INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 8, No. 6, p. 34-42, 2016

RESEARCH PAPER OPEN ACCESS

Effect of molybdenum and nitrogen on *Phaseolus vulgaris* L., *Cicer arietinum* L. and *Lens culinaris* M. seedlings grown under salt stress

Bouzid Salha*, Rahmoune Chaabane

Department of Plant Biology and Ecology, Faculty of Life and Nature Sciences, University of Mentouri Brothers, Constantine 1, Algeria

Key words: Molybdenum, Nitrogen, *Phaseolus vulgaris* L., *Cicer arietinum* L., *Lens culinaris* M., Nitrate Reductase.

http://dx.doi.org/10.12692/ijb/8.6.34-42 Article published on June 20, 2016

Abstract

The leguminous constitute an important food diet component especially in developing countries, they represent 90% of the global consumption, and they are very rich in proteins and relatively adapted to the Mediterranean climate. Soil nutrient deficiencies and salinity are the main factors which reduce plant production in the semi-arid and arid areas around the world. The plant material used is composed by three species from *Fabaceae*; *Phaseolus vulgaris* L., *Cicer arietinum* L. and *Lens culinaris* M. seedlings that were grown in pots under different concentrations of NaCl (3 g/l, 6 g/l, 9 g/l), molybdenum (0,2 ppm) added as ammonium molybdate and nitrogen added as potassium nitrate (0,02 g/l). The fresh shoot, chlorophyll content and nitrate reductase activity were analyzed in order to estimate the effect of molybdenum (Mo) and nitrogen (N) on salt stressed plants. The effect of both molybdenum and nitrogen on lentil has not been well studied and especially for Algerian legumes This work shows the importance of molybdenum and nitrogen added to irrigation water to avoid the negative effect of sodium chloride and to enhance legume species tolerance to salt stress.

* **Corresponding Author:** Bouzid Salha ✉ bouzidsalha@umc.edu.dz

Introduction

The availability of good quality of water is one of the major limiting factors for plant growth as irrigation water may often contain salts and ions that can have negative impacts on the plant growth and development. Salt water in the root zone induces osmotic changes and directly affect nutrient uptake as Na+ reducing K+ uptake or by Cl^- reducing $NO3^-$ uptake (Cornillon and Palloix 1997, Halperin *et al.,* 2003).

Soil salinity, resulting from natural processes or from crop irrigation with saline water, occurs in many arid to semi-arid regions of the world. (Lauchli and Epstein, 1990). In the Maghreb more than 30 % of irrigation waters are loaded in salt, and lead over time to an accumulation of toxins both in the rhizosphere and in the different parts of the plant. These toxins generate damage to cellular ultrastructures by contributing to the reduction of growth and yields of sensitive varieties. (Rahmoune *et al.,* 2008). In Algeria, 4/5 of the surface is desert and the 1/5 left is an arid and semi-arid region (Abdelaguerfi and Ramdane, 2003).

The leguminous constitute an important food diet component especially in developing countries, they represent 90% of the global consumption (Hassan, 2006), they are very rich in proteins and complete often cereals in nutritional quality and they are relatively adapted to the Mediterranean climate. (Abdelaguerfi and Ramdane, 2003).

Chickpea seeds are rich in proteins and minerals (Jain, 1977), common bean is a good source of energy, with high protein content, dietary fiber, complex carbohydrates and also provides folic acid (Edje *et al.,* 1980) and lentil is a major grain and widely distributed legume crop grown under a broad range of climates in many developing countries (Turk *et al.,* 2004)

The assimilatory nitrate reduction pathway is a vital biological process, as it is one of the principal routes by which inorganic nitrogen is incorporated into organic compounds in higher plants, algae, and fungi. After uptake into cells by nitrate transporters, the first and rate-limiting step in this pathway is the reduction of nitrate to nitrite catalyzed by NAD(P)H:nitrate reductase (NR), a molybdenum cofactor (Moco) enzyme (Eckardt, 2005). Unavailability of Mo is lethal for the organism. But even if Mo is available for the cell, it seems to be biologically inactive until it becomes complexed to form Moco thus gaining biological activity. (Mendel and Bittner, 2006).

