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IMPACT OF SOME HERBICIDES ON THE CHEMICAL COMPOSITION OF POTATO TUBERS

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ABSTRACT

The 3-year field experiment researched the impact of weed control with herbicides on the chemical composition of four table potato cultivars. There were observed significant changes in the tuber chemical composition of potatoes treated with herbicides which significantly decreased the contents of dry matter, starch and phosphorus as well as increased the contents of vitamin C, total saccharides and magnesium in tubers, as compared to the object weed-controlled mechanically.

Key words: potato, herbicides, starch, vitamin C, reducing saccharides, total saccharides, potassium, phosphorus, magnesium

INTRODUCTION

Supplying potato plants with adequate conditions for growth and development requires, among others, chemical weed control. Numerous authors [5,6,19,26] observed a favourable impact of herbicides on the potato tuber yields as a result of eliminating weed competition. However there is little information about the effect of herbicides on potato tuber quality characteristics and the research results are often unclear [1,12,25]. Some authors [3,26] showed that herbicides decrease the starch content in tubers yet numerous research did not show a significant impact of herbicides on the contents of starch and dry matter [8,9,15,16]. Herbicides can also cause

changes in the content of ascorbic acid and minerals, yet the opinions diverge [3,4,7,9,14,15]. Many authors [1,2,8,17,18,20, 21,23,27] observed that potato tuber chemical composition is cultivar-specific, changing considerably depending on the weather conditions over the vegetation period.

A necessity of herbicide application in potato cultivation where cereals constitute a forecrop, the plants which provide soil with large amounts of weed seeds, calls not only for effective weed control but also for the effect of herbicides on the yield quality.

As every year new potato cultivars are registered and herbicides are more and more commonly used, the present research investigated the effect of herbicides on the chemical composition of four table potato cultivars.

MATERIALS AND METHODS

The 1995-1997 strict field experiment was conducted at the Zawady Agricultural Experiment Station of the Podlasie University in Siedlce on brown soil of a very good rye soil suitability complex, pH 5.5 - 6.7, a high content of phosphorus, a very high of potassium and low of magnesium.

The experiment was set in random split-plot in three replications with two factors:

A - weed control methods, as presented in Table 1; selection of herbicides depended on the field weed infestation with numerous both dicotyledonous and monocotyledonous weeds.
B - table potato cultivars – 'Ibis', 'Mila', 'Arkadia', 'Irga'.
'Ibis' - mid-early cultivar, leaf habit, quite high yields, contents of starch -15.3%, of vitamin C - 20.6 mg%, quite good flavour.

Table 1. Potato weed control methods employed

Objects	Treatments		
	Between planting and emergence	Right before emergence	After emergence
1.Mechanical weed control – the control	3-4-time hilling combined with harrowing	-	2-time hilling
2.Mechanical weed control + Basagran 600 SL 2.5 l· ha^{-1}	3-4- time hilling combined with harrowing	-	Spraying with Basagran 600 SL at the potato plant height of 10-15cm
3.Mechanical weed control + Basagran 600 SL 1 l· ha^{-1} + Sencor 70 WP 0.25 kg·ha^{-1} (mixture)	3-4- time hilling combined with harrowing	-	Spraying with a herbicide mixture of Basagran 600 SL + Sencor 70 WP at the potato plant height of 10-15cm
4.Mechanical weed control + Bladex 50 WP 1.5 kg·ha^{-1} + Afalon 50 WP 1.5 kg·ha^{-1} (mixture)	2-3- time hilling combined with harrowing	Hilling and spraying with the mixture of herbicides Bladex 50 WP + Afalon 50 WP	-
5.Mechanical weed control + Sencor 70 WP 0.5 kg·ha^{-1} + Titus 25 DF 50 g·ha^{-1} + Atpol 1,5 l·ha^{-1}	2-3- time hilling combined with harrowing	Hilling and spraying with the Sencor 70 WP preparation	Spraying with Titus 25 DF combined with adiuwantem Atpol at the potato plant height of 10-15 cm
6.Mechanical weed control +Basagran 600 SL 1 l·ha^{-1} + Nabu 20 EC 2 l·ha^{-1}	3-4- time hilling combined with harrowing	-	Spraying with Basagran 600 SL, followed by Nabu 20 EC at the potato plant height of 10-15cm

‘Mila’ - mid-early cultivar, leaf habit, average yields, contents of starch -16.1%, of vitamin C - 21.3 mg%, very good flavour
‘Arkadia’ - mid-late cultivar, leaf-and-stem habit, average yields, contents of starch - 16.1%, of vitamin C –17.8 mg%, quite good flavour.
‘Irga’ - mid-early cultivar, leaf-and-stem habit, quite high yields, contents of starch - 14.4%, of vitamin C - 20.3 mg%, quite good flavour.

