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EFFECT OF CLIMATIC AND SOIL FACTORS ON MINERAL COMPOSITION OF VEGETABLES

II. EFFECT OF CLIMATIC AND SOIL FACTORS ON THE CONTENTS OF MACROELEMENTS IN VEGETABLES

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Key words: cabbage, carrots beets, onions, mineral composition, climatic factors, soil factors

The volume of dry matter, ash, total N, Ca, P, Na, K and Mg in samples of cabbage, carrots, beets and onions from four different horticultural regions and from three consecutive years was statistically appraised as to significance of differences and of interdependencies between the content of the above in vegetables and in the soil the tested produce had been cultivated in. Another factor was the soil reaction. Additionally, effect of the following parameters of climate were analyzed: temperature, precipitation and sunlight.

As very already reported [1], the chemical composition variability in plants is influenced not only by genetic and species characteristics but also by the climate and soil factors, although this is not as pronounced as the former. Effect of environmental factors is relatively little known, particularly as regards cultivation of vegetables.

The content and form of majority of mineral elements in a plant is related, among other things, to availability of these in the soil, which in turn, depends on the category and properties of it, as for example, acidity as well as quantity and type of fertilizers which are used on an ever--increasing scale. Fertilizing results in increase of the content of mineral elements in plants since these components are first introduced into the soil as ingredients of the artificial fertilizers [2, 3, 6, 9, 12, 14, 16, 17, 18]. The plants react most vigorously to potassium fertilizing: they are able to take in potassium in quantities excessive of their needs [2].

Hulewicz et al. [9], Kołota [12, 13] and Nurzyński [16] as well as

Perednev [17] observed that fertilizing vegetables with increasing doses of potassium always led to an essential growth of the content of this element in tested vegetables (often the increase was four or five-fold) both in the roots and in parts above the ground.

Interaction between particular components is less well-known. Results of investigations in this regard are often controversial. Thus, it seems that form and quantity of nitrogen in plants depend on contents of assimilable phosphorus and potassium in soil. Perednev [17] observed a drop in total N in carrots and beets in effect of fertilizing with phosphorus and potassium. In turn, increased fertilizing with nitrogen leads to a drop in phosphorus content in vegetables [9, 12]. Fertilizing with strong doses of nitrogen and phosphorus seems to have a positive effect on assimilation of magnesium by plants [8]. Excessive intake of potassium is at the same time linked with a decrease in the content of other minerals: Ca, Na, Mg [4, 8, 9, 10, 16, 20]. The interdependencies between calcium and sodium contents, strongly related to types and species of plants, and other mineral components have not been sufficiently analyzed [4, 8, 9].

Only a handful of studies are concerned with effects of climate on contents of minerals in plants. Most pronouncedly dependent in this regard is the content of potassium. More potassium was found in plants during warm years characterized by moderate precipitation than during wet and cold ones [11, 12, 13, 17]. Throughout dry years more nitrogen was also recorded [12, 17] while decreased precipitation caused plants to assimilate less phosphorus [12].

The aim of the present studies was to define the significance of differences and interdependencies between contents of certain macro-elements in vegetables and soils as well as to report on effects of temperature, precipitation and exposition to sunlight on these contents.

MATERIALS AND METHODS

Origins of the analytical materials and methodology of determinations for plant materials were given in Part I of the present study [1].

Soil samples were collected according to methods typical of the soil analytic work which secure collection of representative materials for the average sample [5]. The routine methods used in Poland [15] were applied to determine forms of mineral elements that are assimilated by plants.

METHODS OF THE STATISTICAL APPRAISAL OF RESULTS

The obtained results were subjected to a statistical analysis by means of methods commonly used for this purpose in experimental agriculture [7, 19].

Significance of differences between results obtained for the investigated regions and years was appraised on the basis of the non-parametric interval test.

The multiple regression analysis was also used to evaluate the interdependencies between the contents of the components in soil and in vegetables. Due to the fact that contents of assimilable forms of majority of mineral elements more or less depend on soil acidification a third variable — pH — was introduced. This made it possible, on the one hand, to observe the effects of content of a given component in soil on its content in a vegetable at a constant soil pH (b_1), and on the other, to see the effect of soil pH on the content of a given component in a vegetable assuming that its contents in the soil is constant (b_2).

RESULTS AND DISCUSSION

Results obtained from the individual regions and years of analysis (mean average values and ranges of fluctuations within the determined components) are presented graphically (Fig. 1, 2, 3, 4).

The comparison of the contents of the determined components in the analyzed vegetables from different regions was carried out in the following way; every single region was regarded as 100 and then was treated as a reference point against which data from other regions were compared. Similar operations were made in the course of comparing the results obtained between the particular years of analysis.