Mo and N may secondarily influence the growth and yield in legumes (Munns 1970; Bell *et al.,* 1989), Therefore, the molybdenum deficiency may show overall reductions in plant growth, poor pod and/or grain development as well as exposing the plant to pest damage (Graham and Stangoulis, 2005).

In literature there is a lake in studies about effect of both molybdenum and nitrogen on lentil and especially Algerian legumes submitted to salt stress, so we oriented our research in this way in order to evaluate the variations that occur on yield and on nitrate reductase activity in three leguminous species *Phaseolus vulgaris* L., Cicer *arietinum* L., and *Lens culinaris* M. the most cultivated food legumes species in Algeria (Abdelaguerfi and Ramdane, 2003), in response to salt stress and with adding both molybdenum and nitrogen in water irrigation.

Materials and methods

Preparation of plant material

The plant material used is composed by three species from *Fabaceae* ; *Phaseolus vulgaris* L., *Cicer arietinum* L., and *Lens culinaris* M. seedlings, they were grown in pots under different concentrations of NaCl (S0:0 g/l, S1:3 g/l, S2:6 g/l, S3:9 g/l), and with adding molybdenum (M+: 0,2 ppm, M-: 0 ppm) as Ammonium molybdate $(NH_4)_6Mo_7O_{24}$ and nitrogen as nitrate potassium (KNO_3) (N+: 0,02 g/l, N-: 0 g/l).

The treatments of sodium chloride (NaCl), molybdenum (Mo) and nitrogen (N) began after 3weeks of sowing the seeds and when they are all in the same development stage (the first leaves) and lasted 5 weeks and then the seedlings are harvested.

Fresh shoot biomass

At the end of the 5 weeks treatment the fresh plants are harvested and then the areal parts biomass was measured with a balance

Chlorophyll content

The measurement of chlorophyll content (Chl) was realized according to McKinney, (1941), and it represents chlorophyll a plus chlorophyll b, the unit is (µg/g FM): microgram by gram of fresh material.

Nitrate reductase activity

The assay of estimation of in vivo nitrate reductase activity (NRA) on leaves were conducted according to a modified method of Ferrari and Varner (1981) and of Jaworski (1971) in Naman *et al.,*(1997), the unit is µmol/h/g: micromole per hour by gram of fresh material.

Statistical analysis

The data obtained were assessed by one way anova, tables (1), (2) and (3) were obtained using the LSD of Fischer at the confidence level of 95%, using minitab system (se: standard error).

Results and discussion

Several biochemical processes are affected by salinity, particularly nitrate assimilation. Nitrate is the most significant source of nitrogen for crop plants, and frequently limits plant growth (Meloni *et al.,* 2004) , the important molybdoenzymes, nitrate reductase (NR, EC 1.6.6.1) is catalyzing the initial step of the assimilatory nitrate reduction; (Koshiba *et al.,*1996 in Zimmer and Mendel, 1999).

Table 1. Fresh shoot biomass (FSB) of *Phaseolus vulgaris* (P.v), *Cicer arietinum* (C.a) and *Lens culinaris* (L.c) (Grp: statistical groups).

