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# PHOSPHORUS – USE EFFICIENCY IN CORN CULTIVARS

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## ABSTRACT

Phosphorus deficiency is one of the principal yield limiting factors for crop production in Egyptian soils. The objectives of this study were to evaluate P-use efficiency in 17 corn cultivars under P-deficient soil and to elucidate some of the putative mechanisms governing P-use efficiency. To achieve this goal, two pot experiments were carried out; in the first experiment the corn cultivars were grown in P-deficient soil at three levels of P (0, 50 and 75 mg P $kg^{-1}$) for 30 days after planting. Shoot, root dry matter production, P uptake and P-use efficiency of corn cultivars were investigated. The results showed that shoot and root dry matter production and P uptake were significantly affected by P treatments and corn cultivars. Based on dry matter production and P-use efficiency, corn cultivars were classified as efficient and responsive (ER), efficient and non responsive (ENR), non efficient and responsive (NER), and non efficient and non responsive (NENR). In the second experiment, four corn cultivars differing in P-efficiency were selected from previous screening. These were as follows; T.W.C.320 (ER), T.W.C. 324 (ENR), T.W.C. 351 (NER) and S.C. 12 (NENR). The corn cultivars were grown in the same P-deficient soil for 18 days after planting with and without P application. Dry matter production of shoot and root, root-shoot ratio, root length and organic acids concentrations in rhizosphere soil were investigated under P-deficient and P-sufficient treatments. The results of this experiment showed that dry matter production of shoot and root, root-shoot ratio, root length and organic acids concentrations were increased in all corn cultivars under P-deficient treatment. The effects on root dry weight, root-shoot ratio, root length and organic acids concentrations in rhizosphere soil were greater for efficient cultivars (T.W.C 320and T.W.C 324) than for non-efficient, (T.W.C 351 and S.C 12).

## INTRODUCTION

Plant species and even varieties of the same species differ in their ability to grow under specific nutritional conditions, particularly under nutritional stress. A wide range of morphological, anatomical, and physiological plant features can be responsible for intraspecific variations in response to nutrient stress and some screening procedures obviously will be more effective than others in identifying phenotypic responses based on specific plant features.

Corn is grown on approximately more than two million feddans in Egypt, where phosphorus deficiency is important limitation to its production. The deficiency of phosphorus can be easily corrected through the use of fertilizers; but due to the natural low phosphorus and the high P-fixation capacity of Egyptian soils, higher dose is required for adequate crop yields. Under these situations, some corn varieties adapted to a lower level of phosphorus would provide a complementary solution for improving crop yield in Egyptian P-deficient soils. A number of studies indicate genetic variations in the response to phosphorus by corn cultivars (Fageria and Baligar, 1997; Gaume *et al.*, 2001 and Liu *et al.*, 2004).

Plant adaptation allowing for an improved growth in low P soils are related to the ability of a plant to take up more P from a deficient soil (higher P acquisition efficiency) or / and given quantity of P (higher P use efficiency). (Marschner, 1995 and Raghothama, 1999).

A higher P acquisition efficiency can be related to (a) the development of a more extensive root system, in association or not with mycrthizal fungi, or specific specialized roots such as proteoid root hairs (McCully, 1999 and Raghothama, 1999), allowing the plant to explore larger volume of soil, and (b) changes in root physiology allowing the uptake of P at lower concentration in the soil solution, and / or the uptake of P from insoluble inorganic or organic forms (Marschner, 1995).

Excretion of organic acids, enzymes and protons by roots may play a major role in the P nutrition of various crops (Gaume *et al.*, 2001; Ming *et al.*, 2002; Singh and Pandy 2003 and Liu *et al.*, 2004). The competition of phosphate and organic anions for similar adsorption sites can increase the concentration of P in the soil solution. The presence of organic acids may also increase the solubility of nutrients such as P, which is phenomenon associated with the rhizosphere of plants (Zhang *et al.*, 1997; Li *et al.*, 1997; Otani and Ae, 1997 and Gaume *et al.*, 2001).

The objectives of this study were to evaluate corn cultivars for P-use efficiency and to elucidate some of the putative mechanisms governing P-use efficiency.

