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Foliar Potassium Fertilization and its Effect on Growth, Yield and Quality of Potato Grown under Loam-sandy Soil and Semi-arid Conditions

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ABSTRACT

A field experiment was conducted to evaluate the response of potato crop to potassium foliar pulverization in terms of improving vegetative growth, tuber yield and tuber size of potatoes grown on a loam-sandy soil in the semi-arid environment of Central East of Tunisia. The experimental layout was a randomized complete block design with 4 levels of potassium nitrate (ranging from 0 up to 2 g L^{-1}) and 3 replicates. Increasing potassium nitrate rates resulted in a significant increase ($p<0.05$) in plant height, leaves number, leaf area, leaf relative water content and chlorophyll a concentration with values of 79.1 cm, 70 leaves $plant^{-1}$, 400 cm^2, 93% and 0.71 mg L^{-1}, respectively at 95 Days After Planting (DAP). Tubers were harvested and evaluated. Statistical analysis among yield parameters showed no significant effect ($p<0.05$) of increasing potassium nitrate rates on tuber yield and tuber number. The average mean values were 1377.58 g and 10.44 tubers per plant, respectively. Under conditions of this experiment, it is concluded that potassium can be sufficient for potatoes over fertigation. The recommended rate for this region was 60 kg potassium sulphate per hectare.

Key words: Potato, potassium nitrate, foliar applications, vegetative growth, tuber quality

INTRODUCTION

Potassium (K) is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of photosynthetic, enabling their ability to resist pests and diseases. Also, potassium is considered as a major osmotically active cation of plant cell (Mehdi *et al*., 2007) where it enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency (Zekri and Obreza, 2009).

Horticultural crops take potassium in large quantities, especially at fruit filing stages. Potassium fertilizer application can be made in several ways by banding, fertigation or by spraying liquid fertilizers on to the leaves. Various sources of K salts are used such as potassium chloride (KCl), potassium sulphate (K_2SO_4), potassium nitrate (KNO_3) and mono-potassium phosphate (KH_2PO_4) (Magen, 2004).

One of the major production factors of potato is fertilization. Potato plants require much more potassium than many other vegetable crops (Al-Moshileh and Errebi, 2004). Zaag (1991) mentioned that potassium fertilizer should be applied to sustain high yields. An adequate supply of potassium strengthens stems to prevent lodging, increases yield and improves tuber quality (Omran *et al*., 1991).

It has been established in various research studies that plant leaves and other above-ground parts are capable of absorbing chemicals and nutrients. Absorption of nutrients by plants is not a function limited to the root system. Foliar nutrition is ideally designed to provide many elements to a crop that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995).

Several researches are being done on supplying fertilizer through the leaves and on viable fertilization alternatives on a number of nutrients like potassium (Weir, 1998), boron (Shaaban *et al*., 2006), phosphorus (Ekelof, 2007) and silicon (Buck *et al*., 2008) using lower amounts that would provide the needed nutrient or else stimulate its beneficial effects. Elwan (2010) mentioned that spraying of di-potassium hydrogen orthophosphate (K_2HPO_4) ameliorated the negative effects of salinity on plant growth, fruit yield and fruit total sugar content of eggplant.

Thus, the advantages of this technique should be explored, such as the smaller fertilizer use (since foliar fertilization consists on supplying small amounts of nutrients directed to the leaves), lower cost, ease of application, good quality of fertilizers used and fertilizers readily soluble in water (Buck *et al*., 2008).

The present investigation was, therefore carried out to study the effects of foliar potassium applications on plant vegetative performance, tuber number, tuber yield and tuber quality (weight, length and diameter) of potatoes grown in a loam sandy soil under semi-arid environmental conditions.

MATERIALS AND METHODS

The present study was carried out in the Experimental Farm of the High Institute of Agronomy Chott-Mariem.

Some physical and chemical properties of the studied soil were measured and determined before planting (Table 1).

