Potassium contents in healthy and virus X infected potato plants at different developmental stages

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In the works on the interdependence of the development of virus diseases and the mineral economy in plants, two trends linked with each other can be seen. The first trend is represented by authors dealing with the question of the influence of different levels of anions and cations on virus multiplication. Investigating the influence of potassium on virus multiplication, Pound and Weathers [11] found that optimum doses for the growth and development of plants were also optimal for the development of the virus in the infected tobacco. Procenko and Smirnova [12] noted, that deficit of potassium caused a decrease of TMV concentration in the leaves of infected tobacco. Schultz [14] reports that high doses of potassium and nitrogen in the nutrient caused a comparatively weaker infection of potato plants with mosaic. Allington and Laird [1] found that increased doses of potassium stimulating plant growth decreased at the same time the TMV contents in tobacco leaves. Rębowska [13] investigating the influence of different doses of potassium on TMV multiplication in tomato plants, found that virus concentration is distinctly conditioned by the amount of potassium. The doses of potassium, optimal for the growth and development of plants, favoured maximal multiplication of TMV. On the other hand, potassium doses bigger than the optimum ones decreased considerably multiplication of this virus. Insolation and temperature, favouring growth, favoured also the development of virus. This problem was also studied by Bawden and Kassanis [2], Kendrick *et al.* [7].

Results of investigation of many authors seem to suggest that conditions favouring the development of the host-plant are also optimal for multiplication of the pathogenic factor [17].

Works concerning the other trend of research — the influence of virus infection upon the level of mineral components in infected plants — are comparatively less numerous. Kender and Smith [6] found that infection of strawberries with a virus complex brought a decrease in dry weight but the level of mineral components N, P, K in leaves and roots increased, as compared with healthy leaves and roots. Bergman and Boyle [3] report that virus infection influenced only to a small degree the contents of K, P, Ca, Mg, B but decreased — almost twice the level of Cu

and Zn in tomato plants. Wynd [16] and Wharton [15] found that virus diseases decreased Ca contents in plant tissues. Similar results were obtained by Rębowska [13] who found that the TMV infected potato plants took up less potassium and calcium than the healthy ones. According to Pojnar [10] the virus — infected potatoes, in their very early stage of development, take up potassium and phosphorus more intesively. This was especially clearly marked in an alkaline medium. Kozłowska [8] found that infection with viruses X, Y and leaf roll causes an increase of K_2O contents in the stems. According to Genkiel *et al.* [4] the leaves and stems of virus infected potatoes contain higher amounts of N and P.

MATERIAL AND METHODS

Ivestigations were carried out in the year 1966 at 3 experimental points in Polanowice and Bachledzki Wierch. In Polanowice the experimental fields were situated on two soils: loess and calcareous soil; on Bachledzki Wierch — on carpathian

Table 1

Soil analyses in the year 1966

No. Locality	Altitude	pH in KCl	Loam — humus compounds (weight percentage of soil)			Total nitrogen percentage of soil	Available (mg/100 g of soil)				Ca/Mg	C/N
			montmorillonite	kaolin	humus		P_2O_5	K_2O	CaO	Mg		
1. Polanowice (loess)	260	5.8	4.3	7.1	3.3	0.21	20.5	26.5	300.0	12.0	25.0	9.66
2. Polanowice (calcareous)	288	6.6	10.8	6.9	4.6	0.23	5.4	20.0	500.0	7.0	71.4	9.04
3. Bachledzki Wierch (mount. clay)	910	3.8	8.8	11.4	12.3	0.49	4.1	15.0	150.0	32.0	4.7	9.32

clay. The experimental points differed not only in the soil conditions but also in the height above sea level. Data concerning physico-chemical properties of soil are presented in Table 1. Full characteristics of the mentioned experimental points were given by Kozłowska *et al.* [8].

MATERIAL

The initial starting material were potato tubers of the variety Epoka, originating from Pomerania. They were planted on experimental fields in 1964. Sixty plants in the stage of 6 leaves were inoculated with the ring-spot strain of PVX, whereas a similar group of plants was left uninoculated for control. For the next successive

