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GRAIN YIELD, DRY MATTER ACCUMULATION AND ROOT DEVELOPMENT IN WINTER WHEAT AS AFFECTED BY IRRIGATION LEVELS AND PHOSPHORUS FERTILIZER

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ABSTRACT

This research was carried out to assess the interactive effects of irrigation and phosphorus on root-shoot development, crop growth, development and yield of wheat. The experiment was carried out at Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad during 2011-2012. The experiment was laid in Split Plot Design using three replications. The irrigation treatments in main plots were included I_1: Irrigation at tillering and earing and, I_2: Irrigation at tillering, earing and grain formation stage. Four phosphorus fertilizer levels were; F_1: 0, F_2: 70, F_3: 85 (Recommended), F_4: 100 kg ha^{-1} was placed in sub-plots. Irrigation and phosphorus levels significantly affected the spike length, number of grains spike^{-1}, 1000-grain weight, biological yield and grain yield of wheat. The effect of phosphorus on root development was found significant, where as maximum root development was observed by application of phosphorus fertilizer @ 100 kg ha^{-1}.

Key words: Wheat, growth, grain yield, root development, irrigation, phosphorus fertilizer

INTRODUCTION

Wheat is significantly affected by irrigation and fertilizer availability since their deficiency creates stress, reduces the chlorophyll content in the leaves and decreases the yield. Water shortage due to inadequate water supply in canal irrigated area causes poor grain development and thus results in considerable reduction in crop production. Wheat crop under water deficit conditions decreases crop growth rate (CGR) and yield regardless of the growth stage at which it occurs in arable crops (Siddique *et al.,* 2000; Atteya, 2003).

Maqsood *et al.* (2002) concluded that maximum grain yield was obtained with four standard irrigation at crown root, booting, anthesis and grain filling stage of wheat. Wajid *et al.* (2002) reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. Moreover, Moghaddam *et al.* (2011) reported that maximum yield was obtained when crop was irrigated at all critical growth stages. Deficit irrigation before stem was stage reduced grain yield 5% and 32% grain yield was reduced when no irrigation was applied before flowering stage and 52% grain yield was reduced at no irrigation before grain filling stage by affecting the spikes/m^2, biomass and harvest index.

Phosphorus plays an important role in several physiological processes viz respiration, energy storage, photosynthesis and cell division/ enlargement. It also stimulates root growth and the associated early maturity of crops. It offers increased disease resistance to plants. It prevents from lodging by providing strength to straw. Its deficiency can cause severe stunting and significant yield losses (Haven *et al.,* 1999). Ali *et al.* (1997) reported that P application resulted in a significant increase in number of tillers, plant height, number of grains per spikelet, 1000-grain weight, and grain yield. Zia *et al.* (2000) concluded that wheat grain yield increased with increasing level of phosphorus over control.

Phosphorus depressed grain yield principally by reducing the number of fertile tillers (Memon and Puno, 2005). With the application of phosphorus, the productive tillers of wheat are increased (Sanjeeve *et al.*, 1999). Phosphorus fertilization has great influence on wheat yield and its deficiency has been reported as one of the main reasons for reduced number of tillers (Prystupa *et al.*, 2003). Phosphorus availability seems to have the main influence on wheat ability to differentiate and expand leaves and tillers (Valle and Calderini, 2010). Plant height is a function of crop nutrition, ecological conditions and the genetic makeup. Balanced combination of NPK increased plant height significantly (Hussain *et al*., 2004). Khalid (1995) concluded that application of P at the rate of 75 and 100 kg ha^{-1} produced the tallest plant. On the other hand severe P deficiency depressed shoot growth within 15 days of sowing and ultimately reduced plant height (Elliott *et al.,* 1997).

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The 1000-grain weight makes major contribution to grain yield of wheat and is greatly influenced by ecological conditions and nutrition supply. 1000-grain weight was increased with increase in phosphorus levels (Kinaci, 2000). Memon and Puno (2005) stated that there was a linear increase in 1000-grain weight with increasing levels of super phosphate and urea but up to a certain limit.

Phosphorus is known to stimulate root growth and associated with early maturity of crops and seed formation. The mean values of data revealed that root biomass was significantly different among the different fertilizer levels. Maximum root biomass of 79.52 g m^{-2} was noted in plots receiving highest dose of P followed by plot applied with 120 kg P_2O_5 (61.23 g m^{-2}) and 90 kg P_2O_5 (61.23 g m^{-2}). The minimum root biomass (27.29 g m-2) was noted in plots with no application of Phosphorus. Memon (2001) and Holten (2002) indicated that lower soil Phosphorus concentration early in the season cause a poorly developed root system. Lower root densities as soil Phosphorus level decreased might have affected shoot Phosphorus concentration mostly when the soil P level was low.