The soil was amended before plantation with organic fertilizer (33 ton ha^{-1}), super phosphate 45 (170 kg ha^{-1}) and potassium sulphate (170 kg ha^{-1}). Potato tuber seeds (Spunta) were planted at the second week of February and harvested after 106 days. Tuber seeds were planted on ridges (80 cm apart) at 25 cm spacing between plants. One month after planting, the application of soluble fertilizer nutrients was done every week with irrigation. The equivalent to 60 kg ha^{-1} ammonium nitrate (33%), 60 kg ha^{-1} potassium sulphate (50% K_2O), 25 kg ha^{-1} magnesium sulphate and 8 L ha^{-1} phosphoric acid (53%) was injected during 8 weeks.

The experiment was arranged in a randomized complete block design with 4 treatments and 3 replications per treatment. Potassium fertilizer in the form of potassium nitrate (46% K_2O) with four levels 0, 0.25, 0.5 and 0.95 g K_2O/L (equivalent to 0, 0.5, 1 and 2 g KNO_3/L, respectively) was supplied as a foliar spray at 45, 55 and 70 Days after Planting (DAP).

Table 1: Physico-chemical properties of the soil

Texture	pH	OM (%)	EC (mmoh cm^{-1})	$CaCO_3$ (%)
LS	7.8	1.2	2.3	2.8

LS: Loam sandy, OM: Organic matter

During the growing season, data were collected on plant height and number of leaves at 10 days intervals from 45 days after planting to 95 days.

At the 95th day after planting, plants (three from each treatment and each plot) were chosen for the determination of the following measurements:

Measurements of leaf area and leaf relative water content: Leaf area of the plant leaves were measured by using an Area meter (LI 3100). After leaf area measurement the relative water content (RWC) was determined for detached leaves using the method of Clarke and McCaig (1982):

$$RWC\ (\%) = (FW-DW)/(TW-DW) \times 100$$

Proline content: The proline content was determined spectrophotometrically adopting the ninhydrin according to method of Bates *et al.* (1973).

Leaf chlorophyll content: Leaf chlorophyll content was measured spectrophotometrically in acetone extract, by determining the Optical Density (OD) at 645 and 663 nm corresponding to absorption maxima of chlorophyll a and chlorophyll b. Concentration of pigments (C; mg L^{-1}) was calculated according to the method of MacKinney (1941).

Tubers were harvested 106 days after planting. At harvest, tubers from each treatment were rinsed free of soil and the number of tubers/plant and mean tuber weight were determined. Total tuber yield was determined by weight. Potato tuber samples were then collected from all treatments for length and diameter determinations.

Statistical analysis: Analysis of Variance (ANOVA) using SPSS 13.0 program was performed to detect differences between treatments. Mean comparison procedure was carried out using the Duncan test with least significant difference at 0.05 probability.

RESULTS

Potassium effect on growth parameters: Data presented in Fig. 1 show the effect of K rates on plant height. Results revealed that increasing K_2O concentration from 0 to 0.95 g L^{-1} significantly and progressively increased height of potato shoots. From the 45th until the 95th day after planting, the 0.95 g K_2O/L gave the highest significant values for plant height compared with

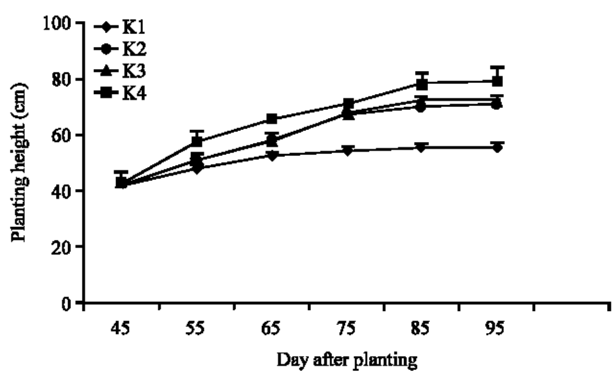

Fig. 1: Effect of different levels of K_2O on the height of potato plant. K1: 0 g L^{-1}; K2: 0.25 g L^{-1}; K3: 0.5 g L^{-1} and K4: 0.95 g L^{-1}. Data are means of 9 replicates (±standard error; p = 0.05)

