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Eco-Physiological Study of the Effect of P Levels and Coated P Fertilizers on the Wheat Grain Yield (*Triticum aestivum* L.), Dirab, Riyadh, Saudi Arabia

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Abstract

The soils in the Kingdom of Saudi Arabia suffer from severe P deficiency. This is attributed to the high soil pH due to the presence of calcium carbonate. Under such conditions, the utilization of fertilizer P by plants is generally very low due to sorption of P by soils. The objectives of this study were to assess the suitability of coating of P fertilizer along with soil P application on available soil P content and wheat yield in calcareous soil. Soil application rates of P (0, 150, 300 and 450 kg ha^{-1}) as di-Ammonium phosphate (DAP) applied just before sowing. Coating types included (No coated, humic acid with different %, bitumen emulsion and bitumen emulsion+ 5% clay). The results indicated that, application of different rates of soil P has a significant effect on the available P soil content. The available P reached 18.9, 31.0, 36.0 mg kg^{-1} under application of 150, 300 and 450 kg DAP ha^{-1}, respectively. The results showed addition of 300 kg DAP ha^{-1} resulted in high content of available soil P and no need for further application of P fertilizer. The coated DAP fertilizer with HA, bitumen emulsion and bitumen emulsion+ clay did not increases the available P in soil compared with no coated. Under current experiment, coating of P fertilizer by HA, bitumen emulsion and bitumen emulsion+5% clay along with medium rates of soil P fertilizer may contribute to improve P fertilizer efficiency and increase wheat grain yield cultivated in calcareous soil.

Keywords: Phosphorus use efficiency; calcareous soil; available phosphorus; coating materials.

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1. Introduction

Phosphorus (P) is the second most limiting plant nutrient after nitrogen. It is vital for plant development and nutrition due to its significant involvement in many physiological processes during plant growth and development. Therefore, it is a crucial nutrient that is not substitutable, and its supply is necessary to sustain agricultural productivity to meet the world's growing population demand of food, feed and fiber. It is unlike N, it cannot be fixed from the atmosphere, and its obtainment is mainly through mining [1[. Phosphorus availability is generally low in most of soils due to its association with soil constituents forming other P compounds that are of low solubility and availability for plant uptake [2, 3]. Approximately two thirds of the world's agricultural soils are P deficient [4]. This represents a challenge for agricultural system as P deficiency has an adverse impact on crop yield. It is therefore compulsory to supply adequate P to meet crop's need of this nutrient. This commonly occurs through application of P fertilizers. However, P fertilizers are mined from rock phosphate, a finite resource whose availability is estimated to decline [5]. This requires efficient use of P fertilizers to ensure that sufficient amount of the nutrient is provided and to avoid excessive use of fertilizers that can lead to environmental degradation. Therefore, a proper management of P fertilization is required.

Phosphorus use efficiency is governed by several factors, such as soil chemical and physical properties in addition to agricultural management practices. In particular, fertilizer P efficiency in Saudi Arabia agricultural soils is very low ranging from 10-15%. This is attributed to the high content of free $CaCO_3$, low organic matter and light texture. Therefore, there is a growing interest in finding an effective approach to improve P fertilizer use efficiency. Soils of Saudi Arabia are mostly coarse textured and characterized by low available P and high amounts of $CaCO_3$ and low organic matter content. Under such conditions the utilization of P by plants is generally very low due to the fixation and adsorption of P by soils. The availability of P to plants for uptake and utilization is impaired in alkaline and calcareous soil due to the formation of poorly soluble calcium phosphate minerals. The formation of insoluble compounds due to soil chemical reactions limits the plant available P making phosphate fertilization use efficiency very low by crops [6]. Available P in calcareous soil was negatively correlated to the amount of $CaCO_3$ [7] Application of P fertilizers in agricultural calcareous soils has introduced some problems mainly due to P fixation, low recovery and accumulation in soil. Information on the chemical forms of P is fundamental to understanding P dynamics and its interaction in calcareous soils that is necessary for management of P. **Recently, [8] found that,** with increasing the time of incubation, P availability in some Saudi Arabia calcareous soil significantly decreased for both organic compost and chemical P fertilizer and the most critical time of incubation is the first week. In this time the soil loses almost 50% of the added P. Availability of the P is directly affected by the chemical and physical properties of soils [9]. It is thought that coating of P fertilizer could reduce the negative impact of some soil properties [10]. Previous studies indicated that the positive response of foliar application of P in wheat and corn yields [11]. Therefore, the objectives of this study were to assess the suitability of coating of P fertilizer along with soil P application on available soil P content and wheat yield in calcareous soil.