Examination of the averages for all three years put together showed that 46 inter-regional dependencies (out of total 147 considered), that is, about 1/3 of all, turned out to be statistically significant, and 26 of that figure reached the level of very high significance.

Potassium was the most differentiated component in the light of the statistical inter-regional analysis: ca 25% of all the statistically proved differences concerned this component and almost all appeared to be of very high significance. The least level of differences — four (ca 10%) — related to calcium. When comparisons were made as to calcium it was observed that in many cases the comparative data showed considerable deviations from the figure of 100. The statistical assessment of these great differences may point to their occasional and incidental nature. Similarly, considerable differentiation in sodium content in beets was not confirmed by the statistical evaluation.

On the other hand, small differences between average contents of magnesium as well as a limited range in the contents of this element (between minimum and maximum) were confirmed by the statistical analysis: only a few of the investigated values reached levels of statistical significance.

A considerable convergence of the levels of ash content in samples

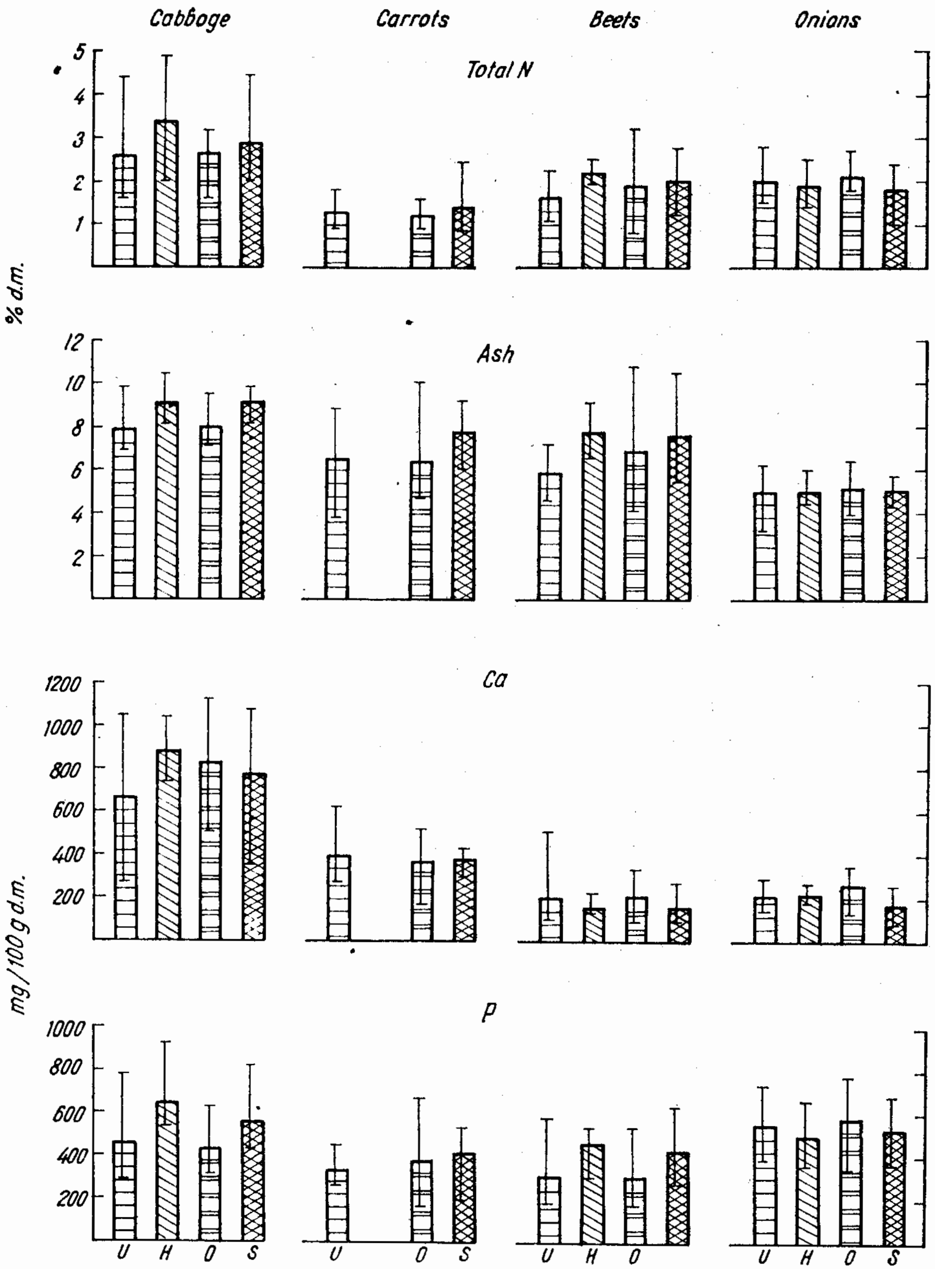

Fig. 1. The contents of total N, ash, Ca and P in vegetables (dry substance) from different regions (average for 3 years). Explanations: U — Ursynów, P — Powsin, H — Henryków, O — Ożarów, S — Siedlce. Vertical lines on the tops of pillarets are indicating the range of oscillations (spread).

of onions from particular regions and years is also quite characteristic: nearly all of the compared values oscillate around 100, and none of the differences was statistically significant.

