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Effect of Soil Moisture on Growth and Phosphorus Uptake by Wheat

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ABSTRACT. A greenhouse experiment was conducted to investigate the effect of soil moisture on growth and phosphrus uptake by wheat. The experiment consisted of three soils and five available water depletion levels: 30, 40, 50, 60, and 70%, each replicated four times in randomized complete block design. The plants were harvested 50 days after planting. In all soils, both shoot and root growth as well as P uptake increased significantly ($P = 0.05$) with the decrease in available water depletion (AWD). Decrease in AWD from 70 to 30% increased shoot growth in the loamy sand, sandy loam, and sandy clay loam soils by 33.6, 22.9, and 9.9%, respectively. While root dry matter increased in the same soils 33.1, 29.3 and 10.1, respectively. Dry matter yield and phosphorus uptake uptake as a function of water availability were described using the model $Y = a + b \ln X$.

Plant growth is accomplished by cell division, followed by cell expansion and differentiation of individual cells. However, there are other related events that are required for growth such as uptake of water and nutrients and transport of substances between cells. Therefore, the rate of growth is strongly influenced by water status.

Ion transport in the soil can be affected by soil properties, water content, ion concentration and ion distribution in the soil and by the rate of root growth (Barrow 1980; Barber and Mackay 1985). Adequacy of soil moisture level is important to ensure non-limiting availability of water as a vital growth factor but also to provide less resistant pathways for nutrient movement. Soil water content affects nutrient uptake by influencing solute transport to the root surface by diffusion and mass flow (Barber and Mackay 1985; Classen *et al.* 1986). Nye and Tinker (1977) noted that, in dry soil, movement of ions to plant roots is restricted by low rates of mass flow and diffusion. Barber *et al.* (1963) stated that mass flow can account for most of the transport of Ca, Mg, and N but is inadequate to account for much of the transport of P and K. Begg and Turner (1976) reported that the uptake rates of N and P are frequently increased more rapidly than plant growth rates when adequate water is supplied to the crops resulting in better availability of nutrients in moist soils as compared with dry soils. O'Toole and Baldia (1982) showed in their study on rice that transpiration is highly correlated with nutrient uptake of N, P and K during the development of even mild soil and plant stress. The purpose of this study is to investigate the effect of soil moisture on growth and phosphorus uptake of wheat and to find a mathematical model to describe this plant growth and P uptake.

Materials and Methods

The surface layer (0-25 cm) of three soils differing in texture were collected from the Experimental Station of College Agriculture at Dirab. Physical and chemical properties of the soil samples are shown in Table 1. Mechanical analysis, EC, pH, organic matter, $CaCO_3$ content, and exchangeable cations were determined according to the procedure described by Jackson (1971) and the U.S. Salinity laboratory staff (Richards 1954). Available phosphorus was extracted using $NaHCO_3$ (1:20 pH 8.5) solution according to Olsen *et al.* (1954).

Samples of the three soils were prepared by air-drying and sieving through a 2-mm stainless steel sieve. Chemical fertilizers were mixed throughly with each soil to obtain concentrations (mg nutrient/kg soil) as follows: 150 N, 75 P, 35 K, 10 Fe, 7 Mn and 5 Zn. Then, 3 kg of an appropriate fertilizer treated soil was placed into plastic pots with perforated drainage holes. The experiment consisted of three soils and five available water depletion levels: 30, 40, 50, 60 and 70%, each replicated four times in a randomized complete block design. Fifteen wheat seeds were planted in each pot and after ten days, the germinated seedlings were thinned to four. All pots were watered to raise the soil moisture to field capacities, and then weighed periodically (2-3 days). Pots were rewatered to field capacity whenever the soil moisture in a pot reached the predetermined available water depletion.

The plants were harvested 50 days after planting by cutting the top about one centimeter above the soil surface to avoid any contamination from the soil to the shoots. The roots were carefully removed from the soil and washed immediately with distilled water. Roots and shoots were dried at 60°C in a hot air oven and ground in a Wiley mill with stainless steel parts. The plant materials were digested in acid mixture, $HNO_3-H_2SO_4-HClO_4$ (Takker and Singh 1978), and phosphorus concentration was determined colorimetrically (66 nm) by ascorbic acid - molybdate blue colour method of Murphy and Riley (1962).