Phosphorus and irrigation are important determinants of grain yield in wheat. Present study was designed to investigate the effect of different doses of phosphorus and irrigation levels to determine the suitable combination/level for getting higher yield.

MATERIALS AND METHODS

The investigation on the growth and yield of AARI-2011 wheat variety as affected by different levels of Irrigation and Phosphorus was conducted at Agronomic Research Area, University of Agriculture, Faisalabad. On a sandy loam soil having 0.05% N, 8.8 ppm P_2O_5 and 286 ppm K_2O. The experiment was conducted during the Rabi season 2011-2012. The experiment was laid out according to randomized complete block design with split plot arrangements in three replications. The irrigation frequencies were randomized in the main plots and fertilizer level in the sub plots. The net plot size was 2.0 m x 6.0 m with 22 cm apart rows. The experiment comprised of the following treatments. Two irrigation treatments kept in main plots were; I_1: Irrigation at tillering and earing and, I_2: Irrigation at tillering, earing and grain formation stage. Four phosphorus fertilizer levels P_1: 0 (no phosphatic fertilizer application), P_2: 70 kg ha^{-1} P_2O_5, P_3: 85 kg ha^{-1} P_2O_5 (Recommended), and P_4: 100 kg ha^{-1} P_2O_5 were applied in sub-plots. By planting the wheat variety (AARI-2011) according to above mentioned experimental design, each irrigation level block in main plot was further subdivided into four sub-plots to apply phosphorus fertilizers doses. This deign helped to investigate main effects of irrigation (I) and phosphorus (P) as well as interaction (I×P) effects on wheat yield.

The field was well prepared by giving four cultivations with a tractor mounted cultivator to approximate depth of 22 cm. One planking was given after two cultivations. Wheat crop was sown on December 10, 2012 with a hand drill when the field was at proper moisture level. The seed rate was 125 kg ha^{-1}, while distance between rows was approximately 25 cm is maintained. Nitrogen was supplied from urea and di-ammonium phosphate (DAP); phosphorus (P_2O_5) was provided from DAP and potassium was supplied from Sulphate of Potash (SOP). All nutrients were mixed well in soil at the time of sowing. The crop was kept free of weeds by manual labor to avoid competition between weeds and wheat crop. The crop was harvested on April 30, 2012.

Yield and yield components

Plant Height (cm)

Wheat crop height was measured at maturity from the base of the plant to the tip of the ear. Five plants per subplot were selected randomly.

Number of productive tillers

The tillers were counted in a area of 1 m^2 from every treatment.

Number of grains per spike

The number of grains per spike were counted from five randomly selected spikes.

1000-Grain weight (g)

The samples taken for total biomass were threshed manually for grain yield and 1000-grain weight was recorded.

Biological yield

The crop was harvested from three quadrates of 1 m^2 randomly selected in each subplot. Total biomass was determined and converted to ton. ha^{-1}.

Grain Yield

The samples taken for total biomass were threshed manually for grain yield and converted to ton. ha^{-1}.

Harvest Index (%)

Harvest Index (%) = Grain Yield / Biological yield x 100

Root development

Root length (cm), number of lateral roots, root basal diameter (mm) and root biomass were examined at tillering and maturity stage of the crop. Wheat root samples were taken manually within rows. Roots were washed with the help of root washing systems / manually. Roots were oven dried at 65 °C for 24 hours and then weighed. Root length of samples was measured with the help of Delta T-Scan by carefully putting root sample on the screen of scanner.

The data collected were analyzed by fisher analysis of variance techniques at 5% level of probability and employed to test the differences among the treatments means (Steel and Torrie, 2000).

RESULTS AND DISCUSSION

Plant height

Plant height at maturity was highly significantly influenced by different phosphorus rates (Table 1). All the phosphorus rates differed significantly with one another P_4 (100 kg ha^{-1}) produced the more plant height of 96.60 cm followed by P_3 (85 kg ha^{-1}) which produced 92.17cm of plant height and the lowest was observed in P_1 (0 kg ha^{-1}) which produced the plant height of 84.40 cm. Increase in plant height with phosphorus levels might have been due to balanced fertilizer application at higher levels. Phosphorus deficiency caused stunted plant growth, thin stems and retarded plant development while excessive dose might have reduced the uptake of other nutrients due to which plant height decreased. Memon and Puno (2005) observed the similar results in plant height due to varying phosphorus in combination with nitrogen.

