Available online at http://www.journaldynamics.org/jdar
Journal of Dynamics in Agricultural Research Vol. 3(4), pp.46-52, December 2016.
Article ID: JDAR/JDYA42677627

ISSN: 2488-9776

Original Research Paper

Effect of Phosphorus Fertilizer Application on Some Yield Components of Wheat and Phosphorus Use Efficiency in Calcareous Soil

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Received 20 October, 2016; Accepted 8 December, 2016; Available on-line 15 December, 2016.

ABSTRACT

The current study was conducted during winter 2014. The treatments included different phosphorus fertilizer rates (0, 150, 200 and 250 kg P_2O_5 ha^{-1}). The experimental units were arranged using Randomized Complete Block Design (RCBD) with three replicates. Results indicated that most of the yield components of wheat were found to be significantly affected. Moreover, the results revealed that chlorophyll content in the leaf; protein content (%), grain N(%), and P (%) were also affected significantly. The data further revealed that the maximum P uptake by wheat grain (11.70) kg ha^{-1} was recorded from T_4 while the minimum (3.30 kg ha^{-1}) in control. However, the lower phosphorus use efficiency (PUE) was seen at higher P application rates. The grain P physiological efficiency index (PEI) was influenced by the rate of P application. The lowest value of PEI (0.46 kg g^{-1}) was found from T_4 while the highest value was (1.55 kg g^{-1}) found from control. Results indicated that the use of soil P fertilizer had a beneficial effect on phosphorus use efficiency (PUE).

Keywords: Wheat yield components, Phosphorus fertilizers, Phosphorus use efficiency, Calcareous soil.

INTRODUCTION

Wheat (*Triticum aestivum* L) is one of the most important cereal grain crops for human nutrition due to high protein content (9% - 15%) and has been cultivated in calcareous soil in the arid and semi-arid region as well as in Kurdistan Region of Iraq.

The high yield potential of modern wheat cultivars required high supplying phosphorus fertilizer (Clark, 1990); phosphorus plays a vital role in the storage and transfer of energy within the cells, speeds up root development, and higher grain protein content. Phosphorus is an essential nutrient required by the plant for normal growth in the semiarid region of the Kurdistan Region of Iraq, because most of the agricultural soil in Kurdistan region suffer from severe P deficiency. Phosphorus deficiency is a common soil problem in the area having a calcareous nature. It is, therefore, imperative to manage it properly to achieve maximum benefits (Malik *et al*., 1992). More than 80% of added P to such soil will be fixed, and only a part of it get dissolved in the soil solution which may be either taken up by plants or precipitates (Leytem and Mikkelsen, 2005). The efficiency for phosphorus fertilizer uses by plants ranged from 10 to 30% for applied fertilizer P yearly, the remaining 70 to 90% becomes part of the fixed P pool in the soil (Malhi *et al*., 2002).

The release of P adsorbed on the solid phase of the soil into soil solution is very slow, and consequently, phosphorus fertilizer efficiency remains low in calcareous soil (Delgado *et al*., 2002). The reaction of phosphate in the soil has an important contribution to crop growth and fertilizer use efficiency (Sushanta *et al*., 2014). The availability of P to crops for uptake and utilization is a decline in alkaline and calcareous soil due to the decreases of solubility calcium phosphate minerals (Al Harbi *et al*., 2013). The formation of insoluble compounds due to soil chemical reactions limits the plant available P making phosphate fertilization use efficiency very low by crops (Barber, 1995). The difference in P uptake involves the difference in changing rhizosphere pH, release of organic compounds, and root surface area (Lynch and Brown, 2001; Gahoonia and Nielsen, 2004).

The most important factors controlling the availability of P to plant roots are its concentration in the soil solution and the P-buffer capacity of the soil, the rate of desorption of P from the solid phase of the soil, which is faster in soils with a high buffer capacity. Also important are the size of the root system and the extent to which roots grow into the soil, and the efficiency with which roots take up P (Syers *et al*., 2008).

