

## Effect of Water Shortage and Potassium on Efficiency of Symbiotic Nitrogen Fixation in Some Legumes

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**P**POTASSIUM (K) is reported to improve plants resistance against environmental stress. A frequently experienced stress for plants in the tropics is water shortage. It is not known if sufficient K supply would help plants to partially overcome the effects of water stress especially that of symbiotic nitrogen fixation which is often rather low in the tropics when compared to that of temperate regions. Thus, the impact of three levels of fertilizer potassium (0.2, 1.0 and 3.3 mM) on symbiotic nitrogen fixation was evaluated with two legumes under high (field capacity to 23% depletion) and low (less than 46% of field capacity) water regimes. Plants were grown in single pots in silica sand under controlled conditions with 1.3 mM N ( $^{15}\text{N}$  enriched  $\text{NH}_4\text{NO}_3$ ). The species were broad bean (*Vicia faba* L.) variety Giza blanca, a temperate, amide producing legume and pea (*Pisum sativum* L.) variety little marvel, a tropical, ureide producing species. In both species, 0.2 mM K was insufficient for nodulation at both moisture regimes, although plant growth was observed. The supply of 1.0 or 3.3 mM K allowed nodulation and subsequent nitrogen fixation which appeared to be adequate for respective plant growth. High potassium supply had a positive effect on nitrogen fixation, on shoot and root growth and on water potential in both water regimes. Where nodulation occurred, variations caused by either K or water supply had no consequences on the percentage of nitrogen derived from the symbiosis. The present data indicate that K can apparently alleviate water shortage to a certain extent. Moreover, it is shown that the symbiotic system in both broad bean and pea is less tolerant to limiting K supply than plants themselves. However, as long as nodulation occurs, N assimilation from the symbiotic source is not selectively affected by K as opposed to N assimilation from fertilizer.

**Keywords:** Water stress, Symbiotic nitrogen fixation, Potassium fertilization, Nodulation, Peas, Broad bean.

Grain legumes are an important component of the food production systems in tropical agriculture (Carangal *et al.*, 1987 and Kramer & Boyer, 1995). These crops are very adaptable, produce protein-rich edible material and fix atmospheric nitrogen through symbiosis (Wood & Myers, 1987 and Maurel, 1997). In Asia and Africa, the principal regions cultivating legumes for direct human consumption, yields are generally low (FAO, 1995 and Schaffner, 1998). The principal factor affecting growth, yields and nitrogen fixation of most food legumes in the tropics is considered to be soil moisture (APO, 1980; Patanothaia & Ong, 1987 and Moreshet *et al.*, 1996).

Potassium is an essential element for all living organisms. In plants, it is an important cation involved in physiological pathways (Beriner *et al.*, 1983; Duke & Collins, 1985 and Steudle, 1994). In particular, the ability of ATPases in membranes to maintain active transport is highly dependent on adequate K supply. Thus efficient cell development and growth of plant tissues, translocation, storage of assimilates and other internal functions, which are based on many physiological, biochemical and biophysical interactions, require adequate K in the cell sap (Lindhauer, 1989; Marschner, 1995 and Ruggiero *et al.*, 1999). In the tropics, where water is a major limiting factor for successful legume production (Wiersama & Christie, 1987 and Steudle & Peterson, 1998), K may temper water stress due to its role in cell turgor control and metabolic activity (Beringe *et al.*, 1983; Lindhauer, 1989 and Abou-Arab *et al.*, 1998). However, in most tropical soils, K contents are low.

The influence of K on growth and yields of food legumes has been demonstrated (Hanway and Johnson, 1985; Sangakkara, 1990, and El-Sayed & Ghaly, 1996 a&b). However, little is known about the importance of K in partially overcoming its effects of moisture stress in temperate and tropical food legumes, and on the process of symbiotic nitrogen fixation. Thus a study was undertaken to evaluate symbiotic nitrogen fixation and vegetative growth in a temperate and in a tropical legume under three K fertilizer regimes under high and low soil moisture conditions. The species selected were broad bean, an amide-producing temperate legume and pea, a tropical ureide-producing species.

### Material and Methods

#### *plant materials and growth conditions*

Broad bean (*Vicia faba* L.) variety Giza blanca and pea (*Pisum sativum* L.)

variety little marvel were grown from five seed in PVC pots (10 cm diameter, 30 cm height) containing 1.50 kg of air dried silica sand (diameter 0.7-1.2 mm) in growth greenhouse of Faculty of Agriculture in Assiut, Al-Azhar University, during the winter season 2000/2001. The nutrient solution was similar to that of Hammer *et al.* (1978) containing 0.2 m *Mf*, 1.0 mM or 3.3 mM potassium. The nutrient solution containing 1.3 mM N in the form of  $^{15}\text{N}$  labeled  $\text{NH}_4\text{NO}_3$  at 1.0%  $^{15}\text{N}$ -atom excess. The planting medium of pots containing broad bean were inoculated with 4 ml of a broth containing *Rhizobium leguminosarum* biovar. *Viciae* (strain 482; ICARDA) was obtained from Microbiology Research Center, Cairo Mircen, Egypt (EMCC), Fac. of Agric., Ain Shams Univ., Cairo, Egypt, at two day intervals on five occasions, beginning the day after planting. The same procedure was carried out for pea with an inoculum broth containing *Rhizobium tropicii* (Strain ARC 203; was obtained from Microbiology Research Center, Cairo, Mircen, Egypt (EMCC), Fac. of Agric., Ain Shams Univ., Cairo, Egypt). A prophylactic application of Benlate (concentration of 5 ppm) was carried out at 5, 10 and 16 days after planting to prevent fungal infections in pea. Number of pods plant<sup>-1</sup> and number of grains pod<sup>-1</sup> in peas and broad bean were recorded.

