Pak. J. Bot., 43(5): 2391-2396, 2011.

EFFECT OF FYM, POTASSIUM AND ZINC ON PHENOLOGY AND GRAIN YIELD OF WHEAT IN RAINFED CROPPING SYSTEMS

KHALID NAWAB[1]*, AMANULLAH[1], MUHAMMAD ARIF[1], PAIGHAM SHAH[1], ABDUR RAB[1], M. AZIM KHAN[1], MUHAMMAD ANWAR KHAN[1] AND KHALID KHAN[2]

[1]*Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan*
[2]*Department of Zoology, PMAS Arid Agriculture University, Rawalpindi, Pakistan.*

Abstract

Little work has been done on potassium (K) and zinc (Zn) in combination with farm yard manure (FYM) under rainfed conditions of NWFP. This study was designed to examine the effects of un-irrigated cropping patterns and organic and in-organic fertilizers on wheat crop. Field experiments were conducted to investigate the effect of cropping patterns and farm yard manure, potassium and zinc on phenology and grain yield of wheat under rainfed (barani or un-irrigated) conditions at Agricultural Research Station, Serai Naurang Bannu for two years during 2001-02 and 2002-03. The experiment was designed in RCB design with split arrangements. Two factors were studied in the experiment. Effects of five cropping patterns i.e., fallow-wheat, groundnut-wheat, mungbean-wheat, sorghum-wheat & pigeon pea-wheat and three organic and in-organic fertilizers on subsequent wheat crop were observed. Data revealed that both the cropping patterns and manures/fertilizers had non-significant effect on days to anthesis, seed fill duration and days to maturity of wheat. Highest grain yield (3194 kg ha^{-1}) was produced by wheat fallowing mungbean. Based on two years average, it is concluded that wheat following mungbean produced more yield and wheat following groundnut produced less yield under dryland conditions. The present findings revealed that pigeon pea-wheat cropping pattern seems to be more sustainable in terms of yield under rainfed conditions and use of FYM, K and Zn should be included in integrated crop management approaches for sustainable crop production.

Introduction

In Pakistan, wheat being the staple diet is the most important crop and cultivated on the largest acreages (8.303 million hectares during the growing season 2005-06) in almost every part of the country. It contributes 13.7 % to the value added in agriculture and 3 % to GDP. Over the past three decades, increased agricultural productivity occurred largely due to the deployment of high-yielding cultivars and increased fertilizer use.

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. 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 (Khan *et al*., 1989).

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). 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 plants 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 crops 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 range 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 (Zn) 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).

Previous research has showed 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. A greater effect of previous crop on corn yields has been observed in dry years than in wet. Asghari & Hanson (1984) 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 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 studies were conducted with the aim to investigate benefits of integrated nutrient management in wheat under dry land cropping systems.

*Corresponding author email: nawab_aup@yahoo.com

Materials and Methods

Field experiments were conducted at Agricultural Research Station, Serai Naurang, Bannu for 2 years during 2001-02 and 2002-03 in order to investigate impact of integrated nutrient management on phenology and grain yield response of wheat under rainfed (dryland) cropping pattern. The station is located in the southern unirrigated belt of the NWFP (North West Frontier Province). Five cropping patterns and FYM, K and Zn each at two levels were studied in the experiment as described below:

Cropping patterns were; C_1 = Fallow-Wheat, C_2 = Groundnut-Wheat, C_3 = Mungbean-Wheat, C_4 = Sorghum-Wheat and C_5 = Pigeon pea-Wheat. While manures/fertilizers included were FYM @ 0 and 25 t ha^{-1} (F1= No FYM applied, F2= 25 t FYM ha^{-1} applied) Zn @ 0, and 7 kg ha^{-1} (Z1=No Zn applied, Z2= 7 kg Zn ha^{-1} applied), K @ 0, and 150 kg ha^{-1} (K1=No K applied, K2= 150 kg K ha^{-1} applied).

