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REGULAR ARTICLE

# Iron and manganese content and uptake with the yield of potato tubers as affected by herbicides and biostimulants, and potato tuber nutritional value

**Marek Gugała[1], Krystyna Zarzecka[1]*, Iwona Mystkowska[2] and Anna Sikorska[3]**

*[1]Department of Agrotechnology, Siedlce University of Natural Sciences and Humanities, 08-110 Siedlce, Poland, [2]Department of Environment Sciences, Pope John Paul II State School of Higher Education in Biała Podlaska, 21-500 Biała Podlaska, Poland, [3]Department of Agriculture, The State Higher School of Vocational Education in Ciechanów, 06-400 Ciechanów, Poland*

ABSTRACT

The study material consisted of table potato tubers produced in a three-year field experiment. The following factors were examined: three potato cultivars – Bartek, Gawin and Honorata, five herbicide application methods: herbicides alone (Harrier 295 ZC and Sencor 70 WG) and mixed with growth regulators (Harrier 295 ZC + Kelpak SL, Sencor 70 WG + Asahi SL), and a control unit where weeds were mechanically controlled. The objective of the study was to assess the effect of herbicides and their mixtures with growth regulators on potato tuber nutritive value as well as iron and manganese contents and uptake with the yield of potato tubers. Iron and manganese contents of tubers and uptake with tuber yield were significantly affected by cultivars, herbicides and biostimulants applied as well as weather conditions during the growing season. The herbicides and biostimulants increased iron and manganese contents and uptake with the yield of potato tubers compared with control tubers. The highest amounts of the examined microelements were accumulated by cv. Honorata compared with cv. Bartek and Gawin. Consumption of 100 g potato tubers in 9 and 21% satisfied the daily requirement for iron and manganese, the daily requirements in the human diet being 14.0 and 2.0 mg, respectively.

**Keywords:** Cultivars; Microelements; Plant protection products; *Solanum tuberosum* L.

## INTRODUCTION

*Solanum tuberosum* L. is a crop native to South America, but it is cultivated and consumed in more than 160 countries worldwide (Camire et al., 2009; Andre et al., 2014). The potato has a high biological, nutritional and health-related value, which is insufficiently appreciated. Protein is another important component because of its high biological value which is due to the protein's content of all the exogenous amino acids and dietary fibre (Lisińska et al., 2009; Leonel et al., 2017). Also, potatoes are an important source of many vitamins (C, $B_1$, $B_2$, $B_3$, $B_6$, PP, E) as well as health-promoting compounds (total phenolics, total carotenoids) in the human diet (Andre et al., 2007, Zarzecka et al., 2019). The potato tuber is an abundant store of macroelements and microelements of which potassium, calcium and magnesium are particularly valuable because they are mainly building blocks in the plant and contribute to alkalinisation. Moreover, their presence in the diet counteracts the acidifying influence of meat and cereal products (Ekin, 2011; Wierzbowska et al., 2016). In turn, microelements are components of various enzymes and activators. The most important microelements include iron, manganese, zinc and copper. Iron is a biologically essential component of every living organism. It participates in cell respiration processes, protein synthesis and DNA biosynthesis. Iron is also an important component of hemoglobin, myoglobin and heme enzymes. Iron deficiency results in anaemia as well as metabolism, circulatory system and nervous system disorders (Lieu et al., 2001; Abbaspouret al., 2014). Manganese is an element necessary for the proper functioning of the human body where it is an activator of many enzymes taking part in cholesterol metabolism and energy production process which control the metabolism of glucose and other sugars. In the plant, iron participates in photosynthesis, oxidation-reduction processes, fatty

***Corresponding author:**
Krystyna Zarzecka, Department of Agrotechnology, Siedlce University of Natural Sciences and Humanities, Prusa 14, 08-110 Siedlce, Poland. **E-mail:** kzarzecka@uph.edu.pl