Table 2

Stages of development at which samples were taken for analyses

Localities	Date of planting	Health conditions	I. Before tuberisation			II. Flowering			III. Fruit setting			IV. End of vegetation			V. Harvest
			date	height of haulms (cm)	yield (dkg)	date	height of haulms (cm)	yield (dkg)	date	height of haulms (cm)	yield (dkg)	date	height of haulms (cm)	yield (dkg)	date
Polanowice loess	9.V	healthy	14.VI	18.5	—	6.VII	43.8	11.3	5.VIII	58.4	66.4	19.VIII	—	—	27.VIII
		virus X infected		28.4	—		34.0	16.3		42.3	31.8		—		
Polanowice calcareous	10.5	healthy	15.VI	17.0	—	7.VII	32.9	20.0	6.VIII	72.1	50.0	20.VIII	—	—	28.VIII
		virus X infected		19.6	—		37.7	46.1		75.5	28.7		—		
Bachledzki Wierch	17.V	healthy	26.VI	28.0	—	22.VII	37.5	74.2	24.VIII	50.2	41.0	7.IX	—	—	4.X
		virus X infected		28.2	—		35.4	42.3		49.6	31.5		—		

years — 1965 and 1966 — the tubers harvested separately from each plant, were reproduced. In 1966 during the whole vegetation period each plant was subjected to individual examination of development and its health conditions. Before the material was taken up for analysis an additional serological test for the presence of viruses X and S had been carried out both on healthy and PVX infected plants. On the basis of those investigations samples of healthy and virus X infected plants were taken up for analysis. It must be noted that plants taken for analysis did not show any symptoms indicating the presence of virus Y (streaks) or other viruses. They were sampled in four different developmental stages: (1) setting the flower buds (the beginning of tuberisation); (2) flowering; (3) at the end of flowering (fructification phase); (4) and in the phase when the top and middle leaves begun to decay. Additionally also the tubers, were analysed. The terms of colecting samples and the state of plants at the moment of sampling are presented in Table 2.

PREPARATION OF THE MATERIAL FOR ANALYSIS

Plants taken for analyses were divided into following parts: roots, subterranean stems, above-ground stems, leaf petiols and leaf blades. Leaves were additionally divided into 3 groups according to their position on the stem: (1) bottom leaves; (2) middle leaves; (3) top leaves.

Potassium content in the plant material was estimated by the photometric method according to Humphries [5], and calculated as percentage of dry weight.

RESULTS

POTASSIUM CONTENTS IN HEALTHY AND VIRUS X INFECTED POTATOES, IN RELATION TO SOIL AND CLIMATE

Soils on which the experiments were carried out differed in the contents of available potassium. The highest quantities of available potassium were present in the loess soil in Polanowice (26.5 mg per 100 g of soil). Physico-chemical properties of loess soil secured excellent conditions for raising potatoes. The uptake of potassium by plants grown on this soil was high. Particularly high quantities of potassium were found in stems of both, healthy and virus X infected potatoes. In the flowering stage, big differences in potassium contents appeared between the stems of healthy and infected plants. They reached 0.71% to the advantage of the diseased plants. Leaf petioles and top leaves of virus infected plants also showed an increase of potassium content but that increase was still lower than in stems. The remaining organs of infected plants contained lower or similar amounts of potassium as healty plants (Table 3).

In Polanowice, on calcareous soil, the uptake of potassium was weaker. This fact can be explained by smaller contents of that element in soil (20 mg K_2O per 100 g of soil) and partially by an antagonistic influence of calcium. A slight decrease in the content of potassium in plants grown on calcareous soil — as compared with those grown on loess — results from the fact that antagonistic influence of calcium is distinctly marked only when there is a deficit of potassium in the nutrient [9].

Table 3

K_2O content in healthy and virus X infected potatoes variety Epoka cultivated at Polanowice on the loess soil

Locality	Plant parts	Development stages				
		1	2	3	4	5
Polanowice loess healthy	top leaves	3.13	2.47	2.42	1.91	
	middle leaves	3.69	2.67	2.30	1.33	
	bottom leaves	3.88	2.98	1.32	1.18	
	petioles	8.41	8.61	7.25	3.09	
	stems	6.79	6.07	5.23	5.40	
	underground part of stems	4.95	4.45	2.81	2.16	
	roots	3.12	2.50	1.77	1.24	
	tubers	—	1.89	1.43	—	1.36
Polanowice loess virus X infected	top leaves	3.20	2.79	2.55	1.55	
	middle leaves	3.32	2.77	2.24	0.99	
	bottom leaves	3.64	2.31	1.78	1.06	
	petioles	8.16	9.32	6.31	3.69	
	stems	7.66	6.96	4.71	4.55	
	underground part of stems	4.73	3.09	2.42	2.02	
	roots	3.08	2.37	1.24	1.03	
	tubers	—	1.78	1.63	—	1.53

Table 4

K_2O content in healthy and virus X infected potatoes variety Epoka cultivated at Polanowice on the calcareous soil