#### *Regimes to control water supply*

Prior to seedlings, the water content of the planting medium at field capacity, 23% and 46% depletion of available moisture was determined by methods described by Black (1965); Evenhuis & De Waard (1978) and Cottenie *et al.* (1982). Plants were grown at high (field capacity to 23% depletion) and low (over 46% depletion) soil moisture regimes from the moment the cotyledons appeared. Randomly selected pots (three per replicate per treatment) were weighed daily and deionized water was added to bring the planting medium of pots maintained at a high soil moisture content to 83 to 88% of field capacity. Any drainage was prevented. Pots designated to be maintained at a low soil moisture regime received no liquid until the planting medium reached a soil moisture of over 46% depletion. At this stage, equal quantities of the respective nutrient solutions were added to all pots with the quantities being determined by weighting, as above.

Broad bean were harvested at 25, 30, 35 and 40 days after seedling (DAS) and peas at 19, 24 and 29 (DAS). Relative growth rates were calculated over the entire experimental period using methods described by Hardwick (1984).

#### *Measurement of water potential*

Water potential was determined in peas at the V4/5 growth stage (27 DAS) using a Scholander pressure bomb.

### *Nitrogen and potassium determination*

All plant material was dried at 65°C for 48 hr in a drying oven. Total K content of plants was determined from the final harvests by flame photometric analysis (PFP-7 flame photometer, Jensions Scientific, UK). Total nitrogen and  $^{15}\text{N}$ -atom-%- excess were determined by GC-MS (Europa Scientific, UK) (FAO, 1980 and Page *et al.*, 1982). The amount of nitrogen derived from symbiosis was calculated as follows: %  $\text{N}_{\text{sym}} = (1 - \text{atom}\% \text{ } ^{15}\text{N} \text{ exc. in legume plant} / \text{atom}\% \text{ } ^{15}\text{N} \text{ exc. in nutrient solution}) * 100$ .

### *Statistical analysis*

The experiments were laid out as a randomized block design. The first experiment, using both legumes, had 3 replicates (blocks) each replicate consisted of 6 pots (total of 18 pots). For the last harvest, 12 pots per replicate (block) were used (total of 36 pots). The second experiment with peas had 3 replicates (blocks), each one containing 4 pots (total of 12 pots). Data were analyzed using the general linear model technique of SAS with a 2-factor factorial design to identify the significance of treatment differences and interactions (SAS Institute Inc., 1988, Snedecor & Cochran, 1967). Nodulation at the various K nutrition levels was double checked twice.

## **Results and Discussion**

### *Effects of potassium supply on symbiotic nitrogen fixation and plant growth*

Unexpectedly, nodulation was completely prevented in plants growth with 0.2mM K in broad bean and peas under both water regimes (Table 1). Such a finding has never been reported before. Potassium supply, although sufficient for plant growth (Tables 2 and 3), was not sufficient to support the development of a symbiosis. These data support the concept that the ecological range of the symbiosis is narrower than that of the plant itself as also reported for low temperature (Hirasawa & Ishihara, 1991; Hazaizeh *et al.*, 1992; Bordeleau & Prevost, 1994, Abou-Arab *et al.*, 1998) and excess temperature (Cruz *et al.*, 1991, Huang *et al.*, 1991; Sangakkara *et al.*, 1996 and El Sayed, 1998 a & b). The symbiosis ceases when it is exposed to extreme conditions.

Since viable rhizobia were used as inoculum it is suggested that either the infection process or the subsequent nodule development was obstructed at a certain stage due to the low K supply to the plant. As an important pre-requisite

TABLE 1. Nodulation and biological nitrogen fixation by broad bean and peas at flowering (R1; 40 DAS for broad bean, 29 DAS for peas) as affected by soil moisture and potassium. Symbiotic nitrogen fixation was quantified from  $^{15}\text{N}$ -isotope-dilution. Means of 3 replicates (blocks), each replicate containing 12 pots (total of pots) are shown.

