Effect of levels calcium nitrate addition on potatoes fertilizer

Wissem HAMDI[1], Lokman HELALI[1], Rihab BEJI[2], Kawther ZHANI[1],

Sarra OUERTATANI[3], Azaiez GHARBI[3]

[1]*High Institute of Agronomy, Chott Meriem 4042, Sousse, Tunisia (Sousse University)*

[2]*Faculty of Sciences of Monastir, Tunisia (Monastir University)*

[3]*Soil Sciences Laboratory, Higher school of Agriculture of Kef (ESAK) / BP 138 Barnoussa, Kef 7100, Tunisia.*

---***---

Abstract - *In an attempt to increase the potato (Solanum tuberosum L.) plant production, the effect of calcium nutrition was investigated. A field experiment was conducted in an isohumic soil in the research station of the Agronomic Height Institute of Chott-Mariem, Tunisia. Seven fertilization treatments with seven doses of calcium nitrate as a calcium source (0, 20,40,60,80,100 and 120) were involved in this study. For each treatment three replications were used. The results have showed that applying additional calcium nitrate had significantly ($P \leq 0.01$) effect at plant growth such a tuber weight and dry matter. In contrast, addition of Ca level reduced the number of tubers per plant but significantly ($P \leq 0.01$) increased tuber size. Moreover applying additional calcium nitrate can be increasing the Ca level in leaf and tuber but not have a negative influence on the uptake of other nutrient elements.*

Keywords: *Potatoes, calcium nitrate, plant growth, nutrient elements.*

1. INTRODUCTION

Calcium (Ca) is one of the most important elements in soil and it is also a very important determinant of plant growth and production such a potato (Solanum tuberosum L.) [1]. This plant is a great consumer of Ca for forming abundant vegetative mass and a high quantity of tubers. Calcium play many crucial roles in plant membrane structure and function for forming abundant vegetative mass and a high quantity of tubers [2]. It contributes to maintenance of cell membrane stability and wall structure [3]. It confers some resistance to pests and diseases in plants via its calcium deficiency influence on growth pattern, anatomy, morphology and chemical composition of the plant [4]. It was unlikely to show leaf symptoms and brown blotches may develop around the stolon end of the tuber [5]. The youngest leaves are pale green and small, and curl downwards at the ends of the leaves [5]. Foremother Ca deficiency has been linked to many disorders especially, such as brown center, hollow heart that was thought to be related to tuber Ca level. Ozgen et al., [3] have shown that the Ca content of tubers may affect their susceptibility to bacterial soft rot and internal defects of tubers and were able to restore the tuberization response by adding Ca into the medium, suggesting that lack of Ca in media can decline tuberization. Whereas Arvin et al., [6] revealed that increasing plant Ca has been shown to enhance resistance to plant tissue macerating bacterial phytopathogens. It also enhances the structural integrity of cell walls and membranes. An effective way of applying calcium is through fertigation [7] while less soluble fertilizers can be applied by side dressing before the last hilling [8]. Calcium can be applied as calcium chloride, calcium nitrate, calcium sulphate and lime [9]. Studies by Ahmad et al., [10] showed that calcium nitrate was highly soluble and more effective in increasing Ca concentration in soil solution. Even so liming and fertilization does not guarantee an increase in calcium content in storage organs by the required amounts due to inefficient distribution of Ca in the storage organs. Moreover Ozgen et al., [3] showed that the application of gypsum was not effective in increasing the calcium concentration in tuber tissue. The potato production in Sahel region of Tunisia usually is organized on private farms on small fields with different soils and production techniques. One of regions, with greatest potato production is Chott Mariem. Most of producers in this region plant potato more than twice time on same field or have very narrow crop rotation. Most of soils in region show alkaline reaction and usually farmers apply different materials like organic matter to reduce soil alkalinity, but without any lab control or recommendation. However, soil mineral reserves and soil fertilization are not always sufficient to satisfy the needs of crops. Thus, the efficient management of Ca by farmers with limited resource is a very important part of successful soil and crop management system. The aim of research was to investigate the effect of calcium addition in increasing plant growth.

