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AN ATTEMPT TO EVALUATE THE FLUCTUATION OF CHEMICAL COMPOSITION OF POTATO TUBERS IN CHANGING CONDITIONS OF ARABLE FIELD

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A b s t r a c t. Analyses are based on data collected from field experiments carried out in the years 1990-1992 on podzolic soil derived from light loamy sand in Parczew. The calculation of correlation and regression coefficients allowed us to analyze the effect of some climatic factors on the contents of dry mass, starch, sum of sugars, as well as vitamin C, in tubers of 37 potato varieties. It was found that raising of temperature in the period of July-August increased the content of dry mass and sum of sugars in tubers, and at the same time decreased the content of starch and vitamin C. The content of available phosphorus and potassium in soil, as well as its acidity, did not show any distinct effects on qualitative traits of tubers.

K e y w o r d s: potato, chemical composition, varieties, rainfalls, temperature

INTRODUCTION

Qualitative requirements pertaining to potato appropriated for a direct consumption and food processing are continuously increasing. Therefore, the knowledge of causes responsible for fluctuation of tubers' chemical composition, the main factor deciding their quality, is very important. The content of many components such as dry mass, starch, sugars, vitamin C, depends not only on genetic features of varieties, but also on changing environment conditions [1,3,5-8,10-12]. Mica [6] describes the modification of the above contents by environmental factors as 'dumping' of varietal features. Therefore, the aim of this paper is to determine the relationship of some qualitative traits of potato with selected weather factors of a cultivated field.

MATERIALS AND METHODS

The studies were based on the results of a field experiment carried out in the years 1990-1992 in Parczew, Biała Podlaska voievodship, on the soil derived from light loamy sand. The soil had a medium to high content of phosphorus, a high content of potassium and its reaction was from light acid to neutral.

50 tubers from each of 37 potato varieties, including 34 Polish cultivars, (Aster, Atol, Beryl, Bliza, Bogna, Brda, Bronka, Bryza, Bzura, Certa, Ceza, Cisa, Dryf, Duet, Elida, Elipsa, Fala, Fauna, Fregata, Frezja, Heban, Irys, Jaśmin, Lotos, Mila, Orlik, Perkoz, Pilica, Pola, Ronda, Ruta, Sokół, Stobrawa, Tarpan) 3 Dutch cultivars (Premier-early, Escort-middle early and Diamant-middle late) and of all earliness groups were used in the experiment. The potatoes were fertilized with manure in a doze of 250 dt ha^{-1} and with mineral fertilizers in amounts of: 100 kg N, 100 kg P_2O_5, 150 kg K_2O ha^{-1}. The seedling material of the tested varieties was (at the degree of superelite).

The analyses of the fresh material were conducted directly after the harvest. The dry mass of potato tubers was determined by means of the oven-drying method; starch was determined by means of Ewers' method, using a polarimeter Polamat S type; vitamin C was determined by means of Tillmans' method; sum of sugars was determined by means of Hegedorn-Jensen's method modified by Brzeski and Kaniuga. Each analysis was repeated three times for each variation. The obtained results were statistically worked out by means of the analyses of variance, correlation and of regression. Function parameters were determined by means of the method of least squares. Verification of significance was done by means of the Student's test. In the statistical elaboration, a dependent variable (y) was the content of the particular tuber components in the percentages of fresh matter, and independent variables were:

x_1 - the average air temperature in the period May-June (°C);
x_2 - the average air temperature in the period July-August (°C);
x_3 - the sum of rainfalls in the period May-June (mm);
x_4 - the sum of rainfalls in the period July-August (mm);
x_5 - sunshine in the period May-June (hours);
x_6 - sunshine in the period July-August (hours);
x_7 - the soil acidity - pH in KCl;
x_8 - the content of available P_2O_5 in soil (mg/100g of soil);
x_9 - the content of available K_2O (mg/100g of soil);
x_{10} - length of vegetation period (days).

