Ali Hulail Noaema
Barbara Sawicka
University of Life Sciences in Lublin
Department of Technology and Commodity Plant Production
ul. Akademicka street 15, 20-950 Lublin, Poland
e-mail: ali.algayashe@gmail.com

The effect of fertilizing potato with micronutrients foliar fertilizers

Efekt nawożenia ziemniaka dolistnymi nawozami mikroelementowymi

ABSTRACT

Potato tubers are an important source of minerals. They contain 0.5 to 2.0% of the mineral components, such as nitrogen, potassium, phosphorus, magnesium, calcium, sodium, chlorine, copper, zinc, iron, iodine and others. The problem of low soil fertility and plant malnutrition affects not only potato yields, but also the quality of potatoes. This study as a review of many refereed authors was conducted with the aim of highlighting the effects of plant nutrition on the yield and quality of potato tubers. Emphasis was placed on job clarification through which the elements of different nutrients affect biochemical processes and eventually affect the total quality of potato tubers and their products. Nutrients reviewed in this paper included microelements such as zinc (Zn), sodium (Na), iron (Fe), manganese (Mn), copper (Cu), molybdenum (Mo), chlorine (Cl), and nickel (Ni). Moreover, there are some trace elements such as, aluminium (Al), silicon (Si), vanadium (V), cobalt (Co) and others. The potato quality characteristics mostly reported to be affected by plant nutrition include proteins, carbohydrate, sucrose content in tubers of potato; vitamins like vitamin C content in tubers; potato tuber density; and frying colours. Also application of foliar-fertilization with fertilizers containing micronutrients affects the nitrogen economy of plants. For example, effects of elements such as magnesium, iron, and zinc are enhanced by the effect of photosynthesis, while zinc, manganese, copper, boron, and iron manganese, increase the plant resistance to diseases. It has been noted that essential and beneficial nutrient elements contribute to potato quality through functioning as raw materials for the synthesis of various plant components that have food value to humans and animals. The elements like Zn and Fe are involved in enzyme synthesis, activation or as electron carriers and hence affect quality of tubers greatly. It has been noted that potato quality is also greatly influenced by the synergistic and antagonistic interactions in various nutrients uptake and utilization. Therefore, balanced nutrition is noted to be of paramount importance. From this review, it can be concluded that potato quality is a very important area to consider advancing and putting up resources for research since it has a huge bearing on human health and socioeconomic effect on farmers through its influence on the marketability of potato tubers and products.

Key words: potato quality, micronutrients, nutrition value, potato tubers, foliar fertilization.

STRESZCZENIE

Bulwy ziemniaka są ważnym źródłem minerałów. Zawierają 0,5 do 2,0% składników mineralnych, takich jak azot, potas, fosfor, magnez, wapń, sód, chlor, miedź, cynk, żelazo, jod i inne. Problem niskiej żyzności gleby

i niedożywienie roślin mają wpływ nie tylko na plony ziemniaków, ale również na ich jakość. Niniejsze badanie jako przegląd wielu recenzowanych autorów zostało przeprowadzone w celu podkreślenia wpływu odżywiania roślin na plon i jakość bulw ziemniaka. Położono nacisk na wyjaśnianie działań dzięki którym elementy różnych składników odżywczych wpływają na procesy biochemiczne i ostatecznie wpływają na całkowitą jakość bulw ziemniaka i ich produktów. Przegląd składników odżywczych w tym artykule obejmuje mikroelementy, takie jak: cynk (Zn), sód (Na), żelazo (Fe), mangan (Mn), miedź (Cu), molibden (Mo), chlor (Cl) i nikiel (Ni). Ponadto istnieją pierwiastki śladowe, takie jak aluminium (Al), krzem (Si), wanad (V), kobalt (Co) i inne. Cechy jakości ziemniaków, o których najczęściej donoszono, że mają wpływ na odżywianie roślin obejmują białko, węglowodany, sacharozę w bulwach ziemniaka; witaminy, takie jak: zawartość witaminy C w bulwach; gęstość bulw ziemniaka i smażone frytki. Również zastosowanie nawożenia dolistnego nawozami zawierającymi mikroelementy wpływa na gospodarkę azotową roślin. Na przykład efekty działania takich pierwiastków, jak: magnez, żelazo i cynk są wzmacniane przez efekt fotosyntezy, podczas gdy cynk, mangan, miedź, bor, żelazo i mangan zwiększają odporność roślin na choroby. Zauważono, że niezbędne i korzystne składniki odżywcze przyczyniają się do wzrostu jakości ziemniaka poprzez funkcjonowanie, jako surowiec do syntezy różnych składników roślinnych, które mają wartość pokarmową dla ludzi i zwierząt. Pierwiastki, takie jak: Zn i Fe biorą udział w syntezie enzymów, aktywacji lub jako nośniki elektronów, a tym samym w znacznym stopniu wpływają na jakość bulw. Zauważono, że na jakość ziemniaka duży wpływ mają również synergistyczne i antagonistyczne interakcje w pobieraniu i wykorzystaniu różnych składników odżywczych. Z tego względu zbilansowane odżywianie ma ogromne znaczenie. Z przeglądu można wywnioskować, że jakość ziemniaków jest bardzo ważnym obszarem, który należy rozważyć w zakresie zwiększania środków na badania, ponieważ ma to ogromny wpływ na zdrowie ludzi i społeczno-ekonomiczny stan rolników poprzez ich wpływ na zbywalność bulw ziemniaka i jego produktów.