2. MATERIAL AND METHODS

2.1. Site description

The experiments were conducted from September to December in the research station of the Agronomic Height Institute of Chott-Mariem (35° 54’ N 10° 36’ E), Sousse, Tunisia. The topography is irregular dominated by a string of folds generally oriented NE-SW (N045). The climate is semi-arid with an annual precipitation varied between 150 and 550 mm. Annual temperatures varied between 10 to 19 °C in winter and 22 to 39°C in summer. The soils in Sousse are generally deep, well drained with low to moderate status.

2.2. Experimental materials and design

The experiment was laid out as a randomized complete block design with seven doses of calcium nitrate (0, 20,40,60,80,100 and 120) associated with the N (90 kg ha^{-1}); P (70 kg P_2O_5 ha^{-1}) and K (120kg K_2O ha−1) formed respectively the following treatments (T_1, T_2, T_3, T_4, T_5, T_6 and T_7). Each treatment was replicated three times in each block. The fertilizer was placed about 5 cm away from the plants to avoid scorching. The fields were irrigated when necessary.

2.3. Soils analysis

Soil samples were collected annually from the 0 to 20 cm depth layer before the fertilizer application, air- dried, crushed with a wooden roller to pass through a 2mm sieve and stored at ambient temperature after homogenization. Soil pH was determined potentiometrically in 1:2 soil/distilled water suspensions after shaking. Soil organic matter was measured using the walkley and black method. The Kjeldahl method was used to determine the soil total nitrogen (N_{tot}). A total P (P_{tot}) was determined using Olsen’s method. Exchangeable K was determined using a flame photometer. Exchangeable Ca and Mg were determined using anatomic absorption spectrophotometer.

2.4. Plant analysis

In the context to determine leaf and tuber nutriment concentration, leaf samples were taken from the fourth leaf from the growing point of 10 randomly chosen plants per plot. For tuber analysis, five tubers were randomly selected at harvest from each treatment per block and taken as the representative sample. The dry matter of tuber, tuber weight and tubers size were determined from 20 randomly selected plants in each treatment during harvesting. All samples of leaf and tubers were oven-dried at 104 °C for 2 h and then washed with water and dried with filter paper. Samples of leaf and tuber were mixed with 1 ml of 30% trichloroacetic acid and 50 ml of distilled water, and then triturated in a blender until a homogeneous mass was achieved. The homogeneous mass was centrifuged at 2000 r/min for 15 min, and then 5 ml of the supernatant was placed to a 100 ml volumetric flask and the volume completed with distilled water. The nitrogen (N) was determined using the Kjeldahl method. The phosphorus (P) was analyzed by the molybdenum blue method and the potassium (K) was determined by flame photometry. Finally the calcium (Ca) and magnesium (Mg) contents were determined by atomic absorption spectrophotometer.

2.5. Statistical analysis

Data were analyzed using mixed model procedures (SPSS.13) and subjected to the combined analysis of variance. For comparing average values, Student test was used when F test was significant at the level of ($P \leq 0.01$).

3. RESULTS AND DISCUSSION

3.1. Soil characteristics

Initial soil physicochemical characteristic were show in the Table1. The soil of the experiment was in sandy loam in texture. The value of pH is 8.2 indicated that is a neutral soil. Soil analyses gave values of 8 meq/100g (CEC), 0.8 % organic matter (OM), and nutrients 90 (N), 66 (P), 160 (K), 50 (Ca) and 10 (Mg) (mg.kg^{-1} soil). Sandy loam soils normally have a moderate cation exchange capacity and potato tubers harvested from them are moderate in calcium and therefore susceptible to deficiency symptoms compared to those high in calcium.

Table 1: Soil characteristics

Soil proprieties	pH	CEC (meq/100g)	OM (%)	N_{tot} mg.kg^{-1}	P_{tot} mg.kg^{-1}	K mg.kg^{-1}	Ca mg.kg^{-1}	Mg (mg.kg^{-1})	Texture
	8.2	8	0.8	90	66	160	50	10	sandy loam