The effects of rainfalls, temperatures and of sunshine on the content of the particular component in potato tubers were studied from May to the end of August. It is the period of vegetation of very early, early and middle early varieties; it is 90 % of vegetation period of middle late varieties and 80 % of vegetation period of late varieties. However, September rainfalls can be used by the late varieties, they do not result in significant changes of the tubers chemical content. The period was divided into two parts: I - May-June and II - July-August. The air temperatures, the intensity of rainfalls and the sunshine time of those periods varied. On the basis of simple correlation coefficients, variables of multifactorial linear regression were selected. Regressions, presented in the tables, were calculated according to the following formula: $y = a+b_jx_j$, where y stands for a dependent variable, a - a free term, b - a value of regression coefficient and x stands for an independent variable.

Partial coefficients of regression (b_j) show how much the content of dry mass, starch, vitamin C and of sum of sugars changes, if a given factor changes by one unit.

Variability of the analyzed results was characterized by means of: arithmetic mean; by means of standard deviation and of variation coefficient, calculated according to the formula: V=s/x 100 %, where s stand for a standard deviation and x is an arithmetic mean.

The air temperatures and the intensity of rainfalls during vegetation periods in the particular years, varied (Table 1).

RESULTS

The evaluated elements of the chemical content of tubers appeared to be dependent on the varieties' features which was certified by

Table 1. Rainfalls and air temperature during potato vegetation of potato in the years 1990-1992 in comparison with many years averages, according to IMGW at Włodawa

Years	Rainfalls in mm						Air temperature in °C					
	IV*	V	VI	VII	VIII	IX	IV	V	VI	VII	VIII	IX
1990	52	15	34	70	63	81	8.3	13.1	16.6	16.6	17.3	10.8
1991	22	90	60	87	43	35	7.0	11.0	15.7	18.5	17.7	14.1
1992	59	74	53	23	9	113	7.8	12.6	17.5	19.1	21.3	12.2
Mean for 1961-1980	32	58	67	78	64	48	7.4	13.0	16.4	15.5	17.1	12.9

* month

significant differences among varieties and by variation coefficients of the particular earliness groups of potato varieties (Table 2). The highest content of dry mass was observed in tubers of the middle early varieties, whereas the lowest content occurred in the very early varieties. The content of starch in tubers increased with the extension of their vegetation. The largest amount of soluble sugars was observed in the case of the middle late varieties, whereas the smallest amount was observed in the case of the late ones. The lowest variation coefficients were found in the dry mass of tubers with a mean coefficient V = 16.3 % and the range of results from 13.0 % (very early varieties) to 20.5% (middle early varieties). It proves a high stability of that feature. The concentration of vitamin C was one of least stable features with a mean coefficient V = 41.2 % ranging between 29.3 % (very early varieties) and 51.4 % (middle early varieties).

The rise in the air temperature by 1 °C, in the range from 13.5 to 15.3 °C, in the period May-June negatively affected accumulation of dry mass in tubers of the middle late varieties. The air temperature in the period July-August, determined the dry mass concentration in tubers of the very early, early, middle early and of late varieties. The rise in that temperature by 1 °C, in the range from 17.3 to 19.9 °C, resulted in the increase of dry mass content by values presented in Table 3, assuming that other factors, included in the function model, are on a middle level. Also, the sum of rainfalls in the period May-June determined the amount of dry mass in tubers of the very early, middle early and of late varieties. On one hand, it affected the increase of the dry mass content in tubers of the middle early to late varieties and, on the other hand, it decreased the concentration of dry mass in tubers of these varieties by values presented in Table 4, per each rainfall increase by 10 mm, in the range from 30 to 164 mm. The rainfalls of the period July-August, in the range 27-125 mm, resulted in the increase of dry mass content in

T a b l e 2. Content of some important tuber components expressed in per cents or mg % of fresh matter (means for years 1990-1992)

Earliness group	No. of varieties	Dry matter		Starch		Sum of sugars		Witamin C	
		mean	V	mean	V	mean	V	mean	V
Very early	5	19.81	13.0	12.4	21.4	0.564	30.1	21.29	29.3
Early	6	20.55	14.2	13.0	23.5	0.609	35.7	16.16	38.7
Medium early	8	20.76	14.7	13.6	19.1	0.589	28.4	17.13	51.4
Medium late	10	20.55	19.2	14.1	29.1	0.639	26.8	18.83	44.4
Late	8	20.13	20.5	15.3	32.3	0.555	29.4	18.22	42.0
Mean	7	20.36	16.3	13.7	25.1	0.591	30.1	18.33	41.2
LSD ($\alpha \leq 0.05$)	-	0.54	-	0.8	-	0.058	-	1.73	-