Cereals (winter wheat, winter triticale) acted as a potato forecrop. In autumn, manure was applied at the dose of 25 $t \cdot ha^{-1}$ as well as phosphorus and potassium fertilisers at the doses of 90 $kg \cdot ha^{-1}$ of P_20_5 and 120 $kg \cdot ha^{-1}$ of K_2O. Nitrogen fertilisers were applied in spring prior to planting at the dose of 90 $kg \cdot ha^{-1}$ of N. Potatoes were planted in the third decade of April and the first decade of May at the row-spacing of 62.5 x 40 cm. The planting field size amounted to 18.75 m^2, while harvest field size to 15 m^2. The tubers were harvested in the second and the third decade of September. Over the harvest 7-10 kg of tubers were sampled to define chemical composition. Tuber fresh weight starch content was defined with the polarimetric method, vitamin C content with the Tillmans method, reducing saccharides and total saccharides - the Luff-Schoorol method. The dry matter was defined drying the pulp at 60-70°C, which was followed by final drying at 105°C to the minimum weight. The tuber dry matter potassium content was defined with the flame photometry, phosphorus content with the colorimetric method and the magnesium with the ASA method.

The results obtained were analysed statistically applying the mathematical model for split-plot with two factors [22]

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

where:

Y_{ijl} - value of the characteristic researched; i level of A (weed control methods),
j - level of B (cultivars) in the 1st block (replication),
m - experimental mean,
a_i - effect of i-level of A (weed control methods),
g_l – effect of the 1st replication,
$e^{/1/}_{il}$ - random effect of A (weed control methods) with replications,
b_j – effect of j-level of B (cultivars),
ab_{ij} – effect of interaction of A (weed control methods) and B (cultivars),
$e^{/2/}_{ijl}$ – random effect II
The significance of the differences obtained was verified with the Tukey test.

RESULTS

The weather conditions over the research years varied (Table 2). 1995 remained warm and dry; May through August with a considerable rainfall shortage (98.3 mm as compared with the multi-year mean rainfall). Such conditions showed unfavourable for potato yielding yet they enhanced tuber dry matter and starch accumulation. The 1997 vegetation period was warm while rainfall distribution varied considerably; specially high rainfall in July (exceeding by 111.3 mm the multi-year mean), while August showed a rainfall shortage (as much as 62.3 mm below the multi-year mean). The conditions most favourable for potato development and yielding were observed in 1996 which were both moist and warm. However the nutrient accumulation in potato tubers was most essential in September which was wet and cold.

Tuber dry matter and starch contents depended significantly on the weed control method and weather conditions over the research years (Tables 3-4, Fig. 1). Most starch and dry matter were contained in the potato tubers harvested from objects controlled mechanically, while in the plots where mechanical control was accompanied by herbicide and herbicide mixture application, the contents of the components researched were lower by 0.1-0.2%. Out of all the cultivars investigated, the highest contents of starch and dry matter were found in ‘Arkadia’ and ‘Mila’, then ‘Ibis’, and the lowest in ‘Irga’. There was no evidence of the interaction between weed control methods and the potato cultivar. There was observed a significant variation in the percentage of dry matter and starch over respective research years. Over warm and dry year 1995, the contents of dry matter and starch were highest. Significantly lower contents of these components were noted in the other years, while higher contents of both dry matter and starch were noted in 1996 which was warmer and showed a more regular rainfall distribution.