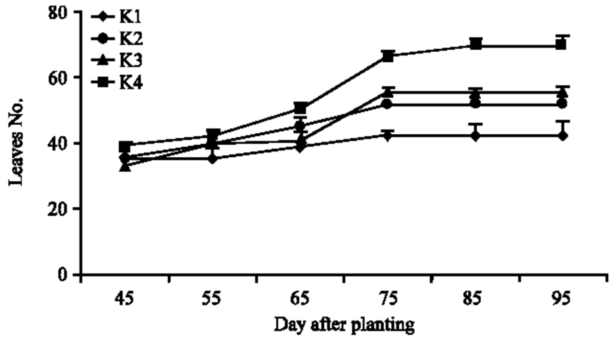

Fig. 2: Effect of different levels of K_2O on leaves number of potato plant. K1: 0 g L^{-1}, K2: 0.25 g L^{-1}; K3: 0.5 g L^{-1} and K4: 0.95 g L^{-1}. Data are means of 9 replicates (±standard error; P = 0.05)

Table 2: Effect of foliar pulverization of potassium nitrate levels on leaf area, leaf relative water content, chlorophyll a, chlorophyll b and proline content at 95 days of planting

Treatment (g KNO_3/L)	Leaf area (cm^2)	Leaf relative water content (%)	Chlorophyll a (mg L^{-1})	Chlorophyll b (mg L^{-1})	Proline (mg g^{-1} FW)
0	280^a	88^a	0.62^a	0.41^a	0.40^a
0.5	280^a	95^b	0.69^b	0.43^a	0.12^b
1	320^b	97^b	0.72^b	0.45^a	0.60^{ab}
2	400^c	93^b	0.71^b	0.51^a	0.12^b

Mean values with same letter are not significantly different from each other based on SPSS General Linear Model procedure. Duncan test (α = 0.05)

other treatments (79.1 cm at the 95 day). As compared with the control, the main effect of K_2O rates showed increases of about 27, 31 and 43.5% at 0.25, 0.5 and 0.95 g K_2O/L, respectively.

Examining the effect of potassium levels on the number of leaves plant^{-1} (Fig. 2), results clear that this vegetative growth parameter was gradually and significantly increased by increasing the level of potassium application. Plants treated with 0.95 g K_2O/L had the maximum number of leaves which developed from 39 leaves at 45 days after planting to 70 leaves at the end of experiment. The difference between the control and treatment K4 was significantly which is about 28 at the 95th day.

The significant leaf area differentiation between treatments was achieved at 95 days after planting (Table 2). Leaf area ranged from 280 cm^2 at no foliar potassium applied (control) to 400 cm^2 with pulverization of 2 g KNO_3/L.

The data regarding effect of potassium on Leaf Relative Water Content (LRWC), chlorophyll and proline content, respectively are presented in Table 2. Results indicated that after 95 days LRWC was affected significantly with treatments over control. There was a gradual significant increase in the leaf water content from treatment K1 to K4. The lowest water content (88%) was in the case of K1 (control) while the highest value (97%) was noted in K3 (1 g KNO_3/L). Statistically non-significant difference was noted between K2, K3 and K4, their effect was similar on the leaf relative water content.

The biosynthesis of pigment fractions (chlorophyll a, chlorophyll b) was affected by foliar pulverization of potassium in a different way. Thus, there was an increase of 15.8% of chlorophyll a concentration in response to the 1 g KNO_3/L treatment when compared to the control at 95 DAP (Table 2). In the case of chlorophyll b, no statistical significant effect of potassium supply was revealed; concentration was ranged between 0.41 and 0.51 mg L^{-1}.