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acid synthesis and vitamin C synthesis (Jędrzejczak, 2004; Kabata-Pendias and Mukherjee, 2007; Kehl-Fieand Skaar, 2010; Umar et al., 2014). Scientists claim that potato nutritional value is so high that, for some time, tubers may be the only component of the human diet without a negative effect on the body's health (Lisińska et al., 2009; Andre et al., 2014). In the available literature, there is a paucity of information on the effect plant protection chemicals and biostimulants have on microelement content in crop plants, including potato tubers (Baćmaga et al., 2007; Wierzbowska et al., 2015; Godlewska and Ciepiela, 2016). Thus, the aim of the study was to determine the effect of herbicides and biostimulants on iron and manganese contents and uptake with the yield of tubers and potato nutritional value.

## MATERIALS AND METHODS

### Experimental and Agronomic Management

Research results were obtained in a three-year (2012-2014) field experiment carried out in Wojnów (52°12'59"N, 22°34'37"E), central-eastern Poland. The experiment was set up on the soil that was classified as Haplic Luvisol according to the WRB FAO (2014), had the texture of sand, and belonged to quality class IVb which represents the rye very good class of agricultural suitability. Soil pH ranged from slightly acidic to neutral (5.60-6.35 pH in KCl), and was characterised by a high to very high available phosphorus content, moderate to very high potassium content and high magnesium content (Table 1). The experiment was set up as a split-plot arrangement with three replicates. The first factor included three mid-early edible potato cultivars – Bartek, Gawin and Honorata, the second factor consisted of five methods of an application of herbicides and biostimulants (Table 2). In autumn, farmyard manure was applied at a rate of 25.0 t ha$^{-1}$ in addition to mineral fertilisers used at the following rates: 44 kg ha$^{-1}$ P (in the form of 46% triple superphosphate, autumn), 125 kg ha$^{-1}$ K (in the form of 60% potassium salt, autumn) and 100 kg N per 1 ha (in the form of 34% ammonium salt, spring). Potatoes were planted by hand at the spacing of 0.675 x 0.370 m in mid-April and harvested in early September at the stage of physiological maturity. During the growing seasons, potato blight was controlled using the following fungicides: metalaksyl-M 3.8% and mankozeb 64% (Ridomil Gold MZ 68 WG) – 2.0 kg ha$^{-1}$ and fluazinam (Altima 500 SC) – 0.4 dm$^3$ ha$^{-1}$, and Colorado potato beetle was controlled using the insecticides: alfa-cypermethrin (Fastac 100 EC) at a rate of 0.08 dm$^3$ ha$^{-1}$ and clothianidin (Apacz 50 WG) at a rate of 0.04 kg ha$^{-1}$.

### Fe and Mn determination

Before harvest, tuber samples from 10 plants per plot were collected in all the experimental units and used for chemical analyses. The potato tuber contents of iron and manganese were determined by atomic absorption spectrophotometry (AAS) after tubers had been cut, dried and mineralised in a laboratory oven (Ostrowska et al., 1991). Determinations of the analysed elements in the dry matter of tubers were performed in three replicates with SpectroBlue ICP-OES, company producer Spectro Analytical Instruments, Germany manufacturer. Weight of about 0.3 g of sample was transferred to the PTFE vessel and $HNO_3$ and HCl was added, 3:1 respectively. Mineralized samples were transferred to the 50 ml flasks through filtering paper and diluted with ultra-pure water. Analytical curves were built by diluting Bernd Kraft Der Standard Spectro Genesis ICAL Solutions and VHG SM68-1-500 Element Multi Standard 1 in 5% $HNO_3$. Operating parameters for ICP OES instrument: coolant flow: 12 l/min; auxiliary flow: 0.90 l/min; nebulizer flow: 0.78 l/min; pump speed: 30 Rpm.

### Statistical analysis

The results of the study were subjected to statistical analysis using the analysis of variance, and the significance of differences was assessed using Tukey test at the significance level of $p = 0.05$. Statistical calculations were performed in Excel using the authors' own algorithm based on the split-plot mathematical model with two factors (Trętowski and Wójcik, 1991).