2. Materials and Methods

2.1 Experimental design

Field experiment site was carried out at Agricultural Experimental and Research Farm at Dirab, Riyadh, Kingdom of Saudi Arabia. The soil was air-dried, ground and passed through a 2-mm sieve. Some physical and chemical properties of the soil are presented in Table 1.

Table 1: Soil physical and chemical properties used for wheat cultivation

Available elements (mg kg^{-1})			pH	EC	CaCO3	OM	Particle Size Distribution		
N	P	K		(dS m^{-1})	%	%	Clay%	Sand%	Silt%
4.90	2.65	312	8.1	2.90	31.2	0.29	9.10	81.5	9.40

2.2 Soil and coating material

Soil application levels of P (0, 150, 300 and 450 kg ha^{-1}) as Di-Ammonium Phosphate (DAP) applied just before sowing. Nitrogen @ 170 kg N ha^{-1} as urea was applied to all the treatments in five equal splits during the growth stage. Potassium was applied @ 25 kg K ha^{-1}as foliar on three equal splits. Coating material included (No coated, Humic acid (HA5%, HA10%, bitumen emulsion and bitumen emulsion + 5% clay). Humic acid was obtained from previous experiment [12]. A completely randomized block design (CRBD) with three replications was used. The winter wheat variety *Triticum aestivum* L. (Yecora rojo) planted in November. Uniform cultural practices were carried out to each treatment plot throughout the crop growth period.

2.3 Plant, soil sampling and P determination

Plant samples were harvested after 90 days after sowing and dry weight recorded. Plant samples digested with mixture of concentrated acids and then, total P concentration measured [13] using spectrophotometer. Soil samples also were collected after harvesting and analyzed for available P.

2.4 Statistical analysis

The collected data were analyzed statistically and the significant ($P<0.05$) differences among the mean was analyzed by the SAS statistical.

3. Results and Discussion

3.1 Available Soil P

The application of different rates of P applied has a significant effect on the concentration of available P soil content (Figure 1). The available P reached 18.9, 31.0, 36.0 mg kg^{-1} under application of 150, 300 and 450 kg DAP ha^{-1}, respectively. The lowest available P was recorded under control (2.70 mg kg^{-1}). Application of 150 kg DAP ha^{-1}, resulting in 600% increase over control. The amount of fertilizer required to maintain the initial soil test can be determined graphically by plotting soil test level as a function of the applied fertilizer rate[14]. In the present work, the amount of fertilizer required to maintain the soil P test at 10 mg kg^{-1} (the minimum required available) in the studied soil was estimated to be 280 kg DAP ha^{-1}. This value was less than the value reported by [9] on the calcareous soils of Saudi Arabia [15, 16]. The results showed additions 300 kg DAP ha^{-1} in resulted in high content of available soil P and no need for further application more P fertilizer. These results are in agreement with those reported [17]. Figure 2 shows the effect of coating types of DAP fertilizer on availability of P in soil. The highest available P in soil was observed under control (no P coated), however the coated DAP fertilizer with HA, bitumen emulsion and bitumen emulsion+ clay did not increases the available P in soil compared with no coated. Similar results were reported by [18] who indicated that coating of P fertilizers with S had a negative effect on P uptake and productivity of maize.

