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Phosphorus Disturbances Associated with Potato Leafroll Virus Infection

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Abstract. Potato leafroll virus induces considerable disturbances of phosphorus metabolism in leafroll-infected potato plants. Each variety reacts differently in this respect on the infection, to some extent being dependent on the susceptibility of the respective variety to leafroll and to the season as well. In varieties particularly susceptible to leafroll as in Apta and Sieglinde there is a decrease of total P after infection On the contrary, varieties showing medium susceptibility such as varieties Tatranka, Rita and Ambra react to leafroll infection with a considerable increase of total P. In the comparatively less susceptible variety Krasava, there is no change in the level of total P after infection. In autumn, however, a slight decrease of total P even in the medium susceptible variety Tatranka, and the less susceptible variety, Krasava, can be found. Our results shed a new light on existing controversies in literature regarding phosphorus content in leafroll-infected potato plants.

When the changes in the contents of various phosphorus fractions in the infected plants are compared we can observe a tendency of lowmolecular fractions to rise. Among the different phosphorus fractions one common feature could be seen, except for the hypersensitive resistant variety Apta, namely, that the acid-soluble organic phosphates in the stems of all varieties examined, were considerably higher than in healthy stems.

Many papers have been devoted to the pathophysiology of potato leafroll-infected plants. Some older papers were summarized by ESMARCH (1932) in his monograph concerning potato leafroll virus. Recent results have been published in the comprehensive paper of VERHOEKS (1965).

References concerning the changes in phosphorus metabolism in connection with potato leafroll infection are scarce. HOVELAND *et al.* (1954) investigating the effect of mineral nutrition on the expression of potato leafroll virus symptoms found a distinct decrease of phosphorus in the leaves of infected plants grown in a greenhouse or field. These authors further proved that phosphorus deficiency produced symptoms ranging from slight to severe rolling of the leaves and from light to heavy anthocyanines formation as the amount of phosphorus decreased. Symptoms of extreme phosphorus deficiency in non-virus plants were similar to those produced by the virus. Hoveland carried out all experiments with potato plants, variety Chippewa.

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VERHOEKS's (1965) conclusion was, however, the opposite. He found a general increase of phosphorus content in diseased leaves as compared with that of healthy leaves. This author used in all his experiments material from potato plants, variety Alpha, grown in an experimental field and after having been infected in the previous year with a moderately virulent strain of the virus. The variety Alpha, reacts to leafroll infection with moderately severe symptoms.

The aim of our present work is to throw some new light on existing controversies regarding phosphorus content in leafroll-infected potato plants. For this purpose we investigated six different potato varieties with various susceptibility to leafroll infection. The results obtained with the hypersensitive resistant variety of potato, Apta, have been partly published in our previous paper (ULRYCHOVÁ and LIMBERK 1967). We found that the leafroll infection in potato plants, variety Apta, is associated with considerable disturbances in phosphorus metabolism. A distinct activation of phosphorus compounds after infection which is manifested especially by the increase of the low-molecular phosphorus fractions, is followed by a steep decrease of all phosphorus fractions. Two months after infection the plants are emptied as regards phosphorus compounds. The total P in the leaves fell to a quarter in comparison with healthy plants and the inorganic P diminished to one tenth.

Material and Methods

In our experiments we used the following varieties of potato plants: Apta, Sieglinde, Tatranka, Ambra, Rita and Krasava. The plants were grown from the tuber of healthy plants. All experiments were carried out in a greenhouse. The plants were infected at an early stage of development by grafting with scions of diseased potato plants, variety Sieglinde. The plant material was ready for analyses 6—8 weeks after grafting. Two experimental series

Table 1
Dry weight of leaves and stems of healthy (H) and diseased (D) potato plants in per cent

Variety	Date of grafting	Leaves			Stems		
		H	D	in % of H	H	D	in % of H
Apta	3. 6.	11·79	17·15	145	6·70	14·19	212
Sieglinde	3. 6.	9·30	15·05	162	7·00	9·26	132
Tatranka	3. 6.	12·62	16·49	131	11·40	8·04	70
Tatranka	18. 8.	11·44	12·96	113	5·79	6·09	105
Rita	3. 6.	12·96	13·96	108	6·36	6·80	107
Krasava	3. 6.	16·80	16·32	97	8·26	8·44	102
Krasava	18. 8.	12·08	14·09	117	6·16	8·68	140
Ambra	infection from last year	10·55	16·05	152	7·00	10·17	145