Locality	Plant parts	Development stages				
		1	2	3	4	5
Polanowice calcareous healthy	top leaves	2.17	3.52	2.32	1.69	
	middle leaves	2.42	2.51	1.80	1.63	
	bottom leaves	2.41	2.03	1.40	0.97	
	petioles	5.48	7.04	6.70	4.29	
	stems	5.21	6.25	4.44	2.97	
	underground part of stems	3.12	2.46	2.25	1.92	
	roots	2.72	1.98	1.57	1.06	
	tubers	—	1.65	1.65	—	1.61
Polanowice calcareous virus X infected	top leaves	2.74	2.49	2.54	1.23	
	middle leaves	3.13	2.65	1.75	0.98	
	bottom leaves	3.22	2.28	1.46	0.94	
	petioles	6.62	7.63	4.72	3.08	
	stems	6.15	7.51	3.70	1.40	
	underground part of stems	3.47	3.26	1.98	1.68	
	roots	2.96	2.34	1.36	0.87	
	tubers	—	1.70	1.57	—	1.65

This decrease was most distincly marked in the above-ground parts of stems. After the flowering stage a decrease of potassium contents was found in all analysed parts of the diseased plants, as compared to the healthy ones. These differences were most distinct towards the end of vegetation. And, thus, for instance the content of potassium in the stems of diseased plants was twice as low as that of healthy plants (Table 4).

Despite the fact that carpathian clay in Bachledzki Wierch contained the lowest quantity of available potassium (15 mg K_2O per 100 g of soil), the plants grown on this soil showed a high content of potassium. This increase in potassium uptake was probably caused by climatic factors. Increased sum of rainfalls favourises the uptake of that compound, although its content in the soil is low. Rainfalls at Bachledzki Wierch are twice as big as those in Polanowice (Polanowice — 350.2 mm, Bachledzki Wierch — 626.1 mm). This difference was especially big in July and

Table 5

K_2O content in healthy and virus X infected potatoes variety Epoka cultivated at Bachledzki Wierch

Locality	Plant parts	Development stages				
		1	2	3	4	5
Bachledzki Wierch healthy	top leaves	2.63	3.07	2.26	1.75	
	middle leaves	2.91	3.48	3.05	2.63	
	bottom leaves	2.96	2.84	2.46	2.15	
	petioles	8.14	8.79	6.70	5.97	
	stems	7.53	6.99	3.09	2.54	
	underground part of stems	4.16	3.59	1.93	1.76	
	roots	2.66	1.91	1.10	0.90	
	tubers	—	1.98	1.55	—	1.74
Bachledzki Wierch virus X infected	top leaves	2.69	3.17	1.74	1.61	
	middle leaves	2.97	3.26	2.35	2.04	
	bottom leaves	3.12	3.12	2.15	1.99	
	petioles	8.81	8.91	8.50	6.88	
	stems	8.55	6.76	3.44	2.09	
	underground part of stems	4.14	4.05	2.02	2.25	
	roots	2.55	2.10	1.56	0.74	
	tubers	—	1.95	1.48	—	1.72

August. Climatic factors had undoubtely a modifying influence on the deposition of potassium in leaves. And thus the top leaves of plants raised in Bachledzki Wierch showed, trough the whole period of vegetation, a smaller content of potassium than the middle and bottom leaves. A similar relation appeared in Polanowice only prior to the flowering stage of plants. In the petioles the highest content of potassium was maintained in Bachledzki Wierch through the whole period of vegetation whereas in Polanowice it gradually decreased. This phenomenon may be also connected with the influence of climatic conditions (Table 5).

DISTRIBUTION OF POTASSIUM IN HEALTHY AND VIRUS X INFECTED POTATO PLANTS IN THE COURSE OF VEGETATION

Investigating the course of potassium uptake by potato plants during the whole period of their vegetation, one may find some regularities. Essentially, the content of potassium in in all analysed organs decreased gradually with time. The rate of uptake was similar to the rate of growth. Highest contents of potassium could be found at the beginning of tuberization and at the stage of flowering. Some differences appearing between the individual experimental points resulted from the modifying influence of the environmental conditions. On the background of changes in potassium content caused by the different age of plants there appear very characteristic differences in the distribution of this compound between healthy and virus X infected plants. In the phase of tuber formation as well as in the flowering stage, virus infected plants contained distinctly higher amounts of potassium in the stems and