The purposes of the present study are to investigate the effect of phosphorus fertilizer application rates on wheat grain yield, yield components of wheat and phosphorus use efficiency in calcareous soil**.**

MATERIALS AND METHODS

Experimental Design

The present study was conducted at the Faculty of Agricultural Research Farm, University of Sulaimani, Bakrajo, Kurdistan Region of Iraq. (35°32' 4'' N and 45°21'' 53'' E 785 m. a.s.l.) During winter growing season of 2014, the soil was uniform and highly calcareous in nature. Phosphorus application to the soil was as triple super phosphate (TSP) 45% P_2O_5. The treatments including T_1 = 0, T_2 =150, T_3 = 200 and T_4= 250 kg P_2O_5 ha^{-1} were applied to the soil at the time of sowing. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replicates, net plot size of 3m x 2m and the distance between the experiment units was 1meter while the distance between blocks was 2meters. The wheat variety *Semito* was sown on 12th November during winter growing season 2014 using a seeding rate of 140 kg ha^{-1}. The nitrogen and potassium fertilizers were applied at the rate of 200 kg N, and 150kg K_2O ha^{-1} as urea, and potassium sulfate, respectively. The nitrogen and potassium fertilizers were applied in all treatments, through broadcast at the time of sowing. The manual practices were used for weed control. The crops were harvested at maturity on 4th July 2015 (eight months after sowing).

Sample Collection and Physicochemical analysis

Soil samples were taken from (0 -30 cm) of the soil used in the field experiment and were prepared for some physical and chemical analysis. Soil particle size distribution was determined by the pipette method according to Gee and Bauder (1986). The Electrical conductivity (Ec_e) and soil reaction (pH) were measured for the soil saturation extract with an EC meter, model (HI 2314) and pH meter (HANA), model (HI 83141), respectively. Some cations and anions in the soil saturation extract were determined according to the soil analysis methods described by Page *et al.* (1982). The organic matter (O.M.) content was determined by dichromate oxidation (Walkley and Black procedure) as described by Nelson and Sommer (1986). Cation exchange capacity (CEC) of the soil particles was obtained by saturating the soil sample with 1*M* ammonium acetate (NH_4OAc) at pH 8.1 as an extraction solution according to the method described by Suarez (1996). Total calcium carbonate ($CaCO_3$) in the soil, was determined by a rapid titration method according to Rayment and Higginson (1992). The active lime or active equivalent of $CaCO_3$ (AECC), which is a fine particle size calcite, was estimated by the 0.5 *M* NH_4-oxalate method as described by Drouineau (1942). The available phosphorus concentration from the soil samples was determined by extracting the samples with 0.5 *M* $NaHCO_3$ (Olsen *et al*., 1954). The data are shown in Table 1.

After harvesting, the plant samples were dried at 70^{o}C; the dried samples were grounded and after grinding the sample should be thoroughly mixed and stored for analysis. Grinding apparatus was cleaned after grinding each sample by using a brush or vacuum system (Yash, 1998).

Wet digestion was used for destruction of organic matter, acids that have been used in these procedures include sulfuric (H_2SO_4), and Hydrogen peroxide (H_2O_2) which was also used to enhance reaction speed and to complete the digestion.

Measurement Parameters

The measurement parameters comprises most of the yield components of wheat such as plant height (cm), grain yield (ton ha^{-1}), biological yield (ton ha^{-1}), the number of spike per square meter, spike length (cm), the number of spikelet per spike and number of grain per spike.

Harvest Index (HI%)

Harvest index (HI)(%) was calculated by using the following formula:

Table 1. Some physical and chemical properties of soil used in a field experiment.

Properties		Location
		Bakrajo
Particle Size Distribution(PSD) g kg^{-1}	Sand	75.40
	Silt	518.40
	Clay	406.20
Texture Class		Silty Clay
pH		7.52
ECe dS m^{-1} at 25°C		0.33
Soluble ions mmol L^{-1}	Ca^{2+}	2.20
	Mg^{2+}	0.58
	Na^{+}	0.49
	K^{+}	0.09
	HCO_3^{-}	2.34
	Cl^{-}	0.40
	SO_4^{2-}	0.88
O. M. g kg^{-1}		19.00
CEC $cmol_c$ kg^{-1}		47.00
Available P mg L^{-1}		36.55
$CaCO_3$ equivalent g kg^{-1}	Total	327.00
	Active	117.00

$$\text{Harvest index}\ (\%) = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100 \qquad (1)$$

Phosphorus Uptake by Grain

Total P uptake by grain was calculated using the following formulae:

$$\text{P uptake by grain}(kg\ ha^{-1}) = \frac{\text{P content}(\%)\text{in grain x Grain yield}\ (kg\ ha^{-1})}{100} \qquad (2)$$

Phosphorus Use Efficiency

The phosphorus use efficiency (PUE): The efficiency of phosphorus was calculated according to the equation described by Doberman (2005):

$$Phosphorus\ Use\ Efficiency\ (PUE) = \frac{Wheat\ grain\ yield(kg\ ha^{-1})}{Fertilizer\ applied\ (kgP_2O_5ha^{-1})} \qquad (3)$$

Grain Protein Content (%)

Grain protein contents were estimated as described by Merrill and Watt (1973) Protein contents were calculated by multiplying nitrogen with a factor of 5.70.

