Short Communication

Vitamin C Content in Potato Tubers as Influenced by Insecticide Application

Marek Gugała, Krystyna Zarzecka*

Department of Plant Cultivation, Faculty of Life Sciences,
University of Natural Sciences and Humanities in Siedlce, Prusa 14, 08-110 Siedlce, Poland

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Abstract

The objective of this study has been to determine vitamin C content in tubers of edible potato following an application of systemic insecticides to control the Colorado potato beetle.

A field experiment was conducted on soil of a good rye complex in 2004-06. The experiment was designed as randomized sub-blocks with three replications. Experimental factors included three cultivars of potato – Wiking, Mors, Żagiel – and six Colorado potato beetle control treatments using the following insecticides: Actara 25 WG (thiametoksam) at the rate of 0.08 kg/ha, Regent 200 SC (fipronil) at the rate of 0.1 dm^3/ha, Calypso 480 SC (thiacloprid) at three rates (0.05, 0.075, 0.1 dm^3/ha), and a control treatment without chemical protection. The content of vitamin C was dependant on cultivar, insecticide treatment, and environmental conditions with each year. The insecticides applied significantly increased vitamin C content (amounted to 1.7 mg/kg) compared with the tubers harvested from the control treatment where no chemical protection was applied. Tubers of Mors cultivar had the highest vitamin C content, and Wiking cultivar lowest.

Keywords: potato, tubers, vitamin C, insecticides

Introduction

Plant-derived foods, including potato, are sources rich in biologically active substances, both nutritional and anti-nutritional [1, 2]. Among bioactive substances, antioxidants play an important role in protecting the organism against lifestyle diseases (diabetes, blood circulation system diseases, cancer) [3, 4]. The compounds with anti-oxidative activity mainly include vitamins C and E, carotenoids, and polyphenols [5, 6]. As a result, antioxidants as preventative factors have recently become a major topic of interest of many research centres. Moreover, potato is described as an edible, healthy, and pro-health plant. Potato tubers are a basic component of the everyday diet of Poles because it is consumed in amounts of 121 kg per capita per year [7].

The tubers of Polish cultivars contain between 124 and 278 mg/kg vitamin C, with daily consumption of 200 g potatoes meeting 50% of vitamin C demand [1]. Potato consumption worldwide and in Europe is 34 and 96 kg per capita, respectively [8]. Potato consumption in the USA is also high and averages 63 kg per capita. Of 34 fruits and vegetables commonly consumed, potato is the third highest source of antioxidants [9].

In an era of intense methods of agricultural production and coincidental negative public perceptions about the impact of plant protection chemicals on the nutritional composition of produce, studies were undertaken to examine the impact of new-generation insecticides on the nutritive value of potato tubers [10, 11].

The purpose of this study was to determine vitamin C content in potato tubers following an application of systemic insecticides to control the Colorado potato beetle.

*e-mail: kzarzecka@uph.edu.pl

Materials and Methods

Materials

A study was carried out on potato tubers obtained from a field experiment conducted in 2004-06 at the Zawady Experimental Farm owned by the University of Natural Sciences and Humanities in Siedlce. The soil belonged to a good rye complex. The experiment was established in a randomized sub-block design including two factors: factor I – three edible potato cultivars (Wiking, Mors and Żagiel), and factor II – six methods of Colorado potato beetle control involving two of the newest generation insecticides:

1) control treatment with no chemical protection
2) Actara 25 WG (thiametoksam) at the rate of 0.08 kg/ha
3) Regent 200 SC (fipronil) 0.1 dm^3/ha
4) Calypso 480 SC (thiacloprid) 0.05 dm^3/ha
5) Calypso 480 SC (thiacloprid) 0.075 dm^3/ha
6) Calypso 480 SC (thiacloprid) 0.1 dm^3/ha

At the beginning of the experiment, there was no recommendation regarding the rate of Calypso 480 SC, thus the amount applied was 0.05-0.1 dm^3/ha. At present the recommended rate is 0.075-0.1 dm^3/ha. Insecticides were applied only once during the occurrence of Colorado potato beetle larvae. The plot area was 15 m^2.

