Pak. J. Bot., 43(2): 991-1002, 2011.

PHYSIOCHEMICAL TRAITS, PRODUCTIVITY AND NET RETURN OF WHEAT AS AFFECTED BY PHOSPHORUS AND ZINC REQUIREMENTS UNDER ARID CLIMATES

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Abstract

The present study was aimed to optimize phosphorous and zinc doses to maximize wheat productivity under arid climate. Varying levels of phosphorus (P_1= 60, P_2 = 90 and P_3 = 120 kg ha^{-1}) and zinc (Zn_1 = 10, Zn_2 = 15 and Zn_3 = 20 (kg ha^{-1}) were applied in a silty loam to which wheat was grown till maturity. From the results of the present study, it was found that application of P had a positive influence on growth and grain yield of wheat. However, maximum growth and yield of wheat was recorded at 120 kg ha^{-1} P_2O_5 application. In contrast, Zn application did not change in growth or yield of wheat. However, combined application of P and Zn caused an increase in growth of wheat particularly in terms of Leaf Area Index (LAI). The highest grain-P content was recorded with application of 120 kg ha^{-1} P_2O_5 and 15 kg ha^{-1} Zn while highest straw-P was accumulated with comparatively lower rates of both (90 kg ha^{-1} P_2O_5 and 15 kg ha^{-1} Zn). The highest grain and straw-Zn contents were recorded for 15 kg Zn ha^{-1} with 60 and 90 kg ha^{-1} P_2O_5, respectively. Combined application of 120 kg P_2O_5 and 20 kg ha^{-1} Zn depicted the highest NFB and BCR during both cropping seasons.

Introduction

The farming community of Pakistan is using inadequate and imbalanced plant nutrients for different crops including wheat. For example, during 2000-03 farmer used fertilizers has averaged NPK ratio 1:0.28:0.01 (Ahmad & Rashid, 2004) that is not matching with the recommended ratio of 1:1:0.5 (Ahmad & Rashid, 2004). Of various macronutrients, phosphorus plays a vital role in crop production as it is involved in CO_2 fixation, sugar metabolism, energy storage and transfer (Taize & Zeiger, 2006). Phosphorus has been reported to increase the strength of cereal straw, stimulate root development, promote flowering, fruit production, and formation of seeds and it hasten maturity of the crops (Gupta, 2003).

Zinc is also an important micronutrient and a constituent of a number of enzymes e.g., superoxide dismutase (SOD), alcohol dehydrogenase. Deficiency of Zn in plant leads to the reduction of sucrose and starch content, decreasing auxin, upsetting protein synthesis and increase in organic acid content (Sahai, 2004; Ahmed *et al*., 2009). It is reported that 52% soils of Pakistan are deficient in zinc (FFC, 1997, NFDC, 1997). Hence there is need to evaluate the level of Zn in soil and its interaction with other nutrients particularly with phosphorus in the soil and plant under specific environment. Many research workers (Nayak *et al*., 1997; Raghuwanshi *et al*., 1997; Rajput, 1997 and Sharma *et al*., 2000) reported a positive effect of Zn on grain yield of wheat. All the growth characters (LAI, LAR, NAR, RGR and dry matter accumulation) were higher at high Zn levels (Shukla & Warsi, 2000). Rupa *et al*., (2003) also reported that application of 7.5 mg Zn kg^{-1} of soil showed the maximum utilization by wheat (0.87-1.17%) as compared to other Zn levels.