## MATERIALS AND METHODS

The objectives of this study were to evaluate growth and P-use efficiency of 17 corn cultivars under P-deficient soil and to elucidate some of the putative mechanisms governing P-use efficiency. To achieve this goal, two pot experiments were carried out.

**The first experiment:**

A green house experiment was conducted to evaluate P-use efficiency in 17 corn cultivars under P-defficient soil. Surface soil sample (0-30 cm) was taken from Nubbaria region. The soil having the following chemical properties: pH 7.6 (1:1 soil-water ratio) after Richards (1954), extractable P 1.9 mg $Kg^{-1}$ determined after Olsen *et al.*, (1954), Organic matter percent was 0.10% determined by oxidizing with cromic acid according to Walkley and Black (1934). And calcium carbonate percent was 4.25% estimated using Collins calcimeter according to Wright (1939). Phosphorus added at three levels, low ($P_0$) 0 mg P $kg^{-1}$ , medium (P1) 50 mg P $kg^{-1}$, and high (P2) 75 mg P $kg^{-1}$ by using single superphosphate (15% $P_2O_5$). A complete randomized design was used in a factorial arrangement, and treatments were replicated three times.

The study was conducted in plastic pots with 7 kg of soil in each. Each pot received 2.52 g ammonium nitrate (33.5% N) and 0.35 g potassium sulphate (48% $K_2O$) which is equivalent to 360 kg ammonium nitrate / feddan and 50 kg potassium sulphate / feddan, respectively. Both fertilizers were mixed well with the soil.

The seeds of each corn cultivar were selected carefully for uniformity of size and colour. A constant weight of selected seeds was evenly spread on the surface of each pot, covered with a thin layer of soil and irrigated up to field capacity. Each pot contained 4 plants which were frequently watered to maintain moisture at approximate field capacity. Plants were harvested at 30 days after planting. At the harvest time, shoots and roots were removed from each pot using a water jet. Roots and shoots were washed several times with distilled water. Dry weight of plant material was recorded after oven drying at 70°C and then milled. Ground plant material was digested with sulphuric acid as reported by Yoshida *et al.*, (1976) and analyzed for P colorimetrically by using molybdenum blue method described by El-Hineidy and Agiza (1959). These data were statistically analyzed according to Snedecor and Cochran (1980).

**The second experiment:**

Four corn cultivars differing in P-use efficiency were selected based on the results of the first experiment, these were as follows: T.W.C 320 (efficient and responsive), T.W.C 324 (efficient and non responsive), T.W.C 351 (non efficient and responsive) and S.C 12 (non efficient and non responsive). Seeds of each cultivar were grown in the same P-deficient soil which used in the first experiment. Phosphorus added at two levels (low and medium) which used as described in the first experiment. A complete randomized was used in a factorial arrangement, and treatments were replicated six times.

The four corn cultivars were grown for 18 days after planting in plastic pots filled with 7 kg of soil. Using the same basal application of fertilizers in the first experiment. The seeds of each four corn cultivars were selected carefully for uniformity of size and colour. A constant weight of selected seeds was evenly spread on the surface of each pot, covered with a thin layer of soil and irrigated up to field capacity. Each pot contained 4 plants which were frequently watered to maintain moisture at approximate field capacity. At the harvest time, the shoots and the roots were removed from each pot using a water jet. Roots and shoots were washed several times with distilled water.

Plants of three replicates from each treatment, separated into shoots and roots then dry weight of each was recorded after oven drying at 70°C. Plants of another three replicates of each treatment were used for root length measurements. Plants were rinsed with distilled water, separated to shoots and roots. Fresh root used for root length measurements by using the method described by Newman, (1966) after root weights were recorded. After the seedling were removed from the pots, the entire root system from all four seedlings in each pot was treated as one unit, rhizosphere soil was separated from bulk soil by gently shaking the root system. Soil adhering to the root system was defined as rhizosphere soil (Rovira and McDougall 1967). To determine organic acids of rhizosphere, soil sample was passed through a 2-mm sieve. 10 g sample of sieved soil was placed in disposable plastic filter flasks fitted with 0.45 μm nylon membrane filters. Twenty milliliters of distilled water adjusted to pH 4.3 with HCl was added to each flask and allowed to leach under gravity for 12h. The extracting solutions were acidified to approximate the pH of the soil. The flasks were then attached to a vacuum pump and residual leaching solution was extracted under a vacuum of 83 KPa for 15 min. All leachate was collected and analyzed for organic acids at the same day. Organic acids were measured by Gas chromatography (Mass Selective Detectors 5972 series). Data were statisticall / analyzed according to Snedecor and Cochran (1980).