Table 1. Soil physical and chemical properties

Soil texture	Clay %	Silt %	Sand %	pH	EC** mmhos/cm	0.M*** %	$CaCO_3$ %	SAR $(mmole/L)^{1/2}$	P ppm	F.C. %	PWP %	FC-PWP %
L.S*	9.3	6.6	84.1	7.8	2.3	0.64	34.0	4.7	0.80	10.7	3.10	7.60
S.L*	12.3	4.0	82.7	7.4	6.1	0.51	33.4	8.7	0.85	18.5	4.83	13.67
S.C.L*	19.3	26.0	54.7	7.4	6.2	1.09	30.6	6.3	1.45	21.5	6.14	15.36

* L.S. = loamy sand; S.L. = sandy loam; and S.C.L. = sandy clay loam

Soil family:

L.S. = Sandy, mixed (calcareous) hyperthermic, Typic Torrifluvents; S.L. = Coarse-loamy, mixed (calcareous) hyperthermic, Typic Torrifluvents; S.C.L. = Fine-loamy, mixed (calcareous) hyperthermic, Fluvents Camborthids.

** EC = Electrical conductivity mmhos/cm

*** Organic matter.

Results and Discussion

Shoot and root growth as well as P uptake for all three soils increased significantly (P = 0.05) as available water depletion (AWD) decreased from 70% to 40% (Table 2). There was no additional significant increase in threse parameters with a further decrease of AWD to 30%. Decreasing in AWD from 70 to 30% increased shoot growth in the loamy sand, sandy loam and sandy clay loam by 35.6, 22.9 and 9.9%, respectively. While the increase in roots for the same soils were 33.1, 29.3 and 10.1%, respectively. The mean value of the roots/shoots ratio at different AWD for loamy sand, sandy loam and sandy clay loam were 0.33, 0.47, and 0.47, respectively. As AWD decreased from 70 to 30%, P uptake of the shoots grown in the loamy sand, sandy loam and sandy clay loam increased by

Table 2. Wheat matter production and total phosphorus uptake of roots and shoots

% Available water depletion	Dry shoots	matter roots	Root/shoot	P uptake Shoots	P uptake Roots
	-- gm/pot --			-- mg/pot --	
		Loamy sand			
70	3.660	1.275	0.35	0.518	0.098
60	4.132	1.335	0.32	0.599	0.108
50	4.932	1.487	0.30	0.735	0.131
40	5.682	1.907	0.34	0.917	0.201
30	5.762	1.902	0.33	0.908	0.198
LSD	0.340	0.194		0.067	0.017
		Sandy loam			
70	4.090	1.807	0.44	0.591	0.153
60	4.390	2.022	0.46	0.675	0.177
50	4.750	2.335	0.49	0.801	0.198
40	5.302	2.555	0.48	0.904	0.272
30	5.255	2.535	0.48	0.948	0.254
LSD	0.287	0.183		0.045	0.041
		Sandy clay loam			
70	6.612	3.107	0.47	1.139	0.305
60	6.685	3.105	0.46	1.180	0.349
50	7.027	3.325	0.47	1.297	0.366
40	7.335	3.457	0.47	1.465	0.391
30	7.107	3.367	0.47	1.363	0.365
LSD	0.205	0.327		0.087	0.054

about 44, 35 and 16.5%, respectively. On the other hand, the increase in phosphorus uptake by roots were, 51, 77 and 22%, respectively, for the same soils by raising the (AWD) level from 30 to 60%. However, there was no significant increase in phosphorus uptake by both shoots and roots due to a decrease in AWD from 40 to 30%.

The relationship between the water availability and the dry matter and phosphorus uptake of roots and shoots are plotted in Fig. 1. A regression analysis was carried out for the three soils and the results are shown in Table 3. The models which describe the dry matter yield and phosphorus uptake with respect to water availability are nonlinear. The nonlinearity of the curves suggested that, an increase of water availability will increase the dry matter and phosphorus uptake, however, a further increase in the water availability will not increase the plant growth or phosphorus uptake with the same magnitude.