FSB (g)	P.v		se	Grp	C.a		se	Grp	L.c		se	Grp
N-M-S0	1.365	±	0.02	gh	0.79	±	0.05	de	0.055	±	0.04	j
N-M-S3	1.26	±	0.03	gh	1.58	±	0.15	a	0.25	±	0.07	f
N-M-S6	3.05	±	0.01	bc	0.98	±	0.07	bcde	0.27	±	0.06	ef
N-M-S9	2.135	±	0.19	ef	1.277	±	0.22	abcd	0.36	±	0.04	d
N-M+S0	1.31	±	0.31	gh	1.435	±	0.08	ab	0.085	±	0.01	hi
N-M+S3	2.73	±	0.51	cde	1.177	±	0.24	abcd	0.78	±	0.08	a
N-M+S6	3.64	±	0.16	ab	1.413	±	0.02	abc	0.43	±	0.04	c
N-M+S9	2.91	±	0.23	bcd	1.157	±	0.07	abcd	0.28	±	0.04	e
N+M-S0	1.71	±	0.34	fg	1.135	±	0.035	abcd	0.09	±	0.01	hi
N+M-S3	0.817	±	0.06	h	0.817	±	0.03	cde	0.11	±	0.02	h
N+M-S6	4.17	±	0.32	a	1.31	±	0.04	abcd	0.38	±	0.02	d
N+M-S9	2.34	±	0.21	cdef	1.2	±	0.07	abcd	0.25	±	0.03	f
N+M+S0	2.3	±	0.45	def	0.49	±	0.88	e	0.065	±	0.02	ij
N+M+S3	4.115	±	0.45	a	1.31	±	0.07	abvd	0.16	±	0.01	g
N+M+S6	2.725	±	0.75	cde	1.13	±	0.12	abcd	0.56	±	0.06	b
N+M+S9	2.93	±	0.96	bcd	0.74	±	0.07	de	0.1	±	0.02	h

Out of several nutrients provided to plants, nitrogen is a major and essential nutrient for better plant growth and yield. It is considered as most important nutrient for the crop to activate the metabolic activity and transformation of energy chlorophyll and protein synthesis and can constitute 40-50 of protoplasm of plant cell on dry weight basis and can be a limiting factor under such condition (De, 1993, in Kaneez *et al.,* 2013)

Fresh shoot biomass

The important fresh biomass value for lentil is 0.78 g correspond to N-M+S3 treated plants; with molybdenum adding, which is more than 10 times higher than the control plants that represent the lowest value.

Statistical results anova for chickpea showed that the difference between the mean values is not too much significant so we cannot define which element has the most important effect on fresh biomass seedlings (Table 1), it seems like neither molybdenum nor nitrogen have any specific effect on the fresh biomass for this species.

For common bean plants, results show a significant difference between the fresh shoot biomass values, the higher ones are 4.170 g and 4.115 g, which are 3times higher than control plants (N-M-S0), these seedlings were submitted to these treatments N+M-S6 and N+M+S3 respectively, and which represent the same statistical group (a), these plants were grown on a medium containing nitrogen, 3 g/l and 6 g/l of NaCl.

Table 2. Chlorophyll content (Chl) of *Phaseolus vulgaris* (P.v), *Cicer arietinum* (C.a) and *Lens culinaris* (L.c).

Chl (µg/gFM)	P.v		se	Grp	C.a		se	Grp	L.c		se	Grp
N-M-S0	1.106	±	0.021	f	0.351	±	0.004	m	0.119	±	0.003	l
N-M-S3	1.158	±	0.004	e	3.583	±	0.002	c	0.701	±	0.008	g
N-M-S6	1.095	±	0.001	f	3.457	±	0.069	d	0.721	±	0.001	fg
N-M-S9	0.549	±	0.001	l	2.67	±	0.001	f	0.742	±	0.002	ef
N-M+S0	1.679	±	0.003	c	1.729	±	0.002	k	0.768	±	0.002	e
N-M+S3	1.073	±	0.002	g	4.08	±	0.004	a	1.844	±	0.003	a
N-M+S6	0.516	±	0.003	m	2.628	±	0.027	g	0.862	±	0.064	d
N-M+S9	0.964	±	0.001	i	1.502	±	0.001	l	0.697	±	0.004	g
N+M-S0	1.726	±	0.006	b	3.082	±	0.048	e	1.201	±	0.003	b
N+M-S3	3.857	±	0.006	a	3.857	±	0.006	b	0.468	±	0.005	h
N+M-S6	0.987	±	0.013	h	2.505	±	0.001	h	1.011	±	0.005	c
N+M-S9	0.959	±	0.011	i	2.024	±	0.005	j	0.407	±	0.001	i
N+M+S0	1.352	±	0.002	d	0.169	±	0.013	n	0.303	±	0.002	j
N+M+S3	0.969	±	0.004	i	4.07	±	0.004	a	0.413	±	0.001	i
N+M+S6	0.834	±	0.013	j	2.472	±	0.007	h	1.182	±	0.003	b
N+M+S9	0.566	±	0.003	k	2.432	±	0.001	i	0.18	±	0.002	k

Since these three plants have a higher biomass value in presence of sodium chloride salt in irrigation water, it lead us to say that these legumes are not so much sensitive to salt stress and they behave differently for bean it was the combination between molybdenum and nitrogen which gives the important shoot biomass, but for lentil adding only molybdenum enhance shoot biomass.