## RESULTS AND DISCUSSION

**I- The first experiment:**

**Evaluation of P-use efficiency for corn cultivars**

There were significant difference among cultivars for each P level for root and shoot dry weight (Table 1). Root and shoot dry weight varied significantly at "low", "medium" and "high" P levels. In the case of root dry weight, the variation was 2.02 to 6.99 g $pot^{-1}$ at the low P level, 1.55 to 6.91 g $pot^{-1}$ at the medium P level, and 1.91 to 6.34 g $pot^{-1}$ at the high P level.

**Table (1): Root and shoot dry weight of different cultivars of corn under different P levels**

| Cultivar | Root dry weight (g/pot) | | | | Shoot dry weight (g/pot) | | | |
|---|---|---|---|---|---|---|---|---|
| | Po | P1 | P2 | Mean | Po | P1 | P2 | Mean |
| 1. S.C. 10 | 3.10 | 2.98 | 2.97 | 3.02 | 2.39 | 3.43 | 3.68 | 3.17 |
| 2. S.C 122 | 4.27 | 3.80 | 3.71 | 3.93 | 3.39 | 5.94 | 6.53 | 5.29 |
| 3. S.C.123 | 5.83 | 5.40 | 5.53 | 5.59 | 3.20 | 6.42 | 6.93 | 5.52 |
| 4. S.C.124 | 5.80 | 5.56 | 5.16 | 5.51 | 3.10 | 6.36 | 6.38 | 5.28 |
| 5. S.C.155 | 5.33 | 5.22 | 5.48 | 5.35 | 2 .32 | 6.86 | 7.48 | 5.55 |
| 6. S.C. 12 | 2.02 | 1.55 | 1.91 | 1.83 | 1.35 | 2.18 | 2.76 | 2.10 |
| 7. S.C. 13 | 4.55 | 4.51 | 4.12 | 4.39 | 2.76 | 5.12 | 5.90 | 4.59 |
| 8. S.C. 14 | 5.20 | 4.83 | 4.76 | 4.93 | 2.89 | 5.75 | 6.02 | 4.89 |
| 9. T.WC.310 | 4.84 | 4.31 | 4.37 | 4.51 | 3.40 | 6.80 | 7.86 | 6.02 |
| 10.T.WC.320 | 6.99 | 6.91 | 6.34 | 6.75 | 3.42 | 7.73 | 7.47 | 6.21 |
| 11.T.WC.321 | 5.60 | 5.46 | 5.16 | 5.41 | 3.10 | 7.91 | 7.65 | 6.22 |
| 12.T.WC.324 | 6.00 | 4.73 | 4.46 | 5.06 | 3.31 | 6.72 | 6.63 | 5.55 |
| 13.T.WC.351 | 4.14 | 4.04 | 4.00 | 4.06 | 1.84 | 5.62 | 5.70 | 4.39 |
| 14.T.WC.311 | 4.67 | 4.61 | 4.60 | 4.63 | 3.10 | 6.30 | 6.38 | 5.26 |
| 15.T.WC.314 | 4.41 | 4.37 | 4.30 | 4.36 | 3.02 | 5.62 | 6.08 | 4.91 |
| 16.T.WC.326 | 5.85 | 5.78 | 4.96 | 5.53 | 2.27 | 6.23 | 5.97 | 4.82 |
| 17.S. C | 2.72 | 2.71 | 2.47 | 2.63 | 2.24 | 4.21 | 4.37 | 3.61 |
| Mean | 4.78 | 4.52 | 4.37 | 4.56 | 2.77 | 5.84 | 6.11 | 4.91 |
| Treatment | $L.S.D_{0.05}$ | | | | $L.S.D_{0.05}$ | | | |
| A | 0.253 | | | | 0.21 | | | |
| B | 0.106 | | | | 0.09 | | | |
| AB | 0.436 | | | | 0.37 | | | |

A = Cultivar B = P level AB= Intera : ion

S.C. = single cross, T.WC. = Three ways cross,

S.C. = An open pollinated variety (sweet corn)

