J. Agric. Sci. Mansoura Univ., 30 (6): 3513 - 3520, 2005

EVALUATION OF NUTRIENT ABSORPTION BY SOME PLANTS AS INFLUENCED BY EXCHANGE SITES

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ABSTRACT

A hydroponic study was carried out to determine the absorption capacity of some plants in the presence of ion exchange membranes with nutrient solution. Two rice species Giza 176 and Sakha 101 and two millet species Pearl millet and Berayard millet were used as test plants for the absorption of nutrient elements either from nutrient solution alone, in the presence of cation membrane M-Cation-40, or in the presence of anion membrane M-Anion-40.

The obtained results revealed that the absorption from the nutrient solution without any resins was significantly better than that with them. This was referred to that the nutrient solution alone provided the plants with more balanced nutrients than the other ones. It was also observed that cation resins increased the absorption of cations on the account of anions, while the opposite was true for anion resins. The existence of exchange complexes in the root zone significantly affects the absorption of nutrient elements by the roots. It is advisable to apply well-decomposed organic materials to proliferate easy exchange of nutrients for plants, i.e. a good mediator between plants, soil and sources of mineral fertilizers. It is also recommended to apply nutrients in a balance with other nutrients as far as possible.

The objective of this study was to assess the absorption capacity of the roots of some plants as influenced by the presence of cation and anion resins in the nutrient medium.

Keywords: Rice roots, Millet roots, Absorption, nutrient solution, membrane resins.

INTRODUCTION

Soil fertility, by definition, means that root growth medium has to sustain essential elements at the required rate, i.e. an appropriate nutrient flux. Bugbee 2003 reported that the flux of NO_3, NH_4, P, K, and Mn to plant roots follows active uptake, i.e. fast removal from the nutrient medium. But, Mg, S, Fe, Zn, Cu, Mo, and C follow intermediate uptake, while Ca and B follow passive uptake, i.e. slow removal. Chaney and Coulombe 1982 mentioned that phosphorus level in the plant was 3 times higher than the optimum in most plants and induced iron and zinc deficiency. Bugbee 2003 recorded that ammonium ion decreased the uptake of K, Ca, Mg, and micro-nutrients, so it should be used cautiously. Phosphorous and potassium are rapidly drawn down to very low levels. But, this simply means that the plants are healthy and actively absorb these elements from the solution. Calcium requirements of monocots grasses are always low. Calcium is nontoxic, even at high tissue concentrations, but it accumulates in solution if too much is added with the refill solution. Magnesium is highly mobile and can accumulate to toxic levels in upper leaves. He also reported that a dilute refill solution 1/3 Hoagland solution can be used at later growth stages.

Macía *et al.* 2003 found no significant difference due to four N: K ratios using Duncan's test. From another standpoint, Terada *et al.* 2003 reported that the amount of K uptake increased when K concentration increased. Calcium uptake decreased when K increased. Also, increasing the Ca concentration in the solution led to an increase in Ca uptake. However, Mg uptake decreased as Ca concentration increased. Gupta 1997 reported that P additions increased Mo uptake by replacement on the exchange complex and release of Mo to solution. S depressed Mo uptake by direct competition on root adsorption sites. Mo with Mn affects Fe uptake in tomato. With respect to anion exchange, Bentley *et al.* 1999 reported that the amount of P extracted using anion exchange membranes AEM-Pi increased with extraction time, but it was generally independent of the extraction ratio. Maximum AEM-Pi was 3.61$\mu g.g^{-1}$ after eight hours extraction Abrams and Jarrel 1992.

The objective of this study was to achieve the roots' absorption capacity of some plants as affected by cation and anion resins in the nutrient solution.

MATERIALS AND METHODS

A laboratory experiment was carried out to assess the absorption capacity and the uptake of the adopted plants of nutrient elements from a nutrient medium. In addition, the effect of cation and anion resins that were saturated in the nutrient solution was also targeted in this study. Therefore, two rice varieties Sakha 101 and Giza 176, pearl millet grass and Barnyard millet were sown in sawdust medium and watered to sustain moisture content at field capacity for ten days. The obtained seedlings of the four proposed varieties and species were dipped in a nutrient solution for one day, after which seedlings were rinsed with distilled water to dilute the nutrient elements off the root surfaces. The elemental composition of the nutrient solution is depicted in Table 1.