Soil moisture	Potassium (mM)	Nodule/ plant (nod)	Nodule/plant dry weight (nod/g)	Nitrogen from symbiosis (mg)	Nitrogen fixed per nodule (mg/N sym /nod.)	No. of pods/plant	No. of grains/pod	% Ndfs
Pea Over 46% depletion	0.2	0	0	0	0	0	0	0
	1.0	29	23	33	1.15	115.60	3.6	89
	3.3	45	27	47	1.08	76.80	3.4	89
Field capacity to 23% depletion	0.2	0	0	0	0	0	0	0
	1.0	40	27	43	1.06	78.9	3.2	91
	3.3	45	25	56	1.22	71.7	3.2	90
<i>P</i>	Moisture (M)	<0.005	<0.01	<0.005	<0.05	<0.01	<0.05	<0.01
	Potassium (K)	<0.005	<0.05	<0.01	<0.01	<0.05	<0.01	N.S
	MxK <sup>a</sup>	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	N.S
Broad bean over 46% depletion	0.2	0	0	0	0	0	0	0
	1.0	20	21	24	1.15	81.20	3.1	83
	3.3	38	33	33	0.85	70.60	3.2	82
Field Capacity to 23% depletion	0.2	0	0	0	0	0	0	0
	1.0	38	33	37	0.96	69.5	3.4	85
	3.3	67	41	54	0.79	61.7	3.3	87
<i>P</i>	Moisture(M)	<0.05	<0.005	<0.005	<0.05	<0.01	<0.05	<0.01
	Potassium (K)	<0.01	<0.005	<0.01	<0.05	<0.05	<0.01	N.S
	MxK <sup>a</sup>	<0.05	<0.05	N.S	NS	<0.05	<0.05	<0.05

<sup>a</sup>The interaction was tested between 1.0 and 3.3 mM potassium supply only.

**TABLE 2.** Influence of soil moisture and potassium on vegetative growth of broad bean and peas. Relative growth rates were calculated from 0 over harvests at days 25, 30, 35 and 40 DAS in broad bean and from 0 over days 19, 24 and 29 DAS in peas. All other parameters are from the last harvests (R1-stage).

Soil moisture	Potassium (mM)	Relative growth rate (g dry weight increase/g dry weight/day)	RGR-ratio <sup>a</sup>	Total dry weight (mg)	Specific leaf weight (mg/c m <sup>2</sup> )	Shoot/root ratio
Pea Over 46% depletion	0.2	0.136±0.007	1.00	1046	5.2	0.53
	1.0	0.148±0.002	1.09	1243	4.7	0.59
	3.3	0.173±0.012	1.27	1574	4.0	0.65
Field capacity to 23% depletion	0.2	0.144±0.007	1.00	1111	4.8	0.67
	1.0	0.173±0.011	1.20	1455	4.4	0.66
	3.3	0.191±0.002	1.33	1755	3.9	0.67
P	Moisture (M)			<0.05	<0.01	<0.005
	Potassium (K)			<0.005	<0.005	<0.005
	MxK			NS	NS	<0.05
Broad bean over 46% depletion	0.2	0.026±0.013	1.00	678	5.0	1.30
	1.0	0.050±0.003	1.92	980	4.3	1.44
	3.3	0.062±0.006	2.38	1145	3.3	1.70
Field Capacity to 23% depletion	0.2	0.044±0.003	1.00	908	4.3	1.37
	1.0	0.061±0.007	1.39	1141	3.5	1.51
	3.3	0.100±0.011	2.27	1638	2.7	1.78
P	Moisture(M)			<0.005	<0.005	<0.01
	Potassium (K)			<0.005	<0.005	<0.005
	MxK			NS	NS	<0.05

<sup>a</sup> RGR - ratio = RGR of a treatment / RGR of 0.2 mM K.

for infection, the presence of root hairs as the location of infection at the tap root of the germinating plant (Sprenst & Minchin, 1985; Husain *et al.*, 1990; Rieger & Motisi, 1990; Lafolie *et al.*, 1991 and El-Sayed & Abdel-Mawly, 1999) was evaluated. Although root hair density and percentage of the tap root covered with root hairs was reduced with low K (Table 4), potential infection sites were still present under 0.2 mM K. Nevertheless, nothing resembling nodule structures appeared. Thus it is very likely that nodule development was obstructed either before infection, at infection or very shortly after rhizobia invaded root hairs.

TABLE 3. Effect of soil moisture and potassium on nitrogen and potassium concentration of broad bean (40 DAS) and peas (29 DAS). Means of 3 replicates (blocks), each replicate containing 12 pots (total of 36 pots) are shown.

Soil moisture	Potassium m M	N concentration (mg N/g dry weight)	K concentration (mg K/g dry weight)
Pea Over 46% depletion	0.2	28.4	15.0
	1.0	30.3	24.8
	3.3	33.6	31.9
Field capacity to 23% depletion	0.2	32.3	14.5
	1.0	33.2	24.0
	3.3	34.9	30.7
<i>P</i>	Moisture (M) Potassium (K) MxK	<0.005 <0.005 <0.05	<0.005 <0.01 <0.05
Broad bean Over 46% depletion	0.2	27.4	12.7
	1.0	29.9	21.9
	3.3	35.5	33.3
Field capacity to 23% depletion	0.2	31.7	11.9
	1.0	38.6	21.3
	3.3	44.1	25.9
<i>P</i>	Moisture (M) Potassium (K) MxK	<0.005 <0.01 <0.05	<0.005 <0.01 <0.05

The finding of Gober & Kashket (1987) and El-Sayed (1997) that sufficient K supply is essential for bacteroid development in cowpea *Bradyrhizobium*, emphasises the importance of K for the development of the symbiosis. One link to explain the complete suppression of nodule formation could be that K is used in higher concentrations for protein synthesis than for enzyme activation (Davies & Zhang, 1991; Marschner, 1995; Abdel-Mawly & El-Sayed, 1999). This leads to the reported K stress-induced accumulation of soluble nitrogen compounds such as amino acids, amines, amides and nitrate (Hirasawa *et al.*, 1991; Sarkar & Kar, 1992 and DePascale & Barbieri, 1997), all molecules known or believed to suppress nodulation (Parsons *et al.*, 1993; Streeter, 1988 and Steudle, 1994). Further work is required on this hypothesis.