Chickpea which is known to be sensitive to salt stress (Tejera *et al.,* 2006) in this work chickpea seedlings behave as tolerant when grown under 3g/l of NaCl.

For bean plant biomass, adding nitrogen alone has no significant effect, but it seems that the combination of nitrogen and molybdenum has more positive effect and may adjust a damage that could caused by an irrigation water moderately saline, abiotic stresses are responsible for yield losses estimated at 50% for most crops (Vincent, 2006). These stresses result in changes in morphological, physiological, biochemical and molecular level that affects negatively plant growth and productivity (Ben Naceur *et al.,* 1998), but the application of N fertilizers to growing plants under soil salinity conditions may increase their tolerance (Cordovilla *et al.,* 1994; Van Hoorn *et al.,*2000).

Sidari *et al.,*(2007) reported that four lentil (*Lens culinaris* M.) genotypes were treated with salt stress (0, 50, 100, 150 or 200 Mm NaCl), increasing NaCl concentration had reduced the germination percentage, the growth parameters and the relative water content. Since grain legumes especially lentil are salt sensitive, farmers do not consider growing them in a saline environment, though; there is a considerable difference in salt tolerance among crops/accessions (Ahmed, 2009.), but for our lentil we observed that lentil could keep a higher level of shoot biomass at 3 g/l of sodium chloride but with molybdenum

Chlorophyll content

We observe that sodium chloride and molybdenum enhance chlorophyll content for the three species, for bean plants, the important chlorophyll content value was 3,857 µg/g FM (Table 2) registered for seedlings submitted to these treatment N+M-S3 (Table 2) which is 3 times higher than control plants (1.106 µg/g FM), we note that these seedlings were grown on a soil moderately saline and with nitrogen, for chickpea plants, the superior value is 4.070 µg/g FM and 4.080 µg/g FM (10 times higher than control plants with only 0.351 µg/g FM) observed in plants grown on soil containing 3g/l and with the presence of molybdenum. Lentil plants recorded a higher value of chlorophyll content with 1.844 µg/g FM (which is much more than 10 times the control plants), where there is a moderate salt stress (3 g/l) but when molybdenum is present in water irrigation also. We note that for lentil and chickpea adding molybdenum alone enhance considerably chlorophyll content, but for bean it was the nitrogen which gives the important one.

Table 3. Nitrate reductase activity (NRA) of *Phaseolus vulgaris* (P.v), *Cicer arietinum* (C.a) and *Lens culinaris* (L.c)s.

NRA(µmol/h/g)	P.v	se	Grp	C.a	se	Grp	L.c	se	Grp
N-M-S0	33.254	± 0.168	m	43.365	± 0.054	i	49.74	± 0.037	a
N-M-S3	46.07	± 0.153	f	43.946	± 0.169	h	37.79	± 0.053	h
N-M-S6	48.102	± 0.032	d	47.132	± 0.037	e	43.82	± 0.077	g
N-M-S9	49.801	± 0.025	a	47.953	± 0.032	c	47.03	± 0.496	c
N-M+S0	40.851	± 0.59	k	40.554	± 0.466	j	45.879	± 0.22	d
N-M+S3	43.301	± 0.239	i	46.119	± 0.086	g	44.37	± 0.086	f
N-M+S6	48.414	± 0.032	c	49.57	± 0.042	a	45.45	± 0.075	de
N-M+S9	47.769	± 0.037	e	47.613	± 0.032	d	45.88	± 0.077	d
N+M-S0	39.81	± 0.193	l	40.101	± 0.093	k	47.953	± 0.798	b
N+M-S3	43.712	± 0.085	h	43.712	± 0.085	h	43.84	± 0.074	g
N+M-S6	47.628	± 0.054	e	47.599	± 0.077	d	43.46	± 0.085	g
N+M-S9	47.514	± 0.077	e	48.357	± 0.032	b	44.64	± 0.013	f
N+M+S0	41.446	± 0.075	j	32.772	± 0.295	l	44.363	± 0.687	f
N+M+S3	44.576	± 0.068	g	46.119	± 0.086	g	45.39	± 0.065	e
N+M+S6	48.881	± 0.08	b	46.813	± 0.112	f	44.77	± 0.064	f
N+M+S9	48.449	± 0.074	c	48.201	± 0.044	bc	43.8	± 0.032	g