Table 2. Comparison of weather conditions over research years with the multi-year means

Years	Multi-year means and their monthly and yearly deviations						
	Months						
	IV	V	VI	VII	VIII	IX	IV-IX
Rainfall, mm							
1950-1980	33.0	50.0	75.0	80.0	68.0	47.3	353.3
1995	+5.8	-27.5	-11.3	-46.8	-12.7	+45.1	-47.4
1996	-22.3	+26.0	-42.5	+16.4	-7.7	+44.5	+14.4
1997	-1.5	+25.5	-23.5	+111.3	-62.3	-35.8	-47.3
Temperature, °C							
1950-1980	7.1	12.6	16.6	17.7	16.9	12.7	13.9
1995	+1.4	+0.6	+1.5	+4.3	+2.5	+0.8	+1.9
1996	+1.1	+3.7	+0.9	+0.2	+2.4	-2.7	+1.9
1997	-2.0	+2.3	+1.1	+2.2	+3.5	+1.2	+1.4

Table 3. Weed-control method – related content of some components in potato tubers (means of 1995-1997)

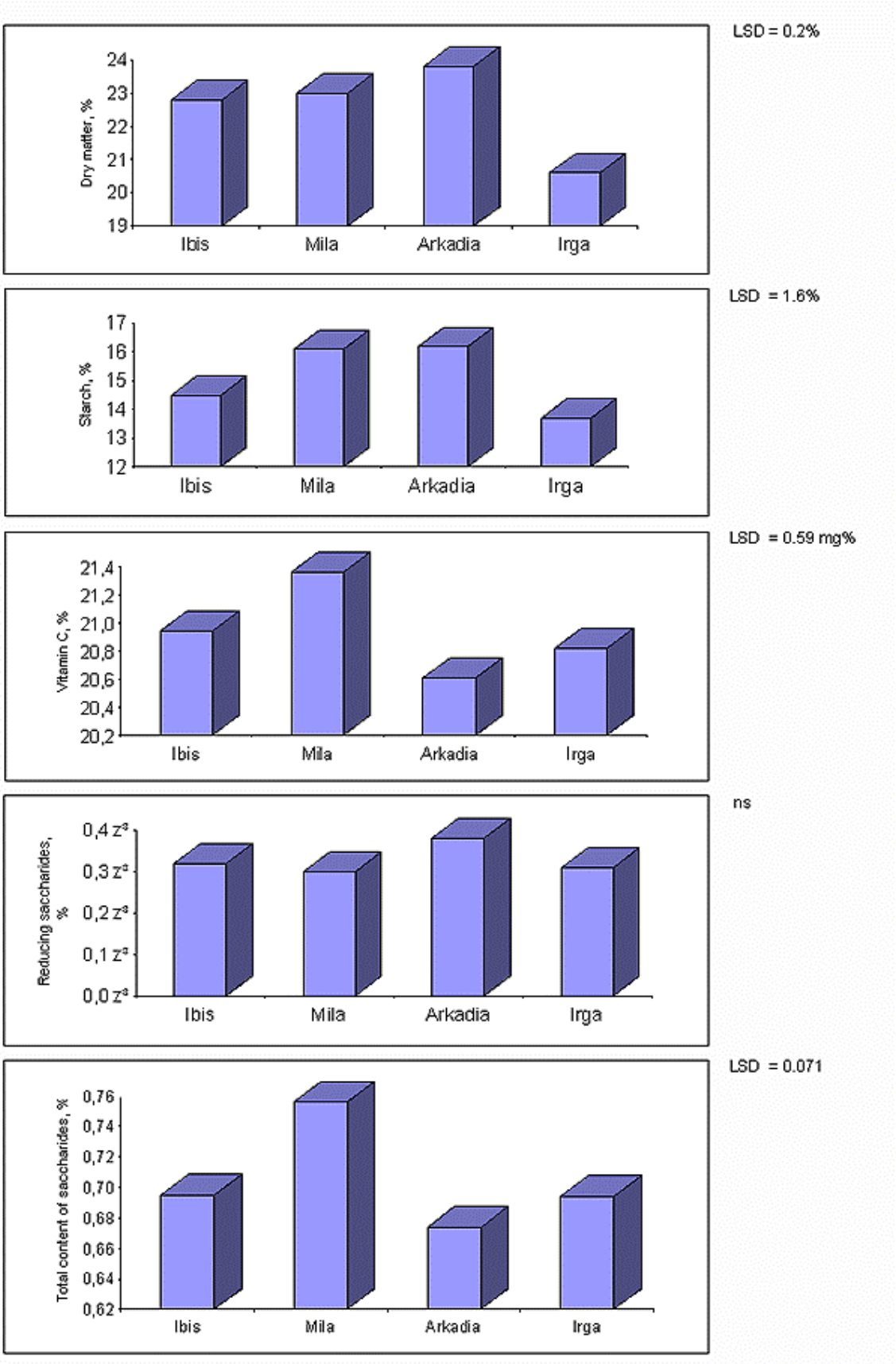
Weed control methods	Dry mass %	Starch %	Vitamin C mg %	Reducing saccharides %	Total saccharides %
Mechanical weed control	22.7	15.3	20.66	0.316	0.663
Mechanical weed control + Basagran 600 SL 2.5 $l \cdot ha^{-1}$	22.5	15.2	20.84	0.324	0.689
Mechanical weed control + Basagran 600 SL 1 $l \cdot ha^{-1}$ + Sencor 70 WP 0.25 $kg \cdot ha^{-1}$ (mixture)	22.5	15.1	20.86	0.339	0.702
Mechanical weed control + Bladex 50 WP 1.5 $kg \cdot ha^{-1}$ + Afalon 50 WP 1.5 $kg \cdot ha^{-1}$ (mixture)	22.5	15.1	21.05	0.341	0.702
Mechanical weed control + Sencor 70 WP 0.5 $kg \cdot ha^{-1}$ + Titus 25 DF 50 $g \cdot ha^{-1}$ +Atpol 1.5 $l \cdot ha^{-1}$	22.6	15.1	21.08	0.334	0.688
Mechanical weed control + Basagran 600 SL 1 $l \cdot ha^{-1}$ + Nabu 20 EC 2 $l \cdot ha^{-1}$	22.6	15.1	21.10	0.337	0.712
$NIR_{0.05}$	0.2	0.1	0.17	ns	0.022