Potato was cultivated after winter wheat. Each year the same organic and mineral fertilization was applied. The amount of farmyard manure was 25.0 t/ha, and the respective rates of N, P, and K were as follows: 100.0, 44.0, and 124.5 kg/ha. Potato tubers were planted manually in the third decade of April at spacing of 67.5×37 cm. Potatoes were harvested in technological maturity phase in the first and second decades of September. Samples of potato tubers (50 tubers) for chemical analyses were taken from plots during harvest and storage in temperature 10-12ºC. Chemical analyses were performed using fresh material in three replications.

Determination of Vitamin C (Sum of Ascorbic Acid and Dehydroascorbic Acid)

Vitamin C content was determined by means of Tilman's method as modified by Pijanowski [12]. Ten g of fresh potatoes were homogenized and placed in a 100 ml graduated flask. Next, 2% oxalic acid ($C_2H_2O_4{\cdot}H_2O$) was added, the suspension mixed and left to settle. Ten ml of the solution was placed in a cone-shaped flask and 3.5 of normal sulphuric acid (H_2SO_4) was added. After mixing, 1.75 ml of 1M solution of sodium sulfide (Na_2S) was added and finally water was added to obtain the volume of 100 ml. The flask contents were carefully mixed and filtered through a folded filter paper No. 388. The solution was titrated with 2,6-dichlorophenolindophenol (DCPIP) until a fixed pink color persisted for 30 sec. Vitamin C content was expressed in mg per 1 kg of fresh matter.

Statistics

Results of the study were statistically analyzed using analysis of variance and the means were compared with Tukey's test at the significance level of p=0.05.

Table 1. Weather conditions during potato vegetation season 2004-06 according to the Zawady Meteorological Station.

Months	Sielianinow's hydrothermic coefficient*		
	2004	2005	2006
April	1.50	0.47	1.18
May	2.69	1.60	0.99
June	1.14	0.92	0.47
July	0.90	1.51	0.24
August	1.14	0.84	4.18
September	0.50	0.35	0.45
April-September	1.24	1.00	1.26
Rainfalls in the vegetation period (mm)	320.9	268.8	358.6
Deviation from many-year average	-22.8	-74.9	+14.9
Mean air temperature (ºC)	14.1	15.0	15.8
Deviation from many-year average	+0.1	+1.0	+1.8

*up till 0.5 – strong mild drought
0.51-0.69 – mild drought
0.70-0.99 – weak mild drought
≥1 – fault mild drought

The characteristics of the hydrothermal conditions in the years 2004-06 are presented with the aid of Sielianinow's coefficient in the following form:

$$K = P/0.1\sum t$$

...where: P – monthly total of atmospheric rainfall in mm
$\sum t$ – monthly sum of air temperature > 0ºC.

The devision of K coefficient into several value classes was accepted for the interpretation of the hydrothermal conditions (Table 1).

Results

Climatic conditions varied over the growing periods of potato cultivation (Table 1). The years 2004 and 2006 were wet and warm, and rainfall was higher compared with the multi-year precipitation; 2005 was also warm, but the rainfall was lower.

Vitamin C content in potato tubers ranged between 213.5 to 227.6 mg/kg fresh matter and significantly depended on insecticide treatments, cultivars and weather conditions over the study years (Tables 2-4). The insecticides increased vitamin C content amount to 1.7 mg/kg as compared to the untreated control. A significantly higher vitamin C concentration was found following the insecticides Regent 200 SC and Calypso 480 SC applied at the respective rates of 0.075 and 0.1 dm^3/ha.

Table 2. Content of Vitamin C in potato tubers (mg/kg fresh matter).

Objects	Cultivars			Mean
	Wiking	Mors	Żagiel	
1. Control object	215.6	222.9	219.1	219.2
2. Actara 80 WG 0.08 kg/ha	217.6	223.9	220.4	220.6
3. Regent 200 SC 0.1 dm^3/ha	216.8	223.8	221.7	220.8
4. Calypso 480 SC 0.05 dm^3/ha	216.8	223.3	219.9	220.0
5. Calypso 480 SC 0.075 dm^3/ha	219.2	223.9	221.3	221.5
6. Calypso 480 SC 0.1 dm^3/ha	218.5	224.3	221.9	221.6
Mean	217.4	223.7	220.7	220.6
$LSD_{0.05}$				
between cultivars				1.0
between insecticides				1.4
in interaction cultivars × insecticides				n.s.

n.s. – not significant

Table 3. Content of Vitamin C in potato tubers depending on research years (mg/kg fresh matter).

