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Short Communication

Growth and potassium uptake by Maize (*Zea mays* L.) in three soils differing in clay contents

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Abstract: Soil texture affects nutrient availability in soil hence affects plant growth. Soils high in clay contents retain more K^+, and generally plants grown on these soils do not respond to applied K^+. A pot experiment was conducted to evaluate growth response and K^+uptake by maize plants grown on three different textured soils. There were four K^+ levels 0, 50, 100 and 150 mg K^+/kg soil. Ten seeds of hybrid maize (cv. Magic) were sown in each pot which was replicated four times. Crop was harvested after seven weeks. Root and shoot dry matter was recorded and samples were analysed for K^+ concentration. Soil texture significantly ($p< 0.05$) affected biomass production by maize plants. Shoot dry matter produced was maximum in plants grown in sandy soil. Root growth was minimum in soil high in clay contents compared to plant grown in sandy soil. Root to shoot dry matter ratio correlated negatively with clay contents ($r = 0.91$) showing limited root growth in soils high in clay contents. It also influenced total dry matter (TDM) as indicated by its positive correlation ($r = 0.83$). Potassium application did not affected plant growth in soil high in clay content, however, K^+ uptake was increased with an increase in K^+level in soils low in clay contents. Total dry matter was significantly correlated ($r = 0.83$) with root K^+uptake, but correlation with shoot K^+uptake was not significant.

Key words: Soil texture, potassium, maize

نمو وإمتصاص البوتاسيوم بواسطة محصول الذرة في ثلاثة ترب مختلفة المحتوى من الطين

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ملخص: يؤثر قوام التربة على جاهزية العناصر الغذائية ونمو النبات. التربة ذات المحتوى العالي من الطمي تحتفظ أكثر بعنصر البوتاسيوم، وبشكل عام فإن نمو النباتات في هذا النوع من التربة لايستجيب إلى إضافة عنصر البوتاسيوم. أجريت تجربة حقلية باستخدام الأصص لتقييم إستجابة نمو وإمتصاص عنصر البوتاسيوم بواسطة محصول الذرة المزروع في ثلاثة أنواع من التربة مختلفة القوام. تم استخدام أربع مستويات من عنصر البوتاسيوم (صفر، 5، 10 و 150 ملغم بوتاسيوم / كغم تربة). تم زراعة عشر بذور من هجين الذرة صنف ماجيك في كل أصص في أربع مكررات. حصد المحصول بعد سبع أسابيع. تم حساب وزن المادة الجافة للجذور والسيقان وتركيز عنصر البوتاسيوم في أجزاء النبات المختلفة. أثر قوام التربة معنوياً ($P < 0.05$) على الإنتاج الكلي. كان نمو الجذور الأقل في التربة ذات المحتوى الطمي العالي بالمقارنة مع النباتات النامية في التربة الرملية. نسبة المادة الجافة للجذور إلى المادة الجافة للسيقان ترتبط بشكل عكسي (سلبي) ($P = 0.91$) مع محتوى التربة من الطمي. لتبيـن نمو محدد للجذور في التربة ذات المحتوى الطيني، كما تؤثـر بشكـل إيجابـي على إنتـاج المادة الجافة ($R = 0.83$). إضافة عنصر البوتاسيوم لاتؤثر على نمو النباتات في التربة ذات المحتوى العالي من الطمي لكن إمتصاص العنصر يزداد بزيادة إضافة البوتاسيوم إلى التربة ذات المحتوى المنخفض من الطمي. إنتاج المادة الجافة الكلي يرتبط معنوياً بإمتصاص الجذور لعنصر البوتاسيوم ولايرتبط معنوياً بامتصاص السيقان لعنصر البوتاسيوم.

كلمات مفتاحية: قوام التربة، البوتاسيوم، الذرة.