Shoot dry weight across P levels varied from 1.35 to 3.42 g pot$^{-1}$ at the low P level, 2.18 to 7.91 g pot$^{-1}$ at the medium P level, and 2.76 to 7.86 g pot$^{-1}$ at the high P level. Cultivar T. W.C 320 produced significantly higher shoot dry weight at the low P level as compared to other cultivars S.C.12 had significantly lower shoot dry weight at the low and medium P levels. Values were 1.35 g pot$^{-1}$ at the low P level and 2.18 g pot$^{-1}$ at the medium P level. Phosphorus X cultivar interactions for root and shoot dry weight were significant.

Phosphorus uptake in root and shoot under three P levels differed significantly among cultivars (Table 2).At low P level, P uptake in root ranged from 3.70 to 11.28 mg pot$^{-1}$ , at the medium P level, from 3.86 to 13.82 mg pot$^{-1}$, and the high P level, from 4.83 to 15.17 mg pot$^{-1}$. In the case of P uptake in shoot the variation was 2.43 to 9.75 mg pot$^{-1}$ at the low P level, 7.24 to 25.23 mg pot$^{-1}$ at the medium P level and 9.33 to 25.48 mg pot$^{-1}$ at the high P level. P uptake in shoot are related to dry matter production. Cultivar T.W.C 320 had the highest P uptake in root and shoot. For an average values were 12.68 mg pot$^{-1}$ and 19.28 mg pot$^{-1}$ respectively. Cultivar S.C12 had the lowest P uptake in root and shoot. Values were 4.13 mg pot$^{-1}$ and 6.33 mg pot$^{-1}$, respectively. phosphorus-use efficiency also differed significantly among cultivars across P levels (Table 3). Cultivar T. W. C 351 had the highest P-use efficiency, and cultivar S. C 10 had the lowest.

**Table (2): Phosphorus uptake in root and shoot of different cultivars of corn under different P levels.**

| Cultivar | P uptake in root (mg/pot) | | | | P uptake in shoot (mg/pot) | | | |
|---|---|---|---|---|---|---|---|---|
| | Po | P1 | P2 | Mean | Po | P1 | P2 | Mean |
| S.C. 10 | 3.72 | 5.96 | 6.24 | 5.31 | 5.74 | 10.56 | 13.40 | 9.90 |
| S.C 122 | 4.70 | 7.26 | 7.75 | 6.57 | 6.85 | 16.10 | 19.65 | 14.20 |
| S.C.123 | 5.25 | 8.10 | 9.40 | 7.58 | 6.53 | 18.30 | 24.25 | 16.36 |
| S.C.124 | 6.03 | 8.34 | 8.93 | 7.77 | 5.89 | 16.35 | 19.71 | 13.98 |
| S.C.155 | 4.69 | 8.35 | 10.41 | 7.82 | 3.94 | 15.78 | 24.68 | 14.80 |
| S.C. 12 | 3.70 | 3.86 | 4.83 | 4.13 | 2.43 | 7.24 | 9.33 | 6.33 |
| S.C. 13 | 8.55 | 10.01 | 10.26 | 9.08 | 5.24 | 14.34 | 17.70 | 12.43 |
| S.C. 14 | 7.75 | 9.27 | 10.71 | 9.24 | 6.07 | 20.07 | 21.91 | 16.02 |
| T.WC.310 | 4.36 | 9.78 | 10.27 | 8.14 | 6.46 | 20.40 | 25.15 | 17.34 |
| T.WC.320 | 10.90 | 13.82 | 13.31 | 12.68 | 9.75 | 23.96 | 24.13 | 19.28 |
| T.WC.321 | 5.60 | 9.23 | 15.17 | 10.00 | 6.60 | 25.23 | 25.48 | 19.10 |
| T.WC.324 | 11.28 | 9.08 | 9.81 | 10.06 | 6.65 | 20.90 | 22.14 | 16.56 |
| T.WC.351 | 6.96 | 10.02 | 10.36 | 10.11 | 4.05 | 15.06 | 15.62 | 11.58 |
| T.WC.311 | 2.29 | 11.66 | 11.73 | 8.56 | 9.05 | 23.00 | 24.24 | 18.76 |
| T.WC.314 | 6.84 | 10.18 | 10.71 | 9.24 | 8.82 | 20.46 | 22.37 | 17.22 |
| T.WC.326 | 3.80 | 6.01 | 7.49 | 5.77 | 4.74 | 21.81 | 22.03 | 16.19 |
| SW | 4.08 | 6.69 | 6.92 | 5.90 | 4.93 | 13.18 | 14.86 | 10.99 |
| Mean | 5.91 | 8.68 | 9.67 | 8.10 | 6.10 | 17.81 | 20.39 | 14.77 |
| Treatment | $L.S.D_{0.05}$ | | | | $L.S.D_{0.05}$ | | | |
| A | 0.706 | | | | 0.74 | | | |
| B | 0.297 | | | | 0.31 | | | |
| AB | 1.220 | | | | 1.28 | | | |