3.2. Plant growth analysis

3.2. 1. Dry matter

An important element of the quality of the potato is the dry matter content. The percent moisture content in the leaves was higher than that of the tubers. For this raison the tuber produced higher dry matter than the leaves. In this work we determined the effect of calcium nitrate addition on potato dry matter produced only in tuber and the results were showed in Fig1. The percent dry matter in the tubers ranged from 9.7 % to 15. 8%. It can be seen that the increase in calcium fertilizer increased plant's dry matter. The highest percent was also produced by plants treated with high level of calcium nitrate (T_7) while the least dry matter was still produced by the control treatment (T_1). Moreover the dry matter production in tubers despite the use of different calcium nitrate fertilizer treatments, was increased significantly ($P \leq 0.01$) above the control (T_1) and the differences here also were significantly ($P \leq 0.01$) in one treatment than in the other. In fact this increase is generally attributed to the calcium effect on the physiological cycle of the potato, which delays the maturity of tubers and development of starch into sugars [11]. Calcium abundance enhances enlarging and growth of cells and also photosynthesis and transport of photo assimilate in potato [5]. Aranda et al., [12] indicate that adequate doses of calcium is necessary for maximum weight and biological quality associated decline indicate that we seek high returns by calcium fertilization is done at the expense of quality for the consumer and a compromise must be found between maximum performance and highly quality.

3.2. 2. Tuber weight

Another important element of the quality of the potato is the tuber weight. Tubers were harvested 90 days after planting. At harvest, tubers from each pot were rinsed free of soil, weighed individually and graded. The effect of calcium nitrate addition on potato tuber weight is shown in Fig1. The results show that Ca was effective in enhancing average tuber weight. The percent dry matter in the tubers ranged from 120 to 184 g. The highest level was also found at plants treated with high level of Ca while the least tuber weight was still found at the control plots (T_1). Furthermore the tuber weight production in tubers despite the use of different nitrate calcium fertilizer treatments, was increased significantly ($P \leq 0.01$) above the control (T_1) and the differences here also were significantly ($P \leq 0.01$) in one treatment than in the other. However El-Beltagy al., [2] found that tuber yield to increase with increasing Ca to medium levels. Iqbal, et al., [13] indicate that the Ca concentration influences the tuberization signal via changing the biochemical processes such as altering the hormonal balance at the stolon tip. In contrast, Hirschi, [14] report tuber weight not to be affected by applied Ca.

3.2. 3. Correlation study

Linear correlation study showed that tuber weight was high positively correlated with dry matter (R^2=0,978) while enjoyed low positive correlation with skin damage tuber weight (R^2= 0,862) as indicated by the slopes and intercepts of the respective equations.

Dry matter; $y = 1.07x + 7.857$; R^2=0,978 (Eq 1)

Tuber weight; $y=9.642x + 121.7$; R^2=0,862 (Eq2)

The slope of the equation 1 indicated that rate of increase in tuber weight increase in dry matter was. The results revealed that the tuber weight of potatoes is largely dependent on tuber dry matter content and finally increase in calcium nitrate level enhanced tuber dry matter and produced higher tuber yield. The data also suggest that with the increase in calcium nitrate level tuber weight increase but skin damage tuber production was increased in fewer amounts.

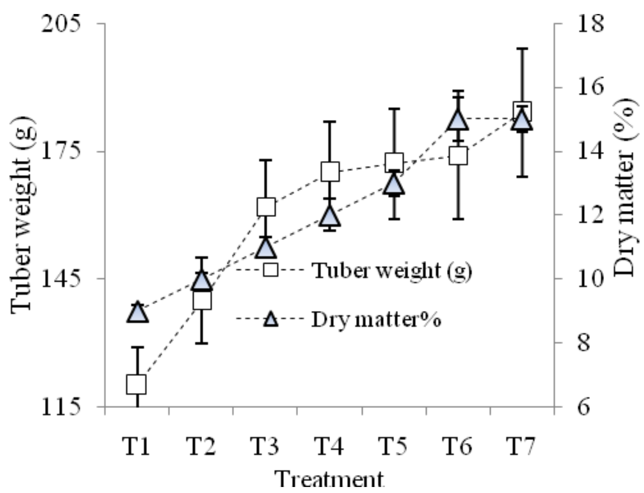

Fig1. Effect of addition calcium nitrate on variation of dry matter and Tuber weight

Tuber size

The different tuber size was determined when the harvest was achieved. The different results were shown in the Fig 2. It can be seen that calcium nitrate is effective in increasing average tuber size. The tuber size ranged from 61 to 72 mm. In fact the tuber size was affected by the tuberization in potato plant. This tuberization was affected by same nutrition and environmental factors such a Ca. Irfan, [15] suggested that Ca had a role in time of tuber forming and also tuber production start. Lardet et *al*., [16] indicated that deficiency of Ca can decline tuberization and revealed that a short days and cool night temperatures promote tuberization whereas long days, high night temperatures, and high nitrogen fertilization delay or inhibit this process.