Table 3: Effect of foliar K_2O levels on tuber number, tuber quality (weight, diameter and length) and tuber yield of potato

Treatment ($g\ K_2O/L$)	Tuber number/plant	Mean tuber weight (g)	Tuber diameter (cm)	Tuber length (cm)	Tuber yield ($g\ plant^{-1}$)
0	10.00^{a}	110.44^{a}	4.02^{a}	11.18^{a}	1246.33^{a}
0.25	11.66^{a}	128.76^{ab}	4.51^{ab}	11.26^{a}	1405.44^{a}
0.5	10.22^{a}	139.36^{ab}	5.13^{b}	11.28^{a}	1405.44^{a}
0.95	9.88^{a}	154.57^{b}	5.42^{b}	11.71^{a}	1454.22^{a}

Mean values with same letter are not significantly different from each other based on SPSS General Linear Model procedure. Duncan test ($\alpha = 0.05$)

Moreover, the potassium sprayed on leaves increased proline concentration (Table 2). Proline was more abundant in leaves treated with 0.5 and 2 g KNO_3/L concentration was about 0.12 mg g^{-1} FW, it was 3 times higher than proline concentration in control leaves.

Potassium effect on yield and its quality: Data in Table 3 show the effect of KNO_3 foliar pulverization on tuber number, tuber yield and tuber quality (weight, length and diameter).

The foliar potassium application gave no significant effects on tuber number which was arranged between 9.88 (plants treated with K1, K3 and K4) and 11.66 (plants treated with K2). Although, all potassium treatments showed significant effects on mean tuber weight, the highest significant value (154.57 g) was recorded with treatment K4. The application of K2 and K3 treatments gave intermediates values ranged between 128.76 and 139.36 g, in comparison with control mean tuber weight was about 110.44 g.

In addition, there was a significant difference among treatments for the diameter of tuber. Average tuber diameter was highest in the potassium nitrate treatments; it was arranged between 4.51 and 5.42 cm. Tubers produced by untreated plants had a mean diameter of 4.02 cm. However, there were no significant effects off potassium treatments on the mean tuber length. Plants produced tubers whose length varied between 11.18 and 11.71 cm.

Moreover, there were no significant differences in total tuber yield among treatments. The foliar potassium applications induced an increase on the total tuber yield which reached 1454 g $plant^{-1}$. The lowest value (1246 g $plant^{-1}$) was recorded with control.

DISCUSSION

Developing healthy plants necessary for maximum tuber growth requires that all essential nutrients be supplied at optimal rates. Both deficit and excess fertilizer situations can reduce tuber bulking rates. Potatoes are heavy nutrient requiring crop because of their bulk yields within a short time having shallow root systems (Bari *et al*., 2001). In recent years, there has been renewed interest in the use of foliar fertilizers on potatoes and other crops (Hiller, 1995).

In this study, supplying small amounts of potassium directed to the leaves using potassium nitrate as a readily soluble fertilizer in water is effective for plant growth. Increasing the foliar potassium treatment beyond 2 g L^{-1} increase plant height, Abo-Sedra and Shehata (1994) reported that application of k increased plant height. As reported by Shakh *et al*. (2001), proper vegetative growth is needed for potato cultivation because more tubers were obtained from the plants from more vegetative growth and development.

As well leaves number and leaf area surface of treated plants maintain higher value. This increment in vegetative growth of potato plants by increasing the levels of foliar potassium application may be due to the role of potassium on plant nutrition. Potassium is essential to obtain maximum leaf extension and stem elongation.

Hussein *et al.* (2008) showed that K_2PO_3 foliar fertilization positively affected parameters of cowpea grown under salinity stress conditions such as plant heights, number of green leaves par plant and both fresh and dry weights.

The parallel increase in proline content with the leaf relative water content suggested that proline might be involved in the osmotic adjustment. The results in the present study suggest that foliar spray of potassium induced proline synthesis and this accumulation might have served as a compatible solute. Although the role of proline in osmotic adjustment and drought tolerance is still debated (Hong-Bo *et al.*, 2006; Tan *et al.*, 2006). El-Latif *et al.* (2011) reported that adequate potassium levels in the plant help it to withstand water stress during periods of drought. Potassium regulates the osmotic turgor of the cells and the water balance. Crops grown with adequate potassium availability use less water per unit weight of plant biomass and are therefore better able to survive periods of drought.