Słowa kluczowe: jakość ziemniaka, mikroelementy, wartość odżywcza, bulwy ziemniaka, nawożenie dolistne.

Introduction

In general, potato plant requires 17 nutrients to complete their life cycle. Basic plant nutrients are divided into macro and micronutrient groups. The macronutrients are nitrogen (N), phosphorus (P), potassium (K), carbon (C), hydrogen (H), oxygen (O), calcium (Ca), magnesium (Mg) and sulphur (S). Moreover, the micronutrients include manganese (Mg), boron (B), molybdenum (Mo), zinc (Zn), copper (Cu), iron (Fe), chlorine (Cl), and nickel (Ni) (BRADY AND WEIL, 2002). Moreover, there are some trace elements such as sodium (Na), aluminium (Al), silicon (Si), vanadium (V) and cobalt (Co)) (WADAS AND DZIUGIEL, 2013). However, depending on essentiality point of view in the plant, all nutrients are equally important for plant growth. The air and water supply the first three macronutrients (C, H, O) to plants. Thus, their supply to plants is not a problem. Thus, the remaining 14 nutrients must be present to plant growth in sufficient quantity and proportion for growth (QADRI ET AL., 2015). Deficiency of nutrients during vegetation, caused by various causes, such as intensive plant development, drought, agricultural errors, etc., lack of element, may occur in the case of inadequate quantity in the environment or in the inability to absorb the component of unfavourable environmental conditions when roots cannot provide the necessary food (SZEWCZUK AND MICH-

ALOJC, 2003; TRAWCZYNSKI, 2015). In addition to deficiency of nutrients during the vegetation period, symptoms of nutrient deficiency in potato plants first appear on the upper or lower parts of the plant. The older leaves are not severely affected due to the fact that the immobile ingredients (calcium, boron, copper, iron, manganese, molybdenum) are not moving from the older to younger parts of the plant (FERNANDEZ ET AL., 2013).

The objective of this review is to critically discuss the effects of some micronutrients (Zn, Fe, Mo, Mn, Cu and Na) on in some of quantity and quality characteristics of potato tubers.

Foliar fertilization

Foliar fertilization is the spraying of liquid fertilizer (a mineral salt solution or a chelate with a surface tension reducing agent) on plant leaves and stems and the absorption of nutrients at these sites. It is a supplying complementary dose of minor or major nutrients to plants (FERNANDEZ ET AL., 2013; TRAWCZYNSKI, 2015). Using it in the situation of difficult nutrient uptake of soil represents an alternative way to supply plants with missing macronutrients and micronutrients (SAWICKA AND SKIBA, 2009). It is the most efficient way to deliver a plant the trace elements and micronutrients. The use of timing of foliar fertilization coincides with specific growth periods, using specific fertilizer fittings depending on crops and location (FAGERIA ET AL., 2009). It has been shown that foliar fertilization is an excellent way to supply plant requirements for secondary nutrients (magnesium, calcium, and sulphur) and micronutrients (manganese, zinc, copper, iron, molybdenum, and boron) while completing the NPK needs for critical periods of growth. Foliar fertilization affects the yield, both quantitatively and qualitatively (TRAWCZYNSKI, 2015; PARMAR ET AL., 2016).