**A = Cultivar** **B = P level** **AB= Interaction**

**Table (3): Dry matter yield at low P level and P use efficiency of different cultivars of corn.**

| Cultivar | Dry matter yield at low P level (mg/pot) | P use efficiency (mg dry matter/mg P absorbed) |
|---|---|---|
| S.C. 10 | 5490 | 120.65 |
| S.C 122 | 7660 | 168.47 |
| S.C.123 | 9030 | 170.41 |
| S.C.124 | 8900 | 191.86 |
| S.C.155 | 7650 | 232.13 |
| S.C. 12 | 3370 | 127.69 |
| S.C. 13 | 7310 | 203.72 |
| S.C. 14 | 8090 | 150.93 |
| T.WC.310 | 8240 | 156.05 |
| T.WC.320 | 10410 | 225.24 |
| T.WC.321 | 8700 | 173.11 |
| T.WC.324 | 9310 | 150.31 |
| T.WC.351 | 5980 | 254.82 |
| T.WC.311 | 7770 | 132.61 |
| T.WC.314 | 7430 | 170.37 |
| T.WC.326 | 8120 | 166.42 |
| S.C | 4960 | 162.44 |
| Mean | 7554.12 | 173.96 |
| $L.S.D_{0.05}$ | 230.51 | 4.54 |

**P use efficiency = (dry matter yield of root and shoot across medium and high P level – dry matter yield of root and shoot at low P level) / (p accumulation in root and shoot across medium and high P level – P accumulation in root and shoot at low P level**

All growth and P uptake parameters increased significantly with increasing levels of soil P. This means that the soil used in the experiment was appropriate for screening purposes. One of the pre requisites of varietals screening for mineral stress in that the growth medium should be deficient in the nutrient under investigation (Fageria, 1989).

Based on dry matter production (root plus shoot) at the low P level and P-use efficiency, the cultivars were classified into four groups (Fig.1), according to the methodology by Fageria and Baligar (1993). These groups were as follows:

1- Efficient and responsive: Cultivars which produced dry matter yield higher than the average of seventeen cultivars at the low P level and responded well with the addition of P (average P-use efficiency, higher than the average of seventeen cultivars), were classified as efficient and responsive. Cultivars S.C 124, S.C 155 and T.W.C 320 fall into this category.
2- Efficient and non responsive : in this group are cultivars which produced dry matter yield higher than average dry matter yield, but P-use efficiency was lower than the average of seventeen cultivars. Cultivars S. C 122, S.C. 123, S. C 14, T.W.C. 310, T. W.C. 321, T.W.C.324, T.W.C. 311 and T.W.C 326 fall into this category.