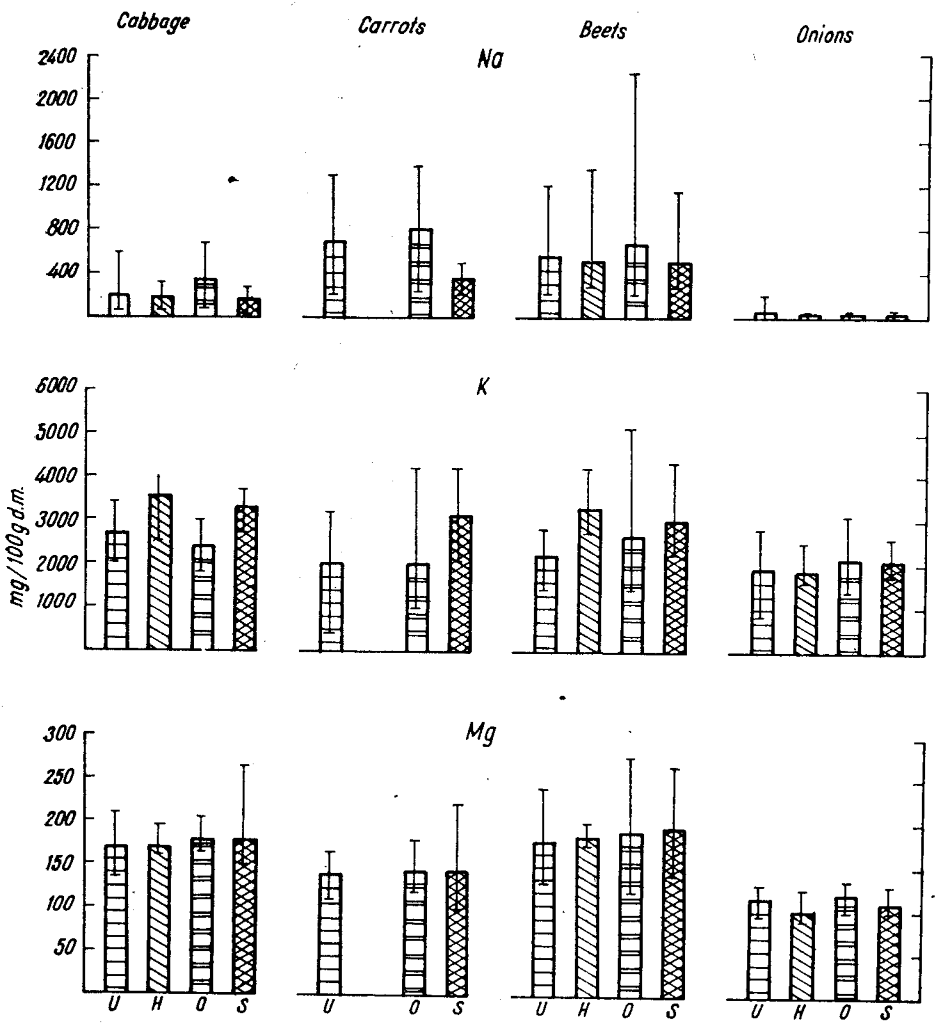

Fig. 2. The contents of Na, K and Mg in vegetables (dry substance) from different regions (average for 3 years). For explanations see Fig. 1.

As far as particular vegetables are concerned, cabbage showed the highest variability of its chemical composition. About 40% statistically confirmed differences concerned this vegetable and they were very significant statistically. The lowest variability was found in carrots — ca. 10% of the compared values were statistically confirmed.