Research on foliar fertilization was started in the last 1940s and early 1950s (GIRMA ET AL., 2007). At the beginning of the 1980s, studies on the foliar fertilization of fertilizers investigated for selected crops, especially to micronutrients in high-value crops such as potato (*Solanum* L.), began (LEWIS AND KETTLEWELL, 1993).

Importance of foliar fertilization with micronutrients of potato

Foliar fertilization is essential when soil absorption is limited. The shortage or presence of a nutrient in a frighteningly soluble form becomes a cause of stress and affects disturbances in plant metabolism, which prevent the full use of the potential yield (FERNANDEZ ET AL., 2013). This is often the case with metallic micronutrients (Fe, Cu, and Mn); these components are purely ineffectually inoculated by soil particles and become difficult to access by plants. Application of foliar-fertilization with fertilizers containing micronutrients affects the nitrogen economy of plants. For example, effects of elements such as magnesium, manganese, iron, and zinc (WADAS AND DZIUGIEL, 2013) are enhanced by the effect of photosynthesis, while zinc, manganese, copper, boron, and iron manganese, increase the plant resistance to diseases. Among plant crops, respond best to foliar fertilization. According to SZYUKZUK AND MJOLJEK (2003), the precise elements used as a foliar treatment are 10, some of which are 30 times more effective than plants compared to soil fertilization. Foliar fertilization can also affect the degree of weed infestation in potato farms. In addition, foliar fertilizers can be used in conjunction with crop protection agents to the Colorado beetle and late blight, which reduces the cost of fertiliza-

tion and the overall costs of potato production. The foliar fertilization of plants has also beneficial effects on plant resistance to pathogens (TRAWCZYNSKI, 2014). BOLIGLOWA (2003) recorded an increase in the proportion of tubers with the symptoms of normal scab under the influence of the application of the aqueous solution of urea, but limiting them to 2-fold by Ekosol K fertilizer did not result in *Rhizoctonia solani*. JABLONSKI (2009A), after application Yaravita, observed reduction in 40% of common scab infestation in the number of tubers with symptoms of spotted brown. Research by MILLS ET AL. (2006) and MAHMOUD ET AL. (2007), has shown that foliar inorganic salts are used to reduce tuber infestation by *Ralstonia solanacearum* and *Erwinia spp.* during storage. CWALINA-AMBROZIAK ET AL. (2010) also showed that foliar fertilizers contribute to a weaker tuber infection by *Rhizoctonia solani* and *Streptomyces scabies*.TRAWCZYNSKI (2014), after applying the foliar fertilizers (type Ekosol) showed a reduction in the share of tubers infected with common scab. Also, the same author (2015) found that foliar fertilizers affect the reduction of the share in the total yield of tubers with defects appearance (greening, deformations). Research by JABLONSKI (2009c) have shown that the use of foliar fertilizers reduces paralysis virus diseases, reduces infection with the common scab, rust spots. SAWICKA (2003) claims that the use of bio-stimulator Asahi SL and foliar fertilization allows delaying the appearance of Phytophthora infection on the potato plantation and extending plant vegetation, depending on the variety, by 2-14 days. Studies by MILLER ET AL. (2005) have shown that the combined use of foliar fertilizers and fungicides increase the efficiency of potato protection against pathogenic agents, thereby contributing to an increase in tuber yield, due to the reduction of labour costs and thus the reduction of production costs.