V* - variation coefficient in %

T a b l e 3. The statistical characterization of independent variables (mean for years 1990-1992)

Independent variables									
x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Arithmetic means									
14.4	18.6	97	76	497	491	6.1	13.8	13.1	127
Standard deviations									
0.9	1.3	67	49	68	77	0.5	3.3	1.0	24

x_1 - temperature of air V-VI in °C); x_2 - temperature of air VII-VIII in °C; x_3 - sum of rainfalls V-VI in mm; x_4 - sum of rainfalls VII-VIII in mm; x_5 - insolation V-VI in hours; x_6 - insolation VII-VIII in hours; x_7 - soil acidity pH in KCl; x_8 - content P_2O_5 in mg/100g of soil; x_9 - content K_2O in mg/100 g of soil; x_{10} - length of vegetation in the days.

tubers of the very early and middle early varieties and, on the other hand, they resulted in decreasing the amount of dry mass in tubers of the late varieties. It is important, however, to realize that both the rainfalls and the air temperatures are not direct reasons of that phenomenon. They establish, especially in case of heavy rains in July-August, favorable conditions for the development of *Phytophthora infestans* and other fungus diseases which limit plants assimilation. Because of that, they do not allow potato varieties for achieving a maximum content of dry mass in tubers. The sunshine time of the period May-June, in the range of 429-569 h, appeared to be very important to dry mass of the very early varieties, The sunshine time of the period July-August, in the range of 414-568 h, was important to the very early, middle early and to late varieties. The extension of the sunshine time by 10 h in those periods and in the given range, resulted in the increased amount of dry mass in tubers of these potato varieties. The soil acidity significantly affected the dry mass content in tubers of the early to middle late varieties. The increase of the dry mass concentration in tubers of those varieties occurred when the soil reaction was changing from light acid to neutral. The increase of available P_2O_5 in soil by 1 mg/100 g of soil in the range from 10.5 to 17.1 mg, resulted in the increase of the amount of this component only in tubers of the very early varieties. The increase of available K_2O in soil by one unit, in the range from 12,1 to 14,1 mg/100 g of soil, resulted in the increase of the amount of this element in tubers of the very early to middle early varieties (Table 4). Extension of vegetation period of those varieties, in the range from 103 to 151 days, resulted in the increase of dry mass content in tubers of the early to late varieties. Except the early varieties, a determination coefficient of the arrangement of equations presented in Table 4, compelled with a 60 % level postulated by Kranz and Royle [2].

The rise in the air temperature in the period May-June, in the range of a standard deviation from the arithmetic mean, resulted in the decrease of starch content in tubers of the early varieties, whereas, in the period July-August, it resulted in the decrease of starch content in tubers of the very early and middle early to late varieties (Table 5). Also, the rainfalls of the period May-June, in the range of a standard deviation from the arithmetic mean, negatively affected that feature in all the earliness groups of the tested varieties. The rainfalls of the period July-August, in the range from 27 to 125 mm, negatively affected the starch concentration in tubers of the very early

Table 4. Influence of weather factors and soil quality on the content of dry matter in potato tubers in %

Terms of regression equation	Unit	Value of coefficients of regression				
		Degree of varieties earliness				
		Very early	Early	Middle early	Middle late	Late
Constant regression		8.819	35.147	-135.190	-14.534	-143.837
		Independent variables				
Temperature of air V-VI	1 °C	-	-	-	-0.747	-
Temperature of air VII-VIII	1 °C	0.028	1.235	0.367	-	2.264
Sum of rainfalls V-VI	10 mm	0.007	-	-0.189	-0.041	-0.132
Sum of rainfalls VII-VIII	10 mm	0.082	-	0.380	-	-0.259
Insolation V-VI	10 h	0.032	-	-	-	-
Insolation VII-VIII	10 h	2.260	-	0.293	-	0.294
Soil acidity pH	1 pH	-	0.200	-	0.077	-
Content P_2O_5	1 mg/100 g	-	0.233	-	-	-
Content K_2O	1 mg/100 g	0.005	0.201	0.122	-	-0.295
Length of vegetation	1 day	-	0.076	0.011	0.001	0.086
Determination coefficient	%	57.3	36.7	57.3	62.4	69.3