Introduction

A number of soil properties are influenced by soil texture particularly nutrient availability and in turn it affects plant growth (Tagar and Bhatti, 1996). Soils rich in clays and organic matter contents hold more nutrients than sandy soils (Brady, 1974). Potassium (K^+) is an important macronutrient and is elusive in the soil with respect to plant availability. Most of its elusiveness is the consequence of the amount and type of clay minerals present in the soil (Ranjha, 1988). Furthermore, low hydration energy of K^+ ion favours its entrapment in lattice voids of the micaceous structure (Maclean, 1978). Joshi et al. (1978), while working on K^+ fixation and forms in Jodpur soils of India, noted significant correlation of clay contents with K^+ -fixing capacity of soil. Clay minerals have the capacity to reduce plant available K^+ through K^+-fixation (Blake et al., 1999). In alluvial soils, quartz and feldspar largely constitute the coarse fraction, where as finer particles mainly contain micas and illitic minerals which are much rich in K^+ (Kanwar, 1961). When the concentrations of soil solution K^+ and /or exchangeable K^+ depleted due to uptake by plants and leaching, interlayer K^+releases to fulfil demands of growing plants (Hinsiger and Jaillard, 1993). Fine textured soils hold more potassium than coarse textured soils (Eldamaty et al., 1963), hence crops response to applied K^+varies from soil to soil. The study was conducted to evaluate the effect of soil texture and K^+application on biomass production and K^+ uptake by maize plants.

Materials and Methods

The experiment was conducted in a wirehouse at University of Agriculture Faisalabad, Pakistan, where mean temperature was 35°C and 18°C at day and night respectively during the whole growth period. Three soils dominant in Mica clay minerals and differing in texture (S_1, S_2 and S_3) were used in this experiment and characteristics of these soils are presented in Table 1. The soils were air dried and grounded in a mechanical grinder to pass through a 2 mm sieve after mixing it thoroughly. The prepared soil was filled in earthen pots at rate of 11 kg soil per pot. The pots were earlier lined with polyethylene sheets. Four levels of K^+*viz*, 0, 50, 100 and 150 mg K^+per kg of soil along with N and P at rates of 150 mg N per kg and 100 mg P per kg of soil, were added to respective pots and mixed thoroughly. A randomised complete block design was employed with three replications. Pots were irrigated with distilled water to get optimum moisture level for seed sowing. After 5 days of fertiliser addition, ten seeds of hybrid maize (cv. Magic) were sown in each pot. Plants were thinned after a week of germination to maintain five plants per pot. Plants were harvested after seven weeks of germination and washed with distilled water to remove any dust particles. Washed samples were oven dried at 80°C for 48 hours to record their oven dry weight. Dried samples of shoots and roots were grounded in a mechanical grinder to pass 40 mesh and were digested in di-acid mixture of perchloric and nitric acid (3:1) (Miller, 1998). Sample digest were analysed for K^+ concentration to calculate K^+ uptake by roots and shoots separately. The data was statistically analysed following the method of Steel and Torrie (1980).

Table 1. Physico-chemical characteristics of soils used in the experiment

Parameters	Soil -1	Soil -2	Soil -3
pH	8.6	8.3	8.2
Sand (%)	54	45	38
Silt (%)	27	26	25
Clay (%)	19	29	37
Textural class	Sandy loam	Sandy clay loam	Clay loam
N (%)	0.04	0.05	0.07
P (mg/kg)	6.3	8.6	9.1
K (mg/kg)	182	211	239

Results and Discussions

Biomass production

Soil texture affects plant growth by influencing soil aeration, root penetration, water holding capacity and nutrient availability in soil (Tagar and Bhatti, 1996). Data regarding shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM) and root shoot ratio (RSR) of maize plants grown in three soils (Table 2) revealed significant effect of soil texture on all of these parameters. Shoot dry matter production is a good indicator of economic yield hence is considered as suitable parameter to study growth response of plants at seedling stage. SDM production by maize plants was increased in S_1 and S_2 when K^+ levels were increased although increase was non- significant. However, K^+application did not affected SDM in S_3 having maximum clay contents (37 %). Soils high in clay contents generally are rich in available $K^+$and have more K^+fixing capacity hence, crops grown on these do not respond to applied K^+ as in our study. Shoot dry matter production was higher in S_3 when no K^+ was applied, but it was higher in S_1 and S_2 when averaged over all K^+ levels. Soil texture affects root growth by affecting aeration, moisture and density of soil. Root growth is maximum in soils high in sand percentage (S_3) as roots have to explore more volume in search of nutrients and ease of growth. In this study RDM negatively correlated (r = 0.85, p> 0.05) with clay contents and was significantly higher in S_1 compared to S_2 and S_3. However, K^+ application did not affected root growth by maize plants significantly in all of these soils. Particle size distribution in soils affected biomass partitioning between shoots and roots as exhibited by higher RSR values in S_1. However, K^+ application did not affected RSR in all of these soils. Root shoot ratio was correlated negatively with clay contents (r = 0.91) showing limited root growth in soils high in clay contents. McKenzie et al. (2001) also observed limited root growth in soils high clay contents due to more strength. RSR influenced TDM as indicated by positive correlation (r = 0.83) that plants with higher RSR produced maximum TDM. Total dry matter was also higher in S_1 compared to S_2 and S_3 and it was attributed to increased growth of roots in S_1.