**Table 1: Selected chemical properties of soil on which the experiment was conducted**

| Study years | Acidity (pH in KCL) | Organic matter (g kg$^{-1}$) | Available nutrients (mg kg$^{-1}$ soil) | | | | |
|---|---|---|---|---|---|---|---|
| | | | P | K | Mg | Fe | Mn |
| 2012 | 5.60 – slightly acidic | 15.0 | 68.6 (high) | 149.4 (very high) | 50.0 (high) | 570.5 (low) | 80.8 (average) |
| 2013 | 5.60 – slightly acidic | 16.0 | 73.4 (high) | 129.0 (high) | 51.0 (high) | 570 (low) | 80.1 (average) |
| 2014 | 6.35 – neutral | 18.7 | 110.0 (very high) | 99.6 (average) | 56.0 (high) | 465.0 (low) | 83.4 (average) |

**Table 2: Factors of the field experiment**

| Factor I – Three potato cultivars: Bartek, Gawin and Honorata |
|---|
| **Factor II – Five methods application of herbicides and biostimulants (treatments)** |
| 1. Control – mechanical weed control – no herbicides or biostimulants<br>2. Harrier 295 ZC (linuron+chlomazon) at a rate of 2.0 $dm^3 \cdot ha^{-1}$-7-10 days after planting tubers<br>3. Harrier 295 ZC (linuron+chlomazon) at a rate of 2.0 $dm^3 \cdot ha^{-1}$-7-10 days after planting tubers and growth regulators Kelpak SL* at a rate of 2.0 $dm^3 \cdot ha^{-1}$ - the end of plant emergence<br>4. Sencor 70 WG (metribuzin) at a rate of 1.0 $kg \cdot ha^{-1}$ - just before the emergence of potato plants<br>5. Sencor 70 WG (metribuzin) at a rate of 1.0 $kg \cdot ha^{-1}$ - just before the emergence of potato plants and growth regulators Asahi SL** at a rate of 1.0 $dm^3 \cdot ha^{-1}$ - the end of plant emergence |

*Kelpak SL (alga extract for *Ecklonia maxima* – auxins and gibberellins)
**Asahi SL (para-nitrofenolan sodium, ortho-nitrofenolan sodium, 5-sodium nitroguajakolan)

$$Y_{ijl} = m + a_i + g_l + e/^{1/}_{il} + b_j + ab_{ij} + e^{/2/}_{ijl},$$

Where:
$Y_{ijl}$ - value of the characteristic researched; i level of A (cultivars),
j - level of B (cultivars) in the 1st block (replication),
m - experimental mean,
$a_i$ - effect of i-level of A (cultivars),
$g_l$ – effect of the 1st replication,
$e^{/1/}_{il}$ - random effect of A (cultivars) with replications,
$b_j$ – effect of j-level of B (herbicides and biostimulants),
$ab_{ij}$ effect of interaction of A (cultivars) and B (herbicides and biostimulants),
$e^{/2/}_{ijl}$ – random effect II

### Weather conditions

Weather conditions during the study years varied (Table 3). The precipitation sum in 2012 amounted to 264.9 mm and was by 10.6 mm lower than the long-term mean whereas the average temperature over the potato growing season was 15.4°C and was by 0.7°C higher than the long-term mean. Precipitation was the highest in 2013 (441.3 mm). The average monthly air temperature in this year ranged from 7.4 to 19.0°C and the mean temperature in the growing season was 15.0°C. In the 2014 growing season, the rainfall sum was 335.1 mm and was by 60.3 mm higher compared with the rainfall sum averaged across 15 years. Average monthly air temperatures in 2014 ranged from 9.8 to 20.8°C.

## RESULTS AND DISCUSSION

### Iron content and uptake

Tuber quality depends on potato chemical composition and is affected by several factors, including cultivar, soil, weather conditions and agrotechnological practices (Arvanitoyannis et al., 2008). Iron content in potato tubers varies considerably and ranges from 21 to 95 mg $kg^{-1}$ dry matter (Kabata-Pendias and Mukherjee, 2007; Sawicka et al., 2016).