ns - non-significant difference

Table 4. Weather conditions – related content of some components in potato tubers (mean for four cultivars)

Research years	Dry matter %	Starch %	Vitamin C mg %	Reducing saccharides %	Total content of saccharides %
1995	24.6	18.3	22.60	0.345	0.793
1996	21.6	14.0	20.11	0.426	0.880
1997	21.5	13.2	20.10	0.224	0.407
$NIR_{0.05}$	2.1	0.8	1.29	ns	0.230

Fig. 1. Content of some components in tubers of four potato cultivars (means of 1995-1997)



The content of vitamin C was significantly affected by both research factors (Tables 3-4, Fig. 1). There were observed significant increases in the content of vitamin C as a result of combined mechanical control and the application of herbicides, as compared with mechanical treatment only; the highest content was observed as a result of post-emergence spraying applied twice with the following preparations: Basagran 600 SL and Nabu 20 EC, which is desirable as table potato remains the cheapest and most common source of vitamin C. Potato cultivars differed in their contents of vitamin C, while significant cross-cultivar differences were observed between 'Mila' - with the highest content of vitamin C and 'Arkadia' with its lowest content. Over warm and dry 1995 the accumulation of vitamin C was significantly higher than in the other vegetation periods. It was observed that the changes in that component depended on the weather conditions however they were not identical across cultivars. The greatest differences in the vitamin C contents were noted in 'Arkadia' and amounted to 3.62 mg% in 1996 and 2.98 mg% in 1997, as compared with 1995, and the least in 'Irga' and amounted to 1.50 and 1.73 mg%, respectively.

The tuber analysis showed that the content of reducing saccharides (glucose + fructose) was not significantly affected by the factors investigated. Yet there were noted some growth trends in the reducing saccharide content as affected by all the herbicides applied.

The total content of saccharides (glucose + fructose + saccharose) in the tubers of the potato cultivars researched significantly differed as affected by the weed control method and weather conditions over years (Tables 3-4, Fig. 1). The content of saccharides was higher in tubers obtained from plots where herbicides and their mixtures were applied than in tubers from objects where weeds were controlled mechanically. The highest content of saccharides was observed in tubers collected from the plot controlled mechanically and chemically with the Basagran 600 SL and Nabu 20 EC. The cultivars differed in their characteristic investigated; 'Mila' showed the highest level of total saccharides in tubers.