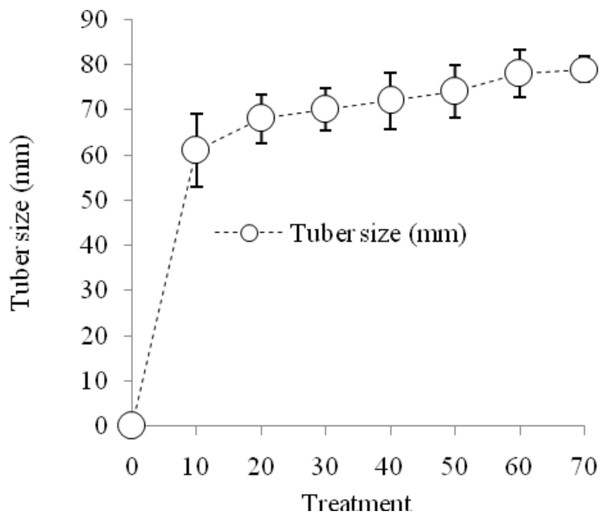

Fig 2. Effect of addition calcium nitrate on variation of tuber size

3.2. 4. Leaf and tuber chemical analysis

3.2. 4. 1. Leaf calcium analysis

The result of leaf chemical analysis of calcium was indicated in Fig 3. The percent of leaf calcium analysis ranged from 24 to 32%. It can be revealed that in the leaf there were significant differences ($P \leq 0.01$) in Ca content among different treatments. However the highest Ca contents for the treatment (T_7) and the lowest for the control treatment (T_1). Increasing leaf calcium can be achieved by improving calcium uptake by placing calcium in root area. Calcium fertilizer should be placed on the hill where tubers develop [17]. Application of calcium to the main root system does not increase tuber calcium since water and nutrients will be transported to the leaves [3]. Leaves have more transpiration rates than the tuber and hence compete effectively for calcium applied to the main root system [18].

3.2. 4. 2. Tuber calcium analysis

The tuber chemical analysis was done to determine the impact of calcium on other nutrient levels when increasing levels of nitrate calcium were applied. The effect of calcium nitrate addition on tuber Ca level is shown in Fig 3. The percent of calcium analysis in the tubers ranged from 4 % to 15%. On other hand it can be revealed that in the tuber there were significant differences ($P \leq 0.01$) in Ca content among different treatments. In the present study the calcium content of the tubers was lower than that of the leaves and sufficient calcium content of the tubers was obtained, which agrees with the findings of Spillman [5]. But a lower calcium content of tubers, ranging from 0.009 to 0.06g Ca/100g dry matter was also reported by Niedz et al,. [19]. The tubers display a low calcium content because they are underground storage organs and have a low transpiration rate, thus the water uptake by the xylem is limited [3]. By cons the high calcium content of the tuber can be attributed to the direct availability of calcium in the soil, which suggests that tubers can absorb calcium directly from the soil solution [20].

