

Effects of Potassium Fertilisation on Potato Late Blight and Yield – Short Communication

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Abstract

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Potato yields and infestation by *P. infestans* are related to the supply of potassium. Potassium was applied as soil fertilisation combined with split foliar applications or only as split foliar treatments at a maximum dose of 150 kg/ha K₂O in both strategies, Lord and Ditta cultivars were used. Additionally, water spraying was included as an alternative treatment in order to maintain uniform moisture in the rows of plants. Plants fertilised with foliar spraying only were more infested than plants fertilised with combined methods. The fertiliser increased the protection impact of copper treatments against *P. infestans*. This may suggest a possible synergistic effect in reducing the symptoms of the disease, however not always statistically significant in both cultivars. Plants sprayed with water but without soil application of fertiliser showed a statistically significantly higher infestation rate, both in Lord and Ditta cultivars, compared to plants with soil application of fertiliser but without watering.

Keywords: organic farming; *P. infestans*; plant defence stimulation; potato cultivars

The beginning of potato flowering is a critical phase when the supply of potassium is necessary. Plant requirement for potassium is quite high, with a yield of 50 t of potatoes per ha a total of 336 kg K₂O/ha is taken, of this 300 kg K₂O/ha is removed from the field with yield and 36 kg K₂O/ha remains in the field with residues. Such a high intake of nutrients must be balanced by fertilisation. This element plays a key role in a number of different metabolic processes and the activation of enzymes during the growing season of plants (PANIQUE *et al.* 1997). Potassium increases the resistance of plants to stresses and supports the natural defences of plants against pathogens such as *Phytophthora infestans* and *Alternaria* spp. (FENG & ZENG 2006; MACHINANDIARENA *et al.* 2012). The availability of potassium ions (K⁺) to plants, despite their prevalence in the environment, is limited because about 90% of the sources of this element are in forms which cannot be assimilated by the plant (ZÖRB *et al.* 2014; MADRAS & KOUBOVÁ 2015).

Late blight (*Phytophthora infestans* /Mont./ de Bary) is a very severe potato disease, which is able to decimate potato plantations in Poland and worldwide. The severity of potato late blight is determined by a variety of factors, including weather conditions, potato cultivar (SADOWSKI 2006) or the applied plant protection chemicals (SHAILBALA & PUNDHIR 2008). Some reports have shown a limiting effect of foliar fertilisation on the development of late blight (BASU *et al.* 2003) and early blight of potato (OSOWSKI 2005). Appropriate nitrogen fertilisation, which slightly increases potassium and is adapted to the needs of the variety being cultivated, can increase the resistance of plants and is a crucial factor for plant health (OSOWSKI 2014).

In this study the influence of potassium on potato infestation by *P. infestans* and yield was evaluated. The aim of this study was to determine the effectiveness of two strategies of K⁺ fertilisation in order to optimise the supply of potassium to plants and to ensure plant health.

MATERIAL AND METHODS

In a field experiment, the influence of two potassium applications on the severity of late blight and yield was determined during the growing season (2016) in two potato cultivars: early cv. Lord and medium cv. Ditta. Cv. Lord is very sensitive to *P. infestans* and cv. Ditta is medium susceptible to *P. infestans*. The experiment was performed in the certified, organic fields of the field experimental station of the Institute of Plant Protection-NRI in Winna Góra (52.2°N, 17.4°E, Wielkopolska region, western Poland), on a soil that was classified as clay soil. Kalisop[®], a commercial product allowed in organic farming as a source of potassium, containing 50% potassium oxide (K₂O) and 45% sulphur trioxide (SO₃), was applied. The strategies for applying potassium included soil and foliar applications. In our experiment it was delivered as a granular product to the soil, while for spraying treatments a water solution of Kalisop was prepared, distributing 300 l/ha of the solution. Two strategies were compared distributing in total 150 kg/ha per season of K₂O: (1) soil application of potassium fertiliser at a dose of 70 kg/ha K₂O followed by four foliar treatments at a dose of 20 kg/ha each, (2) six foliar applications at a dose of 25 kg/ha K₂O applied at intervals of 7–10 days. Additional protection treatments against *P. infestans* based on copper treatments with 0.75 kg/ha/each, up to 3 kg of copper/ha/year, are permitted for organic farming, spraying with water was carried out at the same time as for other foliar treatments. The first foliar treatment was done at BBCH 20. The effectiveness of the treatments was assessed by evaluating the percentage of infestation of potato plants by the pathogen according to EPPO standards (OEPP/EPPO 2008) and in relation to the yield. In each treatment 15 plants were marked and systematically evalu-

ated. Six rows, 50 m long, were included in one plot, with four replications. The presence of *P. infestans* spores in the field was confirmed in the laboratory. *Leptinotarsa decemlineata* was controlled using the insecticide Biospin 120 SC (a.i. spinosad).