Table 2. Biomass production by maize affected by soil texture and potassium application

K^+ /Tex	Root Dry Matter (g / pot)			Shoot Dry Matter (g / pot)			Root: Shoot Ratio			Total Dry matter (g / pot)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
K_1	42	30	30	73	71	76	0.57	0.42	0.39	115	101	106
K_2	43	34	29	77	79	76	0.55	0.43	0.38	120	113	105
K_3	46	30	27	77	80	78	0.60	0.38	0.35	123	110	105
K_4	46	29	28	84	81	76	0.55	0.36	0.37	130	110	104
FV K	1.334^{NS}			0.665^{NS}			5.485*			1.112^{NS}		
S	34.511**			0.233^{NS}			6.551**			30.152**		

FV= F value from ANOVA of K levels and Texture

Potassium concentration

Shoot K^+ concentration and uptake was significantly increased due to K^+ application in S_1, while effect was non-significant in S_2 and S_3. Plants grown in different soils varied significantly for shoot and root K^+ concentration and uptake (Table 3). Potassium concentration and uptake by shoots of plants grown in S_1 was lower compared to plants grown in S_2 and S_3. Higher K^+ concentration in plants grown with S_2 and S_3 indicated that K^+availability was not the limiting factor for reduced shoot growth. But these were higher clay contents which affect plant growth as exhibited by highly significant negative correlation (r = 0.85) between total dry matter and clay contents.

Root K^+ concentration and uptake was significantly higher in plants grown in S_1 at all levels of K^+ supply. Due to low clay contents in S_1, root growth was maximum which significantly increased K^+ uptake by roots. Total dry matter was significantly correlated with root K^+ uptake (r = 0.83), (Table 4, Figure 1 & 2) but correlation with shoot K^+ uptake was non-significant. Potassium application increased shoot and root K^+ uptake in S_1 and in S_2 where as increase was non significant in S_3. Total K^+ uptake by plants increased as K^+ levels was increased from 0 to 150 mg/kg of soil, in soils low in clay contents (S_1 and S_2) and was attributed to maximum shoot and root biomass produced in S_1 and S_2 compared to S_3.

Table 3. Effect of different K^+ levels on K^+ concentration in root and shoot and K^+ uptake by maize plant in different soil textures

K^+ level	Root K^+ Conc. (%)			Shoot K^+ Conc. (%)			Root K^+ uptake (g / pot)			Shoot K^+ uptake (g / pot)			Total K^+ Uptake (g / pot)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
K_1	0.97	0.98	1.21	1.55	2.26	2.22	0.41	0.30	0.36	1.14	1.61	1.68	1.55	1.9	2.04
K_2	0.99	0.97	1.13	1.88	2.27	2.53	0.42	0.33	0.32	1.45	1.79	1.92	1.87	2.12	2.24
K_3	1.09	1.13	1.34	2.05	2.26	2.24	0.50	0.34	0.36	1.57	1.80	1.75	2.07	2.14	2.1
K_4	1.9	1.32	1.41	2.17	2.56	2.25	0.88	0.38	0.40	1.83	2.06	1.71	2.71	2.44	2.11
EV K	19.418**			3.201*			11.588**			3.074*			10.998**		
S	19.348**			14.988**			30.172**			12.460**			28.156**		

FV= F value from ANOVA of K levels and Texture
S= soils

Table 4. Corelation matrix of different growth and physiological parameters of maize plant.