Important synergistic interactions for micronutrients

There are important synergistic interactions where effects of two or more nutrients are involved to bring out an effect on yield and quality potato tubers. Micronutrients such as Zn, Fe, Mo, Cu, Mn and Na are known to be essential for plant growth. For example, zinc (Zn) and iron (Fe) are the most important micronutrients necessary for plant growth (EPSTEIN AND BLOOM, 2005). Iron is involved in chemical reactions that are a source of energy; it is also a component of many proteins and enzymes, it is part of haemoglobin and myoglobin, which allows the transport of oxygen in the body (KURAS ET AL., 2015), hence its content in the foods is very important. Zinc is one of the main metal components and is an active promoter of several enzymes involved in metabolic activities and biochemical pathways (BRADY AND WEIL, 2002). The average zinc content, which regulates normal growth and development in the body, influences on the activity of the immune system, and is present in the active centres of approximately 200 enzymes (KURAS ET AL., 2015). Also, manganese is an element necessary for the proper functioning of the body, activating enzymes involved in the metabolism of proteins, lipids and sugars (ZAWADZKI ET AL., 2008). Copper, which is responsible in the body for the production of energy in cells, removal of free radicals, formation of collagen and elastic, involved in the transmission of nerve impulses (KRZEPTOWSKI ET AL., 2014). Molybdenum is a component of nitrate reductase enzyme; it is known to play an important role in the metabolism of nitrate in the plant (CHAIRIDCHAI, 2000). In case of, sodium in dry matter of potato tubers, which regulates the body's water balance, is responsible for the hydration status

of cells and tissues, and together with potassium, is responsible for maintaining the proper osmotic pressure in the blood.

Effect of foliar fertilization with micronutrients on the yield of potato tubers

The foliar fertilizers have varied impact on total and commercial yield of tubers, its structure, chemical composition and consumption quality of tubers in many studies. According to many authors (SAWICKA AND SKIBA, 2009; JABLONSKI, 2009A; TRAWCZYNSKI, 2014), the use of foliar fertilizers causes a significant increase in the yield of potato tubers. In many studies of TRAWCZYNSKI (2014, 2015), an increase in yield by 5-20%, after application of foliar fertilizers, depending on the fertilizer used, was reported. After applying the foliar fertilizers of manganese in the conditions of Colombia, VILLA ET AL. (2011) obtained significant results depending on the cultivar increasing the yield of potato tubers. ACCORDING TO JABLONSKI (2007), who found an increase in yield by only 4%, compared to the standard object after applying fertilizers Sonata and Symbol-Vita, while in JABLONSKI'S studies (2009b), the use of Sonata Z and Alkalin PK fertilizers 10:20 contributed to the increase in the total yield by 16.1-19.5%, depending on the cultivar. Moreover, study by AL-FADHLY (2016) examining applying foliar manganese and zinc (together or separately), noted significant increase in the tubers yield. MONA ET AL. (2012) argued, using the elements supplied to the plant in the form of spraying that it affects the efficiency of potato plants because it will be the cause of more intensive vegetative growth, more intensive photosynthesis, and increased carbohydrate production.

Impact of foliar fertilization on nutritional value of potato tubers

Quality of potato tubers is associated primarily with their chemical composition. The most important feature of chemical composition of potato tubers is the content of dry matter. The application of foliar micronutrients fertilization can have significant impact on the content of dry matter in potato tubers. MOUSAVI ET AL. (2007), applying zinc and manganese in the form foliar fertilization and ALJOBORI AND AL-HADITHY (2014) using iron, manganese, copper and zinc, also observed an increased content of dry matter in potato tubers. MONA ET AL. (2012) noted that applying foliar fertilization also caused an increase in the content of both types of sugars. PARMAR ET AL. (2016) have shown that using foliar zinc has increased the content of total sugars in potato tubers. In addition, the application of micronutrient fertilizers and Mikrochelat Gama fertilizer, in studies by KOZERA AND BARCZAK (2007), helped to increase the proportion of albumin, and the foliar application of copper and zinc solutions to increase the participation of albumin and globulins. MOUSAVI ET AL. (2007) and PARMAR ET AL. (2016) after foliar zinc and manganese applications, also observed increased protein in potato tubers. In case of starch content in tubers, MOUSAVI ET AL. (2007), after foliar application of zinc and manganese, also noted an increased content of starch in potato tubers. TRAWCZYNSKI (2015), after the use of Eurofertil 33 fertilizer together with foliar fertilizers Fertiliser Gold and Fertiliser Axis, stated an

increase in starch content. According to these authors, the increase in the starch content may result from the supply of potassium, sulphur and magnesium to the plant, which improves the process of photosynthesis and affects the formation of carbohydrates. Content of vitamin C in potato tubers is important because of its health importance. The use of foliar fertilizers, according to many authors (MONA ET AL. (2012) and TRAWCZYNSKI (2014), has beneficial effect on the content of vitamin C in potato tubers, This coincides with the obtained by MONA ET AL. (2012), who noted the highest content of vitamin C after the application of Folifertile fertilizer with higher content of macro- and micronutrients in its composition, may be the result of providing potato plants with micronutrients necessary for carrying out enzymatic reactions.