The experiment was conducted using RCB design with split plot arrangements and four replications with net plot size of 12 m^2 (2.4 x 5m). 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 kg ha^{-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 were kept weed free during kharif (summer) season by repeated disking/harrowing/cultivating followed by immediate 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 days 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 status of the soil is given in Table 1. Data were collected on phenological characteristics (days to emergence, anthesis, seed-fill duration and maturity) emergence m^{-2}, grain and biological yield

Table 1. Physico-chemical status of soil at ARS, Serai Naurang, Bannu.

S. No.	Property	Unit	Value
1.	pH	-	7.9
2.	Electrical conductivity	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}

Statistical analysis: Data were statistically analyzed using MSTATC and means were compared between treatments by least significant difference (LSD) at $p\leq0.05$ confidence level using Student's t- test (Steel & Torrie, 1980).

Results and Discussion

Days to emergence: Data pertaining days to emergence of wheat as affected by cropping patterns and organic/inorganic fertilizers under rainfed conditions are given in Table 2. Statistical analysis of the data showed that the main effects of cropping patterns and organic/inorganic fertilizers were non-significant for days to emergence of wheat. This indicated that both the factors could not affect the emergence of wheat grain. Non-significant differences were observed for the two years regarding days to emergence of wheat. The interaction effects were non-significant as well. Only one interaction year x cropping x cropping pattern x farmyard manure x zinc (YCFZ) has some significant effect on emergence days of wheat. Days to emergence depends mostly on soil temperature. As all the plants were planted on the same date, the temperature was almost the same and thus the speed of germination and rate of emergence was the same. Though non-significantly different from other plots, wheat in plots of pigeon pea emerged a little later, which could be due to lower soil temperature as a result of much pigeon pea residues and leaves. The same could be the reason for slight delay in emergence in plots to which FYM has been applied.

Emergence m^{-2}: Number of wheat plants as affected by cropping patterns, FYM, Potassium and Zinc under rainfed conditions are given in Table 2. Statistical analysis of the data showed that the main effects of cropping patterns, FYM, Potassium and Zinc were non-significant. Only C x Z interaction was significant for emergence m^{-2} of wheat (Fig. 1).

Based on the average of two years, the plots of pigeon pea-wheat had better emergence (222) than the plots of other cropping patterns. Low emergence m^{-2} (204) was observed in sorghum-wheat cropping patterns. Zinc effect on emergence of wheat was not significant, though more plants emerged in the plots to which 7kg ha^{-1} zinc was applied than the plots to which no zinc was applied. These findings are in contrast to Shen *et al*., (1998) who reported that Z in addition to NP fertilizers gave the greatest seedling and tiller numbers.

Table 2. Days to emergence, emergence m^{-2}, and plant height of wheat after different summer crops as affected by FYM, K & Zn under rainfed conditions.

Treatments	Days to emergence	Emergence m^{-2}	Plant height (cm)	Days to anthesis
Fallow-wheat	8.17 b	211	90	118
Groundnut-wheat	8.23 b	210	86	118
Mungbean-wheat	8.31 ab	205	89	119
Sorghum-wheat	9.06 a	204	86	118
Pigeon pea-wheat	8.33 ab	222	85	119
$LSD_{0.05}$	0.7859	ns	3.301	ns
No FYM	8.51	210	87	118
FYM, 25 t ha^{-1}	8.33	212	88	118
Significance level	Ns	ns	ns	ns
No Potassium	8.51	208	87	118
K, 150 kg ha^{-1}	8.34	213	87	118
Significance level	Ns	ns	ns	ns
No Zinc	8.42	208	86	118
Zinc 7 kg ha^{-1}	8.43	214	88	118
Significance level	Ns	ns	ns	ns
Significant interactions	None	C x Z (Fig. 1)	none	none