It is difficult to clearly point out the region supplying vegetables richest in the analyzed elements yet some tendencies can be observed. Samples of cabbage, carrots, and beets from Ursynów region showed generally the lowest levels of most of the tested elements. As regards total nitrogen, ash, Ca, P and K the significance of differences was notable

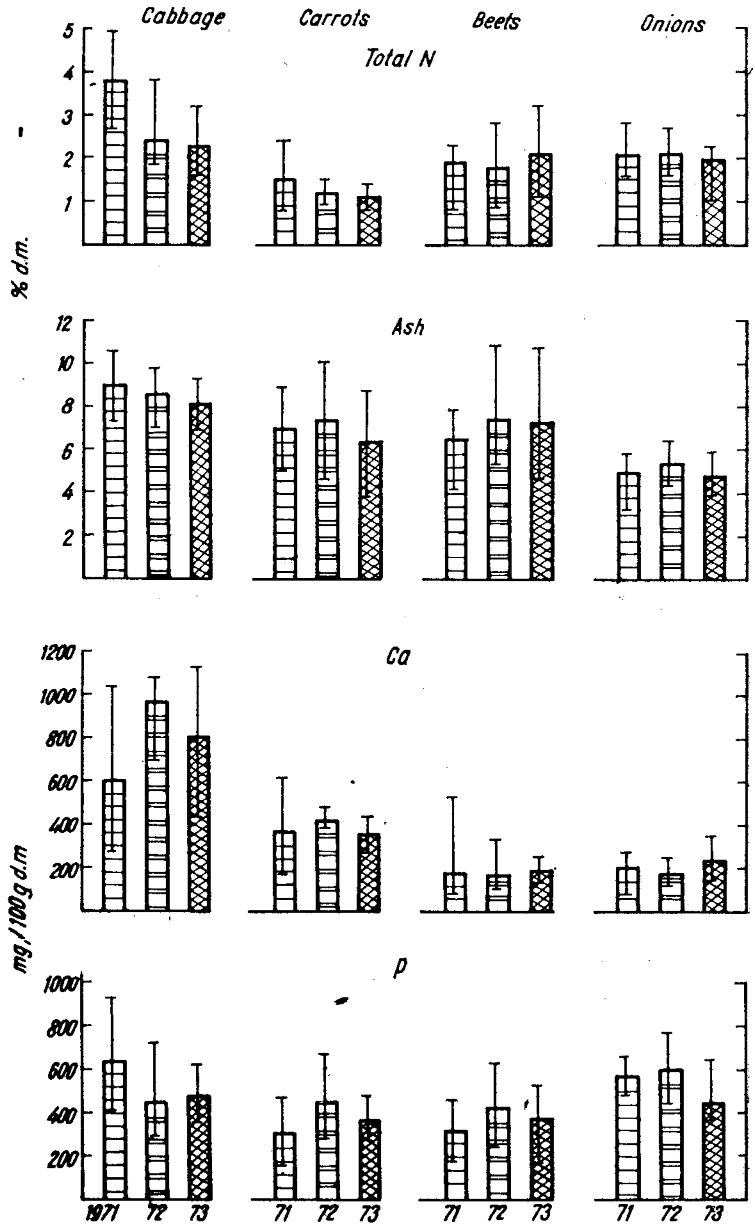

Fig. 3. The contents of total N, ash, Ca and P in examinated vegetables in different years (average from 4 regions). Explanations: 71, 72 and 73 may be understand as the years 1971, 1972 and 1973. Vertical lines on the tops of pillarets are indicating the range of oscillations (spread).

when regions of Henryków and Ursynów were compared. Whereever the differences became significant there the Henryków vegetables were richer in the elements by ca 30 to 40⁰/₀. On the other hand, the Ursynów onions contained a much higher level of the minerals.

