

INTERACTIVE EFFECTS OF APPLIED PHOSPHORUS AND SOIL MOISTURE ON GROWTH OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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INTRODUCTION

Chemical fertilizer remains as one of the most important input to improve crop productivity. Nitrogenous and phosphatic fertilizers are the most needed nutrients for optimum yields of oilseed crops on most Pakistan soils. These arid to semiarid region soils are commonly high in free CaCO_3 and are generally characterized by pH 7.5 to 8.3. Under such conditions P is readily precipitated to insoluble tricalcium phosphate and hence rendered unavailable. Moreover soil moisture stress is a common production constraint for better yields. The nature of phosphorus x moisture interaction prompted a study on selected Pakistan soils planted to sunflower.

Sunflower is habitable to a wide variety of edaphic and climatic conditions but little is known of sunflower growth and development in Pakistan. The present investigation was carried out to study the growth response and P utilization by sunflower under applied P and varied soil moisture.

MATERIALS AND METHODS

A bulk surface soil of Shujabad loam (typic camorthids), collected from experimental farms of National Agricultural Research Centre, Islamabad, was air dried and ground to pass through a 2 mm sieve. The soil was characterized for physico-chemical properties (Table 1)

Table 1

Physico-chemical properties of the soil used
for pot culture study

Mechanical composition	
Sand (%)	32.2
Silt (%)	46.6
Clay (%)	21.2
Textural class	Loam.
pH	8.01
ECe (ds/m)	0.78
CaCO_3 equivalent (%)	1.56
NaHCO_3 -P (mg/kg)	3.68
Organic matter (%)	0.92

according to procedures described by Richard (1954). Seven kg soil was filled in a total of 18 plastic pots which received P O, 37.5 and 75 mg kg^{-1} as $\text{NH}_4\text{H}_2\text{PO}_4$. A uniform level of 37.5 mg N kg^{-1} was made up by adding additional N as urea. All pots were irrigated with distilled water and equilibrated for two weeks before sowing sunflower (*Helianthus annuus* L., Cv. Cargill 204). Six plants were grown in each pot. The pots were maintained initially at field capacity for two weeks and then subjected to stressed and non-stressed moisture regimes. Pots under non-stressed moisture regime were maintained at 14% (V/W)* moisture level throughout the growth period while stressed pots were maintained at 7% (V/W)* moisture level. The experiment was run in triplicate. Three plants were harvested four weeks after sowing while the rest of the three plants were harvested seven days later. The harvested plants were washed with distilled water and blotted before measuring their height and fresh weight. The plant samples were dried at 65°C to a constant weight and weighed. At the conclusion, soil from each pot was mixed and sampled for the estimation of available P content (Olsen *et al.*, 1954).

The dried plant samples were fine-ground and digested with HNO_3 : HClO_4 diacid mixture for P determination by yellow colour method (Kitson and Mellon, 1944). The experimental data were statistically analyzed (Little and Hills, 1978) according to split plot design with moisture regimes in main plots.

RESULTS

The soil was found low in P (NaHCO_3 — extractable P, < 5 ppm, Table 1). Application of 37.5 and 75 mg P kg^{-1} resulted in increase in biomass production of sunflower (Table 2). A biomass increase of 133% and 30% over con-

* V/W = ml of distilled water added per 100 g of soil.

Table 2

Growth response (g/pot) of sunflower to P application at two moisture regimes

Water regimes	P applied (mg/kg)	Harvest I		Harvest II	
		Plant fresh wt.	Plant dry wt.	Plant fresh wt.	Plant dry wt.
Water stressed	0	5.00 ± 0.46	0.70 ± 0.06	7.77 ± 0.68	1.00 ± 0.08
	37.5	8.15 ± 0.67	1.03 ± 0.09	10.45 ± 1.01	1.30 ± 0.11
	75.0	8.45 ± 0.53	1.11 ± 0.10	12.37 ± 1.13	1.67 ± 0.12
Non-stressed	0	6.85 ± 0.52	0.75 ± 0.05	11.85 ± 0.95	1.35 ± 0.10
	37.5	17.20 ± 1.16	2.08 ± 0.18	21.60 ± 1.89	3.15 ± 0.27
	75.0	17.75 ± 1.08	2.18 ± 0.17	24.05 ± 2.07	3.20 ± 0.28