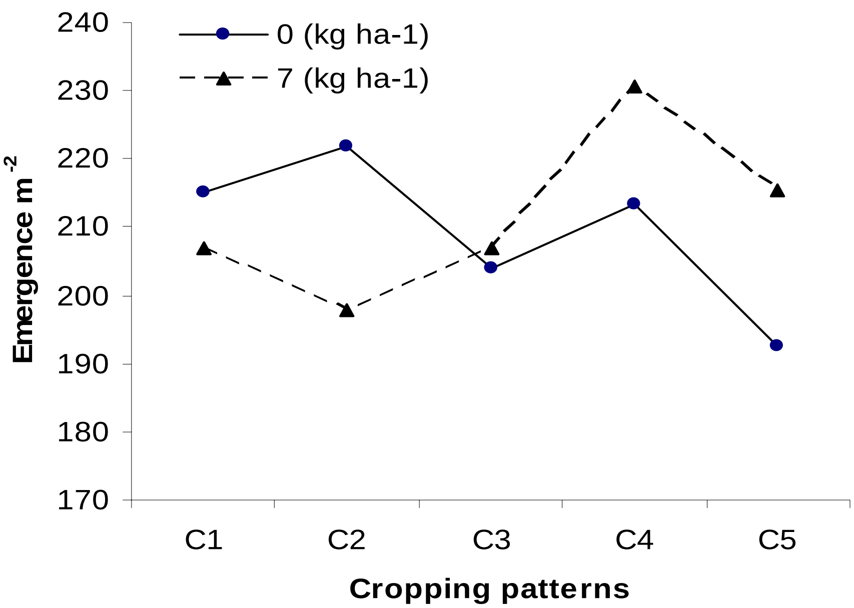

Fig. 1. Emergence m^{-2} of wheat after different summer crops as affected by FYM, K and Zn under rainfed conditions at Serai Naurang, Bannu.

Because the previous crop residues were not decomposed, in year 2 (2002-2003) the emergence of wheat after pigeon pea was highest because of the year 2 built of the residues, some decomposed and released nutrients, improved the emergence in pigeon pea and groundnut plots. Moreover, there was improvement in emergence of wheat following pigeon pea because pigeon pea shades many leaves, which after decomposition and partial decomposition released nutrients, improving water holding capacity and made the soil porous and soft. As FYM was applied shortly before sowing it did not affect emergence. The effects of zinc and potassium on emergence were non-significant because sufficient potassium and zinc may have been available in the soil and because of the fact that germination and seedling emergence mainly depend upon growth of embryo axis which in turn depends mainly upon the food stored in the endosperm.

Plant height: Data relating plant height (cm) of wheat as affected by cropping patterns and manures/fertilizers under un-irrigated conditions are reported in Table 2. Perusal of the data depicted that cropping patterns had significant effect on plant height of wheat crop. Taller plants (90 cm) were noted in plots where wheat was sown after fallow, closely followed by wheat grown after mungbean (89 cm). While in the remaining three cropping patterns almost the same plant height was observed. Manures and fertilizers had non-significant effect on plant height of wheat crop. Year 2 produced comparatively taller plants. These findings are not in conformity with Ravindra *et al*., (1996) who reported that plant height was increased with the optimal application of zinc. The same results were obtained for potassium by Yang *et al*., (1997) who concluded that potassium application produced taller plants. Plant height of wheat following fallow was greater than other plots, which may be due to better moisture status and nutrients availability. Wheat after mung bean also attain more height than wheat after ground nut, sorghum and pigeon pea could be due to the reason that mung bean fixed nitrogen as well as used less water due to lower biomass production. The taller plants in year 2 are mainly due to more rain fall and moisture status of the plant in year 2; greater availability of water increased plant height.

Days to anthesis: Data relating the effects of cropping patterns and manures/fertilizers on days to anthesis of wheat crop under rainfed conditions are reported in Table 2. Based on the statistical analysis of the data both (cropping patterns and manures/fertilizers) had non-significant effect on days to anthesis of wheat. Among the pre-planned meaningful plan comparisons, only groundnut vs mung bean and pigeon pea was significant. Wheat crop sown during Ist year took few more days to anthesis than the 2nd year. Among the interactions, YxCxKxZ had significant effect on days to anthesis of wheat crop. The other two interaction's i.e., YxZ and CxFxKxZ also had some significant effect on days to anthesis of wheat crop sown during both the years. None of the main effects and interactions for days to anthesis was significant. This is because days to anthesis depend upon the rate of development to reproductive stage, which is mainly affected by genetic and environmental interaction. The two most important factors that affect rate of development in plants are photoperiod and temperature. These two factors were uniformly experienced by crops in different plots and thus the development in all plants was uniform and thus days to anthesis were the same. The effect of years was significant. The difference in days to anthesis of two years may be due to date of sowing, rainfall, temperature and moisture status.