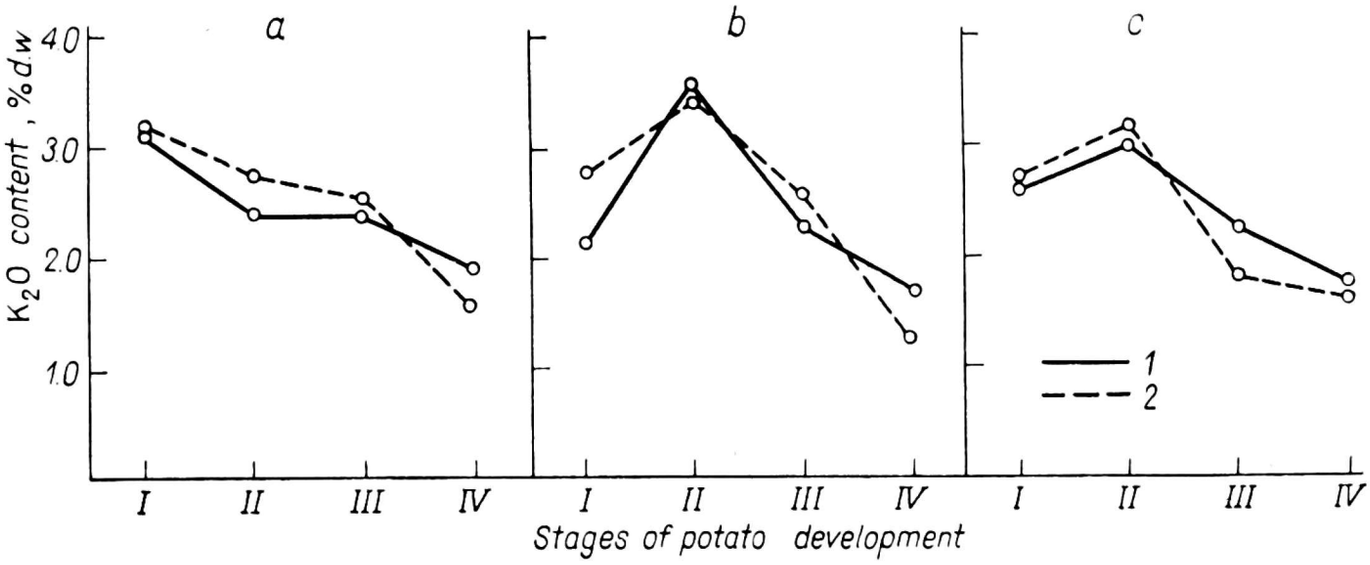

Fig. 1. Top leaves — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

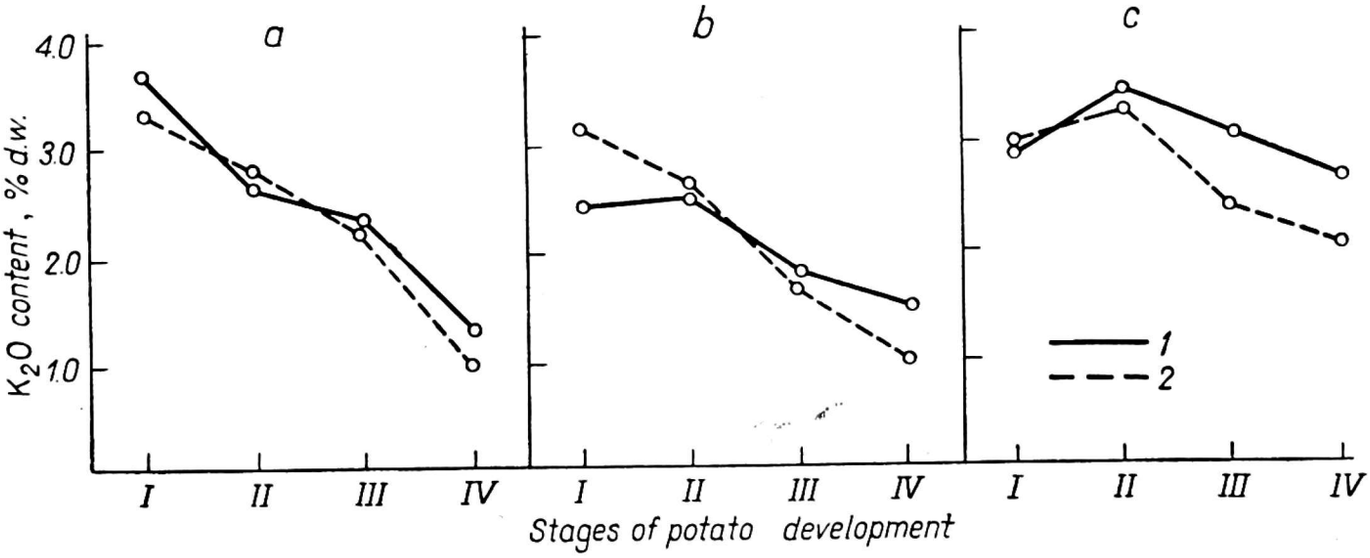