The results were subjected to analysis of variance by means of the Statistica v9.1 program. Data expressed in percentages were log transformed before statistical analyses. A one-way ANOVA was carried out to determine effects of the different strategies of potassium application, Tukey's test ($P = 0.05$) was performed to compare mean values.

RESULTS AND DISCUSSION

The percentage of plants infested by *P. infestans* was considered as an effect of the induction of systemic resistance and/or as a direct effect on the development of the pathogen (Table 1). Soil application followed by foliar applications was more effective than other treatments and statistically significant in contributing to plant health and limiting the infestation by *P. infestans* in comparison with foliar applications alone. On the first date of infestation assessment (July 19, 2016) there was a higher incidence of disease on the plants of cv. Ditta than on cv. Lord, but only in the treatment without Kalisop applied to soil (Table 1). During the next evaluation the infestation rate for cv. Lord ranged between 46.5 and 89.6%, depending on the treatment (Table 1). Plants fertilised only by foliar spraying were more infested (58.7–89.6%). Plants sprayed with water but without soil application of Kalisop showed statistically significantly higher rates of infestation (87.3%) than plants treated with water (58.3%) but fertilised with potassium to soil at a dose of 70 kg/ha K₂O (Table 1).

The highest yield of cv. Lord (19.1 t/ha) was obtained with a combination where the potassium

Table 1. Mean percentage $\pm$ SD of the infestation of potato cultivars by *P. infestans* during two assessments

Cultivar	Date of observation	Kalisop applied to soil 140 kg/ha			Without Kalisop applied to soil		
		4 foliar treatments Kalisop 40 kg/ha	spraying with water	spraying with copper	6 foliar treatments Kalisop 50 kg/ha	spraying with water	spraying with copper
Lord	19.07.2016	7.8 $\pm$ 1.2 ^{bc}	21.0 $\pm$ 2.3 ^a	9.4 $\pm$ 0.8 ^b	10.2 $\pm$ 1.1 ^b	19.8 $\pm$ 2.6 ^a	14.6 $\pm$ 2.0 ^b
	26.07.2016	67.3 $\pm$ 12.0 ^b	58.3 $\pm$ 13.2 ^{bc}	46.5 $\pm$ 34.1 ^c	89.6 $\pm$ 15.9 ^a	87.3 $\pm$ 15.8 ^a	58.6 $\pm$ 8.8 ^b
Ditta	19.07.2016	4.8 $\pm$ 0.6 ^c	10.0 $\pm$ 0.9 ^{bc}	5.2 $\pm$ 0.6 ^c	13.6 $\pm$ 1.4 ^b	49.7 $\pm$ 7.8 ^a	24.6 $\pm$ 2.7 ^{ab}
	26.07.2016	57.2 $\pm$ 12.6 ^b	62.1 $\pm$ 11.1 ^b	53.1 $\pm$ 8.0 ^b	79.1 $\pm$ 5.1 ^a	77.4 $\pm$ 11.7 ^a	58.6 $\pm$ 9.8 ^b

Number of plants considered in each assessment – 15; SD is calculated after log-transformation from percentage data; different letters show statistically significant differences for both dates of observation Tukey's test ($P = 0.05$)

fertiliser was applied to soil followed by four foliar treatments. Without soil potassium application there was a statistically significantly lower yield (16.8 t/ha) (Table 2). Treatments with copper or water applied alone did not impact the yield of plants of cv. Lord. For cv. Ditta the highest yield (22.1 t/ha) was obtained after copper treatments and potassium fertilisation applied in a combined method.

On the second date of assessment the infestation rate for cv. Ditta ranged between 53.1 and 79.1%, depending on the treatment (Table 1). Plants fertilised only with six foliar sprayings were the most infected (79.1%). The effect of copper and fertilisation synergy was not observed on the plants where potassium was applied to the soil before planting. Plants sprayed with water were differently infested in relation to soil or foliar fertilisation (62.1 and 77.4%, respectively).

The highest yield of cv. Ditta (22.5 t/ha) was obtained with a combination where the potassium fertiliser was applied to soil followed by four foliar treatments. Without soil potassium application the yields were statistically significantly lower (12.1–17.3 t/ha) (Table 2). A combination of copper and soil potassium application had an impact on the yield (22.1 t/ha) and it was statistically significantly different compared to copper treatment without soil fertilisation (17.3 t/ha). Water application by spraying and soil potassium application had a very positive impact on the yield of plants of cv. Ditta (20.0 t/ha) compared to water treatment alone (12.1 t/ha).