Similarly the weather conditions showed a significant effect on the content of total saccharides in potato tubers. The lowest content was observed in 1997, with the final months of the vegetation period (August and September) being dry and warm. A higher temperature and rainfall shortage, as compared with the multi-year, helped the accumulation of the total saccharides in tubers. There was observed a varied reaction of cultivars to herbicides under varied weather conditions over the potato vegetation period. The greatest differences in the content of total saccharides, as compared with control tubers, were observed as a result of the application of Basagran 600 SL and Nabu 20 EC herbicides in 'Ibis' and 'Irga' cultivars, and the lowest in 'Mila'. Out of all the cultivars researched, 'Arkadia' showed the strongest reaction to weather conditions over research years; contents of saccharides, as compared with the results of 1997, were the highest.

The analysis results obtained show that the content of minerals varied as affected by the factors researched (Tables 5, 6, Fig. 2). The content of potassium depended significantly on the cultivars cultivated and research years, phosphorus on the weed control method and cultivars, and magnesium on the potato weed control method and weather conditions over vegetation periods. The content of potassium did not change considerably due to the application of herbicides, however there were observed trends towards a decrease in the potassium content in tubers, as compared with mechanically weed-controlled potatoes. The content of phosphorus was significantly decreased by some herbicides, including Basagran 600 SL, Basagran 600 SL plus Sencor 70 WP applied in the mixture and Basagran 600 SL and Nabu EC applied separately. However the other herbicides did not show any effect on the content of phosphorus in tubers, as compared with tubers weed-controlled mechanically. The content of magnesium increased significantly due to the herbicide applied (combined mechanical and chemical control), as compared with the tubers of mechanically weed-controlled potato plants. There was observed no varied reaction of cultivars to the weed control method.

Table 5. Weed-control method- related contents of potassium, phosphorus and magnesium in potato tubers (mean for 1995-1997)

Weed control methods	Contents in dry matter, %		
	potassium	phosphorus	Magnesium
Mechanical weed control + Basagran 600 SL 2.5 l· ha^{-1}	1.595	0.197	0.091
Mechanical weed control + Basagran 600 SL 1 l·ha^{-1} + Sencor 70 WP 0.25 kg· ha^{-1} (mixture)	1.577 1.576	0.193 0.190	0.094 0.097
Mechanical weed control + Bladex 50 WP 1.5 kg·ha^{-1} + Afalon 50 WP 1.5 kg· ha^{-1} (mixture)	1.594	0.198	0.097
Mechanical weed control + Sencor 70 WP 0.5 kg·ha^{-1} + Titus 25 DF 50 g· ha^{-1} + Atpol 1.5 l· ha^{-1}	1.592	0.197	0.097
Mechanical weed control + Basagran 600 SL 1 l·ha^{-1} + Nabu 20 EC 2 l· ha^{-1}	1.575	0.192	0.095
$NIR_{0.05}$	ns	0.004	0.002