Fig. 2. Middle leaves — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

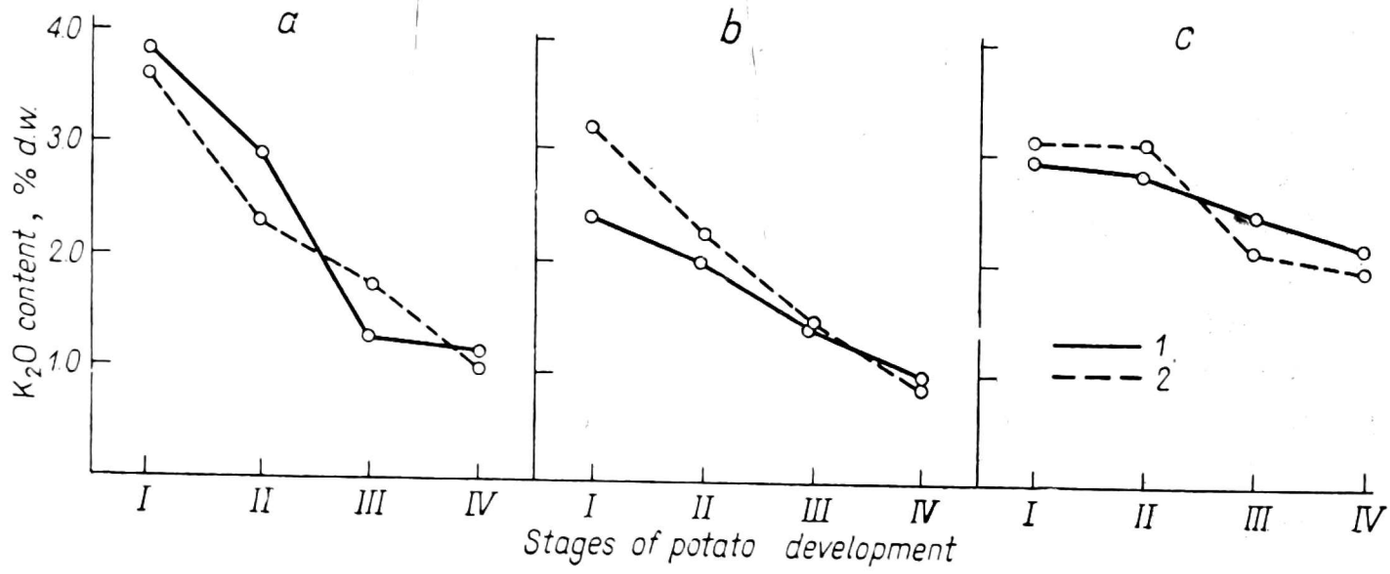

Fig. 3. Bottom leaves — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