TABLE 4. Effect of soil moisture and potassium on the root hair density and the percentage of the tap root covered with root hairs in peas 16 (V<sub>2</sub>; 16 DAS). Means of 3 replicates (blocks), each replicate containing 4 pots (total of 12 pots) are shown.

Soil moisture	Potassium (mM)	Root hair density in the top 2 cm (root hairs)	Percentage of the tap root covered with hairs (%)
Over 46% depletion	0.2	53	37
	1.0	72	50
	3.3	79	94
Field capacity to 23% depletion	0.2	42	54
	1.0	54	55
	3.3	68	89
P	Moisture (M)	<0.05	<0.01
	Potassium (K)	<0.05	<0.1
	M x K	<0.01	<0.05

Nodules were observed with the application of both 1.0 and 3.3 mM in both species (Table 1). The application of 3.3 mM K resulted in higher nodule numbers compared to the 1.0 mM K supply. While in peas, nodulation under 3.3 mM K was increased more or less in proportion to the increased plant growth, in broad bean the beneficial effect of 3.3 mM K in establishing nodules appeared to be consistently greater than expected from plant growth (nodule number per plant dry weight; Table 1). This led to produce more nodules per plant dry weight under 3.3 mM K compared to 1.0 mM K in broad bean (Table 1). Number of pods plant<sup>-1</sup> and number of grains pod<sup>-1</sup> in peas produced more pods and grain per plant than broad bean. However, as evident from the unaffected percentage of nitrogen derived from symbiosis (<sup>15</sup>N dilution), the reduced number of nodules per plant dry weight under 1.0 mM K in broad bean appeared to be compensated by a higher nitrogen fixing activity per nodule (Table 1). Similar results were reported by Chalamet *et al.* (1987) and Cadisch *et al.* (1993). This is in notable contrast to the response of N<sub>2</sub> fixation to phosphorus, where the percentage of nitrogen from fixation decreased with decreasing phosphate supply (Cadisch *et al.*, 1993) indicating increased preference for nitrogen assimilation from mineral sources under low phosphorus. Obviously, in the present experiment, the reduced nodulation still allowed adequate nitrogen fixation as demanded by the relatively poor growth under 1.0 mM K. Thus, the



influence of K on symbiotic N<sub>2</sub>-fixation was to improve nodulation rather than the activity of established nodules. The present finding that K does not affect the percentage of nitrogen from fixation is consistent with the observation that specific nitrogenase activity was not affected by K supply in alfalfa (Barta, 1982). These data indicate that, if low K reduces total N<sub>2</sub> fixation, this effect is indirect, *e.g.* through a nitrogen feedback mechanism (Hartwig and Nosberger, 1994; Hallgren *et al.*, 1994 and Kramer & Boyer, 1995) rather than a specific K-effect on N<sub>2</sub> fixation.

The decreased nitrogen concentrations with decreasing K supply (Table 3) may at least in part, be interpreted as dilution effects of nitrogen through accumulating nonstructural carbohydrates, a phenomenon reported by Guardia and Benloch (1980) and indicated here by the increased specific leaf weight (Table 2). In addition, a possible reduced protein synthesis under low K (Grashoff, 1990 and 1991; Marschner, 1995; Moreshet *et al.*, 1990 & 1996 and Tyree, 1997) could have contributed to this. Compared to nitrogen, K concentrations were reduced much more due to the low K supply suggesting that K limited growth. This would be consistent with the observation that high application of K increased shoot: root ratios (Table 2). Nevertheless, it is noteworthy that even a reduction in K concentration by a factor of 2 to 3 still allowed growth. The plasticity of growth in the selected plant species to variations in K concentrations seems to be extremely high compared *e.g.* to the nitrogen plasticity.

#### *Effects of water supply on symbiotic nitrogen fixation and plant growth*

Nodulation was generally reduced by low water supply in both species except in peas under 3.3 mM K (Table 1). As evident from nodules per plant dry weight, in the other cases, the reduction in nodulation was more severe than would have been expected from growth (Tables 1 and 2), an observation previously made in soybean (Khanna-Chopra *et al.*, 1984; El-Sayed and Ghaly, 1996 a & b and Schaffner, 1998). However, in the case of reduced nodulation, increased nitrogen fixation per nodule could apparently compensate for the relatively low nodule numbers (Table 1). This is also evident from the unaffected percentage of nitrogen derived from symbiosis (Table 1).