Nutrient Physiological Efficiency Index (PEI)

Nutrient Physiological Efficiency Index (PEI) (kg g^{-1}): was calculated by the formulae as described by Ghulam *et al.*(2005):

$$Nutrient\ Physiologycal\ Efficiency\ Index(PEI)(kg\ g^{-1}) = \frac{Grain\ yield\ (kg\ ha^{-1})}{uptake\ of\ nutrient\ (g\ ha^{-1})}$$
(4)

Statistical Analysis

Statistical data analysis like pair-wise comparison (Duncan's multiple range test) was performed by XLSTAT version 7.5 (Addinsoft, 2007).

RESULTS AND DISCUSSION

Yield Components

The different phosphorus application rates had a significant effect on some yield components of wheat (Table 2). Grain yield (ton ha^{-1}) remained unchanged in all

Table 2. Effect of different levels of Phosphorus application to the soil on yield and yield components of wheat at maturity.

Treatments	Plant height (cm)	Grain yield ton ha^{-1}	1000 Grain weight (g)	Biological yield ton ha $^{-1}$	Number of Spike/m^2	Spike length (cm)	Number of Spikelet/Spike	Number of Grain/ Spike	Harvest index%
T_1	104.333^b	5.017^a	34.300^b	14.657^b	419.333^b	10.233^a	18.667^a	56.000^a	34.310^a
T_2	108.333^{ab}	4.677^a	36.300^b	15.050^b	476.667^{ab}	9.333^a	18.333^a	55.000^a	31.143^b
T_3	110.000^a	5.513^a	39.600^a	17.840^a	520.667^{ab}	10.433^a	19.333^a	58.000^a	30.907^b
T_4	112.333^a	5.163^a	36.900^{ab}	16.483^{ab}	572.333^a	9.400^a	18.000^a	54.000^a	31.550^b

Means of each category followed by different letters are significantly different at ($p \leq 0.05$).

phosphorus application rates. Likewise, P application rates also had a non-significant effect on spike length (cm), the number of spikelets per spike and grain per spike. These results are identical to the results obtained by Abdur *et al*., (2012). They reported that the P application rates and methods had a non-significant effect on grain yield, and numbers of grain per spike and the results disagree with the results reported by Shuaib *et al*.,(2009). They found that the application of phosphorus fertilizer showed a significant difference in grain yield of wheat.

Plant Height (cm)

The plant height of wheat was affected by various P application rates. Statistical analysis of data (Table 2) indicated, that there was a significant difference between both of T_3, T_4, with the control treatment, the plant height was increased from 104.30cm to 112.30cm from control to T_4, respectively. The results are in confirmation with the findings of Alam *et al.,*(2003), who reported that the plant height significantly increased with increasing of application rates of phosphorus fertilizer to the soil.

1000-Grain Weight (g)

The data analysis for 1000- grain weight of wheat (Table 2) showed that there was a significant difference between T_3 and both T_1 and T_2 at ($P \leq 0.05$). The results are identical with those proposed by Rahim *et al*.,(2010). They found that 1000-grain weight of wheat increased significantly with increasing P rate application.

Biological Yield (ton ha^{-1})

The Biological yield of wheat was influenced by various P application rates significantly. Statistical analysis of data (Table 2) indicated that there was a significant difference between T_3 and both T_1 and T_2 at ($P \leq 0.05$). These results confirm the findings of Pawel (2013), who indicated that the biological yield production of winter wheat increased with P fertilizer rate applications compared to the control.

Number of Spike Per Square Meter

One of the most important yield determination is the number of spike per square meter which is affected by various factors including balanced nutrition. Statistical analysis of the mean variance illustrated (Table 2) the number of spike per square meter was affected by P application rate, there was a significant difference between T_4 and T_1 at ($P \leq 0.05$). These results were congruent with the finding by El-Gizawy (2009), who deducted that the spikes/m^2 is increased by increasing N and P fertilizer level applications.

Harvest Index (HI%)

The statistical analysis of data (Table 2) showed that the P fertilizer application had no significant effect on the value of harvest index. The highest value of harvest index was 34.31% for the control, and the lowest value was 30.907% for T_3. All the treatments showed more or less similar behavior for HI. These results are identical to what is found by Ghulam *et al*., (2005). They reported that HI did not reach the level of significance.

Chlorophyll Content in The Leaf

The statistical analysis of variance of the data indicated that a significant difference was present between T_3 and T_1 at ($P \leq 0.05$) (Table 3). The results corroborate with the finding of Alam and Shereen (2002); Biljana and Stojanovic (2005). They found that the chlorophyll contents were increased in fertilized soil by the different levels of phosphorus fertilizer application to the soil.