Conclusions

1. The response of potatoes to foliar fertilization varies with micronutrients depending on the environmental conditions, cultivars and the type of elements contained in the fertilizers.

2. From this review, it can be concluded that all micronutrients focused in this study (Fe, Zn, Mn, Cu, Mo, Na) affect quantity and quality of potato tubers.

3. Several previous studies have indicated an increase in the yield and quality of potato tubers due to the use of foliar fertilization with micro-nutrients

References

AL-JOBORI K., AL-HADITHY S. 2014. Response of potato (*Solanum tuberosum*) to foliar application of iron, manganese, copper and zinc. International Journal of Agriculture and Crop Sciences. 7 (7), 358–363.

BOLIGLOWA E. 2003. Effect of foliar feeding of potato on yield, its structure, health and storage stability of tubers. Acta Agrophysica. (85): 99–106, ISSN: 1234-4125. (in Polish).

BRADY N.C., WEIL R. R. 2002. Soil phosphorus and potassium. The Nature and Properties of Soils (13th Ed.). Upper Saddle River. NJ: Prentice-Hall. Inc. pp. 598, doi: # 1 | 11.10 x 1.64 x 8.58l, 4.92.

CHAIRIDCHAI P. 2000. The relationships between nitrate and molybdenum contents in pineapple grown on an incept sol soil. Acta Horticulture. 529, 211–216.

CWALINA-AMBROZIAK B., BOGUCKA B. 2010. Potato tuber tubers fertilized with foliar fertilizers of multi-component microelements. Problematic Journals of Agricultural Sciences. 557, 163–172. (in Polish).

EPSTEIN E., BLOOM A. J. 2005. Mineral nutrition of plants: principles and perspectives, 2nd Edn. Sinecure Assoc. Inc., Sunderland, UK: 243-266. ISBN: 978-0-471-01783-7.

FAGERIA N.K., FILHO M.P.B., MOREIRA A., GUIMARAES C. M. 2009. Foliar fertilization of crop plants. Journal of Plant Nutrition. 32 (6), 1044–1064.

FERNANDEZ V., SOTIROPOULOS T., BROWN P. H. 2013. Foliar Fertilization: Scientific Principles and Field Practices. International Fertilizer Industry Association (IFA). Paris. France. pp: 144. ISBN: 979-10-92366-00-6.

GIRMA K., MARTIN K. L., FREEMAN K. W., MOSALI J., TEAL R. K., RAUN W. R., MOGES S. M., ARNALL D. B. 2007. Deter-

mination of optimum rate and growth stage for foliar-applied phosphorus in corn. Communications in Soil Science and Plant Analysis. 38 (9–10), 1137–1154.

JABLONSKI K. 2007. Effect of foliar fertilization on Alkalin PK 10: 20 potatoes on yield, potato contagion and some quality characteristics of tubers. Progress in Plant Protection. 2 (47), 114–118.

JABLONSKI K. 2009a. Effects of foliar fertilization YaraVita Potato and Red Nutrifol. Polish Potato. 3(19), 24–27. (in Polish).

JABLONSKI K. 2009b. Production and quality effects of foliar fertilization of Sonatina Z and Alkalin Potatoes PK 10: 20. Ann. Univ. Mariae Curie-Sklodowska. 64, 59–67. (in Polish).

JABLONSKI K. 2009c. The influence of the level of nitrogen fertilization on the yields of new starchy potato varieties and their quality. Problematic Journals of Agricultural Sciences. (538), 85–91. (in Polish).

JAWAD T., AL-FADHLY. 2016. Response of potato (*Solanum tuberosum*) to foliar application of zinc and manganese which fertilized by organic fertilizer. Journal of Agriculture and Veterinary Science. 9 (4), 87–91.