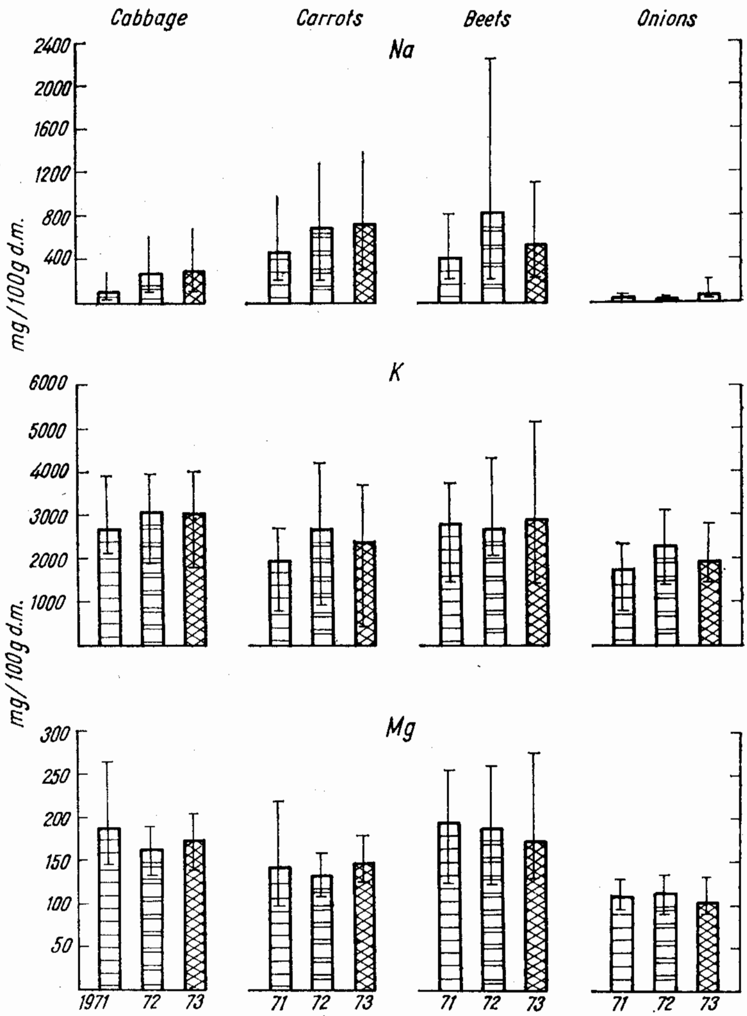

Fig. 4. The contents of Na, K, Mg and Fe in examinated vegetables in different years (average for 4 regions). For explanations see Fig. 3.

When comparing the contents of the determined elements between the years it was observed that deviations from 100 were running in the opposite direction. Increasing or decreasing tendencies appeared rarely, similarly as was frequently observed in the comparison of the regions.

The mean averages for all four regions consisted for a total of 84 dependencies between particular years of analysis. Out of this figure thirty two values were statistically confirmed (with 21 reaching the level of high significance).

The least stable components were total N, P and Ca (it is worth noting that Ca was also very poorly differentiated from region to region). The lowest statistically significant differences in periodic comparisons were found in ash and potassium (in the regional comparison these components showed the highest level of such differences).

As to particular vegetables, the highest chemical composition variability over individual years was found in cabbage (similarly as in the inter-regional comparison). Onions, on the other hand, differed insignificantly from region to region but was much more differentiated during particular years of analysis. The statistically least significant differences were observed in beet samples. Analysis of soils revealed a very wide range of contents of the investigated components, both spatially and temporally. Most of the maximum values were ca 2.5 times higher than the minima but there were also values 10 to 30 times higher. This points to a very distinct and high variability of the contents of the elements in soils, even from a single region. In spite of these very wide differences as to the contents of mineral components in the analyzed soils it became clear that within the inter-regional comparison only 1/4 of the compared values were statistically significant while the comparison of the soil richness from year to year showed that only about 10% of the observed differences were statistically significant.

The richest in the minerals were the Ożarów black soils while those from the Ożarów region had, in most cases, the lowest levels of the minerals. The lowest contents of some of the elements in samples of vegetables from Ursynów, as was mentioned earlier, is linked to the lowest levels of these components in the soil from the area. The Ożarów vegetables, however, did not show any higher contents of the minerals. This may be due to somewhat lower acidity of soils from the region (by 0.5), that is, one pH unit) *) The relatively smallest differentiation between soils from each region was noted for nitrates, phosphorus and potassium, that is, those components which are fed into soil with the most commonly used mineral fertilizers.

Comparison of the contents of the determined elements in vegetables with that in soils and with the soil pH by means of multiple regression revealed that in several cases this kind of inter-dependence was statistically confirmed. Out of 24 coefficients of regression of a given component in a vegetable to its contents in soil eight were statistically significant, while in the same number of regression coefficients for a given element in a vegetable to soil pH values only three turned out to be statistically significant (See Table).

Coefficient b_1 was statistically significant for potassium in all vegetables, for phosphorus — in cabbage, carrots and beets, and for nitrogen — in beets. Increase of potassium level by 1 m in 1 l soil led to a relatively

*) Soils from the region of Ożarów showed the pH value approaching 7, which is related, among other things, to a higher level of base-forming elements (Ca, Na and Mg). Soils from the other regions had their pH values lower by one half of the pH unit (0.5).

Table. Relations of multiple regression coefficients of contents of the analyzed components in the investigated vegetables: to their levels in soil (b_1)[1], to pH value (b_2)[2]; statistic evaluation (I.S.)[3]