Synergistic and antagonistic interactions among P and other nutrients in the soil may exist and it influences the nourishment of plants. Zinc deficiency is aggravated with phosphatic fertilizer application (Sharif, 1985). The antagonism between phosphorus-zinc is observed mainly when both nutrients are deficient. However, in practice only P is applied (Tandon, 1992) to remove nutrient deficiency. Wagar *et al*. (1986) stated that although yield was increased significantly by P and Zn application but Zn uptake was reduced at higher dose of P. Singh *et al*., (1986) and Yokas (1987) also reported that phosphorus induced zinc deficiency in wheat but application of phosphorus along with zinc increased the grain yield of wheat. Similar results were reported by Khan *et al*., (1987) and Tagwari *et al*., (1993) who stated that availability of phosphorus was reduced when lime concentration was increased. Minhas (1994) reported that antagonistic effect between P and Zn was observed more profusely in case where either Zn or P was more available. Siddique *et al*., (1999) studied the phosphorus and micronutrients interaction in calcareous soils and found that increased rate of phosphorus reduced zinc content in plant. Zhu *et al*., (2001) concluded that P availability significantly affected plant biomass production, while Zn supply had no effect on growth parameters of the crop. Alam *et al*., (1989) concluded that application of phosphorus along with Zn generally increased grain yield and dry matter yield. Alam *et al*., (2002) compared broad cast and fertigation of P-Zn application. The results revealed that application of P-Zn at sowing with fertigation of Zn at first irrigation significantly increased the wheat grain yield. The application of N and P increased yield of wheat but Zn application generally had no or little effect on grain yield (Grant & Bailey, 1998).

Although it is known that phosphorus fertilization induces Zn deficiency in different crops (Maltan *et al*., 1970), this effect was enhanced in cold and wet soils during the early growing season. It could be due to restriction of root development around the zone of fertilizer placement. While Sharma & Bhardwaj (1998) stated that optimum P and Zn fertilizer is 90 kg ha^{-1} P_2O_5 and 2.3 kg ha^{-1} Zn respectively to obtain maximum wheat grain yield. The growth parameters like yield attributes, yield, net return and benefit: cost ratio increased significantly with application of 40 kg $ha^{-1}P_2O_5$ and 5 kg ha^{-1} Zn (Dewal & Pareek, 2004). Germa & Minhas (1987) studied the interactive effects of Zn and P in wheat and concluded that added Zn did not increase the grain and straw yield of wheat when P was not applied but when P was applied (20 kg ha^{-1}), Zn responded significantly by increasing grain and straw yield.

In view of these contrasting reports it could be suggested that P and Zn application may yield varying results under different agro-ecological conditions when applied individually as well as in combinations. Thus the present study was planned to evaluate the associated effects of P and Zn on agronomic, physio-chemical traits and net return of wheat in arid conditions.

Materials and Methods

The study was conducted at the Experimental Farm, University College of Agriculture, Bahauddin Zakariya University, Multan, (latitude= 30.15° N 544, longitude= 71.3 0 ° E 885, altitude = 422 ft) during 2007-2008 and 2008-2009. The soils of the experimental station are characterized as silty loam soils. Before sowing soil test showed a pH of 8.08-8.10, organic matter content 0.69-0.76%, nitrogen 0.04-0.05%, P_2O_5 5.25-5.5 ppm, K_2O 250-300 ppm, Zn 0.38-0.36 ppm and $CaCO_3$ 9.0-9.1% in the two growing seasons. All the analyses were done according to methods given in Hand Book No. 60 (US Salinity Lab. Staff, 1954) except available P that was determined by Olsen method (Watanabe & Olsen, 1965), and texture by Moodie *et al.*, (1959).