KOZERA W., BARCZAK B. 2007. Effect of foliar fertilization with potato plant micronutrients on the fractional composition of tubers. Bulletin of the Institute of Plant Breeding and Acclimatization. (243), 167–177. (in Polish).

KRZEPTOWSKI W., PIERZCHALA O., LENARTOWICZ M. 2014. Metabolism of copper and characterization of hereditary disease syndromes against the background of copper deficiency caused by disturbances in ATP7A protein activity. Kosmos. 3 (63), 395–413.

KURAS M., ZIELINSKA-PISKLAK M. P. K. 2015. Iron and zinc the main micronutrients necessary for the proper functioning of the body. The drug in Poland. 25 (288), 6-13.

LEWIS D. J., KETTLEWELL P.S. 1993. A comparison of the uptake of phosphorus from foliar-applied phosphate by the leaves of eleven varieties of potato. Aspects of Applied Biology (United Kingdom). 34, 243–248.

MAHMOUD S. M. 2007. Management of brown rot disease of potato. Arab Universities Journal of Agricultural Sciences. 15 (2), 457–463.

MICHALOJC Z., SZEWCZUK C. 2003. Theoretical aspects of foliar nutrition of plants. Acta Agrophysica. 85, 9–17.

MILLER J. S., ROSEN C. J. 2005. Interactive effects of fungicide programs and nitrogen management on potato yield and quality. American Journal of Potato Research. 82(5), 399–409.

MILLS A. A. S., HURTA R. A. R. 2006. Sensitivity of *Erwinia* spp. to salt compounds in vitro and their effect on the development of soft rot in potato tubers in storage. Postharvest Biology and Technology. 41(2), 208–214.

MONA E. E., IBRAHIM S. A., MANAL M. 2012. Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum* L.). African Journal of Microbiology Research. 6 (24), 5100–5109.

MOUSAVI S. R., GALAVI M., AHMADVAND G. 2007. Effect of zinc and manganese foliar application on yield, quality and enrichment on potato (*Solanum tuberosum* L.). Asian Journal of Plant Sciences. 6, 1256–1260.

PARMAR M., NANDRE B. M., PAWAR Y. 2016. Influence of foliar supplementation of zinc and manganese on yield and quality of potato, *Solanum tuberosum* L. International Journal of Farm Sciences. 6 (1), 69–73.

QADRI R.W. K., KHAN I., JAHANGIR M. M., ASHRAF U., SAMIN G., ANWER A., ADNAN M., BASHIR M. 2015. Phosphorous and foliar applied nitrogen improved productivity and quality of potato. American Journal of Plant Sciences. 6 (1), 144-149.

SAWICKA B. 2003. Effect of foliar application of growth promoters on pike propagation rate of Phytophthora infestans on potato plants. Acta Agrophysica. 85, 157–168. (in Polish).

SAWICKA B., SKIBA D. 2009. Influence of foliar nutrition on plant sanitary conditions in vegetation period of potato. Annales Universitatis Mariae Curie-Sklodowska. Sectio E, Agricultura. 64 (2), 39–51. DOI: 10.2478/v10081-009-001-y. (in Polish).

TRAWCZYNSKI C. 2014. Application of macro- and microelement chelate fertilizers in foliar feeding of potato. Bulletin of the Institute of Plant Breeding and Acclimatization. Bulletin of the Breeding and Acclimatization Institute. 271, 65-77. (in Polish).

TRAWCZYNSKI C. 2015. Comprehensive potato nutrition on the basis of new generation fertilizers. Polish Potato. 25 (3), 14-18. (in Polish).

WADAS W., DZIUGIEL T. 2013. Effect of multi-nutrient complex fertilizers on growth and tuber yield of very early potato (*Solanum tuberosum* L.) cultivars. Acta Agrobotanica. 66 (3), 55–66.

VILLA M. R., RODRIGUEZ L. E., GOMEZ M. I. 2011. Effect of edaphic and foliar management of manganese on the yield of the Criolla Colombia cultivar. Agronomia Colombiana. 29 (3), 447–454.

ZAWADZKI M., GAC P., PORKEBA R., ANDRZEJAK R. 2008. Changes in the cardiovascular system of animals subjected to intoxication with manganese contamination. Occupational Medicine. 59 (5), 387–393.