In the present study, the potato tuber content of iron was found to range from 58.23 to 69.91 mg $kg^{-1}$ dry matter and was significantly affected by cultivar, herbicides and their mixtures with biostimulants as well as weather conditions during the growing season (Table 4). Iron content was similar to values reported by other authors (Gugała and Zarzecka, 2008; Ekin, 2011; Sawicka et al., 2016). Moreover, cv. Gawin accumulated the highest amounts of iron compared with Bartek and Honorata, the differences being significant. The effect of cultivar and weather conditions during the growing season on the potato tuber content of iron was also mentioned by Ekin (2011), Sawicka et al. (2016) and Wierzbowska et al. (2018).

The herbicide Harrier 295 ZC mixed with the growth regulator Kelpak SL (treatment 3), the herbicide Sencor 70 WG (treatment 4) and Sencor 70 WG mixed with the growth regulator Asahi SL (treatment 5) significantly increased iron content in tubers compared with the control where weeds were mechanically controlled. Also Gugała and Zarzecka (2008) demonstrated that herbicides and their mixtures (Sencor 70 WP + Fusilade Super, Basagran 600 SL, Basagran 600 SL + Focus Ultra) contributed to an increase in the potato tuber content of iron. Similar responses were observed by Sawicka et al. (2016) in cv. Jelly treated with herbicides in the integrated versus organic (non-herbicide) crop production system. However, in other cultivars the opposite response was observed − iron content in potato tubers was on the decline. Wierzbowska et al. (2016) found that tubers of plants treated with Kelpak SL contained more iron than control tubers. The concentration of iron in potato tubers was affected by weather conditions in the growing seasons (Table 4), the highest amounts being recorded in 2013 when precipitation was the highest and air temperatures were optimal and similar to the long-term values. No interaction was found between the experience factors and the years.

The total tuber yield averaged 40.31 t $ha^{-1}$ (Gugała et al., 2018) and potatoes took up 607.0 g $ha^{-1}$ iron with the yield (Table 5). In the study by Westermann (2005), iron uptake amounted to 1.491-2.697 g $ha^{-1}$ and it was the lowest for cv. Sylvana whose yield was also the lowest. Researchers (Wierzbowska et al., 2015) observed that biostimulants contributed to an increase in iron uptake compared with control. In the study reported here, iron uptake was significantly affected by cultivars, an application of herbicides and their mixtures with biostimulants as well as weather conditions in the study years. The highest amount

**Table 3: Climatic conditions during the growing seasons according to the Zawady meteorological station**

| Month | Temperature°C | | | | Precipitation mm | | | |
|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | Long-term mean 1987-2000 | 2012 | 2013 | 2014 | Long-term mean 1987-2000 |
| April | 8.9 | 7.4 | 9.8 | 7.8 | 29.9 | 36.0 | 45.0 | 38.6 |
| May | 14.6 | 15.3 | 13.5 | 12.5 | 53.4 | 105.9 | 92.7 | 44.1 |
| June | 16.3 | 18.0 | 15.4 | 17.2 | 76.2 | 98.8 | 55.4 | 52.4 |
| July | 20.7 | 19.0 | 20.8 | 19.2 | 43.0 | 91.3 | 10.0 | 49.8 |
| August | 18.0 | 18.8 | 18.1 | 18.5 | 51.0 | 15.0 | 105.7 | 43.0 |
| September | 14.1 | 11.7 | 14.1 | 13.1 | 11.4 | 94.3 | 26.3 | 47.3 |
| Average/sum | 15.4 | 15.0 | 15.3 | 14.7 | 264.9 | 441.3 | 335.1 | 275.2 |

| Sielianinov's hydrothermic coefficients | | | |
|---|---|---|---|
| Month | 2012 | 2013 | 2014 |
| April | 1.1 | 1.6 | 1.5 |
| May | 1.2 | 2.3 | 2.3 |
| June | 1.6 | 1.8 | 1.2 |
| July | 0.69 | 1.6 | 0.2 |
| August | 0.94 | 0.3 | 1.9 |
| September | 0.3 | 2.7 | 0.6 |
| Average IV-IX | 0.5 | 1.6 | 1.2 |