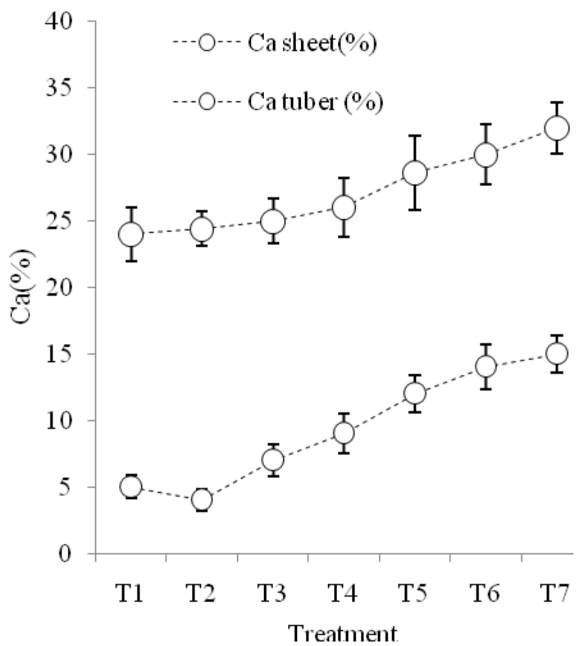

Fig 3. Effect of addition calcium nitrate of calcium content in leaf and tuber

3.2. 5. Concentration of N, P and K in the plants

The contents of nitrogen (N), phosphorus (P) and potassium (K) in the leaf were shown in the Fig 4. The percent of nitrogen (N) ranged from 3.1 % to 3.7%. The percent of phosphorus (P) ranged from 3% to 5.3% and the percent of potassium (K) ranged from 0.25 % to 0.34%. It can be suggested that applying additional calcium nitrate has not a negative influence on the uptake of the elements of N, P and K. These agree with Waterer et al., [21] findings. In contrast Poljak et al., [22] show that Ca fertilizers increase K, and P concentrations in the plant. Moreover the results indicated that N and K were highly in the leaf that P. The leaf N and K contents of the different treatments were the highest but there were no significant differences. Leaf N content of the control treatment was lower than the other fertilization treatments because of the N application rate given by calcium nitrate. Uptake of nitrogen (N), phosphorus (P) and potassium (K) also depends on the general health of the plant and of their availability in the soil, the stage of growth and the source of calcium.

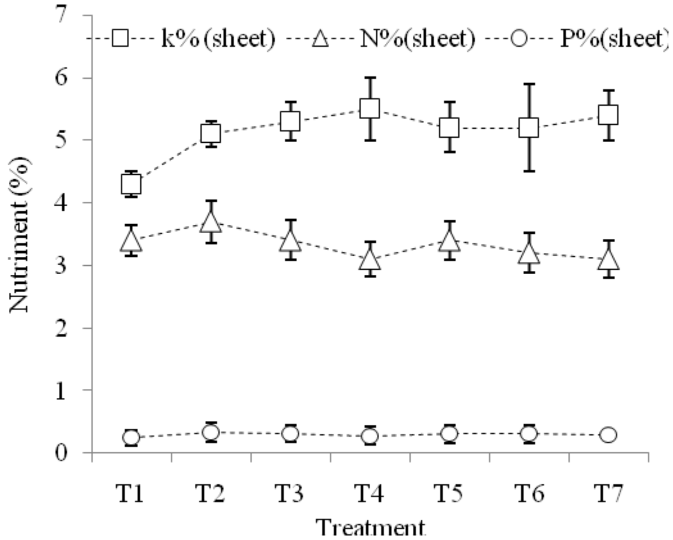

Fig 4. Effect of addition calcium nitrate on nutriment content in leaf

4. CONCLUSION

Application of increasing calcium nitrate levels as a calcium source had positive impact on the potato morphological parameters. Applying additional calcium nitrate had a beneficial effect on the amount of calcium accumulated by the tubers and the tuber quality. However the calcium content of the leaves was higher than that of the tubers. Low calcium content of the tubers might be due to the immobility of calcium in the phloem and limited calcium transport to the potato tuber because of the tuber's displacement from the main transpiration stream. All the nutrient levels were within the acceptable ranges for the potato crop, as indicated by leaf and tuber chemical analysis results. Finally the applying additional calcium nitrate has not a negative influence on the uptake of the elements of N, P and K.

REFERENCES

[1] M.D Kleinhenz, J.P Palta. Root zone calcium modulates the response of potato plants to heat stress. Physiologia plantarum, 2002, 115: 111-118.

[2] M.S EL-Beltagy, A.F Abou-Hadid, S.M Singer, A Abdel-Naby. Response of fall season potato crop to different calcium levels. Acta Hort, 2002, 579: 289-293.

[3] S Ozgen, J.P Palta, M.D Kleinhenz,. Influence of supplemental calcium fertilization on potato tuber size and number. Acta Hort, 2003, 619: 329-334.