Component	Cabbage				Carrots				Beets				Onions			
	b_1		b_2		b_1		b_2		b_1		b_2		b_1		b_2	
	value	I.S.	value	I.S.	value	I.S.	value	I.S.	value	I.S.	value	I.S.	value	I.S.	value	I.S.
N[4]	2.1	—	−218.3	—	−1.6	—	−60.5	—	9.1	× ×	−18.6	—	−3.0	—	−56.0	—
Ca	0.0	—	129.0	× ×	0.0	—	−47.0	—	0.0	—	−17.9	—	0.0	—	16.4	—
P	1.4	× ×	−54.5	—	1.1	× ×	−36.3	—	0.9	× ×	−57.6	—	0.1	—	−44.8	—
Na	0.0	—	109.2	×	0.1	—	279.2	—	0.2	—	155.8	—	0.0	—	53.3	—
K	2.8	×	−151.2	—	5.9	× ×	−730.2	× ×	6.3	× ×	2.8	—	1.9	× ×	−126.4	—
Mg	0.0	—	−2.2	—	0.0	—	0.2	—	0.1	—	−11.7	—	0.1	—	−5.1	—

[1] $b_1 = b_{y_{1.2}}$ stands for the increase of a given component in 100 g d.s. vegetables (Y), which accompanies the increase of content of this component in soil by 1 mg per liter (X_1) at soil pH value kept constant (X_2) within specified limits X_1 and X_2

[2] $b_2 = b_{y_{2.1}}$ stands for the increase of a given component in 100 g d. s. vegetables (Y), which accompanies the increase of soil pH by one unit (X_2) at constant level of the component in soil (X_1) within specified limits X_1 and X_2

[3] I.S. = statistical significance of the determined regression coefficients: xx — highly significant, x — significant, — — lack of significance

[4] N in vegetables as N_{total}, in soil as NO_3^-

fast rise of its level in vegetables — ca 2-6 mg/100 g dry matter. The contents of potassium in dry matter of the analyzed vegetables was about 2-3% on the average, with fluctuations to 5%, while in soils it was 100-200 mg/l soil, at maximum 600 mg per 1 liter of soil.

The regression coefficients for phosphorus reached levels between ca 0.9 mg (carrots, beets) and 1.4 mg (cabbage) of increase in 100 g dry substance of vegetables per 1 mg assimilable form of the given component in 1 liter soil; the average contents of P in vegetables was 400 to 600 mg/100 g dry matter and in the soils there was an average of 80 to 120 mg of the element in 1 liter soil.

The relatively high value of the regression coefficient for nitrogen in beets — ca 9 mg/100 g d.m. — can have a practical significance.

Effect of the soil pH on the contents of the investigated minerals in vegetables (b_2) was marked only in the cases of calcium and sodium in cabbage as well as potassium in carrots. Increase of pH in soils by one unit within the present range of 4.3 to 7.3 the contents of Ca and Na in cabbage increased by more than 100 mg per 100 g d.s. while in carrots the content of K dropped all the way to 730 mg/100 g d.m. of the vegetable.

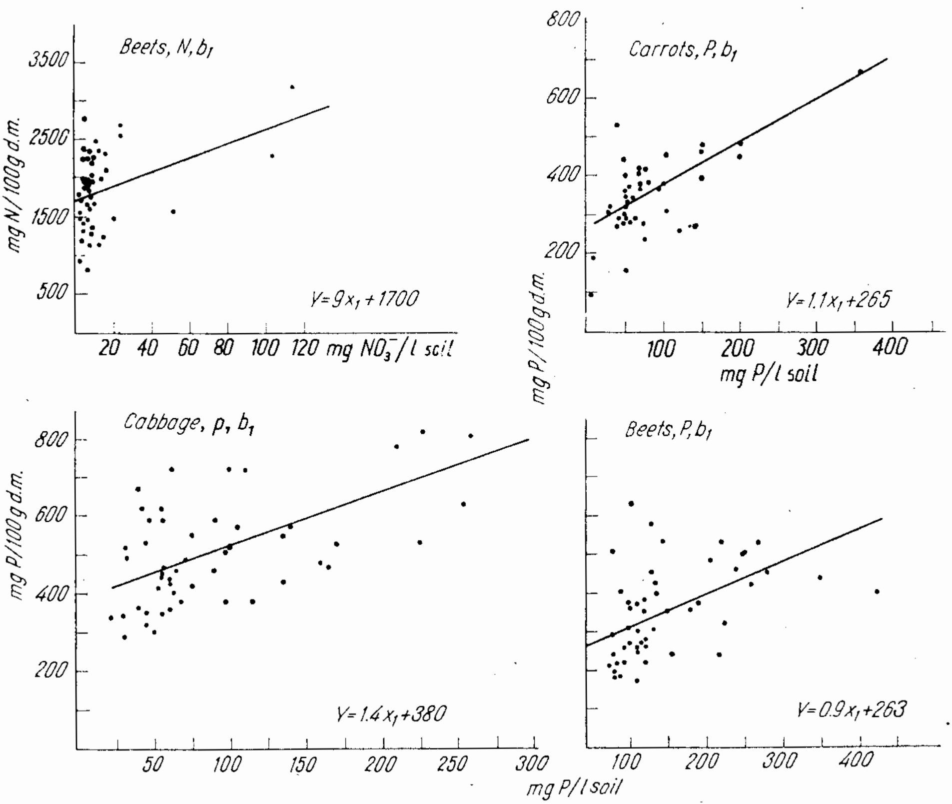

Fig. 5

Lack of statistical significance for the two regression coefficients for magnesium could be due to, among other things, to a relatively smaller differentiation of the content of this component in the analyzed vegetable samples, both regionally and time-wise while its contents in the soils showed much greater differentiation.