The lack of data stands for the insignificance of regression coefficient at the level α=0.05.

the influence of heavier rainfalls in the periods May-June and July-August and increased sunshine time of the July-August period. Changes in the soil reaction from light acid to neutral resulted in the increase of content of sum of sugars in tubers of the very early, early and middle early varieties. A higher content of available P_2O_5 in soil did not differ the sum of sugars in tubers whereas, a higher content of available K_2O in soil resulted in the increase of this content in tubers of all the earliness groups. Extension of the potato vegetation period by unit, in the range of 103-151 days, resulted in a higher concentration of sum of sugars in tubers of all varieties. The low determination coefficient for the arrangement of equations presented in Table 6, may be a result of the weather factors influence, especially of the air and soil temperatures in the period right before the harvest.

The rise in the air temperature in the period May-June had a positive effect on the accumulation of vitamin C in tubers of the early and middle late varieties, whereas, the rise in the temperature in the period July-August, resulted in the decrease of vitamin C content in tubers of all varieties, except the middle late ones (Table 7). Heavier rainfalls from May to June, did not affect significantly the vitamin C concentration in potato tubers. The increase of rainfalls in the period July-August resulted in the decrease of vitamin C concentration in tubers. Change of the soil pH from 5.6 to 6.6 usually caused a decrease in vitamin C concentration in tubers, whereas, the increase in the content of available K_2O in soil resulted in the increase of vitamin C content in tubers of the very early, middle early and of late varieties. The extension of the plant vegetation period resulted in the increase of vitamin C concentration in tubers of all the earliness groups of potato varieties. Also in this case, the determination coefficients for this feature of tubers appeared to be generally low (14.3-42.7 %), which leads to the presumption that the vitamin C content in potato tubers may be affected by yet other weather factors not included in the function model.

DISCUSSION

The studies show that, among all the weather factors, the air temperature in the period July-August had the strongest effect on the content of dry mass, starch, sum of sugars and of vitamin C in tubers. The rise in the temperature in that period stimulated the accumulation of dry mass in potato tubers. Similar conclusions were drawn by

Table 7. Influence of weather factors and soil quality on the content of witamin C in potato tubers in mg %

Terms of regression equation	Unit	Value of coefficients of regression				
		Degree of varieties earliness				
		Very early	Early	Middle early	Middle late	Late
Constant regression		68.73	23.581	72.421	-45.893	118.697
		Independent variables				
Temperature of air V-VI	1 °C	-	0.404	-	1.884	-
Temperature of air VII-VIII	1 °C	-0.264	-0.767	-1.127	-	-3.264
Sum of rainfalls V-VI	10 mm	-0.119	-	0.233	0.064	0.374
Sum of rainfalls VII-VIII	10 mm	-0.023	-	-0.200	-	-0.362
Insolation VII-VIII	10 h	-	-	-	-	-0.369
Soil acidity pH	1 pH	0.379	-0.112	-0.022	-0.108	-
Content P_2O_5	1 mg/100 g	-	0.111	-	-	-
Content K_2O	1 mg/100 g	0.018	-	0.308	-	0.618
Length of vegetation	1 day	0.221	0.118	0.008	0.007	0.168
Determination coefficient	%	14.3	16.5	36.0	33.7	42.7

The lack of data stands for the insignificance of regression coefficient at the level α=0.05.

Zagórska [12], who states that during warm years with regular rainfalls, the content of dry mass is higher. Also, Simonds [8] confirms dependencies between maturation time and dry mass content.