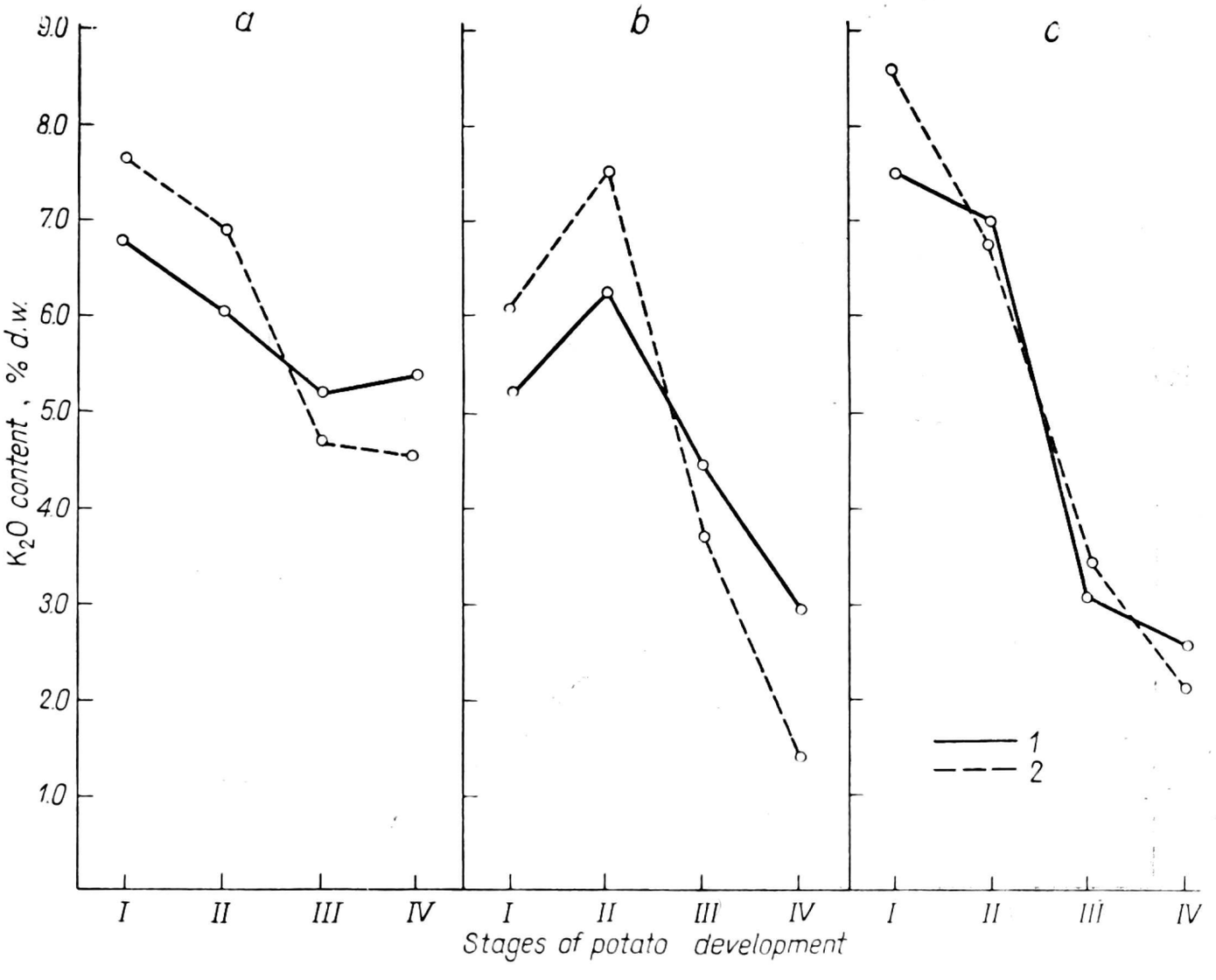

Fig. 4. Stems — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

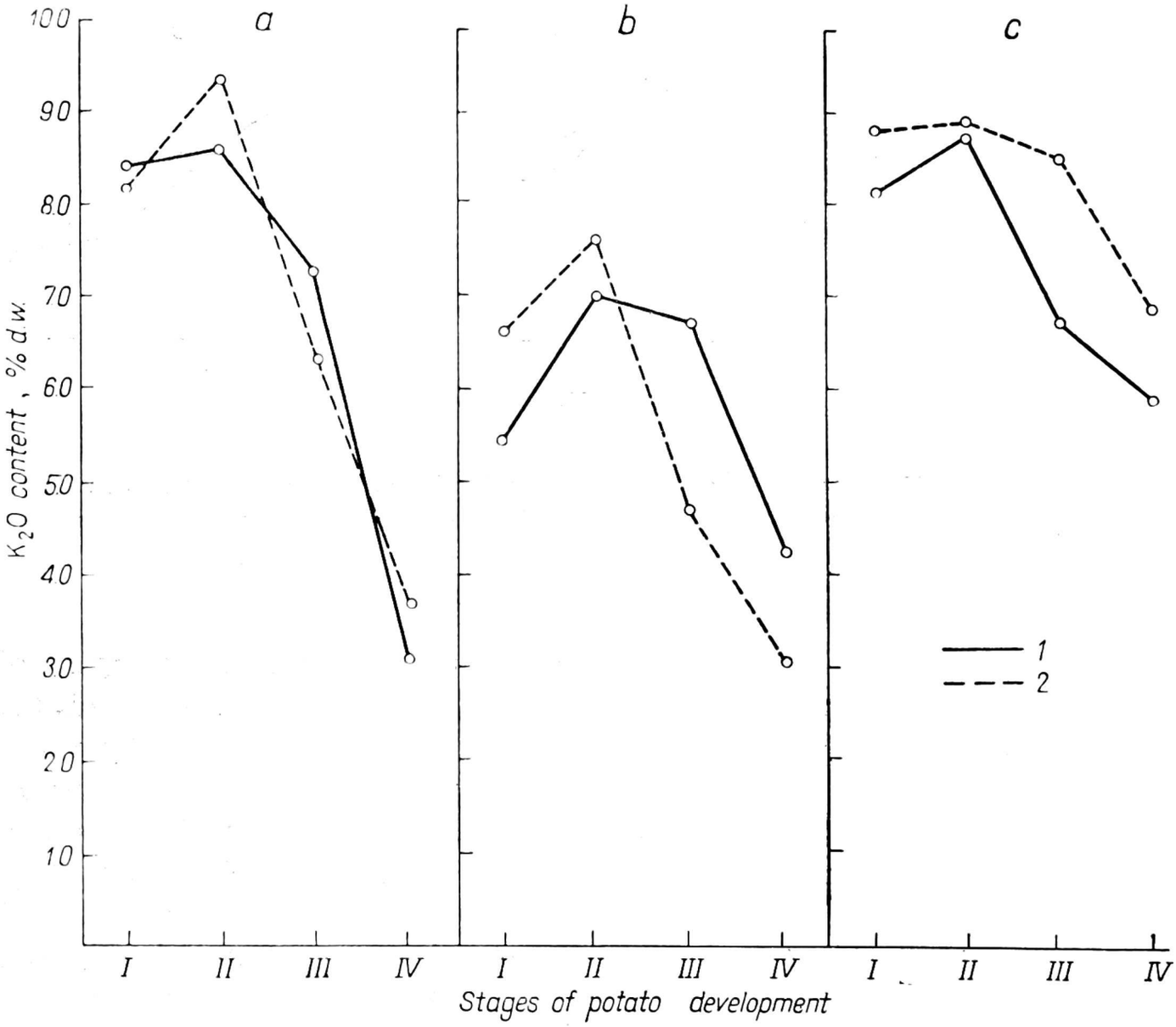