Table 1. Chemical composition of the applied nutrient solution.

Nutrient Element	Concentration (ppm)
N	105.0
P	15.5
K	117.0
Ca	80.0
Mg	24.0
S	32.0
Fe	19.3
Mn	11.8
B	0.3
Zn	8.5
Cu	4.2
Mo	0.1
Cl	4.6

Plants were divided into three groups. The first group was grown in the nutrient solution in the presence of a cation exchange membrane M-Cation-40 resin. The second was grown in the nutrient solution in the presence of an anion exchange membrane M-Anion-40 resin. The third was grown in the nutrient solution alone. Plant growth parameters were recorded. After 20 days, plants were pulled out of the growth medium, rinsed with distilled water to remove superficially absorbed ions by the root.

Plants' roots, stems and leaves were all sampled and analyzed for their content of positively and negatively charged mobile components using the method of chemical autographs based on electrolysis. Oven-dry samples were digested in a mixture of sulfuric acid H_2SO_4 and 30% v/v hydrogen peroxide H_2O_2. Nitrogen was determined using micro-Kjeldahl method Paech and Tracey, 1956. Phosphorus was coloured by ammonium molybdate and ascorbic acid method, then determined by spectrophotometer according to Watanabe and Olsen 1965. Potassium was determined using a Flame photometer. Calcium, magnesium and micro-nutrients Fe, Mn, Zn, and Cu were determined by atomic absorption spectrophotometer PYE UNICAM 1900.

The obtained results were subjected to analysis of variance according to the randomized complete blocks statistical design Gomez and Gomez, 1984 in three replicates, and treatments' means were differentiated according to Duncan 1955.

RESULTS AND DISCUSSION

It is clear from Table 2 that all test plants performed the same regarding the absorption of macro-nutrients from the three nutrient solutions despite being different the absolute amounts absorbed from each element by these plants.

Table 2. Macro-nutrients contents in the dry matter of test plants ppm.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
N	Nutrient solution	46.9 b	44.1 b	38.9 b	35.6 b
	M-Cation	25.7 c	22.3 c	18.5 c	21.5 c
	M-Anion	58.7 a	55.1 a	48.7 a	44.5 a
P	Nutrient solution	16.8 b	16.1 b	14.2 b	13.4 b
	M-Cation	8.9 c	7.9 c	6.3 c	5.6 c
	M-Anion	19.9 a	17.9 a	15.8 a	14.3 a
K	Nutrient solution	32.9 b	34.0 b	35.8 b	36.6 b
	M-Cation	35.7 a	36.9 a	39.4 a	40.9 a
	M-Anion	16.4 c	17.2 c	18.0 c	18.5 c
Ca	Nutrient solution	36.4 b	35.1 b	32.9 b	29.4 b
	M-Cation	40.9 a	39.4 a	36.9 a	33.1 a
	M-Anion	18.5 c	18.0 c	17.2 c	14.7 c
Mg	Nutrient solution	18.5 b	17.7 b	16.8 b	15.0 b
	M-Cation	20.9 a	19.9 a	19.0 a	16.9 a
	M-Anion	9.5 c	9.2 c	8.9 c	7.6 c

Concerning nitrogen and phosphorus, all plants absorbed significantly greater amounts from the nutrient solution containing the anion membrane when compared with the absorption from the nutrient solution alone or in the presence of cation resin. The order of the three nutrient solutions can be defined as M-anion > nutrient solution > M-cation. With respect to the cations K, Ca and Mg, the order was found to be M-cation > nutrient solution > M-anion. This could be attributed to the role played by the exchange complex that is existing in the root zone. In other words, the type of exchange surface regarding its saturation, either with H^+ of with OH^-, encourages the solubility of the ions carrying the same charge, i.e. anion resins encourage anions and their absorption, while cation resins encourage the solubility of cations, consequently their absorption by plant roots. This supports what Bentley *et al.* (1999) found that, P absorption increased with increasing the contact time of using anion exchange membranes AEM-Pi.