This experiment was comprised of studying the impact of different levels of phosphorus and zinc on productivity of wheat. The experimental treatments were as under: Phosphorus levels were P_1= 60, P_2 = 90 andP_3 = 120 and Zinc levels Zn_1 = 10, Zn_2 = 15 and Zn_3 = 20 (kg ha^{-1}). The experiment was replicated four times in a randomized complete block design (RCBD) with split plot arrangements. Sub plot size was 1.6 x 6 m. Phosphorus and Zn levels were randomized in main and sub plot, respectively. Data on biological yield, grain yield, straw yield, leaf area index, harvest index, grain-P content, straw-P content, grain-Zn content and straw-Zn content of the crops were recorded during the course of study for each experiment separately. Wet digestion method was followed to determine Zn and P from the plant material (Ryan *et al.*, 2001). One gram of plant material was digested in 20 mL of concentrated HNO_3 and 10 mL of 72% $HClO_4$ on a hot plate by raising temperature up to 350°C till transparent solution was appeared. After cooling, the digested material was transferred to a 100 mL volumetric flask and made the volume up to the mark with distilled water. Phosphorus was analyzed by developing vanadomolybdo-phosphoric acid yellow colour. The intensity of the colour was measured on a spectrophotometer (PD303S) at 440 nm wave length. And Zn was determined with atomic absorption spectrophotometer (Baker and Amacher, 1982).

Statistical analysis: The data was statistically analyzed by using MSTAT-C (Freed & Eisensmith, 1986). Analysis of variance (ANOVA) was employed to test the overall significance of the data, while the least significant difference (LSD) test at p=0.05 was used to compare the differences among treatment means.

The economic analysis of the data was done according to the methodology described in CIMMYT (1988). The net fields benefit (NFP) and cost benefit ration (BCR) was calculated. The net benefit was calculated by subtracting the total variable cost from the total benefits from each treatment combination.

Results

P application enhanced biological yield by 9-10% and 12-15% when its levels were increased to 90 and 120 kg ha^{-1}, respectively, as compared to 60 kg ha^{-1} P_2O_5. Zn application at 20 kg ha^{-1} increased biological yield only by 2% against the 10 kg ha^{-1} and could not reach to the level of statistical significance (p=0.05). Different combinations of P and Zn had a non-significant influence upon biological yield of wheat in present studies revealing that there was no interactive response (Table 3). During the first year, the crop fertilized with 120 kg ha^{-1} P_2O_5 yielded significantly higher (4.11 t ha^{-1}) grain yield than rest of the two levels (90 and 60 kg ha^{-1} P_2O_5). The yield was also differed significantly at 90 and 60 kg ha^{-1} P_2O_5 which was 3.67 and 3.46 t ha^{-1}, respectively. A similar trend was exhibited during the second year (Table 1).

Application of P significantly and linearly increased HI of wheat with maximum HI (39.70%) realized with the application of 120 kg ha^{-1} P_2O_5. Although Zn application had an increasing effect on HI but it is statistically non-significant. Similarly, various combinations of P and Zn application had a non-significant increasing effect on HI (Table 2).

Table 1. Effect of phosphorus application on physiochemical characteristic of wheat.

Phosphorus Levels	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Leaf area index	Grain-P Content (ppm)	Straw-P content (ppm)	Grain-Zn content (ppm)	Straw-Zn content (ppm)
					P_1= 60 $kgha^{-1}$				
2007-08	8.88 c	3.46 c	5.42 c	39.1 b	4.58 c	3129.75 c	621.42 b	31.52 a	11.50 b
2008-09	9.56 b	3.68 c	6.66 c	38.52 c	4.62 b	3143.33 c	633.83 b	31.64 a	11.61 b
Mean	9.22b	3.57c	5.54c	38.77c	4.60b	3136.54c	627.63b	31.58a	11.56b
					P_2= 90 $kgha^{-1}$				
2007-08	9.36 b	3.67 b	5.68 b	39.26 ab	4.69 b	3414.42b	692.67a	24.22 b	14.80 a
2008-09	9.95 b	3.90 b	6.02 b	39.22 ab	4.73 b	3455.67b	699.42a	24.30 b	14.87 a
Mean	9.66b	3.79b	5.85b	39.24ab	4.71b	3435.04b	695.92a	24.26b	14.84a
					P_3=120 $kgha^{-1}$				
2007-08	10.40 a	4.11 a	6.29 a	39.50 a	4.85 a	3735.42a	524.58c	22.06 c	9.70 c
2008-09	10.91 a	4.36 a	6.70 a	39.94 a	4.89a	3412.92a	532.33 c	22.16 c	9.78 c
Mean	10.65a	4.23 a	6.50a	39.70a	4.87a	3736.67a	528.46c	22.11c	9.74 c
					LSD				
Year1	0.36	0.13	0.23	0.36	0.05	9.77	8.63	0.11	0.12
Year 2	0.42	0.16	0.24	0.18	0.05	8.80	11.38	0.12	0.08