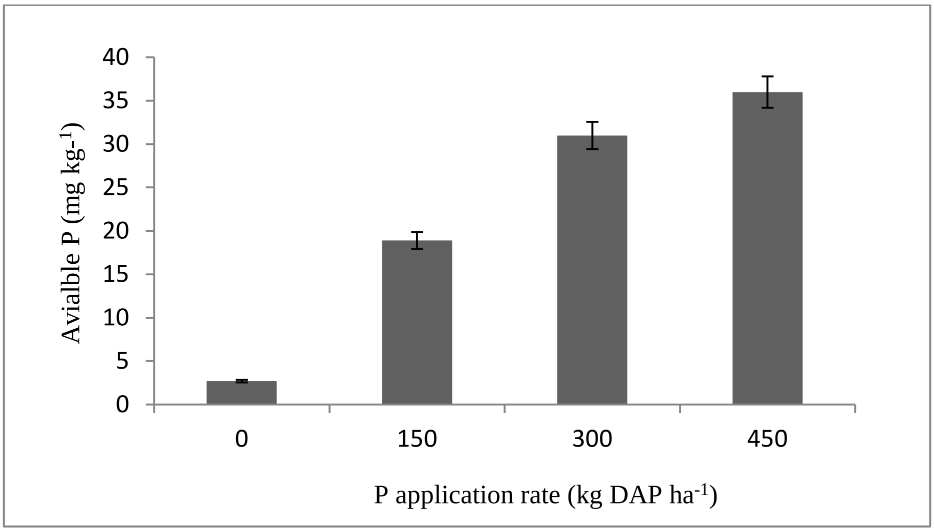

Figure1: Effect of soil P application on available P. Vertical bars indicated ±standard error (SE, N=4)

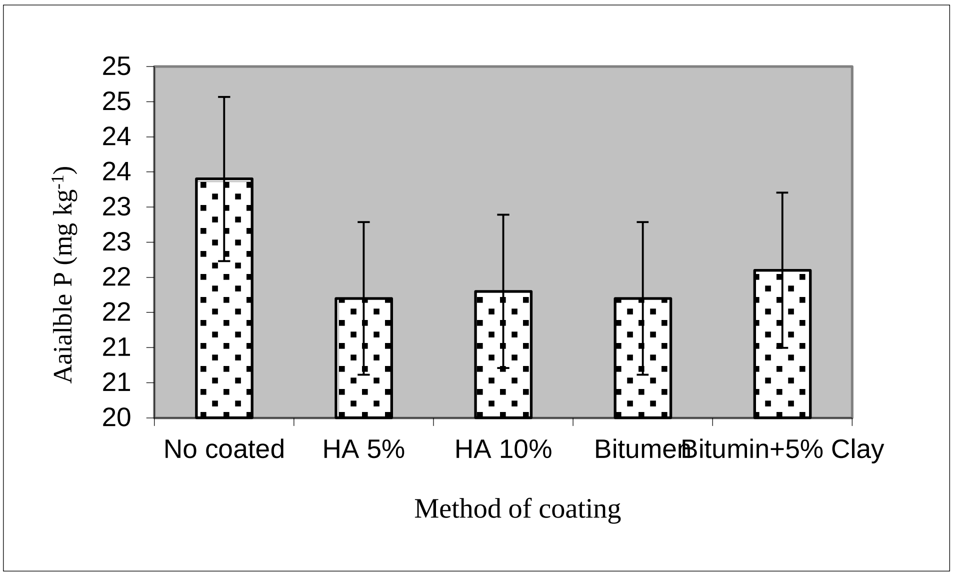

Figure 2: Effect of methods of coating on P availability in soil. Vertical bars indicated ±standard error (SE, N=4)