Salinity is one of the most important environmental factors limiting production and biological N2 fixation of chickpea which is considered to be sensitive to salt stress, in arid and semiarid regions. Several studies were carried out on chickpeas (Zurayk *et al.,* 1998, Soussi *et al.,* 1998, Welfare *et al.,*2002, Singla and Garg 2005, Garg and Singla, 2009), but in this work chickpea seems to tolerate moderate salt stress (3g/l) in presence of nitrogen and molybdenum, and another work realized on chlorosis, it showed that is due to incapacity of plants to form chlorophyll because of molybdenum deficiency (Gupta, 1997 in Hristoskova *et al.,* 2006), so molybdenum has a role in biosynthesis of chlorophyll, because under molybdenum deficiency, intermediates of chlorophyll biosynthesis decrease in winter wheat cultivar (Yu *et* *al.,* 2006), so adding molybdenum and nitrogen in a saline soil can avoid the negative effect of salt stress on chlorophyll biosynthesis for chickpea, bean and lentil plants.

Nitrate reductase activity

Table 3 shows that NR activity increases as NaCl concentrations in water irrigation increase for both chickpea and bean plants with 49.80µmol/h/g (N-M-S9) and 49.57 µmol/h/g (N-M+S6) respectively, for lentil, the highest value of NRA is recorded for the control plants 49.74 µmol/h/g.

There are currently contradictory reports regarding salinity effects on NR activity and nitrate assimilation**.** Several study have shown that salinity decreases NR activity (Aslam *et al.,* 1984; Martinez & Cerda, 1989; Gouia *et al.,*1994 in Silveira *et al.,* (1999)), whereas others have shown opposite results (Misra & Dwiverdi, 1990; Sargi *et al.,* 1997 in Silveira *et al.,* (1999)) or have not observed significant effects on NR activity (Bourgeais- Chaillou *et al.,* 1992; Cramer & Lips, 1995 in Silveira *et al.,* (1999)). Most likely, the salinity effects depend on many other factors such as plant species, NO_3^- level, stress intensity, plant age etc. (Silveira *et al.,* 1999).

For our bean and chickpea plant, it seems that the expression of nitrate reductase activity in shoot is higher as the salt stress is the most pronounced which correspond to a work done on cumin, drought stress increased nitrate reductase activity in cumin root and shoot (Sepehr *et al.,*2012), but for lentil plants it is completely opposite, the NRA level decrease when salt stress increases, several studies have reported that nitrate uptake and nitrate reductase activity (NRA) decrease in plants under salt stress (Rao and Gnaham 1990, Gouia *et al.,* 1994, in Meloni *et al.,* 2004). Drought tolerance of *S. aculeata* was found to be associated with a smaller reduction in number and mass of root nodules, a high activity of nitrate reductase in leaves and nodules, high accumulation of free proline in roots and nodules, and high glycine betaine content in nodules. (Ashraf and Iram,2005).
Molybdenum (Mo), a constituent of nitrogenase (NA) and nitrate reductase (NR), is required for the assimilation of soil nitrates. (Bishop and Premakumar, 1992).