tol was observed with the application of 37.5 mg P kg⁻¹ of soil under non-stressed moisture regimes, respectively. A significantly positive P x moisture interaction was noted both at 37.5 and 75 mg kg⁻¹ rates of applied P (Fig. 1). Neither P application nor soil moisture stress alone affected P concentration in plant shoots. However, application of P yielded in higher P accumulation in plant shoots

at both moisture regimes (Table 3). Phosphorus accumulation in plant tops was markedly higher under optimal moisture regime. The higher P uptake observed in harvest II plants (Table 3) was likely associated with a longer growing period. A highly significant correlation ($r = 0.99$) was obtained between dry matter production and P concentration in plants (Fig. 2).

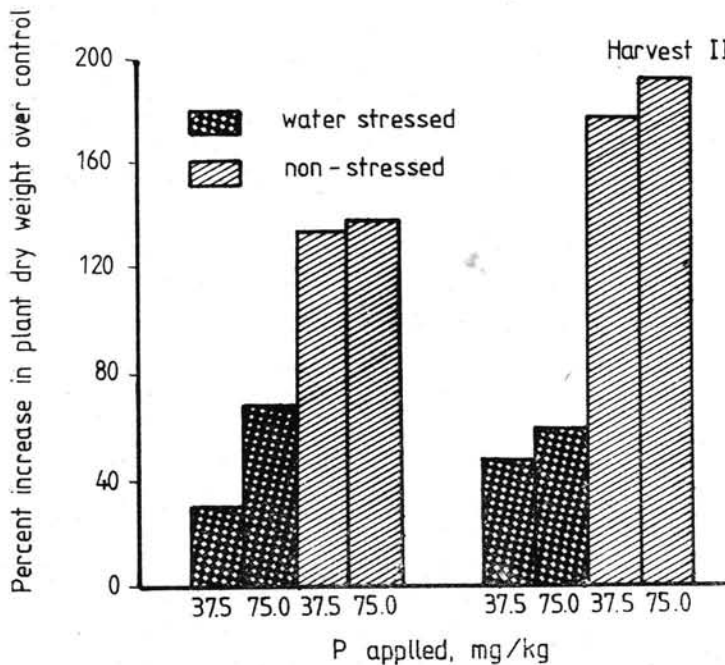


Fig. 1 — Dry weights of sunflower (as percent of control)

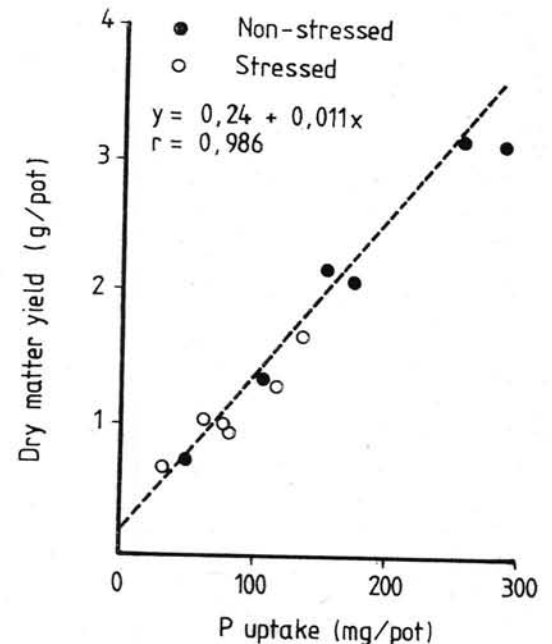


Fig. 2 — Relationship between P uptake and dry weights of sunflower

Table 3

Concentration and uptake of P by sunflower supplied with different P levels at two moisture regimes

Moisture	P applied mg/kg	Harvest I		Harvest II	
		P concentration (%)	P uptake (mg/pot)	P concentration (%)	P uptake (mg/pot)
Water stressed	0	0.05 ± 0.003	35.0 ± 2.8	0.08 ± 0.006	80.0 ± 7.2
	37.5	0.06 ± 0.005	61.8 ± 4.7	0.09 ± 0.008	117.0 ± 10.1
	75.0	0.07 ± 0.005	77.7 ± 5.9	0.08 ± 0.007	133.6 ± 12.5
Non-stressed	0	0.06 ± 0.007	45.0 ± 4.1	0.08 ± 0.008	108.0 ± 9.8
	37.5	0.08 ± 0.006	166.4 ± 11.8	0.09 ± 0.01	283.5 ± 25.4
	75.0	0.07 ± 0.008	152.6 ± 13.3	0.08 ± 0.007	256.0 ± 26.2

The extractable P obtained from soil sampled at the end of the experiment was significantly higher from the soil kept under optimum moisture condition than the soil maintained at sub-optimal soil moisture level (Table 4).