#### *Does high K supply alleviate water stress on symbiotic nitrogen fixation and growth?*

Clearly, high K supply stimulates growth and nodulation also under water limiting conditions (Tables 1 and 2). With peas, in both water treatments, K

could increase the water potential substantially. The values were -0.81, -0.54 and -0.25 MPa for 0.2, 1.0 and 3.3 mM K in the low water treatment and -0.29, -0.13 and -0.05 MPa for the high water treatment, respectively. These data are consistent with those from Abd-Alla & Abdel Wahab (1995) and Mengel & Arneke (1982) indicating that high K fertilization can at least in part compensate water shortage. This conclusion is also in agreement with Robin *et al.* (1989) who demonstrated that K is an essential factor determining plant resistance to water stress. This would support the view that K helps to maintain the osmotic potential of plant cells, an increasingly critical problem by increasing water stress (Beringer *et al.*, 1983). The beneficial effect of high K supply on growth was generally similar in both water treatments with the exception that in broad bean the beneficial effect of 1.0 mM K compared to 0.2 mM K was more pronounced in the low water treatment than in the high water treatment (Table 2). The beneficial effect of high K under water stress can certainly, in part, be explained by the fact that under conditions of restricted water flow into the roots, an increase in nutrient concentration will lead to an increased nutrient intake per unit of water uptake (Fick's Law).

Specific leaf weights were higher when both species were grown at a lower soil moisture, thus indicating the effect of water stress in restricting the movement of photosynthates from leaves to the sinks (Munns and Weir, 1981). Application of K reduced specific leaf weights significantly, and the impact was more prominent in broad bean. This could be related to the effect of K in facilitating the translocation of photosynthates to the sink (Lindhauer, 1989; Thomas & Hungria, 1988 and Steudle & Peterson, 1998). As evident from the strongly adverse effect of both water shortage and low K supply on nodule formation, this process seems to be highly dependent on efficient transport conditions in the plant. On the other hand, in the present study, nitrogen fixation appeared to be similarly affected by the adverse conditions as plant growth itself. This meets the concept that nitrogen fixation is tuned to the demand for symbiotically fixed nitrogen (Hartwig & Nosberger 1994; Hartwig *et al.*, 1994 and Ruggiero *et al.*, 1999). This demand may be sensed from the intensity at which nitrogen is transported to the sink from the amount of nitrogen recycled to the nodules (Heim *et al.*, 1993; Oti Boateng & Silsbury, 1993; Oti-Boaten *et al.*, 1994; Parsons *et al.*, 1993; Ruggiero & Fagnano, 1996 a&b & Maurel, 1997).

### Conclusions

This study demonstrates that in both broad bean and peas the plasticity for nodulation, thus to potentially establish a nitrogen fixing symbiosis, for K shortage is smaller than that for plant growth itself. However, as long as effective nodules get established, symbiotic N<sub>2</sub>-fixation is not selectively limited by low K.

### References

- Abd-Alla, M.H. and Abdel Wahab, M.A. (1995) Response of nitrogen fixation and nodule activities and growth to potassium supply and water stressed broadbean. *J. Plant Nutr.* **18**, 1391.
- Abdel-Mawly, S.E. and El-Sayed, S.A.M. (1999) Relationship between alkalinity and iron deficiency on the growth, nodulation and nitrogen fixation of mungbeans inoculated with different *Bradyrhizobium* strains. *Assiut Journal of Agricultural Science*, **30**(3), 81.
- Abou-Arab, A.A., Mohamed, S.A., Mohamed, M.A. and Ibrahim, A.M. (1998) Plant productivity, nutrient status and uptake as influenced by soil compaction and water stresses. *Egypt. J. Soil Sci.* **38** (1-4), 229.
- APO. (1980) Grain legume production in Asia. *Asian Productivity Organization, Tokyo, Japan*, 240.
- Barta, A.L. (1982) Response of symbiotic N<sub>2</sub> fixation assimilate partitioning to K supply in alfalfa. *Crop. Sci.* **22**, 89.
- Beringer, H., Haeder, H.E. and Lindhauer, M.G. (1983) Water relationship and incorporation of <sup>14</sup>C assimilates in tuber of potato plants differing in potassium nutrition. *Plant Physiol.* **73**, 956.
- Black, C.A. (1965) *Methods in Soil Analysis*, Vol. 1, Am. Soc. Agron. Madison. USA. 1840.
- Bordeleau, L.M. and Prevost, N.D. (1994) Nodulation and nitrogen fixation in extreme environments. *Plant and Soil.* **161**, 115.
- Cadisch, G., Sylvestr-Bradley, R., Boller, B.C. and Nosberger, J. (1993) Effects of phosphorus and potassium in N<sub>2</sub> fixation (<sup>15</sup>N-dilution) of field-grown *Centrosema acutiflorum* and *C. macrocarpum*. *Field Crops. Res.* **31**, 329.