On the basis of the obtained statistically significant coefficients an equation of linear regression was formed. It is presented graphically, with the introduction of particular results (Figs. 5, 6).

Effects of temperature, precipitation and sunlight intake on the content of minerals in the tested vegetables and soils were analyzed with the use of data made available by the Institute of Meteorology and Water Economy.

Mean average monthly temperatures were quite similar during all the three years of tests. Also the mean quarterly averages as well as semi-annual (for the months including the periods of vegetation) did not reveal any substantial differences as to regions and years. Thus, from the point of view of the interdependencies under consideration it is necessary

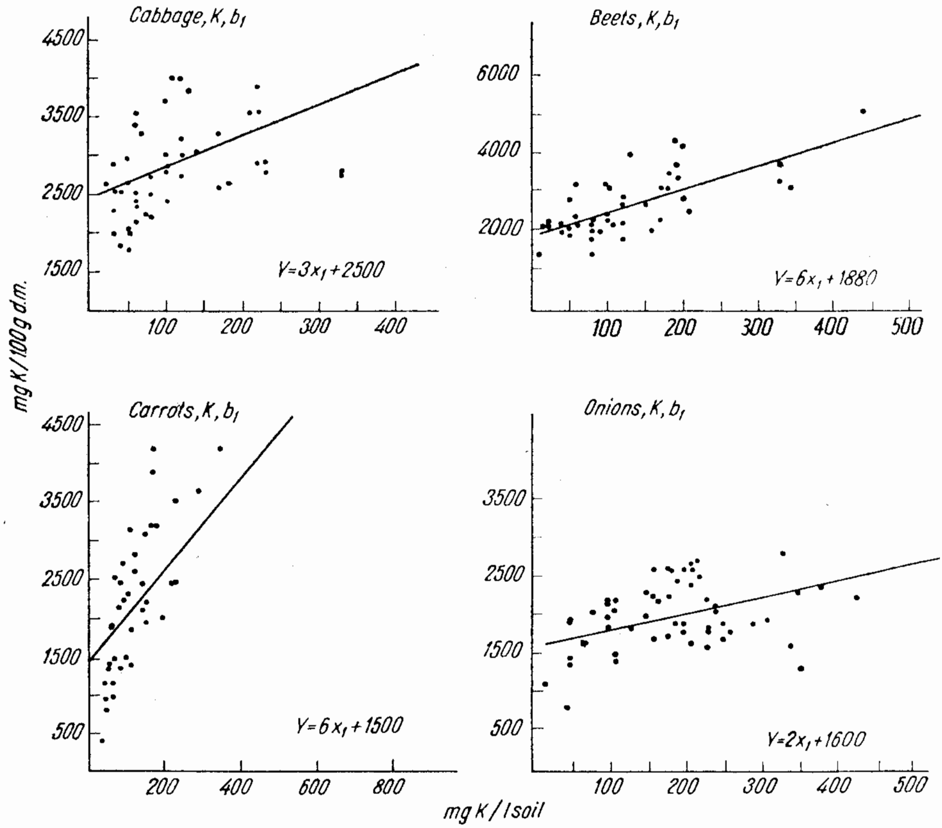

Fig. 5. The content's regression of a given constituent in the given vegetable (y) (dry substance) in relation to the content of this constituent in the soil (X_1), by exclusion of the pH variability.

to exclude temperature as a factor possibly influencing the differentiation in intake and retention of mineral elements by plants.

Totals on precipitation for 1971 and 1973 were about the same while 1972 was characterized by much higher levels. The precipitation totals were also approximately the same during the first half-year (January through June) for all the three years, and a clearly visible differentiation of the 1972 figures occurs only during August-November period, that is, during the time of intensive growth of the plant mass. In spite of that, a comparison of the contents of mineral elements in vegetables with the level of precipitation during particular years does not seem to point to any tangible dependence between the two factors.