Any two means not sharing a letter differ significantly at (p=0.05)

Note: Year 1 and Year 2 are he LSD values for year 2007-08 and 2008-09 respectively

Table 2. Effect of Zinc application on physiochemical characteristic of wheat.

Zinc levels	Biological Yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Leaf area index	Grain-P content (ppm)	Straw-P content (ppm)	Grain-Zn Content (ppm)	Straw-Zn Content (ppm)
					Zn_1=10 $kgha^{-1}$				
2007-08	9.40	3.68	5.71	39.21	4.67 b	3449.75 a	629.42 a	25.01 c	11.12 c
2008-09	9.94	3.90	5.99	39.24	4.71 b	3493.08 a	637.75 a	25.13 c	11.23 c
Mean	9.67	3.79	5.85	39.23	4.69 c	3471.42 a	633.58 a	25.07 c	11.18 c
					Zn_2=15$kgha^{-1}$				
2007-08	9.53	3.74	5.79	39.21	4.70 b	3423.75 b	619.33 a	26.87 a	12.34 b
2008-09	10.16	3.99	6.15	39.22	4.73 b	3430.92 b	628.25 a	26.97 a	12.39 b
Mean	9,84	3.86	5.97	39.22	4.72 b	3427.33 b	623.67 a	26.97 a	12.36 b
					Zn_3=20 $kgha^{-1}$				
2007-08	9.71	3.82	5.89	39.36	4.76 a	3406.08 c	589.92 b	25.91 b	12.56 a
2008-09	10.33	4.06	6.24	39.21	4.79 a	3412.92 c	599.58 b	26.00 b	12.64 a
Mean	10.02	3.94	6.06	39.28	4.78 a	3409.50 c	594.75 b	25.95 b	12.60 a
					LSD				
Zn_1	Ns	ns	Ns	Ns	0.039	6.73	10.84	0.08	0.08
Zn_2	Ns	ns	Ns	Ns	0.038	10.32	9.83	0.07	0.08

Any two means not sharing a letter differ significantly at ($p=0.05$)

Note: Zn_1 and Zn_2 denote LSD values for year 2007-08 and 2008-09 respectively

Table 3. Effect of combined application of phosphorus and zinc on the performance of wheat

Phosphorus and zinc levels	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Leaf area index	Grain-P content (ppm)	Straw-P content (ppm)	Grain-Zn content (ppm)	Straw-Zn content (ppm)
P_1 Zn_1	9.16	3.54	5.49	38.70	4.57	3166.50g	646.38c	30.39c	10.64f
P_1 Zn_2	9.22	3.58	5.55	38.79	4.59	3112.38i	622.50d	32.72a	11.80e
P_1 Zn_3	9.28	3.60	5.57	38.81	4.63	3130.75h	607.00e	31.62b	12.23d
P_2 Zn_1	9.49	3.72	5.74	39.17	4.68	3511.75d	634.63b	12.50f	13.65c
P_2 Zn_2	9.59	3.76	5.82	39.20	4.71	3411.13e	714.50a	25.22d	15.79a
P_2 Zn_3	9.89	3.89	5.99	39.35	4.75	3382.25f	688.63b	24.08e	15.08b
P_3 Zn_1	10.36	4.12	6.32	39.76	4.81	3736.00b	567.75f	21.33i	9.24i
P_3 Zn_2	10.72	4.25	6.54	39.66	4.85	3758.50a	529.00g	22.91g	9.50h
P_3 Zn_3	10.88	4.33	6.63	39.69	4.95	3715.50c	486.63h	22.16h	10.49g
LSD	ns	ns	ns	Ns	Ns	8.41	9.98	0.07	0.08

Any two means not sharing a letter differ significantly at ($p=0.05$)

Table 4. Net income and benefit cost ratio (BCR) of wheat as affected by different levels of zinc and phosphorus application.