Mo application on a leguminous (*Chamaecrista rotundifolia* cv. 'Wynn') grown on red soil, could increase the number of chloroplasts and activities of nitrate reductase in leaf (Weng *et al.,* 2009), salinity induced by 100 mM NaCl in cowpea plants may have induced the decrease on leaf-NR activity (Silveira *et al.,* 1999), 600 mmol.L^{-1} NaCl caused a significant reduction in root and shoot growth, and nitrate reductase activity in leaves and roots were also decreased in *Prosopis alba*. (Meloni *et al.,* 2004), molybdenum application positively affected wheat growth and increased nitrate reductase activity (Abd El-Samad *et al.,* 2005). The supply of molybdenum to Salicornia grown in seawater enhances plant biomass accumulation by increasing the activities of nitrate reductase (Ventura *et al*, 2010). The application of KNO_3 significantly increased leaf area, its fresh and dry weight per plant, and NR activity in leaves irrespective to the growth of plant under non saline or saline conditions (Jabeen and Ahmad, 2011).

These results (Table 1, Table 2, Table 3) indicate that bean, lentil and chickpea plants could be tolerant to a moderate salt stress (3g/l) but behave differently in presence of nitrogen and molybdenum, it corresponds to a previous work that showed that common bean plants are able to maintain an optimum level of morphological parameters and chlorophyll content under mild salt stress of (3g/l) in the presence of molybdenum, (Bouzid and Rahmoune, 2012).

Conclusion

As concluding remarks, the presence of molybdenum and nitrogen together caused the increase of nitrate reductase activity in bean and chickpea plants grown under salt stress. Both molybdenum and nitrogen have a positive effect on yield and nitrate reductase activity for these three plant species that behave differently considering tolerance to salt stress, they could maintain a good yield level at 3 g/l of sodium chloride.

References

Abd El Samad HM, El Komy HM, Shaddad MAK, Hetta AM. 2005. Effect of molybdenum on nitrogenase and nitrate reductase activities of wheat Inoculated with *Azospirillum brasilense* grown under drought stress. General and Applied Plant Physiology **31(1-2)**, 43-54.

Abdelaguerfi A, Ramdane SA. 2003. Evaluation Des Besoins En Matière De Renforcement Des Capacités Nécessaires A La Conservation Et L'utilisation Durable De La Biodiversite Importante Pour L'agriculture. Bilans des Expertises sur «La Biodiversité Importante pour l'Agriculture en Algérie » MATE-GEF/PNUD : Proj*et AL*G/97/G31. P11.

Ahmed S. 2009. Effect of soil salinity on the yield and yield components of Mung bean. Pakistan Journal of Botany **4(1),** 263-268.

Ashraf M, Iram A. 2005. Drought stress induced changes in some organic substances in nodules and other plant parts of two potential legumes differing in salt tolerance. Flora **200,** 535–546. http://dx.doi.org/10.1016/j.flora.2005.06.005

Bell W, Edwards DG, Asher CJ. 1989. External calcium requirements for growth and nodulation of six tropical food legumes grown in flowing solution culture. Australian Journal of Agricultural Research **40,** 85-96.

Ben Naceur M, Ben Salem M, Rahmoune C, Chorfi A, El Jaafari S, Paul R. 1998. Etude comparée du comportement de quelques variétés anciennes et quelques variétés nouvelles de blé dur (*Triticum durum* Defsf.) sous contrainte hydrique. Annales de l'INRA, **71**, 251-273.

Bishop PE, Premakumar R. 1992. Alternative Nitrogen Fixation Systems. In Biological Nitrogen Fixation. Stacey, G., Roberts, G.P. and D.J. Evans, (Eds.) New York: Chapman & Hill, 736-762.

Bortels H.1930. Molybdän als Katalysator bei der biologischen Stickstoffbindung. Archiv für Mikrobiologie **1,** 333–342.

Bouzid S, Rahmoune C. 2012. Enhancement of Saline Water for Irrigation of *Phaseolus vulgaris* L. Species in Presence of Molybdenum. Procedia Engineering **33,** 168 – 173. http://dx.doi.org/10.1016/j.proeng.2012.01.1190

Cordovilla MP, Ligero F, Lluch C. 1994.The effect of salinity on nitrogen fixation and assimilation in *Vicia faba*. Journal of Experimental Botany **45,** 1483-1488. http://dx.doi.org/10.1093/jxb/45.10.1483

Cornillon P, Palloix A. 1997. Influence of sodium chloride on the growth and mineral nutrition of pepper cultivars. Journal of Plant Nutrition **20,** 1085-1094. http://dx.doi.org/10.1080/01904169709365320

Eckardt NA. 2005. Moco mojo: crystal structure reveals essential features of Eukaryotic assimilatory nitrate reduction. The Plant Cell **17**, 1029–1031. http://dx.doi.org/10.1105/tpc.105.032326

Edje OT, Mughogho LK, Rao YP. Msuku WAB. 1980. Bean production in Malawi. In Potential for field beans in Eastern Africa. Proceedings of a Regional Workshop help in Lilongwe, Malawi, 9-14.