Number of productive tillers per unit area m^{-2}

Number of productive tillers per unit area was significantly affected by different phosphorus levels (Table 1). P_4 (100 kg ha^{-1}) produced more no of productive tillers per unit area (306.67) followed by P_3 (85 kg ha^{-1}) which produced 297.50 number of productive tillers and the lowest was observed in P_1 (0 kg ha^{-1}) which produced 275.0 number of tillers per unit area. Results are in line with those by Jarwar *et al*. (2004) who reported a significant effect of phosphorus in wheat on productive tillers. Increase in total number of productive tillers with phosphorus levels might be due to balanced fertilizer applications at higher levels which resulted in better plant growth.

Number of grains per spike

Number of grain per spike was significantly affected by different irrigation levels (Table 1). I_2 (Tillering + Earing + Grain formation) produced more number of grains per spike of 46.62 and the lowest was observed in I_1 (Tillering + Earing) which produced 40.85 number of grains per spike. . Number of grains per spike was also significantly affected by different rates of phosphorus fertilizer. Application of 100 kg ha^{-1} phosphorus (P_4) produced significantly more number of grains per spike which was 46.97 followed by (P_3) 85 kg ha^{-1} which produced 46.17 number of grains per spike. However no application of phosphorus (0 kg ha^{-1} P_2O, P_1), showed the lowest (39.30) number of grains per spike. The number of grains per spike increased with increase in phosphorus level, mainly due to more number of spikelets per spike and greater spike length. Alam *et al*. (2003) reported the same trend in their results that the number of grains per spike increases with the application of phosphorus level.

1000-grain weight (g)

1000-grain weight was significantly affected by different irrigation levels (Table 1). I_2 (Tillering + Earing + Grain formation) produced heavier grain of 39.87g and the lowest was observed in I_1 (Tillering + Earing) which showed 36.18g of 1000-grain weight. The above mentioned results are in close agreement with Singh *et al*. (1980). 1000-grain weight was also significantly affected by different phosphorus rates. Application of phosphorus 100 kg ha^{-1} (P_4) produced significantly higher grain weight of 42.36g followed by (P_3) 85 kg ha^{-1} which showed 40.85g of 1000-grain weight. However no application of phosphorus (P_1) showed the lowest grain weight of 33.73g. Kinaci (2000) reported similar results that the 1000-grain weight was increased with increase in phosphorus level.

Biological yield per hectare (kg)

Biological yield was significantly affected by different irrigation levels (Table 1). I_2 (Tillering + Earing + Grain formation) produced highest biological yield of 10102.78 kg ha^{-1} and the lowest was observed in I_1 (Tillering + Earing) which showed 9518.06 kg ha^{-1} of biological yield. Qiu *et al.* (2008) reported that biomass levels were positively related with water use efficiency. Biological yield was also significantly affected by different rates of phosphorus fertilizer. Application of phosphorus @ 100 kg ha^{-1} (P_4) produced the highest biological yield of 10602.78 kg ha^{-1} followed by application of (P_3) 85 kg ha^{-1} which produced biological yield of 10102.78 kg ha^{-1}. While the application of phosphorus (P_1) 0 kg ha^{-1} showed the lowest biological yield of 9019.44 kg ha^{-1}. Korkmaz *et al*. (2010) concluded that application of phosphorus enhances seed germination, early growth, root development and also enhances response to mineral N fertilizer application. That is why with each increase in phosphorus level up to 120 kg ha^{-1}, the biological yield was increased. Pareek, (2004) also reported that the biological yield was increased with increase in phosphorus level.

Grain yield per hectare (kg)

Grain yield per hectare was significantly affected by different irrigation levels (Table 1). I_2 (Tillering + Earing + Grain formation) produced highest grain yield of 4029.17 kg ha^{-1} and the lowest was observed in I_1 (Tillering + Earing) which showed 3677.78 kg ha^{-1} of grain yield per hectare. These results substantiate the findings of Wajid *et al.* (2002). They reported that wheat yield increased with increasing number of irrigations. Grain yield was also significantly affected by different rates of phosphorus fertilizer. Application of phosphorus @ 100 kg ha^{-1} (P_4) produced the highest grain yield of 4277.78 kg ha^{-1} followed by application of (P_3) 85 kg ha^{-1} which produced grain yield of 4033.33 kg ha^{-1}. While the application of phosphorus (P_1) 0 kg ha^{-1} showed the lowest grain yield of 3430.56kg ha^{-1}.