- Carangal, J., Rao, M.V. and Siwi, B.R. (1987) Limits imposed by management in irrigated farming systems. In: *Food Legume Improvement for Asian Farming Systems*. E.S. Wallis and D.E. Bythe (Eds.) p. 64. ACIAR, Canberra, Australia.
- Chalamet, A., Audergon, J.M., Maitre, J.P. and Domenach, A.M. (1987) Study of influence potassium on the *Trifolium pratense* fixation by  $^{15}\text{N}$  method. *Plant and Soil*. **98**, 347.
- Cottenie, A., Verloo, M., Kiekens, L., Velghe, G. and Camerlynch, R. (1982) *Chemical Analysis of Plants and Soil*. Handbook.
- Cruz, R.J., Jordan, W.R. and Drew, M.C. (1991) Structural changes and associated reduction of hydraulic conductance in roots of *Sorghum bicolor* L. following exposure to water deficit. *Plant Physiol*. **99**, 203.
- Davies, W.J. and Zhang, J. (1991) Root signals and the regulation of growth and development of plants in drying soil. *Annu. Rev. Plant Physiol. Mol. Biol.* **42** 55.
- De Pascale, S. and Barbieri, G. (1997) Effect of soil salinity and top removal on growth and yield of broadbean as green vegetable. *Scientia Horticultura*, **71**, 147.
- Duke, S.H. and Collins, M.M. (1985) Role of potassium in legume dinitrogen fixation. In: *Potassium in Agriculture*. R. Munns (Ed.) p. 443. Soc. Agron., Madison, USA.
- El-Sayed, S.A.M. (1997) Influence of salinity on growth, yield, nutrient uptake and biological nitrogen fixation in guar. *Egypt. J. Agric. Res.* **75** (1).
- El-Sayed, S.A.M. (1998a) Denitrification by guar rhizobia strains in New Valley Governorate. *Egypt. J. Agric. Res.* **76** (2), 451.
- El-Sayed, S.A.M. (1998b) Influence of Rhizobium and phosphate-solubilizing bacteria on nutrient uptake and yield of lentil in the New Valley, Egypt. *J. Agric. Res.* **76** (3), 883.
- El-Sayed, S.A.M. and Ghaly, A.A. (1996a) Effect of K-uptake under saline conditions for rice crop in New Valley Governorate. *J. Agric. Sci. Mansoura Univ.* **21** (9), 3401.
- El-Sayed, S.A.M. and Ghaly, A.A. (1996b) Requirements of lentil-species for iron. *J. Agric. Sci. Mansoura Univ.* **21** (11), 4229.
- El-Sayed, S.A.M. and Abdel-Mawly, S.E. (1999) Effectiveness of *Bradyrhizobium* strains for peanut under different salinity concentrations. *Assiut Journal of Agricultural Science*, **30** (3), 101.

- Evenhuis, B., and De Waard, P.W.F. (1978) Simplified methods for foliar analysis. Royal Tropical Institute, Amsterdam, Holland.
- FAO (1980) Soil and plant testing and analysis. *FAO. Soils Bulletin 38/1*. FAO, Rome, Italy.
- FAO (1995) *FAO Production Yearbook (1994)* FAO, Rome, Italy, 234 p.
- Gober, J.W. and Kashket, E.R. (1997)  $K^+$  regulates bacteroid-associated functions of *Bradyrhizobium*. *Proc. Natl. Acad. Sci. USA* **84**, 4650.
- Grashoff, C. (1990) Effect of pattern of water supply on *Vicia faba* L. 1. Dry matter partitioning and yield variability. *Neth. J. Agric. Sci.* **38**, 21.
- Grashoff, C. (1991) Effect of pattern of water supply on *Vicia faba* L. 3. Plant water relations, expansive growth and stomatal reactions. *Neth. J. Agric. Sci.* **39**, 247.
- Guardia de-la M. and Benlloch, M. (1980) Effects of potassium and gibberellic acid on stem growth of whole sunflower plants. *Physiol. Plant*, **49**, 443.
- Hallgren, S.W., Rudinger, M. and Steudle, E. (1994) Root hydraulic properties of spruce measured with pressure probe. *Plant and Soil*, **167**, 91.
- Hammer, P.T., Tibbitts, T.W., Langhans, R.W. and McFarlane, J.C. (1978) Baseline growth studies of "Grand rapids" lettuce in controlled environment. *J. Am. Soc. Hort. Sci.* **103**, 649.
- Hanway, J.J. and Johnson, J.W. (1985) Potassium nutrition of soybean. In: *Potassium in Agriculture*. R. Munns (Ed. ), p. 754. Am. Soc. Agron., Madison U.S.A.
- Hardwick, R.C. (1984) Some recent developments in growth analysis. A review. *Ann. Bot.* **54**, 804.
- Hartwig, U.A., Heim, I., Luseher, A. and Nosberger, J. (1994) The nitrogen sink is involved in the regulation nitrogenase activity in white clover after defoliation. *Physiol. Plant*. **92**, 375.
- Hartwig, U.A. and Nosberger, J. (1994) What triggers the regulation of nitrogenase activity in forage legume nodules after defoliation? *Plant and Soil*, **161**, 109.