The pathogen *P. infestans* is usually controlled by copper fungicides in organic farming. The permission to use copper pesticides against bacteria and fungi in European organic agriculture was extended to January 31, 2018. New European regulations have led to a search for alternative control measures in order to reduce the use of copper. The induction of plant defence responses by elicitors is a new promising strategy compatible with organic and sustainable

agriculture (KOWALSKA *et al.* 2015; LEGRÈVE 2016). The fertiliser used in this study increased the protection impact of copper treatments against *P. infestans* in the field with potato plants, cv. Lord. This may suggest a possible synergistic effect in reducing the symptoms of the disease, however not always statistically significant in both cultivars. Elicitors offer many advantages because they are not toxic to pathogens; instead, they are recognised by plant membrane receptors and induce the mobilisation of an entire array of plant defences through innate immunity stimulation (BOLLER & FELIX 2009). Potassium ion is also related with plant reaction towards the production of phytohormones, such as jasmonic acid, auxin, cytokinin, and ABA (ARMENGAUD *et al.* 2004, 2010; NAM *et al.* 2012). Several genes involved in jasmonic acid biosynthesis are induced by K⁺ different availability and as a result, the level of jasmonic acid is increased. In this study potassium was used as a factor which can stimulate the system of plant defence e.g. by delivering this element through roots or leaf tissue. GUNADI (2009) concluded that the application of K₂SO₄ for potatoes should be split between soil and foliar application. NELSON (2008) showed that the potassium silicate fertiliser can help to grow seedlings that are more resistant to fungal diseases and some insect pests. Our results indicated that foliar treatments with potassium do not sufficiently stimulate the plant defence system and therefore are not able to protect the plants. We suggest that the first application to soil before planting could be the initial stimulation for the plants (WANG *et al.* 2013). The percentage of potato late blight symptoms noted on plants treated only with foliar potassium was higher than on plants where potassium was delivered by combined treatments.

Potassium has direct synergistic relationships with two micronutrients, namely iron and manganese. Manganese is a very important component of photosynthesis, nitrogen metabolism, and nitrogen as-

Table 2. Yields $\pm$ SD of potato cultivars obtained in relation to different application methods of potassium fertiliser (Kalisop)

Cultivar	Kalisop applied to soil 140 kg/ha			Without Kalisop applied to soil		
	4 foliar treatments Kalisop 40 kg/ha	spraying with water	spraying with water	6 foliar treatments Kalisop 50 kg/ha	spraying with water	spraying with cooper
Lord	19.1 $\pm$ 1.0 ^a	15.3 $\pm$ 0.6 ^b	15.8 $\pm$ 0.8 ^b	16.8 $\pm$ 0.2 ^b	14.3 $\pm$ 0.9 ^b	15.3 $\pm$ 1.1 ^b
Ditta	22.5 $\pm$ 1.3 ^a	20.0 $\pm$ 1.2 ^{ab}	22.1 $\pm$ 1.0 ^a	16.2 $\pm$ 0.2 ^b	12.1 $\pm$ 0.3 ^c	17.3 $\pm$ 0.9 ^b

Total yield from four replications of each treatment; different letters show statistically significant differences, Tukey's test ($P = 0.05$)

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similation; it activates decarboxylase, dehydrogenase and oxidase enzymes. Iron plays a very important part in chlorophyll formation. Iron is also a constituent of peroxidase and catalase, which are plant defence enzymes. Copper has indirect effects on potassium (UJWALA 2011). This fact may explain the observed synergistic effect of the applied potassium fertiliser which increased the impact of copper treatments on *P. infestans*.

Potassium fertiliser form (liquid or granular), source (chloride or sulphate), and time of application (pre-plant or in-season) were evaluated for effects on potato tuber yield and quality in Washington's Columbia Basin (DAVENPORT & BENTLEY 2001). In one of the three years, total tuber yield was reduced by in-season fertilisation with potassium chloride and by 75% in-season liquid K application, while the results were inconsistent over growing seasons. Thus, the study results uphold the current practice of using granular K fertilisers as pre-planting treatment. Our study supported that conclusion, because in our experiment the yield was statistically significantly higher after granular fertilisation as pre-planting treatment followed by foliar application.

Our results clearly showed that delivery of potassium fertiliser to the root zone was more advantageous than to the leaf tissue. The application of potassium fertiliser is an important factor which can support the health of potato plants and has an impact on the yield in organic fields, but the magnitude of the effect depends on the genotype grown. The most effective strategy was the delivery of potassium to soil before potato planting at a dose of 70 kg/ha K₂O, followed by four foliar treatments of 20 kg/ha K₂O.

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