.52	6.54
Significance level	NS	NS

NS = Non-significant

Grain yield: Grain yield of wheat in the different cropping patterns as affected by FYM, K and Zn are reported in Table 3. Cropping patterns has significant effect on grain yield of wheat under irrigated conditions. The highest grain yield (2856 kg ha^{-1}) was produced by the wheat following pigeon pea. Wheat after rice produced more grain yield (2735 kg ha^{-1}) than wheat after maize (2456 kg ha^{-1}), sunflower (2499 kg ha^{-1}) and sorghum (2352 kg ha^{-1}). Potassium application significantly increased yield in year 2. Zinc application also improved grain yield of wheat in both years. Comparing the effects of FYM, K and Zn, it was noted that grain yield of wheat was significantly increased. To compare the sustainability of the factors, relative yield was calculated for the 2 years. Year 1 was subtracted from year 2. The difference was used as criteria for sustainability. The relative yield of wheat after pigeon pea was higher in year 2 than in year 1 with a difference of about 21%. This shows that pigeon pea – wheat cropping pattern is more sustainable than others. The difference in relative yield of sunflower– wheat cropping pattern was negative which indicate that this cropping pattern is declining wheat yield more. These results are in agreement with Thakur *et al.,* (2001) who concluded that 10 kg Zn ha^{-1} increased grain yield of wheat by 4-9%. De Long *et al.,* (2001) concluded that K fertilizer did not have significant impact on grain yields of wheat. Negi & Gulshan (2000) reported that 10 t FYM ha^{-1} caused a significant increase in grain yield of wheat.

The increase in wheat yield after mungbean 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 groundnut 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 1^{st} year, which may be due to tying up of nitrogen by the decomposing leaves of pigeon pea, yet the yield of wheat following pigeon pea was the highest in the 2^{nd} year. The highest yield of wheat after pigeon pea in the 2^{nd} 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 (Shah *et al.*, 2010).

Mean crop growth rate up to anthesis: Mean crop growth rate up to anthesis can be considered criteria for vegetative growth of wheat. Data on crop growth rate up to anthesis are given in Table 3. Statistical analysis of the data showed that difference in crop growth rate of the two years was significant, with year 2 having greater crop growth rate than year 1. Cropping patterns also affected mean crop growth rate during vegetative growth stages. Wheat after pigeon pea had the highest mean crop growth rate (6.99 $g/m^2/day$). Wheat after rice had lower vegetative crop growth rate (5.89 $g/m^2/day$) especially in year 2. Effects of FYM, Potassium and Zinc were not significant, showing that their application did not significantly increased or decreased dry matter accumulation/unit area/unit time during the vegetative period. Only two interactions FK and YFK were significant for mean crop growth rate up to anthesis. These results are in contrast with Yaduvanshi (1995) who reported that dry weight at tillering, earning, grain and straw significantly increased with Zinc application. The greater vegetative crop growth rate in year 2 may be due to early sowing and more favourable growing conditions in year 2. The greater vegetative crop growth rate in year 2 may also be due to greater tillering in year 2 as compared to year 1.

Mean crop growth rate up to maturity: Mean crop growth rate from anthesis to maturity is the measure of dry matter accumulation in reproductive organs/unit area/unit time. The data on mean crop growth rate for the period from anthesis to maturity are reported in Table 3. Effect of year on crop growth rate in the seed fill duration stage did not reach significance level, though year 2 had slightly higher mean crop growth rate. Effects of cropping patterns and fertilizers application also did not reach 5% significance level. Only three interactions FKZ, YCF and YCZ (data not given), had significant effect on crop growth rate from anthesis to maturity. These findings are in contrast with Yaduvanshi (1995) who concluded that dry weight at tillering, earing, grain and straw significantly increased with Zn application.

The reason for higher crop growth rate during seed fill duration in year 2 may be the favourable temperature due to frequent rains and may be due to greater leaf area and photo assimilates availability for accumulation in spikes of wheat. The reason for no effect of the manures and fertilizers may be that all the plots received environmental factors the same and thus photosynthesis and assimilates availability for seed filling from anthesis to maturity were about the same.

Conclusion

Based on average of 2 years, wheat in pigeon pea-wheat cropping patterns produced the highest yield among the different cropping patterns followed by rice-wheat, under irrigated conditions. 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 irrigated conditions.

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