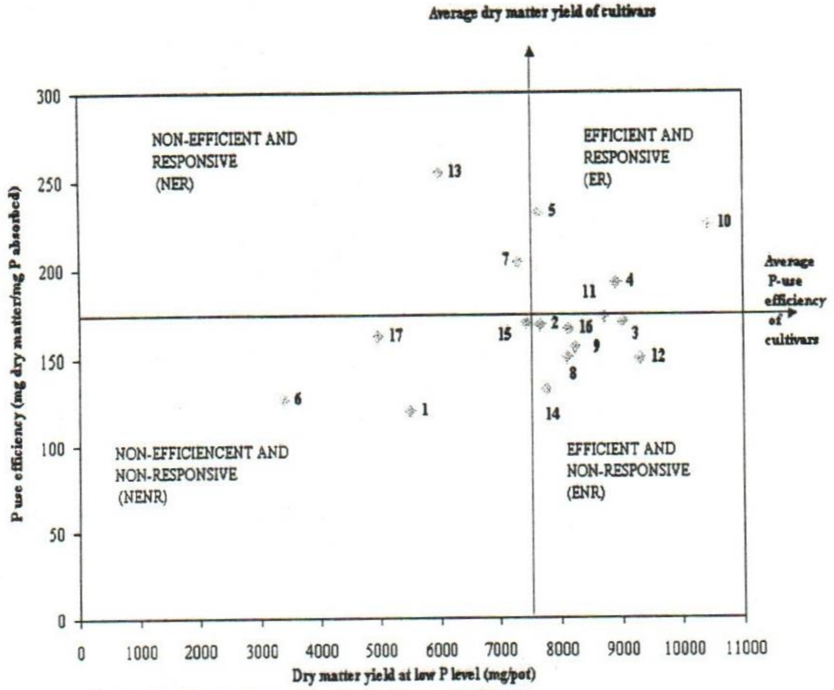


Fig. (1): Classification of corn cultivars for phosphorus - use efficiency.
Values in the figure refer to cultiver numbers, which are numbered in Table 1

3- Non efficient and responsive : in this group are cultivars which produced dry matter yield less than average dry matter yield, but P-use efficiency was higher than average. In this group fall cultivars S.C.13, and T.W.C 351.

4- Non efficient and non responsive : in this group are cultivars which produced lower dry matter yield than average dry matter yield as well as lower than average P-use efficiency. In this group fall the cultivars S. C. 10, S. C. 12, T. W.C 314 and S.C. From a practical point of view, cultivars which fall under the group efficient and responsive are the best ones. These cultivars can produce well under a low P level and respond well with P application. The second group, which can be used under low technology or under a low P level and can produce well, are the efficient and non responsive.

**II-The second experiment:**

**Mechanisms governing P-use efficiency of corn cultivars**

**(1) Shoot and root growth:**

- Shoot growth: Shoot dry weight was significantly influenced by cultivar and P level. Shoot dry weight of all cultivars increased with increasing P level, confirming the severe P deficiency in unamended soil. Considerable cultivar variation in shoot dry weight was observed for all P levels.

Generally the T. W. C 320 and T. W. C 324 (efficient cultivars) had higher shoot dry weight than the T. W. C 351 and S. C. 12 (non-efficient cultivars). This results agreement with Gaume *et al.*, (2001) and Yan *et al.*, (1995 a).

- Root growth: Treatment effects on root dry weight was significant for cultivar, P level and the interaction of cultivar and P level. P deficiency favored root growth over shoot growth, which resulted in the increase of root / shoot ratio (Table 4). Root growth was increased under low P supply. Large cultivar differences were observed for root dry weight. In low P treatment, root dry weight was significantly higher for T. W. C 320 and T. W. C 324 than for T. W. C 351 and S. C 12 (Table 4). Root length followed the same pattern as root dry weight (Table 4) and the same treatment effects were significant. Efficient cultivars (T. W.C 320 and T. W. C 324) had as much as two times more root length than the non-efficient cultivars (S. C 12 and T. W.C 351) in the low P treatment. Root / shoot ratio was influenced by cultivar, P level and P level x cultivar interaction (Table 4). Root / shoot ratio decreased with increasing P level. Cultivars differed in root / shoot ratio, for example, efficient cultivar, T. W. C 320 had a root / shoot ratio of 0.78 while non-efficient cultivar S. C. 12 had a root / shoot ratio of 0.63 with low P level.