**Table 4: Iron content in potato tubers (mg $kg^{-1}$ dry matter)**

| Treatments (II) | Cultivars (I) | | | Years (III) | | | Mean |
|---|---|---|---|---|---|---|---|
| | Bartek | Gawin | Hono rata | 2012 | 2013 | 2014 | |
| 1. Control | 61.42 | 64.73 | 60.18 | 60.69 | 67.42 | 58.23 | 62.11d |
| 2. Harrier 295 ZC | 62.16 | 65.15 | 60.68 | 60.98 | 68.33 | 58.67 | 62.66cd |
| 3. Harrier 295 ZC+Kelpak SL | 62.65 | 66.11 | 61.20 | 61.34 | 69.29 | 59.33 | 63.32ab |
| 4. Sencor 70 WG | 62.55 | 65.44 | 60.91 | 61.15 | 68.61 | 59.15 | 62.97bc |
| 5. Sencor 70 WG+Asahi SL | 63.19 | 66.67 | 61.91 | 61.78 | 69.91 | 60.10 | 63.93a |
| Mean | 62.39b | 65.62a | 60.98c | 61.19b | 68.71a | 59.10c | 63.00 |

The mean marked by the same letter do not differ significantly

**Table 5: Iron uptake with the yield of potato tubers (g $ha^{-1}$)**

| Treatments (II) | Cultivars (I) | | | Years (III) | | | Mean |
|---|---|---|---|---|---|---|---|
| | Bartek | Gawin | Hono rata | 2012 | 2013 | 2014 | |
| 1. Control | 453.4 | 519.6 | 516.3 | 608.3 | 486.6 | 394.3 | 496.5d |
| 2. Harrier 295 ZC | 505.8 | 588.8 | 619.0 | 678.9 | 594.8 | 440.0 | 571.5cd |
| 3. Harrier 295 ZC+Kelpak SL | 564.8 | 651.5 | 651.4 | 795.5 | 603.6 | 468.6 | 622.6bc |
| 4. Sencor 70 WG | 584.1 | 673.4 | 702.5 | 798.3 | 614.2 | 547.4 | 653.3ab |
| 5. Sencor 70 WG+Asahi SL | 622.3 | 718.0 | 734.8 | 831.4 | 662.5 | 581.2 | 691.7a |
| Mean | 546.1b | 630.3a | 644.8a | 742.5a | 592.3b | 486.3c | 607.0 |

The mean marked by the same letter do not differ significantly

of iron harvested from 1 ha was taken up by Honorata, the highest yielding cultivar, it being significantly lower for cv. Bartek. Analysis of variance showed the interaction of cultivars with years (Table 6). The herbicides and biostimulants applied by Gugała et al. (2017) increased tuber yields and iron uptake from a unit of area, which agrees with earlier findings reported by Gugała and Zarzecka (2008).

**Table 6: Iron and manganese uptake with the yield of potato tubers depending on the cultivars and years (g $ha^{-1}$)**

| Cultivars (I) | Iron | | | Manganese | | |
|---|---|---|---|---|---|---|
| | Years (III) | | | Years (III) | | |
| | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 |
| Bartek | 700.6b | 509.2b | 428.4b | 254.7a | 159.2c | 139.7b |
| Gawin | 825.2a | 624.6a | 441.0b | 273.8a | 187.4b | 161.0b |
| Honorata | 701.9b | 643.2a | 589.4a | 241.2b | 220.5a | 197.2a |

The mean marked by the same letter do not differ significantly

## Manganese content and uptake

According to Kabata-Pendias and Mukherjee (2007) manganese content in tuber dry matter ranges from 4 to 15 mg $kg^{-1}$, in research by Sawicka et al. (2016) and Bati et al. (2017) the respective ranges were 6.3-17.3 and 17.2 mg $kg^{-1}$, and in the studies by Mahamud et al. (2015) conducted in USA and Bangladesh it was significantly affected by the cultivar and ranged from 7.4 to 50.6 mg $kg^{-1}$. In the experiment reported here, the tuber content of manganese was from 20.01 to 22.02 mg $kg^{-1}$ and was significantly influenced by cultivars, herbicides applied alone or combined with biostimulants as well as moisture and thermal conditions during the study period (Table 7). An accumulation of manganese was the highest in Gawin,