Table 2

Amount of different phosphorus fractions in potato plants (cv. Apta) infected with potato leafroll virus (in mg P . g^{-1} of dry matter). All analyses were carried out between the 6th and 8th week after grafting. H = healthy plants, D = diseased plants

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	1·97	0·22	11	4·21	1·38	33	
P extractable with 0·2 N $HClO_4$	1·00	0·51	51	1·24	0 73	59	
Lipid P	0·95	0·38	40	0·71	0 44	62	3 6.
RNA P	1·54	0·33	21	0·81	0 42	52	
DNA P	0·13	0·04	31	0·08	0 06	75	
Total Ptheor.	5·59	1·48	21	7·05	3 03	43	
Total P	5·70	1·63	28	7·96	3 42	43	

Table 3

The same as Table 2, for cv. Sieglinde

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	0·62	0·52	84	1·63	1·72	105	
P extractable with 0·2 N $HClO_4$	0·94	0·54	57	0·77	1·03	133	
Lipid P	0·83	0·58	71	0·53	0·37	70	3. 6.
RNA P	1·13	0·62	55	0·67	0·78	116	
DNA P	0·12	0·09	80	0.10	0·09	90	
Total P theor.	3·63	2·35	65	3·70	3·99	108	
Total P	3·52	2·64	75	3·71	4·00	108	

were realized with the varieties Tatranka and Krasava; one in summer (plants were grafted on June 3rd), the second in autumn (plants were grafted on August 18th). The plants of the variety Ambra, were infected in the previous year.

To determine the different phosphorus fractions the apical parts of plants were used. The estimation was made separately in leaves and stems, including petioles. Different phosphorus fractions in both healthy and diseased potato plants were obtained as described by HOLDEN (1952) and MACIEWSKA-POTAPCZYK (1960). As the values of the remaining P were negligible we did not estimate it in our analyses. Total P was determined separately in dry matter. All results were related to the dry matter. For every experiment sprouts from at least five plants were united and one half of this material served for the determination of dry weight, the other half for phosphorus fractionation. Phosphorus was determined according to PONS (1946) and ZELLER (1949).

Table 4
The same as Table 2, for cv. Tatranka

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	0·82	2·18	265	3·96	6·02	152	
P extractable with 0·2 N $HClO_4$	0·36	0·91	250	0·42	1·19	283	
Lipid P	0·79	0·69	87	0·48	1·06	220	3. 6.
RNA P	0·71	0·54	76	0·19	0·52	275	
DNA P	0·17	0·14	82	0·07	0·14	200	
Total P theor.	2·85	4·46	156	5·12	8·93	174	
Total P	2·91	4·61	158	5·59	9·18	164	
Inorganic P	2·04	1·56	76	6·56	4·73	72	
P extractable with 0·2 N $HClO_4$	1·19	1·13	95	1·16	1·43	123	
Lipid P	0·95	0·86	90	0·76	0·88	116	18. 8.
RNA P	1·15	1·34	116	0·54	0·95	176	
DNA P	0·14	0·13	93	0.12	0·10	84	
Total P theor.	5·47	5·02	92	9·14	8·09	88	
Total P	5·85	5·51	94	9·67	8·01	83	

Table 5
The same as Table 2, for cv. Rita

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	1·27	3·58	284	3·71	3·97	107	
P extractable with 0·2 N $HClO_4$	1·32	0·72	55	0·93	1·18	127	
Lipid P	1·02	1·12	110	0·96	0·92	96	3. 6.
RNA P	1·28	1·30	102	0·79	0·91	115	
DNA P	0·14	0·14	100	0·09	0.09	100	
Total P theor.	5·03	6·86	136	6·48	7·07	109	
Total P	4·41	6·49	147		6 52	112	

Results and Discussion

The values of dry matter in leaves and stems of healthy and leafroll-infected plants are given in Table 1.

As can be seen from the table the dry matter is distinctly increased in potato varieties reacting to leafroll infection with severe symptoms. The highest value of dry matter can be observed with the hypersensitive resistant

Table 6
The same as Table 2, for cv. Krasava

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	1·38	1·18	85	5·03	4·36	86	
P extractable with 0·2 N $HClO_4$	0·46	0·78	169	0·17	0·73	430	
Lipid P	0·99	0·85	86	0·78	0·77	99	3. 6.
RNA P	0·89	0·86	97	0·60	0·66	110	
DNA P	0·17	0·17	100	0·10	0·08	80	
Total P theor.	3·89	3·84	100	6·68	6·60	100	
Total P	4·03	3·74	93	7·03	6·53	93	
Inorganic P	1·19	1·21	102	6·56	5·62	86	
P extractable with 0·2 N $HClO_4$	1 00	0·67	67	1·07	1·41	132	
Lipid P	1·01	0·92	91	0·69	0·61	88	18. 8.
RNA P	1·16	0·71	61	0 47	0·41	87	
DNA P	0·21	0·14	67	0·08	0·07	87	
Total P theor.	4·57	3·65	80	8·87	8·12	92	
Total P	4·86	3·62	75	8·91	7·52	84	