- Hazaizeh, H., Gunse, B. and Steudle, E.** (1992) Effects of NaCl and CaCl<sub>2</sub> on water transport across root cell of maize (*Zea mays* L.) seedlings. *Plant Physiol.* **99**, 886.
- Heim, I., Hartwig, U.A. and Nosberger, J.** (1993) Current nitrogen fixation is involved in the regulation of nitrogenase activity in white clover (*Trifolium repens* L.). *Plant Physiol.* **103**, 1009.
- Hirasawa, T. and Ishihara, K.** (1991) On the resistance to water transport in crop plants for estimating water uptake ability under intense transpiration. *Jpn. J. Crop. Sci.* **60**, 174.
- Hirasawa, T., Gotou, T. and Ishihara, K.** (1991) On the resistance to water transport from the roots to the leaves at different position on a stem in rice plants. *Jpn. J. Crop. Sci.* **61**, 153.
- Huang, B.R., Taylor, H.M. and McMichael, B.L.** (1991) Effects of temperature on development of metaxylem in primary wheat roots and its hydraulic consequence. *Annal Botany.* **67**, 163.
- Husain, M.M., Reid, J.B., Othman, H. and Gallagher, J.N.** (1990) Growth and water use of faba beans (*Vicia faba* L.) in a sub-humid climate. *Field Crop Research.* **231**.
- Khanna-Chopra, R., Kirpa, K.R. and Sinha, S.K.** (1984) A simple technique of studying water deficit effects on nitrogen fixation in nodules without influencing the whole plant. *Plant Physiol.* **76**, 254.
- Kramer, P.J. and Boyer, J.S.** (1995) *Water Relations of Plants and Soils.* Academic Press, London, 576.
- Lafolie, F., Bruckler, L. and Tardieu, F.** (1991) Modelling root water and soil-root water transport: 1. Model presentation. *J. Soil Sci. Soc. Am.* **55**, 1203.
- Lindhauer, M.** (1989) Role of potassium in cell extension, growth and storage of assimilates. In *Methods of Potassium Research in Plants.* p. 161. International Potash Institute, Berne, Switzerland.
- Marschner, H.** (1995) *Mineral Nutrition of Higher Plants.* 2<sup>nd</sup> ed. Academic Press, London, UK, 889.
- Maurel, C.** (1997) Aquaporins and water permeability of plant membranes. *Annu. Rev. Plant Physiol. Mol. Biol.* **48**, 399.

- Mengel, K. and Arneke, W.W.** (1982) Effect of potassium on the water potential, the pressure potential, the osmotic potential and cell elongation in leaves of *Phaseolus vulgaris*. *Physiol. Plant*, **54**, 402.
- Moreshet, S., Fuchs, M., Cohen, Y. and Langensiepen, M.** (1996) Water transport characteristics of cotton as affected by drip irrigation layout. *Agron. J.* **88**, 717.
- Moreshet, S., Cohen, Y., Green, G.S. and Fuchs, M.** (1990) The partitioning of hydraulic conductances within mature orange trees. *J. Exp. Bot.* **41**, 833.
- Munns, R. and Weir, R.** (1981) Contribution of sugars to osmotic adjustment in elongating and expanded zones of wheat leaves during moderate water deficits at two light levels. *Aust. J. Plant Physiol.* **8**, 93.
- Oti-Boateng, C. and Silsbury, J.H.** (1993) The effects of exogenous amino acid on acetylene reduction activity of *Vicia faba* L. cv. *Fiord*. *Ann. Bot.* **71**, 71.
- Oti-Boateng, C., Wallace, W. and Silsbury, J.H.** (1994) The effect of the accumulation of carbohydrate and organic nitrogen on nitrogen fixation (acetylene reduction) on *Faba bean* cv. *Fiord*. *Ann. Bot.* **73**, 143.
- Page, A.L., Miller, R.H. and Keeney, D.R.** (1982) Methods of soil analysis Part 2. *Chemical and Microbiological Properties*. American Society of Agronomy, Madison Wisconsin, USA.
- parsons, R.A., Stanforth, A., Raven, A.J. and Sprent, J.I.** (1993) Nodule growth and activity may be regulated by a feedback mechanism involving phloem nitrogen. *Plant Cell Environ.* **16**, 125.
- Patanothai, A. and Ong, C.K.** (1987) Limits imposed by management in rainfed farming systems. In: *Food Legume Improvement for Asian Farming Systems*. E.S. Wallis and D.E. Bythe (Eds.) ACIAR, Canberra, Australia, p. 72.
- Rieger, M. and Motisi, M.** (1990) Estimation of root hydraulic conductivity on intact peach and citrus rootstocks. *Hort. Science.* **25**, 1631.
- Robin, C.L., Shamsun-Noor, L. and Guckert, A.** (1989) Effect of potassium on the tolerance to PEG-induced water stress of two white clover varieties (*Trifolium repens* L.). *Plant and Soil*, **120**, 153.
- Ruggiero, C. and Fagnano, M.** (1996a) Relazioni tra parte aerea, parte ipogea, traspirazione e assorbimento radicale del lupino dolce (*Lupinus albus*). L. cv. "Multitalia". *Riv. di Agronomia.* **1**, 58.