Garg N, Singla R. 2009. Variability in the response of chickpea cultivars to short-term salinity, in terms of water retention capacity, membrane permeability and osmo-protection. Turkish Journal of Agriculture and Forestry **33,** 57-63.

Graham RD, Stangoulis JRS. 2005. Molybdenum and disease. In: Mineral nutrition and plant diseases (Dantoff L, Elmer W, Huber D. Eds) St Paul, MN: APS Press.

Halperin ST, Gilroy S, Lynch JP. 2003. Sodium chloride reduces growth and cytosolic calcium, but does not affect cytosolic pH, in root hairs of

Arabidopsis thaliana L. Journal of Experimental Botany **54**, 1269-1280.
http://dx.doi.org/10.1093/jxb/erg134

Hassan F. 2006. Heterologous expression of a recombinant chitinase from Streptomyces olivaceoviridis ATCC 11238 in Transgenic Pea (*Pisum sativum* L.). Doctorate thesis, University of Damas, Syria.

Hristoskova MV, Geneva M, Stancheva I. 2006. Response of pea plant (*Pisum sativum* L.) to reduce supply with molybdenum and copper. International Journal of Agriculture and Biology **08 (2),** 218-220.

Jabeen N, Ahmad R. 2011. Foliar Application of Potassium Nitrate Affects the Growth and Nitrate Reductase Activity in Sunflower and Safflower Leaves under Salinity. Notulae Botanicae Horti Agrobotanici Cluj-Napoca **39(2),** 172-178.

Jain HK. 1977. Centers of diversity, genetics variability and components of yield and plant type in chickpea. F.A.O. Plant protection and production, 9 p.) Journal of Experimental Botany **53(375),** 1689-1698.

Kaneez F, Nazir H, Pir FA, Mohd M. 2013. Effect of nitrogen and phosphorus on growth and yield of Lentil (*Lens culinaris*). Elixir Applied Botany **57,** 14323-14325.

McKinney C. 1941. Absorption of light by chlorophyll solution. Journal of Biological Chemistry **140,** 315-322.

Meloni DA, Gulotta MR, Martínez CA, Oliva MA. 2004. The effects of salt stress on growth, nitrate reduction and proline and glycinebetaine accumulation in *Prosopis alba*. Brazilian Journal of Plant Physiology **16(1),** 39-46.
http://dx.doi.org/10.1590/S167704202004000100006

Mendel RR, Bittner F. (2006). Cell biology of molybdenum. Biochimica Biophysica Acta **1763(7),** 621-35.
http://dx.doi.org/10.1016/j.bbamcr.2006.03.013

Munns DN. 1970. Nodulation of *Medicago sativa* in solution culture. V. Calcium and pH requirements during infection. Plant Soil **32,** 90-102.

Naman F, Zaoui D, Ouaaka A, Chraïbi A. 1997. Mesures in vivo et in vitro de l'activité nitrate réductase dans les feuilles de la betterave à sucre (Beta *vulgaris var. Maghribel*). Actes Institut Agronomique et vétérinaire **17(2),** 95-101.

Rahmoune C, Ben Naceur M, Cheikh-M'Hamed H, Maalam S. 2008. Les indicateurs précoces de tolérance à la salinité chez les blés durs. Biotech2008. XIes Journées Scientifiques du réseau "Biotechnologies végétales / Amélioration des plantes et sécurité alimentaire" de l'Agence universitaire de la Francophonie. Rennes, France. p.151.

Sepehr MF, Ghorbanly M, Amini F. 2012. Effect of water stress on nitrate reductase activity and nitrogen and phosphorus content in *Cuminum cyminum* L. Pakistan Journal of Botany **44(3),** 899-903.