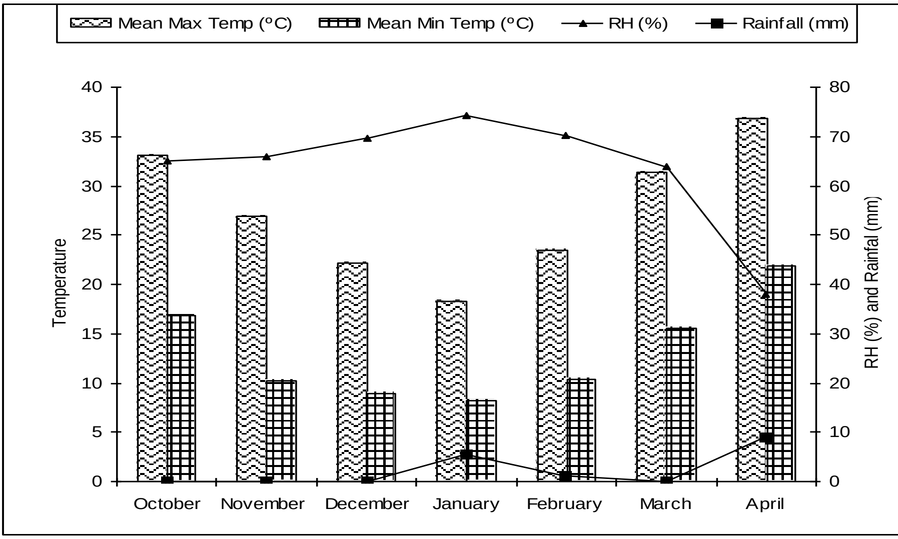
Treatments	Total expenditure (Rupees)	Gross income (Rupees)	Net income (Rupees)	BCR
Year 2007-2008				
P_1Zn_1	23203	34200	10996	1.47
P_1Zn_2	23373	34700	11496	1.48
P_1Zn_3	23543	34900	11696	1.48
P_2Zn_1	24223	36100	12556	1.49
P_2Zn_2	24393	36400	12856	1.49
P_2Zn_3	24563	37700	14156	1.53
P_3Zn_1	25223	40200	14976	1.59
P_3Zn_2	25393	41000	15776	1.61
P_3Zn_3	25563	42000	16776	1.64
Year 2008-2009				
P_1Zn_1	23203	36600	13396	1.58
P_1Zn_2	23373	36800	13596	1.57
P_1Zn_3	23543	37100	13896	1.58
P_2Zn_1	24223	38200	13976	1.58
P_2Zn_2	24393	38800	14576	1.59
P_2Zn_3	24563	40100	15876	1.63
P_3Zn_1	25223	42200	16976	1.67
P_3Zn_2	25393	44000	18776	1.73
P_3Zn_3	25563	44500	19276	1.74

P_1= 60 kg ha^{-1}P_2O_5, P_2=90 kg ha^{-1}P_2O_5, P_3=120 kg ha^{-1}P_2O_5,Zn_1=10 kg ha^{-1} zinc, Zn_2=15 kg ha^{-1} zinc, $Zn_3$240 kg ha^{-1} zinc.

Application of both P and Zn significantly (p=0.05) increased LAI, although the extent of increase was more with the P application. There was a progressive increase in LAI with each increment of P from 60 to 120 kg ha^{-1} P_2O_5 and the maximum values (4.85) were recorded for 120 kg ha^{-1} P_2O_5 against the lowest of 4.58 for 60 kg ha^{-1}P_2O_5. Regarding, Zn levels the maximum LAI (4.76) was observed at 20 kg ha^{-1} Zn. It was followed by 15 kg ha^{-1} Zn (4.70 LAI) and 10 kg ha^{-1} Zn (4.67 LAI), however, these two were statistically at par with each other. The same trend was noted during year 2008-2009 (Table 3).