- Ruggiero, C. and Fagnano, M. (1996 b) Relazioni tra parte aerea, parte ipogea, traspirazione e assorbimento radicale del cece (*Cice, arietinum* L.) Riv. di Agronomia, **1**, 78.
- Ruggiero, C., Pascale, S.D. and Fagnano, M. (1999) Plant and soil resistance to water flow in faba bean *Vicia faba* L. major Harz. *Plant and Soil*, **210**, 219.
- Sangakkara, U.R. (1990) Effect of fertilizer potassium on growth and yield of mungbean (*Vigna radiata*). *J. Appl. Seed Prod.* **8**, 33.
- Sangakkara, U.R., Hartwig, U.A. and Nosberger, J. (1996) Growth and symbiotic nitrogen fixation of *Vicia faba* and *Phaseolus vulgaris* as affected by fertilizer potassium and temperature. *J. Sci. Food Agric.* **70**, 315.
- Sarkar, S. and Kar, S. (1992) Estimation of water uptake pattern of groundnut (*Arachis hypogea* L.) Agric. *Water Man.* **21**, 137.
- SAS Institute Inc. (1988) *SAS User's Guide Statistical Analysis Institute Inc.*, Cary, NC. 1674 p. North Carolina.
- Schaffner, A.R. (1998) Aquaporin function, structure, and expression: are there more surprises to surface in water relations? *Planta.* **204**, 131.
- Snedecor, G.W. and Cochran, W.G. (1967) *Statistical Methods*, 6<sup>th</sup> ed. Iowa State Univ. Press, Iowa, U.S.A.
- Sprent, J.I. and Minchin, F.R. (1985) Rhizobium, nodulation and nitrogen fixation. In: *Grain Legume Crops*. R.J. Summerfield and E.H. Collins. (Eds.) p. 115 Collins. London, U.K.
- Stedle, E. (1994) Water transport across roots. *Plant and Soil*, **167**, 79.
- Stedle, E. and Peterson, A. (1998) How does water get through roots? *J. Exper. Bot.* **49**, 775.
- Streeter, J. (1988) Inhibition of legume nodule formation and N<sub>2</sub> fixation by nitrate. *Crit. Rev. Plant Sci.* **7**, 1.
- Thomas, R.J. and Hungria, M. (1988) Effect of potassium on nitrogen fixation, nitrogen transport and nitrogen harvest index of bean. *J. Plant Nutr.* **11**, 175.
- Egypt. J. Soil Sci.* **43**, No. 2 (2003)



- Tyree, M.T.** (1997) The cohesion-tension theory of sap ascent: current controversies. *Journal of Exper. Bot.* **48**, 1753.
- Wiersama, D. and Christie, B.R.** (1987) Water and agricultural productivity. *In: Handbook of Plant Science in Agriculture*. E.R. Christie(Ed.) pp. 3-56, CRC Press, U.S.A.
- Wood, I.M. and Myers, R.J.K.** (1987) Food legumes in farming systems in the tropics and subtropics. (Eds.), *Food Legume Improvement for Asian Farming* . E.S. Wallis and D.E. Bythe. pp. 34-45, ACIAR. Canberra, Australia.

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## تأثير نقص الماء والبيوتاسيوم على كفاءة تثبيت النيتروجين حيويًا في بعض البقوليات

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يعمل عنصر البيوتاسيوم على تحسين مقاومة النباتات ضد ظروف البيئة السيئة، مثل الانخفاض المائي (النقص الرطوبي) في المناطق الاستوائية. وجود البيوتاسيوم بمقدار كبير في التربة يساعد النباتات في التغلب على الانخفاض المائي (النقص الرطوبي) خاصة في النباتات البقولية التي تقوم بتثبيت النيتروجين حيويًا والتي تكون منخفضة في المناطق الاستوائية عند مقارنتها بالمناطق المعتدلة.

تم دراسة تأثير ثلاثة مستويات من التسميد البوتاسي هي (٢، ١، ٠، ٣، ٢، ١، ٠، ٣، ٢، ١، ٠) على تثبيت النيتروجين حيويًا في النباتات البقولية تحت مستويين مختلفين من السعة الحقلية (٤٦٪، ٢٣٪).

تم نمو الفول صنف جيزة بلانكا وهو يمثل المناطق المعتدلة. والبسلة صنف لتل مارفل وتمثل المناطق الاستوائية في أسر مستعملا تركيز ١، ٢، ٣ ملليمول نيتروجين مشع على هيئة نترات امونيوم.

تشير النتائج أنه عند الانخفاض المائي (النقص الرطوبي) وعند تركيز ٢، ٠، ٣ ملليمول بوتاسيوم حدث نقص في تكوين العقد البكتيرية، وعند زيادة تركيز البيوتاسيوم إلى ١، ٢، ٣ ملليمول بوتاسيوم لوحظ زيادة في تكوين العقد البكتيرية وبالتالي النيتروجين المثبت حيويًا، إضافة البيوتاسيوم بكميات كبيرة في وجود الانخفاض المائي كان مشجعاً لنمو السيقان واجذور والعقد البكتيرية وزيادة النيتروجين المثبت حيويًا، كذلك زاد عدد القرون لكل نبات، وعدد الحبوب في كل قرن في البسلة صنف لتل مارفل عنها في الفول صنف جيزة بلانكا.

أوضحت النتائج أن إضافة البيوتاسيوم يعمل على تخفيف الانخفاض المائي (النقص الرطوبي) وكذلك زيادة قدرة كل من الفول والبسلة على الاحتمال وزيادة كمية النيتروجين المثبت حيويًا