Generally, the absorption of all macro-nutrients by the rice variety Giza 176 was steadily greater than that of the variety Sakha 101 Table 2. The same was also true for the Millet grass compared with Berayard millet. This reflects the genetic advantage of the root system of some varieties to others, i.e. some root systems are more functionally ready to deal with nutrient elements in nutrient solutions than others. This is more likely because all the root systems of the studied plants are adventitious in nature, i.e. they are all approximately alike.

Concerning the concentration of micro-nutrients in the dry matter of whole plants, the overall trends observed for cation absorption in Table 2 were also observed for micro-nutrient cations Table 3. The M-cation resin showed a strong tendency to propel such cations rendering them more available to plant roots and consequently increasing their absorption. Exposing plant roots to the nutrient solution alone helped them to absorb significantly lower amounts of micro-nutrient elements than in the presence of cation resin. However, both solutions were fairly close each other in this regard as they were not significantly different.

Table 3. Micro-nutrients contents in the dry matter of test plants ppm.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
Fe	Nutrient solution	1.11 b	1.46 b	0.93 b	0.71 b
	M-Cation	1.29 a	1.64 a	1.11 a	0.92 a
	M-Anion	0.51 c	0.68 c	0.45 c	0.39 c
Mn	Nutrient solution	0.62 a	0.80 b	0.50 a	0.59 a
	M-Cation	0.68 a	0.93 a	0.57 a	0.56 a
	M-Anion	0.36 b	0.48 c	0.31 b	0.29 b
Zn	Nutrient solution	0.37 b	0.27 a	0.42 a	0.39 b
	M-Cation	0.42 a	0.30 a	0.48 a	0.57 a
	M-Anion	0.23 c	0.21 b	0.24 b	0.27 c
Cu	Nutrient solution	0.23 b	0.16 b	0.25 a	0.27 a
	M-Cation	0.30 a	0.27 a	0.17 b	0.24 a
	M-Anion	0.17 b	0.16 b	0.17 b	0.15 b

Mean values sharing an alphabet are not significantly different at 5% level.

Amazingly, the rice variety Sakha 101 absorbed greater amounts of Fe and Mn only than the other variety Giza 176. This seems as some kind of compensation by the former variety for cation absorption. But, the absorption of all micro-nutrients by rice was still greater than that by millet varieties.

Tracing the concentration of nutrient elements in the nutrient solution at the end of the study duration reflected the absorption that took place in each solution. The highest concentrations of N and P were found in the nutrient solution alone, followed by those in the solution containing anion resin, then by those in the presence of cation resins in a significant order. Also nutrients left behind the growth period was negatively proportional to the absorption of nutrients. These facts were also true for nutrient cations (Table 4). Micro-nutrient left over was, more or less, a reflection of the absorbed amounts, i.e. the greater the absorbed nutrient is, the lower the nutrient left over (Table 5).

Dry matter values, data in Table 6 reveal that plants grown in the nutrient solution alone produced significantly greater amounts of dry matter of all their parts and the whole plant as well. This points to the inability of nutrient concentrations either in plant tissues or in the residual solution at the end of growth period. We have seen in Tables 2, 3, 4 and 5 that anion or cation resins increases analogously charged ions in plant tissues. However, dry matter data in Table 6 point to that the nutrient solution alone was more capable of providing the plants with balanced nutrients diet that led to producing significantly greater dry matter as compared with that in the presence of either cation or anion resin.