On an average at any level of P application, increase in Zn level had a negative bearing upon grain-P content. During 2007-2008 the highest grain-P content (3760.25 ppm) was recorded for 120 kg ha^{-1} P_2O_5 with15 kg ha^{-1} Zn and was statistically significant. The minimum grain-P content was observed (3107.00 ppm) with the application of 60 kg ha^{-1} P_2O_5 and 15 kg ha^{-1} Zn (Table 3).

Application of 90 kg ha^{-1} P_2O_5 yielded highest straw-P contents during both the years. The lower and higher levels had a negative influence upon straw-P content. Similarly, Zn application at 20 kg ha^{-1} had the lowest straw-P content during both the years. A significant influence of various combinations of P and Zn on straw-P content was observed for both the years. Data spoke that at higher levels of application, both P and Zn had an antagonistic effect on straw-P content. During 2007-2008 significantly the highest straw-P content (710.25 ppm) was recorded for the crop fertilized with 90 kg ha^{-1} P_2O_5 with 15 kg ha^{-1} Zn. The minimum straw-P content (485.75 ppm) was recorded for 120 kg ha^{-1} P_2O_5 with 20 kg ha^{-1} Zn ha^{-1}. The same trend prevailed during 2008-2009 (Table 3).



(B)

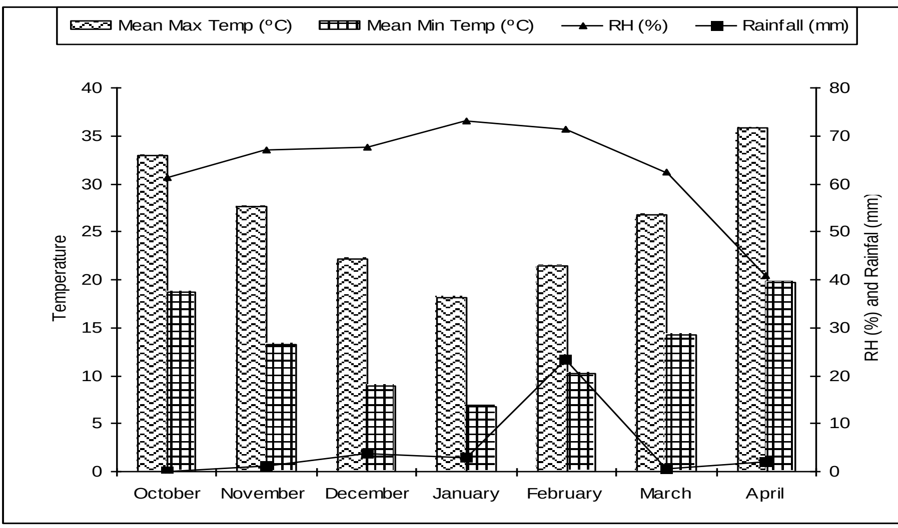


Fig. 1. Meteorological data for growing period of crops during the year 2007-2008(A) and 2008-2009 (B).

The highest value of grain-Zn content (31.52-31.64 ppm) was recorded with the lowest level of P application in these studies for the two cropping seasons (Table 1). Highest grain-Zn content was recorded with the application of 15 kg ha^{-1} Zn for the two seasons (Table 2). The lower (10 kg ha^{-1}) as well as higher (20 kg ha^{-1}) levels of Zn had a negative bearing upon grain-Zn content in these studies. Various combinations of P and Zn levels also significantly influenced grain-Zn content so that during 2007-2008, the crop fertilized at 60 kg ha^{-1} P_2O_5 with 15 kg ha^{-1} Zn accumulated the maximum Zn in grain (32.68 ppm). against the significantly minimum (21.28 ppm) in 120 kg ha^{-1} P_2O_5 with 10 kg ha^{-1} Zn. Similar trend was recorded during 2008-2009 with the highest Zn content in grain at 60 kg ha^{-1} P_2O_5 with 15 kg ha^{-1} Zn and the lowest in 120 kg ha^{-1} P_2O_5 with 10 kg ha^{-1} Zn (Table 3).