**Table (4): Shoot and root dry weight, root/shoot ratio and root length of four corn cultivars grown under two P levels at 18 days.**

| Cultivar | Shoot dry weight (g/pot) | | | Root dry weight (g/pot) | | |
|---|---|---|---|---|---|---|
| | Po | P1 | Mean | Po | P1 | Mean |
| T.WC. 320 | 3.16 | 6.92 | 5.04 | 2.47 | 1.54 | 2.01 |
| T.WC.324 | 3.11 | 5.57 | 4.34 | 2.20 | 1.48 | 1.84 |
| S.C. 12 | 2.11 | 2.56 | 2.34 | 1.33 | 1.19 | 1.26 |
| T. WC. 351 | 2.77 | 3.50 | 3.14 | 1.92 | 1.59 | 1.76 |
| Mean | 2.79 | 4.64 | 3.72 | 1.98 | 1.45 | 1.72 |
| Treatment | A | B | AB | A | B | AB |
| $L.S.D_{0.05}$ | 0.138 | 0.098 | 0.195 | 0.300 | 0.212 | 0.424 |
| **Cultivar** | **Root / shoot ratio** | | | **Root length (m/plant)** | | |
| | Po | P1 | Mean | $P_0$ | P1 | Mean |
| T.WC. 320 | 0.78 | 0.22 | 0.50 | 95.07 | 68.82 | 81.95 |
| T.WC.324 | 0.71 | 0.27 | 0.49 | 73.82 | 56.57 | 65.20 |
| S.C. 12 | 0.63 | 0.46 | 0.55 | 41.25 | 35.28 | 38.27 |
| T. WC. 351 | 0.69 | 0.45 | 0.57 | 48.53 | 40.34 | 44.44 |
| Mean | 0.70 | 0.35 | 0.53 | 64.67 | 50.25 | 57.46 |
| Treatment | A | B | AB | A | B | AB |
| $L.S.D_{0.05}$ | 0.078 | 0.055 | 0.111 | 5.64 | 3.99 | 7.98 |

**A = Cultivar** **B= P level** **AB = Interaction**

**(2) Organic acids in corn rhizosphere:**

Four kinds of organic acids, namely malic, citric, oxalic and succinic acids, were detected in rhizosphere of corn cultivars (Table 5). The amount of malic acid was the highest of the four. Whears succinic acid occurred in low concentrations compared to the others organic acids. The four organic acids in rhizosphere of corn cultivars measured by HPLC are responsive to phosphorus treatments. Release of organic acids from the different cultivars was generally higher under P starvation conditions than with 50 ppm P treatment. P starvation caused one and half fold increase in the amount of the four organic acids in rhizosphere of P-efficient cultivars whereas about one and third fold for P-inefficient cultivars. These results were in agreement with (Zhang *et al.*, 1997) they found that in radish plants, organic acids increased between 15 times and 60 times under P deficient conditions. A significant difference among corn cultivars for the amount of organic acids was observed. Malic, citric, oxalic and succinic acids concentrations in the rhizosphere of P-efficient cultivars increased by 1.3 times in plants grown at $P_0$ and as much as 1.1 when plants grown at 50 ppm phosphorus ($P_1$) compared to P-inefficient cultivars. Gaume *et al.*, (2001) concluded that between genotypes, differences in organic acid root exudation existed. They are found that the efficient maize genotype showed the highest increase in organic acids root exudation with P deficiency.

**Table (5): Organic acids (mg kg$^{-1}$ soil) concentrations in rhizosphere of corn cultivars.**

| Cultivar | Malic | | | Citric | | | Oxalic | | | Succinic | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_0$ | $P_1$ | Mean | $P_0$ | $P_1$ | Mean | $P_0$ | $P_1$ | Mean | $P_0$ | $P_1$ | Mean |
| T. W. C 320 | 144.43 | 98.11 | 121.27 | 86.23 | 57.34 | 71.79 | 23.46 | 15.20 | 19.33 | 3.48 | 2.35 | 2.92 |
| T. W. C 324 | 142.40 | 96.15 | 119.28 | 80.44 | 54.41 | 67.43 | 23.43 | 15.40 | 19.42 | 3.27 | 2.26 | 2.77 |
| S. C 12 | 110.35 | 86.49 | 98.42 | 68.36 | 51.56 | 59.96 | 10.24 | 7.58 | 8.91 | 2.75 | 2.10 | 2.43 |
| T. W. C 351 | 112.52 | 88.42 | 100.47 | 70.26 | 52.32 | 61.29 | 9.38 | 6.95 | 8.17 | 2.39 | 1.80 | 2.10 |
| Mean | 127.43 | 92.29 | 109.86 | 76.32 | 53.91 | 65.12 | 16.63 | 11.28 | 13.96 | 2.97 | 2.13 | 2.55 |
| Treatment | $L.S.D_{0.05}$ | | | $L.S.D_{0.05}$ | | | $L.S.D_{0.05}$ | | | $L.S.D_{0.05}$ | | |
| A | 1.30 | | | 1.41 | | | 0.530 | | | 0.350 | | |
| B | 0.920 | | | 0.990 | | | 0.380 | | | 0.250 | | |
| AB | 1.98 | | | 1.99 | | | 0.754 | | | 0.501 | | |