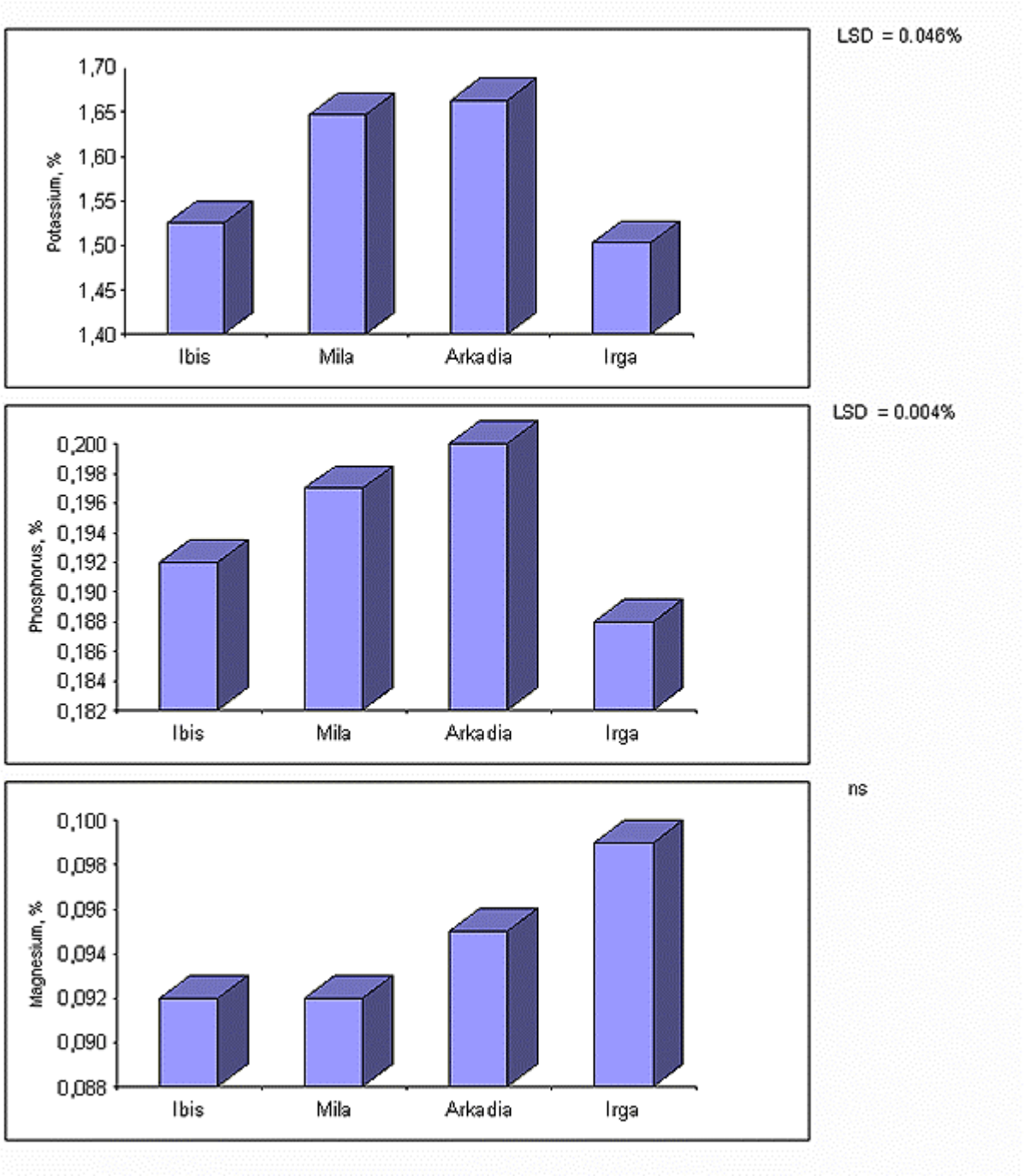
Table 6. Contents of potassium, phosphorus and magnesium in tubers of four potato cultivars

Research year	Cultivars					$NIR_{0.05}$	
	Ibis	Mila	Arkadia	Irga	Mean		
Potassium, %							
1995	1.532	1.669	1.689	1.508	1.599	- across years	0.039
1996	1.539	1.666	1.686	1.514	1.601	- across cultivars	0.046
1997	1.505	1.607	1.613	1.488	1.553	interaction:	
Mean	1.525	1.647	1.663	1.503	-	cultivars x years	0.040
Phosphorus, %							
1995	0.187	0.193	0.195	0.182	0.189	- across years	ns
1996	0.202	0.210	0.212	0.198	0.206	- across cultivars	0.004
1997	0.187	0.189	0.193	0.185	0.189	- interaction:	
Mean	0.192	0.197	0.200	0.188	-	cultivars x years	0.004
Magnesium, %							
1995	0.089	0.089	0.093	0.097	0.092	- across years	0.003
1996	0.096	0.098	0.102	0.105	0.100	- across cultivars	ns
1997	0.090	0.089	0.090	0.095	0.091	- interaction:	
Mean	0.092	0.092	0.095	0.099	-	cultivars x years	ns

Weather conditions showed a significantly high effect on the contents of potassium and magnesium; they were higher in tubers where potato plants were grown under the most favourable conditions of the moist and warm summer of 1996. The content of phosphorus was not affected by varied weather conditions over vegetation periods.

The cultivars researched showed a significant variability in the contents of potassium and phosphorus in tubers. The greatest contents of potassium and phosphorus were accumulated in ‘Arkadia’. There was observed a varied reaction of potato cultivars to weather conditions over the vegetation period. The greatest contents of potassium were noted in ‘Mila’ and ‘Arkadia’ in 1995, ‘Ibis’ and ‘Irga’ in 1996, while the lowest content was observed in all the cultivars in 1997. The highest content of phosphorus was accumulated in four cultivars grown in 1996, while the smallest content in ‘Irga’ tubers in 1995 and 1997.