The maximum values (14.80-14.87 ppm) were recorded with the application of 90 kg ha^{-1} P_2O_5.during both the years (Table 1). Application of Zn fertilizer had a positive influence on straw-Zn content so that highest values (12.56-12.64 ppm) were noted for 20 kg ha^{-1} Zn (Table 2). Changing levels of both P and Zn had also a significant effect on straw-Zn content for first year of the study. The crop fertilized with 90 kg ha^{-1} P_2O_5 and 15 kg ha^{-1} Zn accumulated significantly higher amount of Zn (15.77 ppm) in straw than all other treatment combinations. However, the minimum Zn content in straw was recorded at 120 kg P_2O_5 and 10 kg ha^{-1} Zn (Table 3).

Net field benefits (NFB): The data indicated that the highest net field benefits (NFB) of Rs. 16776 ha^{-1} were recorded for the crop fertilized at 120 kg ha^{-1} P_2O_5 with 20 kg ha^{-1} Zn. It was closely followed 120 kg ha^{-1} P_2O_5 with 15 kg ha^{-1} Zn with NFB of Rs. 15776 ha^{-1}. The lowest NFB (Rs. 10996 ha^{-1}) was recorded for the crop fertilized at 60 kg ha^{-1} P_2O_5 with 10 kg ha^{-1} Zn. Crop fertilized at 120 kg ha^{-1} P_2O_5 with 20 kg ha^{-1} Zn also gave highest BCR (1.64) while lowest BC (1.47) was recorded for crop fertilized with 60 kg ha^{-1} P_2O_5 with 10 kg ha^{-1} Zn. However, the rest of the treatment combinations intermediated showing a BCR ranging between 1.49-1.53. Similar trend prevailed for the next year.

Discussion

Biological yield varied significantly ($p=0.05$) across both the years with relatively higher values (5.91%) during 2008-2009 than the previous year. Data revealed that phosphorus (P) fertilization had highly significant ($p=0.01$) influence, while zinc (Zn) application did not affect the biological yield of wheat during both the years of experimentation. The interaction of P and Zn was also non significant during both the years. P application enhanced biological yield by an average of 9.5 and 13.5% when its levels were increased to 90 and 120 kg ha^{-1} respectively as against lower level of P application. Variable response of wheat in terms of biological yield has been reported elsewhere (Farmanullah *et al.*, 1989, Hameed,2002, Hussain *et al.*, 2004, 2005a, 2008a, 2008b). Dewal & Pareek (2004) reported an increase in yield attributes with combined application of P, S and Zn that is contrary to these findings.

Likewise the yearly effect on grain yield ha^{-1} was significant and on an average the grain yield was higher by 0.23 t ha^{-1} during 2008-2009 than the previous year. This might be attributed to relatively more favorable environment prevailing during this year. P application had caused a considerable increase in grain yield of wheat during both the years of experimentation in present work. During both the years, there was a yield increase of 11 and 16% with the application of 90 and 120 kg ha^{-1} P_2O_5, respectively over 60 kg ha^{-1} P_2O_5 that recorded an average grain yield of 3.46 t ha^{-1}. Grain yield was positively correlated with leaf area index ($r = 0.75$), leaf area duration ($r = 0.71$), and total dry matter ($r = 0.67$) in these studies (data not shown). Sander and Eghball (1999), Sanjeeve *et al.* (1999) and Hussain *et al.* (2005b, 2008a and b) also concluded that increasing phosphorus levels improved the grain yield of wheat. It suggests that plant vigor and health positively contribute to development of tillers and grains.