3.2 Wheat Yield

Figure 3 shows the yield of wheat as affected by application of different P rates. The results showed that soil P application enhanced the grain wheat yield compare to no P added. This may be explained that a long time interaction (aging) of soluble P with soil led to its reaction with solid phase of soil, CaCO3 and the formation of relatively insoluble reaction products with Ca, leading to P fixation [9, 18]. This results showed that application of 150 kg DAP ha^{-1} is quite enough to achieve the highest grain yield under the current experiment and increase of soil application up to 450 kg DAP ha^{-1} resulted in slight non-significant decrease in wheat grain yield compared to 150 kg DAP ha^{-1}. Similar results were reported by [17]. Figure 4 shows the effect of coating types of DAP fertilizer on yield of wheat. The highest grain wield was observed with DAP coated with 5% HA, followed by bitumen emulsion+ clay and lowest in no coated DAP. The positive effect of coating of DAP fertilizer could be attributed to optimum moisture in the soil at appropriate time along with fertilization, which facilitated maximum utilization of applied P to crops [19] . Application of soil P with supplement coating of DAP resulted in a better grain yield in most instances where significant was observed. This suggests that wheat grain yield can be improved by combination application of suitable P fertilizer rates along with coating of DAP.

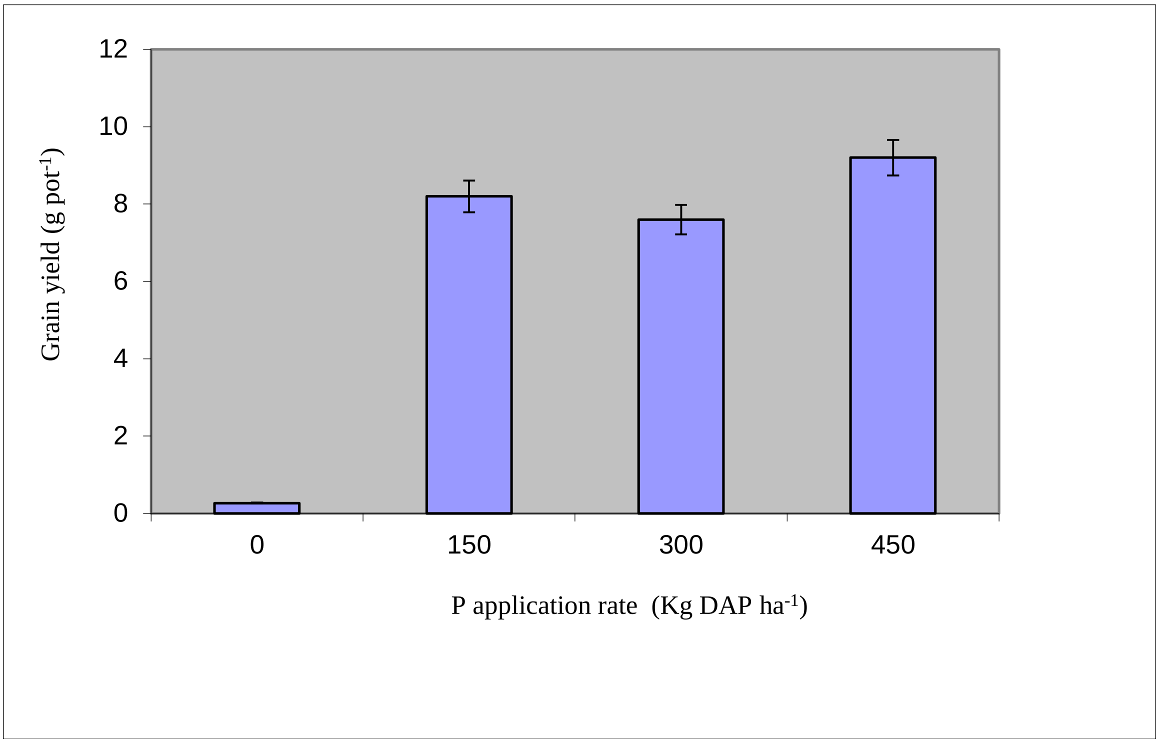

Figure 3: Effect of soil P application on grain yield. Vertical bars indicated ±standard error (SE, N=4)

3.3 P content

Table 2 shows the effects of different soil DAP application rates and coating of DAP on P content in plant. The results showed that application of different soil application rates of DAP and DAP coated with different coating materials resulted in a slight increases in total P content compared with no DAP coated. However, the interaction effect between application rates and coating types were non-significant.