It is well documented that water deficit affects the growth and other physiological processes in plants (Hsiao, 1973; Turner and Kramer 1980). It is clear from the results in Table 2, that the 70% AWD level was too dry to support optimal plant growth. This could be attributed to many reasons such as decreased photosynthesis as described by Hsiao (1973). Also the reduction in the growth may attributed to the low activity and the absorbing power of the roots associated with low water availability (Ritcher and Wagner 1983; Backer and Fock 1986) resulting

Table 3. Relationships between the dry matter and phosphorus uptake of roots and shoots with respect to water availability

Production	Regression equation*	r^2
Soil 1		
Shoots, dry matter	$y = -5.73 + 2.73 \ln X$	0.97
Roots, dry matter	$y = -1.69 + 0.85 \ln X$	0.86
P uptake of shoots	$y = -1.27 + 0.52 \ln X$	0.94
P uptake of roots	$y = -0.38 + 0.14 \ln X$	0.85
Soil 2		
Shoots, dry matter	$y = -1.20 + 1.54 \ln X$	0.94
Roots, dry matter	$y = -1.45 + 0.96 \ln X$	0.96
P uptake of shoots	$y = -0.95 + 0.45 \ln X$	0.98
P uptake of roots	$y = -0.33 + 0.14 \ln X$	0.86
Soil 3		
Shoots, dry matter	$y = 3.88 + 0.79 \ln X$	0.78
Roots, dry matter	$y = 1.65 + 0.42 \ln X$	0.77
P uptake of shoots	$y = -0.07 + 0.35 \ln X$	0.79
P uptake of roots	$y = 0.04 + 0.08 \ln X$	0.75

* y is the dry matter or P uptake and X is the water availability.