Nitrogen % and Percent Grain Protein Content

Analysis of variance showed that the phosphorus fertilizer application to the soil affected significantly ($p \leq 0.05$) the nitrogen and protein content in grain, the data revealed that the highest mean values (1.50% and 8.50%) of nitrogen and protein content respectively were recorded in T_4 in comparison with all other treatments

Table 3. Effect of different levels of Phosphorus application to the soil on some parameters of wheat at maturity.

Treatments	CCI/ Plant	N%	Protein%	P%	Grain P uptake (kg ha^{-1})	PUE (kg kg^{-1}) P_2O_5	PEI (kg g^{-1})
T_1	35.757^{b}	0.840^{b}	4.790^{b}	0.067^{c}	3.333^{c}	0.000^{d}	1.547^{a}
T_2	39.577^{ab}	0.980^{b}	5.737^{b}	0.103^{bc}	4.827^{bc}	31.177^{a}	0.967^{b}
T_3	46.177^{a}	1.120^{ab}	6.537^{ab}	0.151^{b}	8.363^{b}	27.567^{b}	0.717^{bc}
T_4	43.377^{ab}	1.493^{a}	8.513^{a}	0.226^{a}	11.693^{a}	20.653^{c}	0.460^{c}

*Means of each category followed by different letters are significantly different at ($p \leq 0.05$).
*CCI: Chlorophyll Content Index,*PUE: Phosphorus Use Efficiency,*PEI: Nutrient Physiological Efficiency Index.

(Table 3).Similar results were obtained by Rahim *et al.*(2010), who reported that protein content in wheat grains increased at each increment of fertilizer P.

Grain P Concentration (%)

The analysis of data (Table 3) indicated that P concentration in grain of wheat was affected by the levels of P application to the soil. It was increased significantly with increasing P application rate (250 kg P_2O_5 ha^{-1}) to the soil. Higher P concentration of 0.23% in wheat grain was obtained in T_4 as compared to 0.07% in T_1.The results were in agreement with the results finding by Rahim *et al.,*(2010), they found that the higher P concentration of 0.201% in wheat grain was obtained with 111 kg P_2O_5 ha^{-1} as compared with 0.113% in control.

Grain P Uptake

Results revealed that the different levels of P application to the soil increased P uptake by grain over the control. The maximum P uptake by grain wheat 11.70 kg ha^{-1} was recorded from T_4 while the minimum (3.30 kg ha^{-1}) grain wheat uptake P in control (Table 3). These results are in agreement with the results found by Sushanta *et al.*, (2014), who found that the total P uptake by wheat increased with increasing P fertilizer application.

Phosphorus Use Efficiency (PUE) (kg kg^{-1})

Data of Phosphorus use efficiency (PUE) of wheat (Table 3) indicated that lower PUE was seen at higher P rates application. The maximum PUE of 31.20 kg kg^{-1} P_2O_5 was observed at 150 kg P_2O_5 ha^{-1}, and it decreased significantly at higher Phosphorus rates application (250 kg P_2O_5 ha^{-1}). These results were in agreement with finding by Rahim *et al.*,(2010); they found that PUE of wheat decreased significantly at higher Phosphorus rate.

Grain P Physiological Efficiency Index (PEI)

Phosphorus Physiological Efficiency Index (PEI) tells about the absorption, accumulation and utilization of P for grain production. The results clearly indicate that PEI for P was influenced by the rate of phosphorus application (Table 3). The lowest value of PEI for P (0.46 kg g^{-1}) was found from T_4 while the highest value (1.55 kg g^{-1}) was found from control.These results agreed with the finding by Ghulam *et al.*(2005). They found that the grain P physiological efficiency index(PEI) decreased with increasing rate of phosphorus fertilizer application.

CONCLUSION

The presented results indicated that the use of soil P fertilizer had a beneficial effect on phosphorus use efficiency (PUE). There is a need for further treatment using various soil phosphorus levels near 250 kg P_2O_5 ha^{-1} to determine the exact optimum level of soil applied P fertilizer for other grain crops in Kurdistan. The optimal level of soil applied P fertilizer had the lowest efficiency in calcareous soil.

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How to cite this article:

Ghafoor Ahmed Mam Rasul (2016).Effect of Phosphorus Fertilizer Application on Some Yield Components of Wheat and Phosphorus Use Efficiency in Calcareous Soil. J. Dyn. Agric. Res.,3(4):46-52.