	TDM	Root K-Conc.	Shoot K-Conc.	Root K-uptake	Shoot K-uptake	Total K-uptake	Clay Content
SDM	0,57*	0,70*	0,29	0,64*	0,56*	0,81**	-0,18
RDM	0,93**	0,11	-0,67*	0,69*	-0,51	-0,04	-0,93**
RSR	0,83**	-0,06	-0,75*	0,56*	-0,65*	-0,23	-0,91**
TDM		0,35	-0,45	0,83**	-0,22	0,28	-0,85**
K-Conc. Root			0,27	0,78**	0,45	0,80**	0,04
K-Conc. Shoot				-0,20	0,95**	0,67*	0,65
K-uptake Root					0,03	0,57*	-0,55
K-uptake shoot						0,84**	0,51

* = significant (p = 5%)

** = highly significant (p = 1 %)

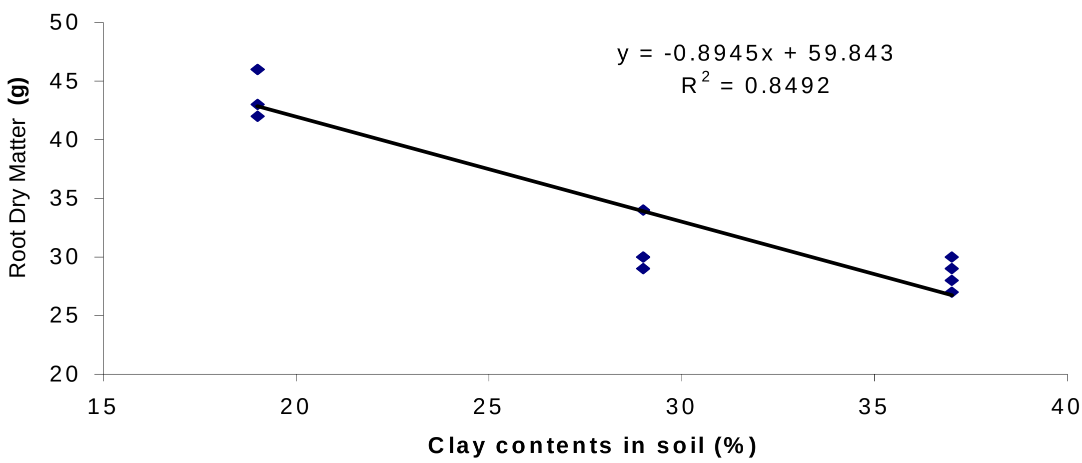

Fig. 1. Correlation between Clay Contents and Root Dry Matter production by maize

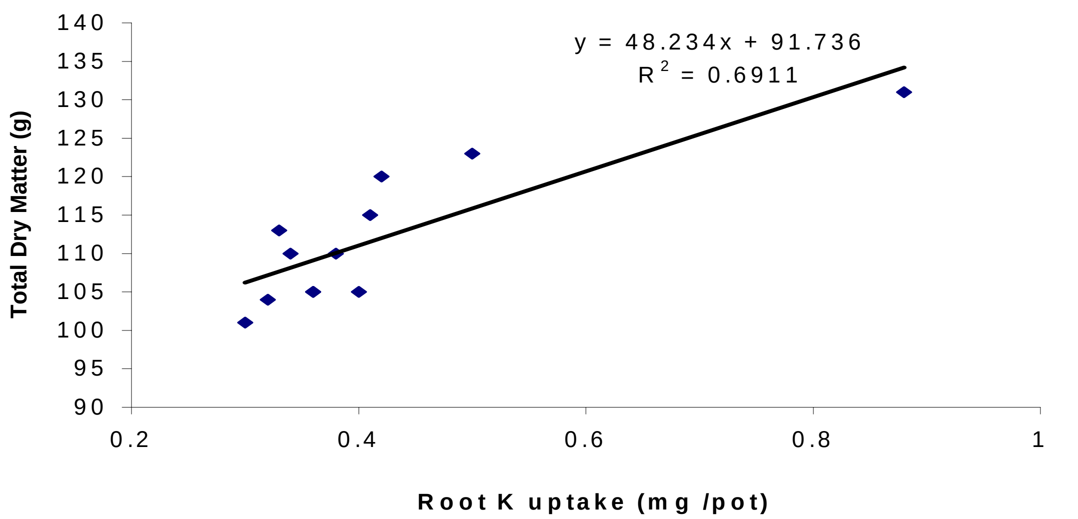

Fig. 2. Dependence of total dry matter on root K uptake

Conclusions

Soil texture affected significantly biomass production by maize plants grown with all K^+ levels. Plants grown in S_3 (high in clay contents) produced lower biomass due to poor growth of roots in S_3 and not due to low K^+ availability as exhibited by higher K^+ concentration in shoots as well as in roots. However, plants did not responded to applied K^+ in soil high in clay content in terms of both biomass production as well as K^+uptake. Total dry matter production negatively correlated (r=0.85) with clay contents and was highest in sandy soil (S_1).

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