Application of P significantly and linearly increased harvest index of wheat crop with maximum HI obtained at higher doses of P, where as Zn and Zn-P interaction did not show significant results. The higher harvest index with the application of P was probably ascribed to better grain development. Promotive effect of high doses of P on harvest index was also reported by Hussain *et al*., (2004, 2008b). Leaf area indices increased slowly up to early February (75 days after sowing) and increased sharply after that probably because of rapid increase in temperature. Maximum values of LAI achieved about 90 days after sowing in all the treatment combinations and during both the years. Thereafter, the LAIs dropped sharply toward crop maturity owing to leaf senescence. Relatively higher average values of LAI were recorded during 2008-2009 crop season showing the year effect to be significant (p=0.05). The average values of present studies are in accordance with reported by Wajid (2004) under similar arid environments in Pakistan. Varying response of wheat regarding LAI to phosphorus and Zn application was also reported by Shukla & Warsi (2000).

Application of P and Zn had highly significant (p=0.05) but opposite bearing upon grain-P content during both the years. The year effect on grain-P content in wheat was significant with relatively higher values recorded during 2008-2009 than the previous crop season values. Phosphorus application linearly increased grain-P content with highest values recorded for 120 kg ha^{-1} P_2O_5 during the two cropping seasons, respectively. Similarly the increasing levels of Zn reduced the grain-P content with minimum being at the highest rates of Zn used in these studies. Various combinations of P and Zn significantly influenced grain-P content. Dewal & Pareek (2004) also concluded that P uptake was reduced at highest level of Zn and Zn uptake was reduced at highest level of P. Promotive effect of Zn on P accumulation in grain at higher phosphorus level is also supported by the findings of Devarajan *et al*., (1980) in pulses, Siddique *et al*., (1999) in cereals and Zhu *et al*., (2001) in wheat.

The year effect on phosphorus content in wheat straw varied significantly (p=0.05) with 1.45% higher straw-P content during 2008-2009. Phosphorus and zinc application levels as well as their combinations had a highly significant (p=0.01) bearing upon straw-P content during both the cropping seasons. An increase in P content in wheat straw at (90 kg ha^{-1} P_2O_5 with 15 kg ha^{-1} Zn) might be due to adequate absorption of P by the plant because of favorable interaction between P and Zn at this level. These results corroborate the findings of Devarajan *et al*., (1980) who reported that application of P increased the P concentration in straw. Similarly the antagonistic effect of P and Zn fertilization on the uptake of both has also been reported by Dewal & Pareek (2004).

Grain-Zn content varied across the years significantly (p=0.05) depicting relatively higher Zn uptake during 2008-2009. Application of P and Zn significantly influenced grain-Zn content for the both seasons. Phosphorus application had an antagonistic effect on grain-Zn content. These results coincide with the findings of Takkar & Randhawa (1978) and Siddique *et al*., (1999) who observed that P exerted a stronger influence on Zn uptake.

Straw-Zn content varied significantly for both the seasons; however, relatively higher uptake was recorded during 2008-2009. Phosphorus application at higher rates had a negative bearing upon straw-Zn content. These results are in consonance with those of Wagar *et al*., (1986) and Zhu *et al*., (2001) who reported that an increase in P caused a significant decrease in Zn uptake by wheat. The data indicated that the highest net field benefits (NFB) were recorded for the crop fertilized at 120 kg ha^{-1} P_2O_5 with 20 kg ha^{-1} Zn.

In conclusion the crop fertilized at 120 kg ha^{-1} P produced the highest grain yield in the both years while Zn application had no significant effect on the grain yield in present studies. The growth and yield parameters studied showed significant differences across the two years suggesting a vital role of agro-climatic conditions on crop productivity.

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(Received for publication 9 May 2010)