Table 4: Macro-nutrients contents of nutrient solutions mg/L after the removal of test plants.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
N	Nutrient solution	21.8 a	22.6 a	23.6 a	25.7 a
	M-Cation	13.3 c	15.8 c	17.8 c	16.1 c
	M-Anion	16.6 b	18.9 b	20.0 b	21.7 b
P	Nutrient solution	6.0 a	7.9 a	9.2 a	10.5 a
	M-Cation	2.7 b	3.2 c	3.5 c	3.8 c
	M-Anion	5.0 c	6.6 b	7.6 b	9.6 b
K	Nutrient solution	12.8 b	11.3 b	9.6 b	8.8 b
	M-Cation	14.8 a	13.0 a	11.0 a	10.1 a
	M-Anion	6.0 c	5.3 c	4.5 c	4.1 c
Ca	Nutrient solution	10.2 b	11.3 b	7.4 b	8.4 b
	M-Cation	11.8 a	13.1 a	8.5 a	9.7 a
	M-Anion	5.9 c	6.6 c	4.3 c	4.8 c
Mg	Nutrient solution	5.4 b	5.8 b	3.8 a	4.4 a
	M-Cation	6.3 a	7.0 a	4.4 a	4.9 a
	M-Anion	3.2 c	3.4 c	2.3 b	2.7 b

Mean values sharing an alphabet are not significantly different at 5% level.

Table 5: Micro-nutrients contents of nutrient solutions mg/L after the removal of the four test plants.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
Fe	Nutrient solution	0.54 a	0.34 a	0.44 a	0.28 a
	M-Cation	0.59 a	0.33 a	0.40 a	0.31 a
	M-Anion	0.29 b	0.27 b	0.18 b	0.14 b
Mn	Nutrient solution	0.28 b	0.13 b	0.23 a	0.19 b
	M-Cation	0.41 a	0.22 a	0.28 a	0.26 a
	M-Anion	0.20 b	0.12 b	0.12 b	0.14 b
Zn	Nutrient solution	0.11 a	0.17 b	0.11 a	0.16 a
	M-Cation	0.06 b	0.22 a	0.14 a	0.15 a
	M-Anion	0.06 b	0.10 c	0.10 a	0.08 b
Cu	Nutrient solution	0.11 a	0.06 b	0.08 a	0.09 b
	M-Cation	0.04 c	0.16 a	0.08 a	0.13 a
	M-Anion	0.07 b	0.04 b	0.05 b	0.06 b

Mean values sharing an alphabet are not significantly different at 5% level.

Table 6: Dry matter production g of studied plants under hydroponic conditions.

Plant part	Treatments	Giza	Sakha	Pearl	Barnyard
Shoot	Nutrient solution	4.3 a	6.1 a	8.4 a	10.3 a
	M-Cation	3.5 b	5.0 b	6.7 b	8.0 b
	M-Anion	2.6 c	3.7 c	4.8 c	5.9 c
Root	Nutrient solution	2.5 a	3.6 a	5.4 a	6.6 a
	M-Cation	2.1 b	2.9 b	4.4 b	5.3 b
	M-Anion	1.6 c	2.2 c	3.3 c	4.1 c
Whole plant	Nutrient solution	6.8 a	9.7 a	13.8 a	16.9 a
	M-Cation	5.5 b	7.9 b	11.1 b	13.4 b
	M-Anion	4.2 c	5.9 c	8.0 c	9.9 c

The total uptake of macro-nutrients (Table 7) was highly strongly supportive of these findings regarding the matter production. Values of total uptake supported the advantages of nutrient solution alone to either anion or cation resin. Generally, anion resin was significantly lower than nutrient solution alone regarding N and P absorption, but cation resin was more often not significantly different from nutrieny solution alone regarding cations (Tables 7 and 8).

In conclusion, the existence of exchange complexes in the root zone significantly affects the absorption of nutrient elements by the roots. Since it is unavoidable to have the root systems contact exchange sites in the typical natural soils, it is advisable to apply well-decomposed organic materials amendments to aid easy exchange of nutrient with plant roots. In other words, this practice will decrease the reliance of plant roots on mineral exchange sites of the soil system to get nutrients. It is also necessary to apply every nutrient element at the proper amount and as balanced as possible with other nutrients according to the essence of soil fertility.