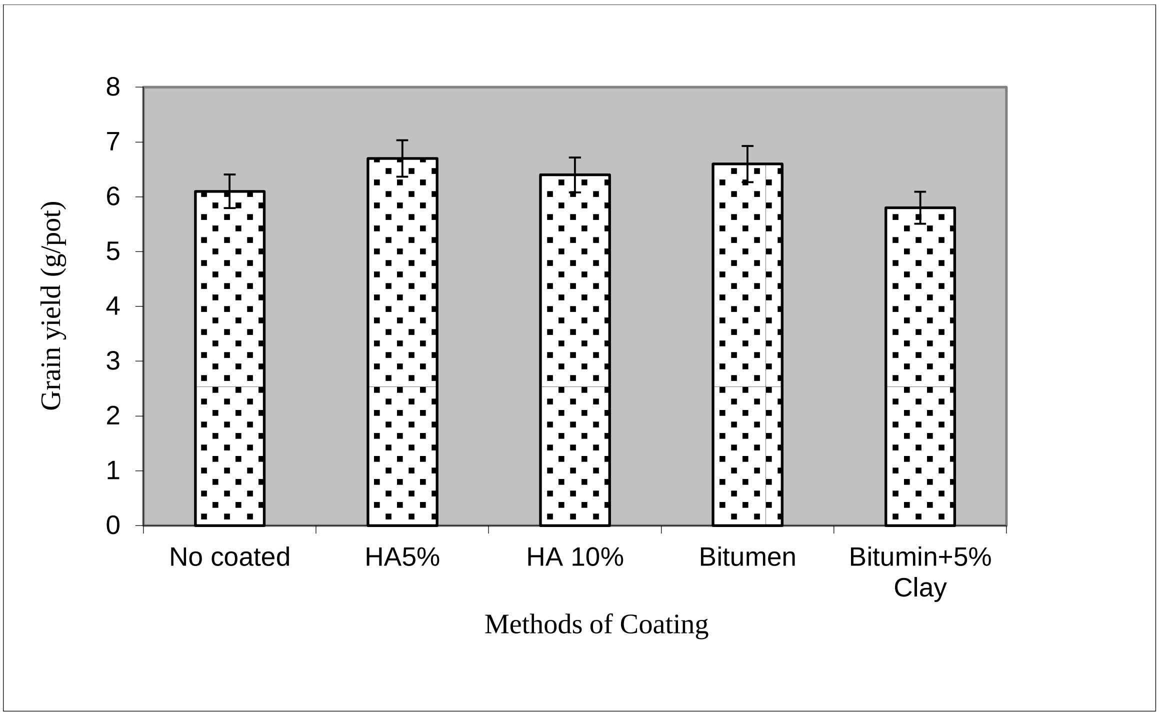

Figure 4: Effect of methods of coating on wheat grain yield. Vertical bars indicated ±standard error (SE, N=4)

Table 2: Effect of soil application and methods of DAP coating on total P content in plant

Mean	Soil application rate (kg DAP ha^{-1})				Methods of Coating
	450	300	150	0	
0.16	0.19	0.19	0.16	0.11	No coated
0.17	0.17	0.18	0.16	0.16	HA 5%
0.17	0.16	0.17	0.17	0.17	HA 10%
0.18	0.19	0.19	0.18	0.16	Bitumen
0.19	0.19	0.18	0.16	0.22	Bitumen + 5% clay
	0.18	0.18	0.17	0.16	**Mean**

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