Fig. 5. Petioles — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

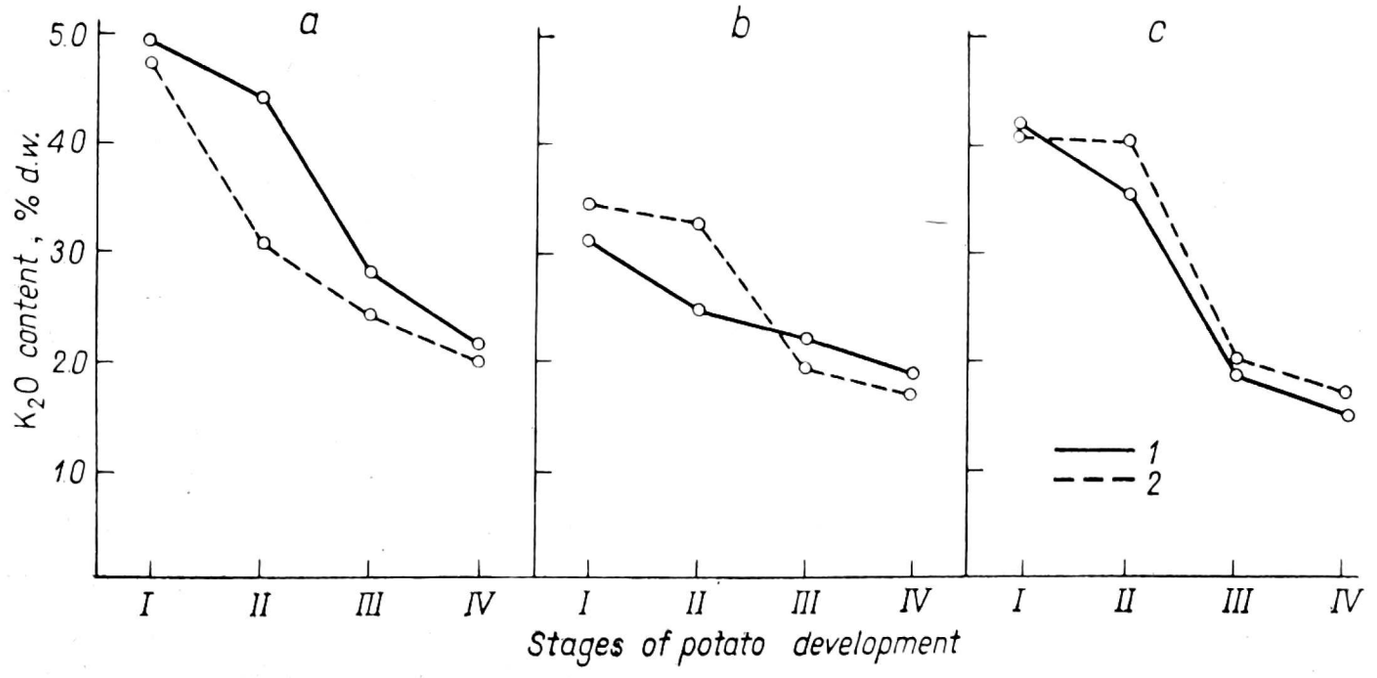

Fig. 6. Underground part of stem — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