**Table 7: Manganese content in potato tubers (mg kg$^{-1}$ dry matter)**

| Treatments (II) | Cultivars (I) | | | Years (III) | | | Mean |
|---|---|---|---|---|---|---|---|
| | Bartek | Gawin | Hono rata | 2012 | 2013 | 2014 | |
| 1. Control | 20.88 | 21.35 | 20.75 | 20.97 | 21.89 | 20.12 | 21.00b |
| 2. Harrier 295 ZC | 20.65 | 21.27 | 20.57 | 20.69 | 21.79 | 20.01 | 20.83b |
| 3. Harrier 295 ZC+Kelpak SL | 21.02 | 21.49 | 20.85 | 21.21 | 21.91 | 20.23 | 21.12ab |
| 4. Sencor 70 WG | 20.87 | 21.24 | 20.67 | 20.88 | 21.76 | 20.12 | 20.92b |
| 5. Sencor 70 WG+Asahi SL | 21.24 | 21.54 | 20.99 | 21.44 | 22.02 | 20.31 | 21.26a |
| Mean | 20.94b | 21.38a | 20.77b | 21.04b | 21.88a | 20.16c | 21.03 |

The mean marked by the same letter do not differ significantly

**Table 8: Uptake of manganese with the yield of potato tubers (g ha$^{-1}$)**

| Treatments (II) | Cultivars (I) | | | Years (III) | | | Mean |
|---|---|---|---|---|---|---|---|
| | Bartek | Gawin | Hono rata | 2012 | 2013 | 2014 | |
| 1. Control | 154.8 | 171.6 | 178.0 | 209.9 | 158.3 | 136.4 | 168.2d |
| 2. Harrier 295 ZC | 168.9 | 192.0 | 209.6 | 230.2 | 190.2 | 150.2 | 190.2c |
| 3. Harrier 295 ZC+Kelpak SL | 191.3 | 219.8 | 222.2 | 281.9 | 191.5 | 159.9 | 211.1b |
| 4. Sencor 70 WG | 196.5 | 219.5 | 238.7 | 272.5 | 195.6 | 186.6 | 218.2ab |
| 5. Sencor 70 WG+Asahi SL | 211.2 | 234.1 | 249.6 | 288.4 | 209.6 | 196.8 | 231.6a |
| Mean | 184.5b | 207.4a | 219.6a | 256.6a | 189.0b | 166.0c | 203.9 |

The mean marked by the same letter do not differ significantly

it being significantly lower in Bartek and Honorata. The effect of cultivar on manganese content in potato tubers was confirmed in the study by Wierzbicka and Trawczyński (2011), Mahamud et al. (2015), Sawicka et al. (2016), Zarzecka et al. (2016).

After Harrier 295 ZC and Sencor 70 WG were applied, a tendency was observed for manganese content to decline in potato tubers compared with control, which was also observed in an earlier study by Zarzecka et al. (2016). By contrast, an application of herbicides and biostimulants increased manganese content, it being significantly higher following Sencor 70WG and Asahi SL. Wierzbowska et al. (2015) demonstrated that the tubers of potatoes treated with Kelpak SL had the highest manganese content compared with other biostimulants whereas Asahi SL did not change the amounts of the discussed microelement. Also meteorological conditions during the study years affected the concentration of manganese in tubers. A significantly higher manganese content was recorded in 2013, when precipitation was high, compared with the remaining study years. An interaction between study years and cultivars was confirmed, which means that cultivars displayed a different response to the weather conditions. The effect of precipitation and temperature on the characteristic discussed was also confirmed by Wierzbowska et al. (2015) whereas Sawicka et al. (2016) and Zarzecka et al. (2016) found no such impact. Analysis of variance showed no interaction between experience factors and years.