Objects	Years			Mean
	2004	2005	2006	
1. Control object	214.2	221.7	221.8	219.2
2. Actara 80 WG 0.08 kg/ha	216.0	223.2	222.7	220.6
3. Regent 200 SC 0.1 dm^3/ha	215.5	224.5	222.3	220.8
4. Calypso 480 SC 0.05 dm^3/ha	215.2	222.1	222.7	220.0
5. Calypso 480 SC 0.075 dm^3/ha	214.9	224.5	225.1	221.5
6. Calypso 480 SC 0.1 dm^3/ha	216.7	223.9	224.2	221.6
Mean	215.4	223.3	223.1	220.6
$LSD_{0.05}$				
between insecticides				1.4
between years				1.0
in interaction insecticides × years				n.s.

n.s. – not significant

Of the cultivars under comparison, Mors had the highest vitamin C content in tubers, on average 223.7 mg/kg, followed by Żagiel and Wiking. An interaction between cultivars and insecticide treatment was detected. The lowest amount of vitamin C was accumulated in tubers in 2004, which was the coldest year. In the remaining growing seasons, vitamin C content was significantly higher. In all the study years there was a tendency for an increase in vitamin C content due the influence of insecticide applications. There was no interaction between insecticide treatment and production year. However, there was observed a varied response of the cultivars to moisture and thermal conditions over the study years. In 2004 low levels of vitamin C were accumulated by the three examined cultivars, whereas in 2005 Mors and Żagiel, and in 2006 Wiking had the highest vitamin C contents. Such a varied response of edible potato cultivars is reflected in a statistically significant interaction between genetic traits of cultivars and study years.

Discussion

Colorado potato beetle is the main pest limiting potato cultivation. It can be effectively controlled by applications of chemical insecticides that in turn can affect tuber chemical composition. Vitamin C is an important component of

Table 4. Content of Vitamin C in potato tubers depending on cultivar (mg/kg fresh matter).

Objects	Cultivars			Mean
	Wiking	Mors	Żagiel	
2004	213.5	216.5	216.3	215.4
2005	214.9	227.6	227.4	223.3
2006	223.9	227.1	218.5	223.1
Mean	217.4	223.7	220.7	220.6
$LSD_{0.05}$				
between years				1.0
between cultivars				1.0
in interaction years × cultivars				1.8

potato tubers from the nutrition and health standpoint [1, 4, 13-15]. In this experiment, insecticides improved vitamin C content, and some treatments (Regent 200 SC and Calypso 480 SC applied at higher doses) increased the content compared with the control. It has been confirmed in studies by other authors [16-19]. In contrast, Antonius et al. [20] did not find a significant impact of insecticides (pyrethrin and azadirachtin) on vitamin C content. However, they noted an influence of weather conditions. Other workers observed increased vitamin C in tubers following an application of fungicides [21] and herbicides [22]. Hamouz et al. [23] have found that ascorbic acid content in potato tubers was influenced by the method of cultivation; higher levels were found in potatoes cultivated in an ecological way without using any chemical protection in comparison with potatoes using conventional methods.

Many authors have found that potato chemical composition was in the first place determined by the cultivar and environmental factors [23-26]. Of the cultivars grown in this experiment, Mors had the highest vitamin C content, followed by Żagiel and Wiking. There are a number of works reporting a significant influence of cultivars on vitamin C content [13, 21, 22, 27]. Also, production-year environment significantly changed vitamin C concentration. The lowest levels of vitamin C were accumulated in tubers in 2004, which was the coldest and moderately wet. High air temperatures favourably stimulated accumulation of vitamin C in potato tubers. The finding corresponds with the results of studies by other workers [13, 22, 28]. Moreover, Mazurczyk [27] and Wadas [26] found that vitamin C represents the characteristics that are of average stability, and is affected mainly by the genotype. Chemical protection of plants helps to obtain a high yield of desirable quality of food, and modern pesticides applied in optimal doses do not seem to present any threat to consumer health or the biological quality of the plant and soil [10]. The insecticides applied to control the Colorado potato beetle did not detract from the nutritional value of potato tubers.

Conclusions

The 3-year study revealed that vitamin C content in potato tubers depended on the insecticides applied to control the Colorado potato beetle, production environment, and cultivar. The insecticides increased vitamin C content compared with the control treatment without insecticides. Vitamin C levels fluctuate widely in potato tubers, depending on the cultivar and environmental factors.

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