The starch content specific for a genotype can be determined, according to Somorowska [9], by the end of April (after 60 time units). Then it is formed according to a negative correlation with the soil moisture. This study shows that the starch content is also formed by temperature and sunshine of the period July-August and by the length of vegetation period. Krauss and Marschner [3] testify the negative effects of the air temperature on the starch content. They observed that high temperature reduced the starch content and the activity of enzymes metabolizing starch but does not affect the incorporation of assimilative substances into a sugar fraction. It shows that, by stopping the change of sugars into starch, the high temperature results in the decrease in the starch content.

The most important soluble sugars are saccharose and reducing sugars. The latter ones can result in bronzing in the production of French fries and chips [9,12]. Their contents, however, are very liable and depend on many factors. The state of balance: reducing sugars - saccharose - starch, changes during vegetation period [9,12]. Somorowska [9] proved that the highest amount of reducing sugars occurs in the first period of tubers growth (before blooming) and then their content rapidly decreases. A high level of saccharose is found in the youngest tubers. It reaches maximum at the peak of blooming and then slowly decreases. Zagorska [12] notices that during warm years with regular rainfalls, the sugar content is lower than in the years with lower temperatures and excessive rainfalls, especially during the final vegetation. She considers the temperature of 45 °C, which results in the increase in sugar content several times, to be critical.

Mazurczyk's and Somorowska's [5,9] studies testify to a strong effect of environment on vitamin C content and lower on varietal features. They suggest that a low repeatedness of vitamin C content may be connected with excessive moisture or draught of the soil during the vegetation period. Also, Leja [4] notices that an excess of water during vegetation period results in irreversible changes of the cell membrane lipids' composition. The changes are similar to those which occur in physiologically 'old' tubers. The accumulation of sugars and the cell penetrability rises and electrolytes and nutrients contained in them leak into the tubers' environment. Somorowska [8] proved that vitamin C content undergoes large oscillations - at first it reaches its maximum (between the 50th and 70th days) and then it decreases. The decrease in the vitamin C content in tubers is caused, in her opinion, by ageing of the aboveground parts which could explain different reactions of varieties of different earliness groups.

As for the soil factors, the content of available potassium and the soil acidity seem to have stronger effects on the tubers' quality than the content of available phosphorus in soil. It is not, however, a distinct or significant effect in every case.

CONCLUSIONS

1. Dry mass of tubers appeared to be the most stable feature of potato chemical composition, with an average coefficient V=16.3 %, whereas, the concentration of witamin C was the least stable, average coefficient V=41.2 %.

2. The determination coefficients of the equation arrangements analysed were usually low except that for tubers dry mass which, on the background of different effects of weather and soil factors, allow us to assure that the contents of starch, sum of sugars and vitamin C one affected by yet other factors not considered in the function models appeared in this study.

3. The rise in the air temperature and the extension of the sunshine time in the period July-August were the most favourable factors affecting increase in potato tubers dry mass.

4. The applied model of multifactorial regression analyses to determine dependences

between selected qualitative features of potato tubers and some weather factors of arable field, appeared to be the most suitable for the evaluation of dry mass of potato tubers. The model fulfilled the determination level suggested by many authors [2,7,8].

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FLUKTUACJA SKŁADU CHEMICZNEGO BULW ZIEMNIAKA W ZMIENNYCH WARUNKACH POLA UPRAWNEGO

Analizę wyników oparto na doświadczeniu polowym, przeprowadzonym w latach 1990-1992 w Parczewie na glebie bielicowej o składzie piasku gliniastego lekkiego. Obliczając wspólczynniki korelacji prostej, a następnie regresji przeanalizowano wpływ wybranych elementów meteorologicznych na zawartość suchej masy, skrobi, sumy cukrów oraz witaminy C w bulwach 37 odmian ziemniaka. Stwierdzono, że warunki meteorologiczne wywierają większy wpływ na skład chemiczny bulw niż cechy genetyczne badanych odmian. Podwyższenie temperatury okresu lipiec-sierpień wywoływało wzrost zawartości w bulwach suchej masy, sumy cukrów, a spadek zawartości skrobi oraz witaminy C. Zasobność gleby w przyswajalny fosfor i potas jak i jej kwasowość nie wywierały wyraźnego ukierunkowanego wpływu na cechy jakości bulw.

S ł o w a k l u c z o w e: ziemniak, skład chemiczny, odmiany, opady, temperatura.