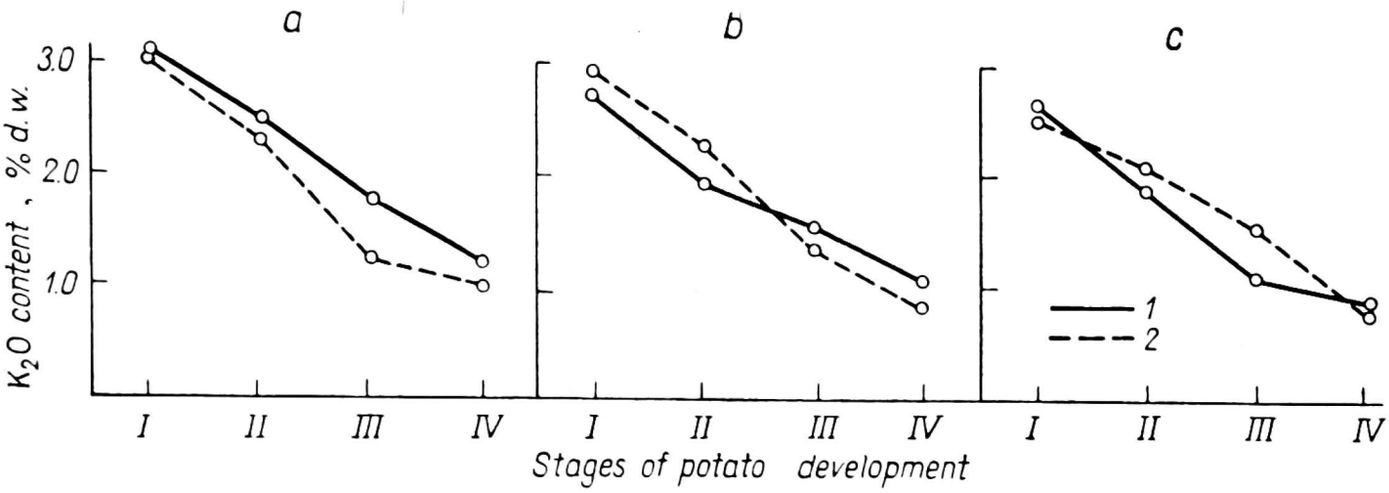

Fig. 7. Roots — K_2O content in different stage of development of healthy and virus X infected potatoes variety Epoka. *a* — Polanowice loess, *b* — Polanowice calcareous, *c* — Bachledzki Wierch; *1* — healthy, *2* — virus X infected.

petioles. After the flowering however the potassium content in those organs of healthy and diseased plants was levelled and it can be even said that towards the end of the vegetation period it could be found in bigger amounts in healthy plants. A similar decrease in potassium contents towards the end of the vegetation period occurred also in the middle and top leaves of the diseased plants whereas in the bottom leaves the content of potassium was similar to that in healthy plants (Fig. 1-7). Differences in potassium contents between the diseased and healthy plants occurred only in tubers derived from the loess soil. Tubers of virus X infected plants grown on that soil contained on an average 0.18% K_2O more than tubers of healthy plants.

SUMMARY

It was found that the uptake of potassium by the potato plants and the distribution of this compound in its organs depends on the stage of plants development. Highest quantities of potassium were found in plants at the stage of flowering; after which its content decreased in all parts of plant. Highest concentrations of potassium, exceeding sometimes 9% of the dry weight were found in the above-ground stems and in the petioles. On the contrary roots contain the least amounts of potassium.

Infection with virus X increses the potassium content of potatoes in initial stages of their development. Towards the end the vegetation period the level of this compound in diseased plants decreases, sometimes quite significantly. This might be perhaps connected with a more buoyant growth of virus infected plants in initial stages. Ecological factors favouring degeneration of potatoes and advancing the ageing of plants cause a distinct decrease of K_2O content in virus infected plants in later stages of development.

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