Table 4

Status of NaHCO_3 extractable P in soil at the conclusion of the experiment

P added (mg/kg)	Moisture regimes	
	Stressed (mg/kg)	Non-stressed (mg/kg)
0.0	4.71 \pm 0.36	4.52 \pm 0.41
37.5	14.65 \pm 1.27	23.67 \pm 1.93
75.0	15.37 \pm 1.21	24.03 \pm 2.04

DISCUSSION

Several researchers (Barber *et al.*, 1963; Olsen and Kemper, 1968) have reported diffusion along a concentration gradient from surrounding soil to root surface as the principal mode of P transport. Moisture status of the soil would affect P diffusion. At a higher moisture content the increase in cross sectional area of the diffusion path and reduced tortuosity (Olsen and Kemper, 1968) would accelerate P diffusion. The higher P availability recorded at higher soil moisture (Table 4) supports the above hypothesis. Moreover, restricted availability of water to roots induces increased hydraulic root resistance (Ramos and Kaufmann, 1979) in plants while hydraulic conductance to shoots has been reported to decrease in P deficient plants (Radin and Eidenbock, 1984). This would suggest a similar physiological response to both water stress and low P availability. The decreased plant growth at water stressed condition appeared to be partially ameliorated with the application of P (Table 2) which would suggest improved plant utilization of added P. Alternatively changes in the ionic balance of the root zone may have been affected by soil moisture (Viets, 1967, 1972) and applied phosphate (Viets, 1962). The magnitude of increase in plant growth with applied phosphate was much higher for non-stressed treatments as compared to that for water-stressed plants. This was most pronounced in the second harvest. While moisture availability was a factor limiting plant growth, interaction with applied phosphate suggests soil moisture status as important to the efficient P utilization by plants. For non-stressed plants, application of 37.5 mg P kg^{-1} of soil resulted in more than 200% increase in plant weight over check.

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LES EFFETS RÉCIPROQUES DE L'APPLICATION DU PHOSPHORE ET DE L'HUMIDITÉ DU SOL SUR LA CROISSANCE DU TOURNESOL (*HELIANTHUS ANNUUS* L.)

Résumé

Le tournesol a été récemment introduit en Pakistan comme culture oléagineuse. La réaction du tournesol à l'application du phosphore en doses de 37,5 et 75 mg kg^{-1} a été étudiée dans une expérience effectuée en serre, avec des régimes d'humidité du sol. L'application du phosphore à un sol argileux — calcarière a augmenté significativement le rendement en biomasse du tournesol. On a observé une interaction significative du phosphore avec l'humidité du sol. A la différence de l'accumulation du phosphore au sommet des plantes, ni le phosphore appliqué ni les régimes d'humidité du sol n'ont pas affecté la concentration du phosphore dans les racines des plantes.

EFFECTOS INTERACTIVOS DEL FÓSFORO APLICADO Y DE LA HUMEDAD DEL SUELO SOBRE EL CRECIMIENTO DEL GIRASOL (*HELIANTHUS ANNUUS* L.)

Resúmen

El girasol fue recientemente introducido en Pakistán como cultura oleaginosa. La reacción del girasol a la aplicación en dosis de 0, 37,5 y 75 mg kg^{-1} se estudió en una experiencia efectuada en invernadero, en dos regímenes de humedad del suelo. La aplicación del fósforo a un suelo arcilloso — calizoso aumentó significativamente la producción de biomasa del girasol. Se ha notado una interacción significativa de del fósforo con la humedad del suelo. A diferencia de la acumulación del fósforo en la planta de las plantas, ni el fósforo aplicado ni los regímenes de humedad del suelo afectaron la concentración del fósforo en las raíces de las plantas.