Shannon M, Crieve M, Francois LE. 1994. Whole-plant response to salinity. In Plant Environment Interactions, Ed. R.E. Wilkinson, Marcel Dekker Inc., New York, 199-244.

Sidari M, Muscolo A, Anastasi U, Preiti G and Santonoceto C. 2007. Response of four genotypes of lentil to salt stress conditions. Seed Science and Technology **35,** 497-503.
http://dx.doi.org/10.15258/sst.2007.35.2.24

Silveira JAG, De Cardoso B, Melo ARB, De Viegas RA. 1999. Salt-induced decrease in nitrate uptake and assimilation in cowpea plants. Brazilian Journal of Plant Physiology **11(2),** 77-82.
http://dx.doi.org/10.1016/S0098-8472(01)00095-8

Singla R, Garg N. 2005. Influence of salinity on growth and yield attributes in chickpea cultivars. Turkish Journal of Agriculture and Forestry **29,** 231-235.

Soussi M, Ocana A, Lluch C. 1998. Effects of salt stress on growth, photosynthesis and nitrogen fixation in chick-pea (*Cicer arietinum* L.). Journal of Experimental Botany **49,** 1329-1337.
http://dx.doi.org/10.1093/jxb/49.325.1329

Tejera NA, Soussi M, Lluch C. 2006. Physiological and nutritional indicators of tolerance to salinity in chickpea plants growing under symbiotic conditions. Environmental and Experimental Botany **58,** 17–24.
http://dx.doi.org/10.1016/j.envexpbot.2005.06.007

Turk MA, Tawaha ARM, Lee KD. 2004. Seed germination and seedling growth of three lentil cultivars under moisture stress. Asian Journal of Plant Sciences **3,** 394-397.
http://dx.doi.org/10.3923/ajps.2004.394.397

Van Hoorn J W, Katerji N, Hamdy A, Mastrorilli M. 2000. Effect of salinity on yield and nitrogen uptake of four grain legumes and on biological nitrogen contribution from the soil. Agricultural Water Management **51,** 87-98.
http://dx.doi.org/10.1016/S0378-3774(01)00114-7

Ventura Y, Wuddineh WA, Ephrath Y, Shpigel M, Sagi M. 2010. Molybdenum as an essential element for improving total yield in seawater-grown *Salicornia europaea* L. Scientia Horticulturae **126,** 395–401.
http://dx.doi.org/10.1016/j.scienta.2010.07.015

Vincent R. 2006. Recherche et étude de marqueurs moléculaires de la réponse au stress chez l'algue brune *Laminaria digitata*. Thèse de doctorat. Biologie. Université de Rennes 1. 237p. France.

Welfare K, Yeo AR, Flowers TJ. 2002. Effects of salinity and ozone, individually and in combination, on the growth and ion contents of two chickpea (*Cicer arietinum* L.) varieties. Environmental Pollution **120,** 397-403.
http://dx.doi.org/10.1016/S0269-7491(02)00109-4

Weng BQ, Huang DF, Xiong DZ, Wang YX, Luo T, Ying ZY, Wang HP. 2009. Effects of Molybdenum Application on Plant Growth, Molybdoenzyme Activity and Mesophyll Cell Ultrastructure of Round Leaf Cassia in Red Soil. Journal of Plant Nutrition **32(11),** 1941 – 1955.
http://dx.doi.org/10.1080/01904160903242409

Yu M, Hu CX, Wang YH. 2006. Effect of Molybdenum on the intermediate of chlorophyll biosynthesis of winter wheat cultivars under low temperature. Agricultural Sciences in China **5(9),** 670-677.

Zimmer W, Mendel R. 1999. Molybdenum Metabolism in Plants. Plant biology **1,** 160-168.
http://dx.doi.org/10.1055/s-2007-978502

Zurayk R, Adlan M, Baalbaki R, Saxena MC. 1998. Interactive effects of salinity and biological nitrogen fixation on chickpea (*Cicer arietinum* L.) growth. Journal of Agronomy and Crop Science **180,** 249-258.