Harvest index

Harvest index was significantly affected by different irrigation regimes (Table 1). I_2 (Tillering + Earing + Grain formation) produced highest harvest index of 39.80 ha^{-1} and the lowest was observed in I_1 (Tillering + Earing) which showed 38.60 ha^{-1} of harvest index. Harvest index was also significantly affected by different rates of phosphorus fertilizer. Application of phosphorus @ 100 kg ha^{-1} (P_4) produced the highest harvest index of 40.31 ha^{-1} which is statistically at par with P_3 (85 kg ha^{-1}) followed by phosphorus at the rate 70 kg ha^{-1} that produced the harvest index of 38.57 ha^{-1}. While no phosphorus addition showed the lowest harvest index (38.03 $ha^{-1)}$.

ROOT DEVELOPMENT

Root Length (cm)

Phosphorus significantly affected the growth of root length (Table 2). Maximum root length (175.92 cm) was observed where at high rate of phosphorus fertilizer was applied (P_4) @ 100 kg ha^{-1} and it is statically same with P_3 @ 85 kg ha^{-1}. With application of phosphorus (P_1) @ 0 kg ha^{-1}, plants produced root length of 102.65 cm which showed decline of 42 % as compared to P_4 treatment. The effect of irrigation levels was non-significant in case of root length. These results are in agreement with Rosolem *et al.* (1994), who reported that P fertilization increases root length and biomass.

Number of lateral roots

Irrigation levels had no significant effect on number of lateral roots (Table 2). Application of different rates of phosphorus fertilizers showed significant effect on number of lateral roots. Maximum number of lateral (12.17) roots was produced where phosphorus fertilizer (P_4) applied @ 100 kg ha^{-1} fallowed by (P_3) @ 85 kg ha^{-1} which produced 10 lateral roots. Minimum number of lateral roots (6.33) produced where Phosphorus (P_1) applied @ 0 kg ha^{-1} (Table 2). Borch *et al.* (1999) reported that low phosphorus application reduced lateral root number and sustained main root elongation, resulting in decreased lateral root density in phosphorus-deficient plants.

Root diameter (mm)

Root diameter not differed significantly among various irrigations and phosphorus levels (Table 2). Phosphorus application @ 85 kg ha^{-1} (P_3) produced maximum 3.95 mm diameter. These results are same with Mollier and Pellerin (1999). They reported that there was no significant effect of Phosphorus deficiency on root basal diameters.

Table 1. Effect of different irrigation and phosphorus levels on the yield and yield components of wheat.

Treatments	Plant height (cm)	Productive tillers m^{-2}	No. of grains $spike^{-1}$	1000-grain wt. (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Irrigation levels							
I_1	93.28^{ns}	288.33^{ns}	40.85b	35.45b	9518.06b	3677.78b	38.60b
I_2	86.83^{ns}	294.17^{ns}	46.62a	39.18a	10102.78a	4029.17a	39.80a
LSD at 5%			2.8711	2.4463	4.303	53.116	0.4349
Phosphorus levels							
P_1	84.40b	275.00b	39.30c	32.75b	9019.44d	3430.56d	38.03c
P_2	87.07b	285.83ab	42.50b	33.64b	9516.67c	3672.22c	38.57b
P_3	92.17a	297.50a	46.17a	40.62a	10102.78b	4033.33b	39.90a
P_4	96.60a	306.67a	46.97a	42.26a	10602.78a	4277.78a	40.31a
LSD: $P\leq.0.05$	4.9089	21.687	2.3263	1.9301	2.179	37.635	0.4408
Interaction (I×P)	NS						

NS: non-significant, Means followed by different letters are significant at $P\leq.0.05$

Table 2. Effect of different irrigation and phosphorus levels on root development of wheat.

Treatments	Root length (cm)	No. of lateral roots	Root diameter (mm)
Irrigation levels			
I_1	136.88^{ns}	9.58^{ns}	3.49^{ns}
I_2	137.69^{ns}	8.83^{ns}	3.70^{ns}
LSD at 5%			
Phosphorus levels			
P_1	102.65b	6.33d	3.47^{ns}
P_2	111.13b	8.33c	3.84^{ns}
P_3	159.45a	10.00b	3.95^{ns}
P_4	175.92a	12.17a	3.13^{ns}
LSD at 5%	17.264	1.5619	
Interaction (I×P) NS			

NS: non-significant, Means followed by different letters are significant at $P\leq.0.05$

CONCLUSION

It can be concluded that for attaining maximum growth and grain yield of wheat crop it should be irrigated 3 times at tillering, earing and grain formation with the recommended dose of P @ 85 kg ha^{-1} under agro-ecological conditions of Faisalabad. Root development parameters were significantly higher @ 85 kg ha^{-1} of P.

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