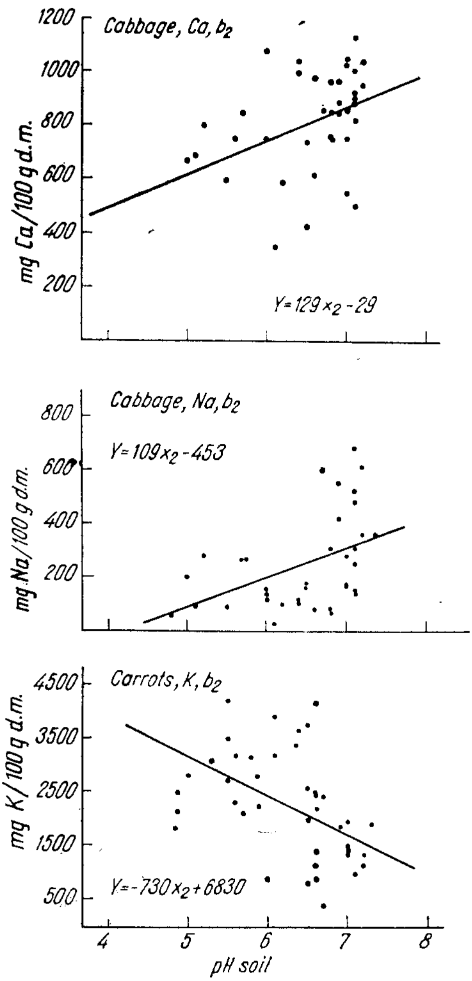

Fig. 6. The regression of the content of a given constituent in the given vegetable (y) (dry substance) in relation to the pH of the soil (X_2), by exclusion of the varliability of this constituent in the soil.

Intensity and displacement of sunlight intake in the analyzed regions during the years show a reverse arrangement in comparison with the totals on precipitation. It follows from this fact that it may be difficult to find any influence of this factor on the contents of mineral elements in the analyzed vegetables.

CONCLUSIONS

1. The differences found between the analyzed regions as regards particular components in the same kind of vegetables included ca 1/3 of the results to be statistically significant or even highly significant. The trend in these differences was, however, variable for particular components and vegetables. In general the lowest contents of the elements were observed in the vegetables from Ursynów while onions from the same region showed the highest levels of them.

2. The trend of changes in the differences between particular years was even less tangible; ca 1/4 of the results turned out to be statistically significant.

3. The calculated coefficients of multiple regression were used to prove that the contents of certain of the analyzed minerals in soils affected their contents in plants: for potassium the dependence was found in all vegetables, for phosphorus — in cabbage, carrots and beets, and for nitrogen — in beets.

4. The regression coefficients were also used to determine that in the case of three components there was an influence of soil on their contents in some of the vegetables: calcium and sodium (positive effect) and potassium (negative effect).

5. Weather conditions (temperature, precipitation and sunlight intake) showed no tangible effect upon the contents of the analyzed elements in plants or in soils.

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WPŁYW CZYNNIKÓW KLIMATYCZNO-GLEBOWYCH NA SKŁAD MINERALNY WARZYW. CZ. II. WPŁYW CZYNNIKÓW KLIMATYCZNO-GLEBOWYCH NA ZAWARTOŚĆ MAKROSKŁADNIKÓW W WARZYWACH

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S t r e s z c z e n i e

W czterech gatunkach warzyw tych samych odmian: kapuście, marchwi, burakach i cebuli pobieranych przez 3 kolejne lata (1971, 1972 i 1973) z 4 ogrodniczych rejonów b. woj. warszawskiego oznaczono zawartość suchej masy, popiołu, $N_{og.}$ oraz Ca, P, Na, K i Mg. W takiej samej ilości próbek gleb spod badanych upraw oznaczono natomiast pH, $N\text{-}NO_3^-$, Cl oraz wszyskie wymienione wyżej składniki mineralne.

Uzyskane wyniki poddano ocenie statystycznej pod względem istotności różnic w zawartościach badanych sładników pomiędzy poszczególnymi rejonami i latami oraz za pomocą metody regresji wielokrotnej analizowano, czy kwasowość gleby oraz zawartość w niej składników mineralnych mają wpływ na zawartość tych samych składników w warzywach.

Przy porównaniu międzyrejonowym 1/3 rozpatrywanych różnic znalazła potwierdzenie w ocenie statystycznej. Kierunek zmian tych wartości w poszczególnych rejonach i latach był jednak bardzo zmienny.

Zawartość niektórych składników mineralnych w glebach wpływała na ich zawartość w warzywach. W 3 przypadkach zaznaczył się również wpływ pH gleby.

Rozpatrywane warunki meteorologiczne (temperatura, opady i usłonecznienie), stosunkowo mało zróżnicowane w poszczególnych latach badań, nie wydają się mieć wpływu na zawartość suchej masy, popiołu i oznaczanych makroskładników mineralnych w warzywach.