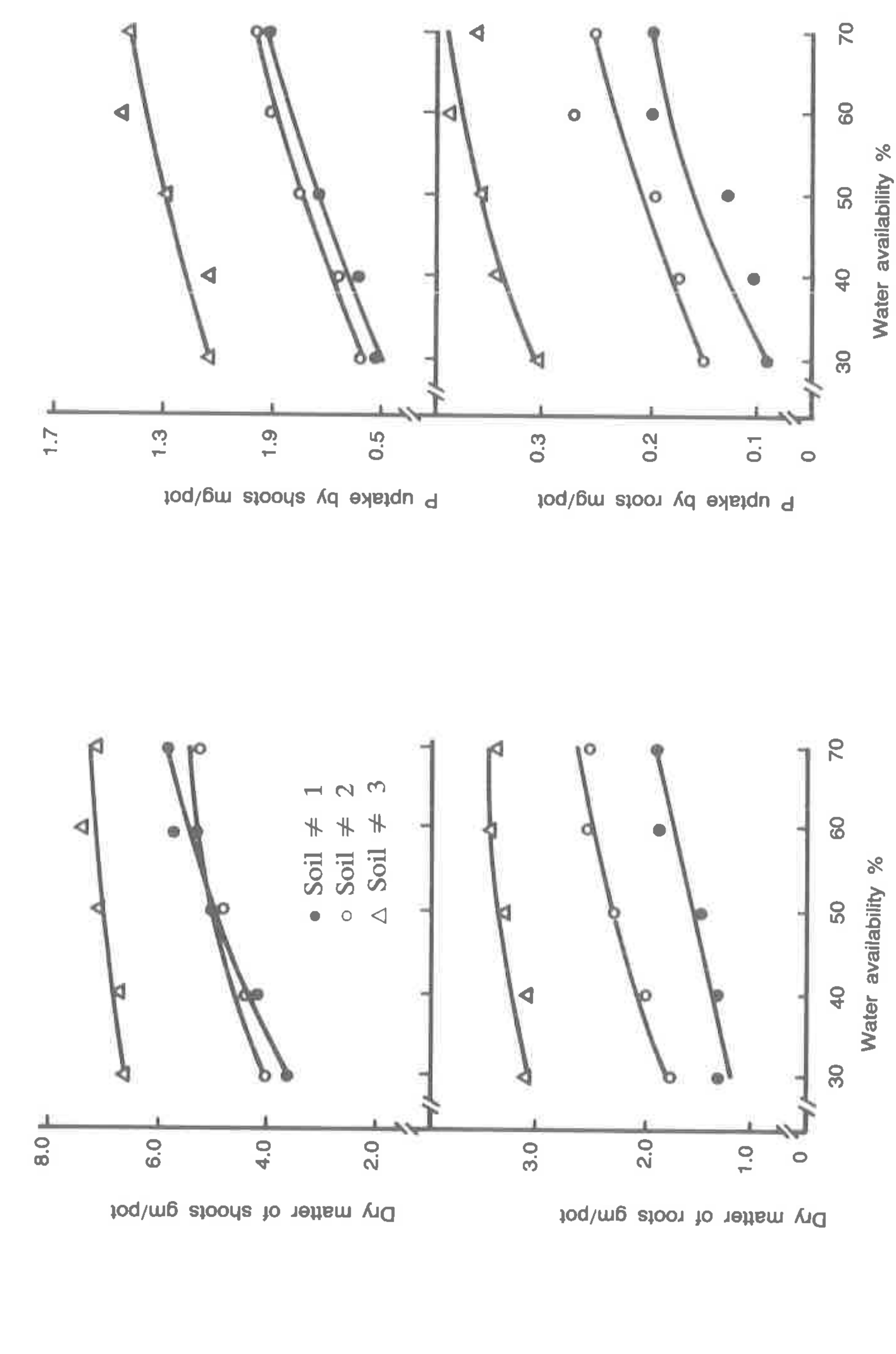

Fig. 1. Dry matter yield and P uptake as a function of water availability using the model Y . a + b lnx.

in reduced overall uptake of the nutrients. The increase of (AWD) affected the root system, especially in the loamy sand soils where the available water was inherently low, and thus the root/shoot ratio was higher for these soils. Kramer (1983) stated that the growth is reduced more than root growth because more severe water deficits develop in the transpiring shoots.

The reduction of total phosphorus uptake with a decrease in water availability as shown in Table 2, might be attributed to the lower mobility of the phosphorus and to the reduction of flow rate in the absorbing zone of the roots. In addition, absorption of phosphorus from soil depends on root growth and diffusion. Moreover, the degree of soil moisture governs the physiological activity and absorbing power of the roots. Therefore, increasing the soil moisture increases total phosphorus uptake and dry matter production of the shoots and the roots of the wheat. Our results also showed that the finer the texture of soils, the greater the plant growth and total phosphorus uptake. This is due to the higher water availability in finer textured soils. These results agree with other studies which showed that both plant growth and total phosphorus uptake increase with increases in soil moisture level (Begg and Turner 1976; O'Toole and Baldia 1982).

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تأثير مستوى الرطوبة على نمو وامتصاص الفوسفور لنبات القمح

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قسم علوم التربة ـ كلية الزراعة ـ جامعة الملك سعود ـ ص. ب ٢٤٦٠ الرياض ١١٤٥١
المملكة العربية السعودية

اعدت التجربة في الصوبة الزجاجية بكلية الزراعة جامعة الملك سعود لدراسة تأثير مستوى رطوبة التربة على كل من النمو وامتصاص الفوسفور لنبات القمح، وتحتوي هذه التجربة على ثلاثة أنواع من التربة (الرملية الطمية، الطمية الرملية والطمية الطينية الرملية) وخمسة مستويات من الرطوبة (نسبة الماء المتاح المستنفذ) وهي: ٣٠، ٤٠، ٥٠، ٦٠، و ٧٠ ٪. وقد كررت كل معاملة ٤ مكررات في تصميم عشوائي كامل. وبعد ٥٠ يوماً من بداية الزراعة حصدت النباتات في جميع الترب الثلاث وكان نمو النبات الخضري (الاوراق والسيقان) والجذري بالاضافة إلى امتصاص الفوسفور يزداد زيادة معنوية (P = 0.05) مع إنخفاض نسبة الماء المتاح المستنفذ (AWD). كما أن إنخفاض نسبة الماء المتاح المستنفذ (AWD) من ٧٠ إلى ٣٠ ٪ أعطت زيادة في النمو الخضري في التربة الرملية الطمية والطمية الرملية والطمية الطينية الرملية بنسبة ٣٣,٦، ٢٢,٩ و ٩,٩ ٪ على التوالي، ووجد أن النمو الخضري والجذري وامتصاص الفوسفور لنبات القمح تحت هذه الظروف وعلاقته بنسبة الماء الميسر يمكن أن يوصف بمعادلة رياضية Y = a + b In X .