The uptake of manganese with tuber yield was affected by the experimental factors (Table 6, 8). It was the highest for cv. Honorata and significantly lower for cv. Bartek. There was confirmed an effect of herbicides and growth regulators on manganese uptake with tuber yield compared with control. According to Wierzbowska et al. (2015), manganese uptake with potato tuber yield was more affected by the cultivar, its yield in particular, than the biostimulants applied. Analysis of variance showed the interaction of cultivars with years (Table 6). Oosten et al. (2017) have reported that biostimulants provide many benefits for plants: they increase nutrient uptake, stimulate growth, increase tolerance to stress, improve yield quality.

### Nutritional value of potato tubers

Man needs to consume at least 25 minerals for correct development and wellbeing (White and Brown, 2010). *Solanum tuberosum* L. tubers are an important source of the nutrients, all the more so because they are a frequent component of human diet. Potato is mentioned as a product which provides 18% of K RDA (Recommended Dietary Allowance), 6% of Fe, P and Mg RDAs as well as 2% of Ca and Zn RDAs (True et al., 1979). According to Regulation (EU) (2011), iron RDA is 14 mg/day and manganese RDA is 2.0 mg/day, and Nkwenkeu et al. (2002) reported that manganese intake is 2.0-8.8 mg/day worldwide, 2.4 mg/day in USA, 2.9 mg/day in Canada, 2.7 mg/day in Germany, 2.9 mg/day in Australia and 2.2 mg/day in India. In the study discussed here, iron content in potato tubers averaged 1.26 mg 100 g$^{-1}$ fresh matter and manganese content was 0.42 mg 100 g$^{-1}$ fresh matter, on average (Table 9). The human daily requirements for these elements are 14.0 and 2.0 mg, respectively (Regulation (EU) (2006). Thus consumption of 100 g potato tubers, respectively, in 9 and 12% satisfies the daily requirement for these microelements. Similar findings were reported by Wierzbicka (2012) who found that iron and manganese contents in potato tubers

**Table 9: Mean daily intake iron and manganese with the diet**

| Component | Range in dry matter (mg kg$^{-1}$) | Mean in dry matter (mg kg$^{-1}$) | Mean in fresh matter (mg 100 g$^{-1}$) | Daily reference intakes* | Per cent of realisation |
|---|---|---|---|---|---|
| Iron | 58.23-69.91 | 63.00 | 1.26 | 14.0 mg | 9 |
| Manganese | 20.12-22.02 | 21.03 | 0.42 | 2.0 mg | 21 |

*Regulation (EU). (2011). No 1169/2011 of the European Parliament and of the Council of 25 October 2011

were 0.97 and 0.15 mg 100 g$^{-1}$ tuber fresh matter. As the daily requirement is 8 and 1.8-2.3 mg, respectively, potato meets the human requirement for these elements in 12 and 7-8%. Also Rubio et al. (2009) demonstrated that consumption of 100g tubers provided the human body with 6% Fe and 9% Mn whereas 48% manganese in the diet was supplied by cereals.

## CONCLUSION

Herbicides and their mixtures with biostimulants applied in the experiment increased the iron content and the uptake of iron and manganese with the yield of potato tubers compared to control. An increase in manganese content was observed only when the herbicide Sencor 70WG had been applied after mixing with the growth regulator Asahi SL. The experimental cultivars affected the concentration and uptake with tuber yield of the analysed microelements. The highest average iron and manganese contents were determined in cv. Gawin tubers, it being the lowest in cv. Honorate. The average iron and manganese contents were, respectively, 1.26 and 0.42 mg per 100 g fresh matter, which in 9 and 21% satisfied the daily requirement for these elements.

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### Authors' contributions

In this study, K.Z. designed and carried out the experiment. M.G. carried out the experiment and conducted the statistical analyses. I.M. performed laboratory analysis. K.Z. and A.S. wrote the manuscript which was read and approved by all the authors.

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