Seed fill duration: The effects of cropping patterns and FYM, K and Z on seed fill duration of wheat under un-irrigated conditions are shown in Table 3. Statistical analysis of the data revealed that main effects of cropping patterns and manures/fertilizers on seed fill duration of wheat were non-significant. Interaction effects were non-significant as well, but only one interaction YxCxKxZ had significant effect on seed fill duration of wheat crop based on the average wheat plants sown after fallow and ground nut, took more days for seed filling, than the other wheat plots. Wheat crop sown during the year 1 took less days for seed filling as compared to the year 2. For year 2 sowing was early so seed filling was early and temperature was low so the seed fill duration was longer, because of early anthesis in year 2 and low temperature due to frequent rainfall. None of the main effects and interactions for seed fill duration was significant. This is because the seed fill duration depends on the rate of development to reproduction stage, which is mainly affected by genetic and environmental interactions. The two most important factors that affect rate of development in plants are photoperiod and temperature, these two factors were uniformly experienced by crops in different plots and thus the development in all plants was uniform due to which seed fill duration was the same.

Table 3. Days to anthesis, seed fill duration, days to maturity and grain yield of wheat after different summer crops as affected by FYM, K & Zn under rainfed conditions.

Treatments	Seed fill duration	Days to maturity	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Fallow-wheat	38.83	152.16	3086 ab	9276 a
Groundnut-wheat	38.69	150.45	2773 c	8039 c
Mungbean-wheat	37.80	151.33	3194 a	9433 a
Sorghum-wheat	37.98	150.41	2804 c	7320 d
Pigeon pea-wheat	37.80	151.00	2915 bc	8461 b
$LSD_{0.05}$	Ns	Ns	229.60	407.00
No FYM	38.14	151.14	2884 b	8389
FYM, 25 t ha^{-1}	38.29	151.00	3025 a	8623
Significance level	Ns	Ns	*	ns
No Potassium	38.02	151.06	2926	8439
K, 150 kg ha^{-1}	38.42	151.08	2983	8573
Significance level	Ns	Ns	ns	ns
No Zinc	38.18	151.01	2926	8449
Zinc 7 kg ha^{-1}	38.26	151.13	2983	8562
Significance level	Ns	Ns	ns	ns
Significant interactions	None	none	none	none

Days to maturity: Effect of cropping patterns, FYM, Potassium and Zinc under rainfed conditions on days to maturity is given in Table 3. Statistical analysis of the data showed that the main effects of cropping patterns and organic and in organic fertilizers on days to maturity of wheat were non-significant. Only three interactions, CxKxZ, CxFxKxZ and YxCxFxKxZ were significant, others were non-significant. Years' effect on days to maturity was highly significant. Effects of cropping patterns and manures/fertilizers on days to maturity under un-irrigated conditions were not significant indicating that under the conditions at Serai Naurang Bannu, the four factors did not affect vegetative as well as reproductive rate of development. Rate of development which determines the days to maturity, depends upon photoperiod and temperature and all the plots received these two environmental factors uniformly.

Grain yield: Grain yield of wheat under rainfed conditions as affected by cropping patterns and manures/fertilizers are given in Table 3. Analysis of the data showed that effects of years and FYM levels were significant. The F value for cropping patters in ANOVA for grain yield was significant ($p<0.05$). Year x potassium and CxFxKxZ 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 $kgha^{-1}$) 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 ground nut. Based on the average of two years, year 2 produced more grain yield than year 1. Application of 25t ha^{-1} FYM increased yield by 141kg ha^{-1}. 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.,*** (2001) who concluded that 10 kg zinc ha^{-1} increased in grain yield of wheat by 4-9%. De Long *et al*., (2001) concluded that K fertilizer did not have a 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 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 the first year, which may be due to the less decomposition of leaves of pigeon pea in the first year. But the yield of wheat following pigeon pea was the highest in the 2nd year which might 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 difference between relative yields of the two years was calculated and used criteria for sustainability of cropping patterns. The differences in relative yields of the two years show that there was much improvement in relative yields of wheat following pigeon pea in second year indicating that pigeonpea-wheat cropping pattern is more sustainable in the study area. The negative values for mungbean-wheat, sorghum-wheat and fallow-wheat showed that continuous use of these cropping patterns may reduce wheat yield. The higher grain yield of wheat following mungbean may be partly due to more spikes m^{-2}, greater leaf area per tiller and higher leaf area index.