**A = Cultivar B= P level AB = Interaction**

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## كفاءة استخدام الفوسفور فى أصناف الذرة

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يعتبر نقص الفوسفور واحد من العوامل الرئيسية المحددة لإنتاج المحاصيل فى الاراضى المصرية وتهدف هذه الدراسة إلى تقييم ١٧ صنف من أصناف الذرة الشامية من حيث كفاءتها فى استخدام الفوسفور وذلك بزراعتها فى أراضى بها نقص من الفوسفور وكذلك دراسة بعض الآليات المسئولة عن الاختلاف فى كفاءة استخدام الفوسفور. ولتحقيق هذه الاهداف، أقيمت تجربتى أصص، حيث تم إنماء أصناف الذرة فى التجربة الاولى فى أرض بها نقص من الفوسفور وذلك تحت ٣ مستويات من الفوسفور (صفر، ٥٠، ٧٥ ملليجرام فوسفور لكل كيلو جرام تربة) لمدة ٣٠ يوما من الزراعة . وتم فى هذه التجربة تقدير المادة الجافة لكل من المجموع الخضرى والجذور وكذلك محتوى كل منهما من الفوسفور.

وقد أوضحت نتائج هذه التجربة أن إنتاج المادة الجافة لكل من المجموع الخضرى والجذور ومحتوى كل منهما من الفوسفور قد تأثر معنويا بكل من معاملات الفوسفور وأصناف الذرة. وأنه بناء على إنتاج المادة الجافة لكل من المجموع الخضرى والجذور وكذلك كفاءة استخدام الفوسفور، تم تقسيم أصناف الذرة إلى أصناف كفؤة وذات إستجابة للفوسفور ، وأصناف كفؤة وعديمة الاستجابة للفوسفور، وأصناف غير كفؤة وذات استجابة للفوسفور، وأصناف غير كفؤة وعديمة الاستجابة للفوسفور.

فى التجربة الثانية تم إختيار ٤ أصناف تختلف فى كفاءة استخدامها للفوسفور بناء على نتائج التجربة الاولى وشملت هذه الاصناف هجين ثلاثى ٣٢٠ (صنف كفؤ وذو استجابة للفوسفور)، هجين ثلاثى ٣٢٤ (صنف كفؤ وعديم الاستجابة للفوسفور)، هجين ثلاثى ٣٥١ (صنف غير كفؤ وذو استجابة للفوسفور)، هجين فردى ١٢ (صنف غير كفؤ وعديم الاستجابة للفوسفور) حيث نميت هذه الاصناف فى نفس التربة المستخدمة فى التجربة الاولى فى وجود أو عدم وجود الفوسفور وذلك لمدة ١٨ يوم من الزراعة، تم فى هذه التجربة تقدير المادة الجافة المنتجة لكل من المجموع الخضرى والجذور ونسبة الجذور إلى الاجزاء الخضرية وطول الجذور وتركيز الاحماض العضوية فى منطقة نمو الجذور وذلك تحت معاملات نقص وكفاية من الفوسفور . وقد أوضحت نتائج هذه التجربة زيادة المادة الجافة لكل من الاجزاء الخضرية والجذور وكذلك نسبة الجذور إلى الاجزاء الخضرية وطول الجذور وتركيز الاحماض العضوية فى منطقة نمو الجذور لكل أصناف الذرة تحت معاملات نقص الفوسفور ، وكانت الزيادة فى المادة الجافة للجذور ونسبة الجذور إلى الاجزاء الخضرية وطول الجذور وتركيز بعض الاحماض العضوية فى منطقة نمو الجذور كبيرة فى حالة الاصناف الكفؤة ( هجين ثلاثى ٣٢٠ ، هجين ثلاثى ٣٢٤ ) بالمقارنة بالاصناف غير الكفؤة (هجين ثلاثى ٣٥١ ، هجين فردى ١٢).