Table 7: The uptake of macro-nutrients mg/plant in dry matter of whole plants.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
N	Nutrient solution	0.32 a	0.43 a	0.54 a	0.60 a
	M-Cation	0.14 c	0.18 c	0.20 c	0.29 c
	M-Anion	0.25 b	0.33 b	0.39 b	0.44 b
P	Nutrient solution	0.11 a	0.16 a	0.20 a	0.23 a
	M-Cation	0.05 c	0.06 c	0.07 c	0.07 c
	M-Anion	0.08 b	0.11 b	0.13 b	0.14 b
K	Nutrient solution	0.22 a	0.33 a	0.49 a	0.62 a
	M-Cation	0.20 a	0.29 b	0.44 a	0.55 a
	M-Anion	0.07 b	0.10 c	0.14 b	0.18 b
Ca	Nutrient solution	0.25 a	0.34 a	0.45 a	0.50 a
	M-Cation	0.23 a	0.31 a	0.41 a	0.44 a
	M-Anion	0.08 b	0.11 b	0.14 b	0.15 b
Mg	Nutrient solution	0.13a	0.17 a	0.23 a	0.25 a
	M-Cation	0.12 a	0.16 a	0.21 a	0.23 a
	M-Anion	0.04 b	0.05 b	0.07 b	0.08 b

Mean values sharing an alphabet are not significantly different at 5% level.

Table 8: Uptake of micro-nutrients µg/plant in the dry matter of whole plants.

Element	Treatments	Giza	Sakha	Pearl	Barnyard
Fe	Nutrient solution	7.6 a	14.2 a	12.8 a	12.0 a
	M-Cation	7.1 a	12.9 a	12.3 a	12.3 a
	M-Anion	2.2 b	4.0 b	3.6 b	3.9 b
Mn	Nutrient solution	4.2 a	7.8 a	6.9 a	10.0 a
	M-Cation	3.8 a	7.3 a	6.3 a	7.5 b
	M-Anion	1.5 b	2.8 b	2.5 b	2.9 c
Zn	Nutrient solution	2.5 a	2.6 a	5.8 a	6.6 b
	M-Cation	2.3 a	2.4 a	5.3 a	7.6 a
	M-Anion	1.0 b	1.2 b	1.9 b	2.7 c
Cu	Nutrient solution	1.6 a	1.6 b	3.5 a	4.6 a
	M-Cation	1.7 a	2.1 a	1.9 b	3.2 b
	M-Anion	0.7 b	1.0 c	1.4 c	1.5 c

Mean values sharing an alphabet are not significantly different at 5% level.

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تقييم امتصاص المغذيات لبعض النباتات وتأثره بأسطح التبادل

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أقيمت دراسة على مزارع مائية لتقدير القدرة الامتصاصية للعناصر لنباتات الأرز صنفي جيزة ١٧٨، سخا ١٠١ ونوعين من الحشائش هما الدخن والدنيبة وذلك إما من المحلول المغذي مباشرة، أو في وجود أغشية التبادل الكاتيوني، أو الأنيوني الراتنج. وأظهرت نتائج التجارب أن امتصاص الجذور للعناصر الغذائية من المحلول المغذي وحده كان أفضل بالمقارنة بوجود نوعي الراتنج، الكاتيونية والانيونية ويرجع ذلك إلي الاتزان بين العناصر الغذائيـــة فيـــه. وأن ســـيادة الكاتيونات في المحلول المغذي تؤدي إلى زيادة امتصاص الكاتيونات على حســـاب امتصـــاص الانيونات والعكس صحيح في حالة المحلول المغذي الانيوني، وقد أكد هـــذا أن تلـــك الأغشـــية الأيونية لها أثرها الفعال مما أدى إلى أن ننصح بضرورة إضافة المواد العضوية الجيدة التحلـــل كمبادل سهل للعناصر بين التربة والنبات ومصادر الأسمدة المعدنية، كما أكد على ضرورة توفير العناصر في صورة متزنة مع العناصر الأخرى.