Fig. 2. Contents of potassium, phosphorus and magnesium in tubers of four potato cultivars (means of 1995-1997)



DISCUSSION

Herbicides, applied for potato cultivation, penetrate into plant tissues and affect metabolism and change the tuber chemical composition [13,24]. The present three-year research showed that the contents of starch and dry matter in tubers decreased due to all the herbicides applied, which is confirmed by the reports of Leszczyński et al. [11] Lisińska and Leszczyński [13], who claim that triazine herbicides (including Bladex, Sencor), urea herbicides (e.g. Afalon) as well as others (e.g. Racer) decrease the amount of these components in tubers. Similar changes were reported by Ceglarek and Księżak [3], Lisińska [12], Łęgowiak and Domańska [14], Woda-Leśniewska [24], Zarzecka [26]. However no significant impact of triazine herbicides (e.g. Bladex, Camparol, Sencor) and urea (Afalon, Aresin) on the contents of dry matter and starch was observed by Kłosińska-Rycerska [7,8], Kołpak et al. [9], Mężykowska and Mazurczyk [15]. In the present research it was noted that the contents of dry

matter, starch, vitamin C and the total content of saccharides was significantly affected by the cultivars as well as weather conditions over the vegetation period, which is confirmed by numerous authors [2,4,17,18,21,23]. The research reported by Zgórska and Frydecka-Mazurczyk [27] showed that differences in the dry matter content over respective years reached up to 4.2%, and in the starch content - exceeded 3%.

In the present research, herbicides showed a favourable effect on the concentration of vitamin C in tubers, which is confirmed by Ceglarek and Księżak [3], Ceglarek et al. [4], Kołpak et al. [9], Woda-Leśniewska [24]. Other authors, including Łęgowiak and Domańska [14], Mężykowska and Mazurczyk [15], however, observed that herbicide application for the potato weed control decreases the content of ascorbic acid in tubers.

The results obtained showed that herbicides increased the total content of saccharides as well as showed a trend towards increase (non-significant) in the content of reducing saccharides, which was also observed by Lisińska [12]. However Leszczyński et al. [11] observed opposite changes due to the application of preparations of the phenoxyacetic acid group, while in the reports by Kłosińska-Rycerska [7] no herbicide of triazine group, derivatives of urea and phenoxyacetic acids, changed reducing saccharides and saccharose significantly.

The content of minerals in potato tubers exposed to herbicides varied along with various conditions of the experiment; the content of potassium did not show any significant changes, the content of phosphorus decreased significantly, while the content of magnesium increased, as compared with the object weed-controlled mechanically. Similar trends were reported by Leszczyński et al. [11], while neither Ceglarek and Księżak [3], Kłosińska-Rycerska [7] nor Kołpak et al. [9] observed any significant changes in the contents of potassium, phosphorus and magnesium in potato tubers due to the application of herbicides. The content of minerals, namely potassium and magnesium, showed a significant impact of weather conditions. The highest mineral contents were noted in tubers of the moist and warm year of 1996, which was also confirmed by Banaszkiewicz [1], Ceglarek and Księżak [3] as well as Kłosińska-Rycerska [7, 8], who observed that changes in the chemical composition of tubers depended on the weather conditions over vegetation; the higher the moisture level, the greater the impact.

CONCLUSIONS

1. Potato herbicide weed control significantly decreased the contents of dry matter, starch and phosphorus and increased the contents of vitamin C, total saccharides and magnesium in tubers, as compared with mechanical weed control.
2. There was noted a significant cross-cultivar variability in the contents of dry matter, starch, vitamin C, total saccharides as well as potassium and phosphorus.
3. Changes in the chemical composition of tubers depended on the weather conditions over the vegetation period. The highest contents of dry matter, starch and vitamin C were observed over the warm and dry year with a considerable deficiency of rainfall from May to August and minerals over the warm and moist period with the most favourable rainfall distribution.
4. The contents of vitamin C, potassium and phosphorus as well as the total content of saccharides in potato tubers of the cultivars researched varied significantly, depending on weather conditions. A varied reaction of cultivars to the weed-control methods applied was observed only in the total content of saccharides.

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