It is also clear from Table 2 that chlorophyll a predominated over chlorophyll b, the values become closer with increasing potassium concentration. The supplement application of potassium nitrate with 0.5, 1 and especially 2 g L^{-1} helps plants to achieve rapid ground cover so maximizing interception of sunlight and thus the rate of growth. The increase in chlorophyll content can be attributed to the supply of nitrogen (Lawlor *et al.*, 1989).

Tuber number and tuber yield were not significantly affected by the foliar applications. Present results disagreed with those of Allison *et al.* (2001), they suggested that tuber yield could be positively affected without an increase of the leaf area. Nevertheless, many researchers recorded an increase of potato tubers yield as a result of the increasing levels of potassium (K) fertilization (El-Gamal, 1985; Humadi, 1986).

These results further show that potassium was effective in increasing average tuber size (diameter). Since, total tuber yield was not influenced; the increase in tuber diameter would result if plant had fewer tubers to bulk. As well, soil potassium levels can alter tuber size and tuber number in potatoes. While, El-Gamal (1985) reported that the formation of large size tubers or increasing of the number of tubers per plant or both increased yield potato tubers.

The major benefits given for the use of foliar potassium application on potatoes are essentially increased plant growth and improved mean tuber weight and tuber diameter. However, the increased concentration of potassium sprayed at the 45, 55 and 70 days after plantation didn't produce increased yields. This compound (potassium solution) was applied early in the growing season, so possible benefits may be obtained of later applications during the tuber-bulking or tuber-maturating stages. Several researches have shown that timing is critical in meeting these additional potassium needs. Weir (1998) suggested that application of foliar potassium to cotton plants at the beginning of two weeks after first bloom given increases in lint yield but later applications in the season produced less response.

CONCLUSION

From this study, it seems be clear that potassium application made over foliar pulverization don't prove any benefits for plant yield. The pronounced effect of foliar potassium fertilizer on the growth of potato was visible as shown in the results. The frequency and the time of potassium nitrate pulverization would be improved in further studies.

REFERENCES

Abo-Sedra, F.A. and S.A. Shehata, 1994. Effect of NK fertilization level and foliar spray with Mn and Mo on growth, yield and chemical composition of potatoes. Zagazig J. Agric. Res., 21: 145-156.

Al-Moshileh, A.M. and M.A. Errebi, 2004. Effect of various potassium sulphate rates on growth, yield and quality of potato grown under sandy soil and arid conditions. Proceedings of the IPI Regional Workshop on Potassium and Fertigation Development in West Asia and North Africa, Rabat, Nov. 24-28, Morocco, pp: 1-6.

Allison, M.F., J.H. Fowler and E.J. Allen, 2001. Effects of soil- and foliar-applied phosphorus fertilizers on the potato (*Solanum tuberosum*) crop. J. Agric. Sci., 137: 379-395.

Bari, M.S., M.G. Rabbani, M.S. Rahman, M.J. Islam and A.T.MR. Hoque, 2001. Effect of zinc, boron, sulphur and magnesium on the growth and yield of potato. Pak. J. Biol. Sci., 4: 1090-1093.

Bates, L.S., R.P. Waldren and I.D. Teare, 1973. Rapid determination of free proline for water-stress studies. Plant Soil, 39: 205-207.

Buck, G.B., G.H. Korndrfer, A. Nolla and L. Coelho, 2008. Potassium silicate as foliar spray and rice blast control. J. Plant Nutr., 31: 231-237.

Clarke, J.M. and T.N. McCaig, 1982. Evaluation of techniques for screening for drought resistance in wheat. Crop Sci., 22: 503-506.

Ekelof, J., 2007. Potato yield and tuber set as affected by phosphorus fertilization. Department of Horticulture, Master Project in Horticultural Science Programme. http://ex-epsilon.slu.se:8080/archive/00001853/.