[4] J.M Ruitz, J,Hernandez, N Castilla, Romero. Effect of soil temperature on k and Ca concentrations and on ATPase and Pyruvate Kinase activity in potato roots. Hort. Sci., 2002, 37(2): 325-328.

[5] A Spillman. Calcium-rich potatoes: It's in their genes. Syngenta , Potato Genebank, ARS National Program: 301, 2003.

[6] M.Arvin , A. Habib and J. Donnelly. Effect of calcium concentrations in medium on microtuberization of potato (Solanum tuberosum L.). Iranian J. Biotech., 3: 3, 2005.

[7] G. Abbas, , K. Frooq, I.A. Hafiz, A. Hussain, N.A. Abbasi and G. Shabbir. Assessment of processing and nutritional quality of potato genotypes in Pakistan. Pak. J. Agri. Sci., 48: 169-175, 2011.

[8] MJ Malakooti. Nitrate control in potato, onion, and vegetable production; a necessity for saving community health. J Sci Res on Soil and Water. 12:1-5, 2000.

[9] P.D. Jenkins, S Mahmood. Dry matter production and partitioning in potato plants

subjected to combined deficiencies of nitrogen, phosphorus and potassium. Ingentaconnect, 143 (2): 105-112, 2003.

[10] M.S.A. Ahmad, F. Javed, S. Javed and A.K. Alvi. Relationship between callus growth and mineral nutrients uptake in salt-stressed Indica rice callus. J. Plant Nutr., 32: 382-394, 2009,.

[11] Afrasiab, H. and J. Iqbal. Biochemical and molecular characterization of somaclonal variants and induced mutants of potato (Solanum tuberosum L.) Cv. Desiree. Pak. J. Bot., 44(5): 1503-1508, 2012.

[12] A.N.Aranda-Peres, A.P. Martinelli, L.E.P. Peres and E.N. Higashi. Adjustment of mineral elements in the culture medium for the micropropagation of three vriesea bromeliads from the brazilian atlantic forest: the importance of Calcium. Hortsci., 44(1): 106-112, 2009.

[13] M., Iqbal, M. Niamatullah, I. Yousaf, M. Munir and M. Z. Khan. Effect of nitrogen and potassium on growth, economical yield and yield components of tomato. Sarhad J. Agri., 27(4): 545-548, 2011.

[14] K.D, Hirschi. The calcium conundrum. Both versatile nutrient and specific signal. Plant Physiol., 136: 2438-2442, 2004.

[15] U.H Irfan. Management of potato (Solanum tuberosum L.) fungal, viral and bacterial diseases in northern areas by FSC and RD, MINFAL, MINKANAA and Agri. Dptt. Northern Areas, Gilgit. pp. 30-53, 2005.

[16] L., F. Lardet, Martin, F. Dessailly, M.P. Carron and P. Montoro. Effect of exogenous calcium on post-thaw growth recovery and subsequent plant regeneration of cryopreserved embryogenic calli of Hevea brasiliensis. Plant Cell Reports, 26(5): 559-569, 2007.

[17] L.R., Lopez-Lefebre, R.M. Rivero, P.C. Garcia, E. Sanchez, J.M. Ruiz and L. Romero. Effect of calcium on mineral nutrient uptake and growth of tobacco. J. Sci. Food Agr., 81: 1334-1338, 2001.

[18] A.S.N Reddy. Calcium: Silver bullet in signaling. Plant Sci., 161: 381-404, 2001.

[19] R.P. Niedz, and T.J. Evens. Regulation of plant tissue growth by mineral nutrition. In vitro Cell. Dev. Biol. Plant., 43: 370-381, 2007.

[20] J.I., Schroeder, G. Allen, V. Hugouvieux, J.M. Kwak and D. Waner. Guard cell signal transduction. Annu. Rev. Plant Physiol. Plant Mol. Biol., 52: 627-658, 2001.

[21] D.Waterer. Calcium nutrition of potatoes, problems and potential solutions. Manitoba Agri., pp. 1-3, 2005.

[22] M., Poljak, M., Herak-Ćustić, T., Horvat, L., Ĉoga, A Majić. Effects of nitrogennutrition on po tato tuber composition and yield. Cereal Research Communications, 35: 937-940, 2007.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 03 | June-2015 www.irjet.net p-ISSN: 2395-0072