Biological yield (kg/ha): Statistical analysis of data revealed (Table 3) 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 biological yield which was significantly higher than the mean biological yield of year 1. The difference of 4147 kg/ha 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 25t ha^{-1} of FYM producing higher yield than plots to which no FYM had been applied. Main effects of FYM, Potassium and Zinc and interactions were non-significant. These results are in agreement with Rajput *et al*., (1995) 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*., (1995) and Agarwal *et al*., (1997) 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 following sorghum may partly be due to the cereal being exhaustive crop and partly due to he fact that legumes fixed nitrogen which was then available to the subsequent wheat crop for enhancing the vegetative growth in biological yield. The comparisons of fallow with other treatments, is significant because fallow plots accumulated some nitrogen from monsoon rainfall during summer.

Conclusion

Wheat-mung bean-wheat cropping pattern produced more grain yield and wheat in groundnut-wheat produced less grain yield under rainfed conditions. As groundnut had allelopathic effect and also caused Ca deficiency, it is therefore, suggested that further research work should be done to investigate impact of gypsum application to wheat following groundnut. 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. FYM should be applied to wheat in both irrigated and rainfed cropping patterns.

References

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. *Indian J. Agric. Res*., 3(31): 174-178.

Asghari, M. and R.G. Hanson. 1984. Nitrogen, climate and previous crop effect on corn yield and grain N. *Agron. J.*, 76: 536-542.

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. *Res. Series Arkansas Agric. Exp. Station*, 480: 27-33.

Khan, A.R., A. Qayyum and G.A. Chaudhary. 1989. A country paper on soil, water and crop management systems for dry land agriculture in Pakistan. In: *Soil, Water and Crop /Livestock Management Systems for Rainfed Agriculture in the Near East Region*, 88-102 (Eds.): C.E. Whitmar., J.F. Parr, R.I. Papendick and R.E. Meyer), ICARDA, USAID.

Lindsay, W.L. 1979. *Chemical Equilibria in Soils*. John Wiley and Sons, New York. p. 449.

Malakouti, M.J. 2008. The effect of micronutrients in ensuring efficient use of macronutrients. *Turk. J. Agric. For.,* 32: 215-220.

Negi, S.C. and M. Gulshan. 2000. Effect of FYM, planting methods and fertilizer levels on rainfed wheat. *Crop Res. Hisar.,* 3(20): 534-536.

Rafique, E. and A. Rashid. 2006. Zinc deficiency in rainfed wheat in Pakistan: magnitude, spatial variability, management and plant analysis diagnostic norms. *Comm. Soil Sci. Plant Anal*., 37: 181-197.

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*). *Indian J. Agron*., 4(40): 598-600.

Rashid, A. 1996. Secondary and micronutrients. In: *Soil Science*; (Eds.): A. Rashid and K.S. Memon. National Book Foundation, Islamabad, Pakistan, pp. 341-386.

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 of Agric. Biol. Res*., 1: 1-2.

Sillanpaa, M. 1990. *Micronutrient assessment at the country level: An international study*. The Govt. of Finland (FINNDA). Food & Agric. Org. of the United Nations. Rome, Italy.

Steel, R.G.D., J.H. Torrie and D. Dickey. 1996. *Principles and Procedures of Statistics*, McGraw-Hill New York.

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 Res. Hisar*, 3(21): 283-286.

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 Agril. Sci*., 1: 47-48.

(Received for publication 9 May 2009)