El-Gamal, A.M., 1985. Effect of potassium level on potato yield and quality. J. Agric. Sci. Mansoura Univ., 10: 1473-1476.

El-Latif, K.M.A., E.A.M. Osman, R. Abdullah and N.A. El Kader, 2011. Response of potato plants to potassium fertilizer rates and soil moisture deficit. Adv. Applied Sci. Res., 2: 388-397.

Elwan, M.W.M., 2010. Ameliorative effects of di-potassium hydrogen orthophosphate on salt stressed eggplant. J. Plant Nutr., 33: 1593-1604.

Hiller, L.K., 1995. Foliar fertilization bumps potato yields in Northwest: Rate and timing of application, plus host of other considerations, are critical in applying foliars to potatoes. Fluid J., 10: 28-30.

Hong-Bo, S., C. Xiao-Yan, C. Li-Ye, Z. Xi-Ning and W. Gang *et al*., 2006. Investigation on the relationship of proline with wheat anti-drought under soil water deficits. Colloids Surf. B: Biointerfaces, 53: 113-119.

Humadi, F.M., 1986. Influence of potassium rates on growth and yield of potato (*Solanum tuberosum*). Iraqi J. Agric. Sci. (Zanco), 4: 69-76.

Hussein, M.M., M.M. Shaaban and A.K.M. El-Saady, 2008. Response of cowpea plants grown under salinity stress to PK-foliar applications. Am. J. Plant Physiol., 3: 81-88.

Lawlor, D.W., M. Kontturi and A.T. Young, 1989. Photosynthesis by flag leaves of wheat in relation to protein, ribulose *Bisphosphate* carboxylase activity and nitrogen supply. J. Exp. Bot., 40: 43-52.

MacKinney, G., 1941. Absorption of light by chlorophyll solutions. J. Biol. Chem., 104: 315-322.

Magen, H., 2004. Potassium in fertigation systems. International Potash Institute (IPI), 5th Fertigation Training Course, Boading, AUH, June 2004.

Mehdi, S.M., M. Sarfraz and M. Hafeez, 2007. Response of rice advance line PB-95 to potassium application in saline-sodic soil. Pak. J. Biol. Sci., 10: 2935-2939.

Omran, M.S., M. Taysee, M.M. El-Shinnawi and M.M. El-Sayed, 1991. Effect of macro-and micro-nutrients application on yield and nutrients content of potatoes. Egypt. J. Soil Sci., 31: 27-42.

Shaaban, M.M., F.E. Abdalla, E.A.A. Abou El-Nour and A.M. El-Saady, 2006. Boron/Nitrogen interaction effect on growth and yield of faba bean plants grown under sandy soil conditions. Int. J. Agric. Res., 1: 322-330.

Shakh, M.N.U., M.A. Awal, S.U. Ahmed and M.A. Baten, 2001. Effect of eyes number in cut seed tuber and different levels of nitrogen on growth, yield and grading of tuber size in potato (*Solanum tuberosum* L.). Pak. J. Biol. Sci., 4: 1184-1187.

Tan, Y., Z.S. Liang, H.B. Shao and F. Du, 2006. Effect of water deficits on the activity of anti-oxidative enzymes and osmoregulation among three different genotypes of *Radix Astragali* at seeding stage. Colloids Surf. B: Biointerfaces, 49: 60-65.

Weir, B., 1998. Foliar potassium bumps cotton yields: California researcher reports consistent yield increases to foliar-applied potassium over a period of years in the San Joaquin Valley. Fluid J., 6: 10-13.

Zaag, D.E., 1991. The potato crop in Saudi Arabia. Saudi potato development Program, Ministry of Agriculture and Water, Riyadh, Saudi Arabia.

Zekri, M. and T.A. Obreza, 2009. Plant nutrients for citrus trees. SL 200, UF/IFAS Extension Service, Institute of Food and Agricultural Sciences, University of Florida.