Table 7
The same as Table 2, for cv. Ambra

Fraction	Leaves			Stems			Date of grafting
	H	D	in % of H	H	D	in % of H	
Inorganic P	0 51	1·02	200	2 63	4·48	170	
P extractable with 0·2 N $HClO_4$	0·82	0·79	96	0·80	1·22	152	Infection
Lipid P	0·78	0·62	79	0·50	0·44	88	occurred
RNA P	0 71	0 64	90	0·38	0·49	129	during
DNA P	0·10	0·08	80	0·08	0·07	88	the
Total P theor.	2·92	3·15	107	4·39	6·70	152	previous
Total P	3·21	3·19	100	4·77	6·37	134	summer

variety Apta (ULRYCHOVÁ and LIMBERK 1967). The varieties Sieglinde and Ambra show a considerable rise of dry matter as well. The varieties Tatranka and Rita reacting to leafroll infection with moderately severe symptoms increase the dry matter slightly. Variety Krasava, showing only very moderate symptoms does not practically change dry matter after infection during summer. In addition, it can be seen from the table that the reaction of plants to leafroll infection is conditioned by the season.

The content of different phosphorus fractions in various potato varieties is given in Tables 2 to 7.

The data show that in all cases there are considerable disturbances of phosphorus metabolism in leafroll-infected plants. We can say that each variety reacts differently in this respect being to some extent dependent on the susceptibility of the respective variety to leafroll and to the season. In varieties particularly susceptible to leafroll infection there is a decrease of total P after infection. But a slight decrease of the phosphorus level was found, too, in the medium susceptible variety Tatranka, and in the comparatively little susceptible variety, Krasava, in autumn. In summer, however, in varieties showing medium susceptibility to leafroll such as Tatranka, Rita and Ambra, there was a considerable increase of total P after infection. The less susceptible variety, Krasava, did not change the level of total P after infection.

As regards changes in the content of different phosphorus fractions we noticed that there was a rising tendency of lowmolecular fractions especially of the inorganic P and of the acid-soluble organic P. Among the different phosphorus fractions one common feature could be observed, except for the hypersensitive resistant variety Apta, namely that the acid-soluble organic phosphates in the stems of all varieties examined were considerably higher than in healthy stems.

Preliminary experiments were carried out with tubers of the varieties Apta, Sieglinde and Krasava. The content of total P was in all cases higher.

The results of our experiments differ considerably from existing ones in literature. The reason of these contradictions was the fact, that the above mentioned authors had worked with different varieties of potato plants and under different experimental conditions. The results obtained show that the changes in the level of phosphorus after leafroll infection are, to some extent, the function of the susceptibility of the respective variety to leafroll and to some extent, the function of the season. It is a certain that the changes of phosphorus metabolism in diseased plants could vary from one year to another as it has been observed on the expression of leafroll symptoms.

The general tendency of low molecular fractions in leafroll-infected plants to rise could probably be in connection with the changes in carbohydrate metabolism and in the changed energetic balance.

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MARIE ULRYCHOVÁ, J. LIMBERK, Ústav experimentální botaniky ČSAV, Praha: **Poruchy v metabolismu fosforu u rostlin bramboru infikovaných virem svinutky bramboru.** — Biol. Plant. **10** : 311—317, 1968.

Virus svinutky bramboru působí silné poruchy v metabolismu fosforu u infikovaných rostlin bramboru. Každá odrůda reaguje na infekci odlišně, do jisté míry v závislosti na citlivosti příslušné odrůdy vůči svinutce a také v závislosti na vegetačním období. Odrůdy velmi citlivé na svinutku jako Apta (ULRYCHOVÁ a LIMBERK, 1967) a Sieglinde reagují na infekci snížením celkového fosforu. Odrůdy středně citlivé Tatranka, Rita a Ambra reagují na infekci svinutkou naopak výrazným zvýšením obsahu celkového fosforu. U poměrně málo citlivé odrůdy Krasava se obsah celkového fosforu prakticky nemění V podzimním období můžeme však pozorovat nepatrné snížení obsahu celkového fosforu i u středně citlivé odrůdy Tatranka a málo citlivé odrůdy Krasava. Výsledky naší práce vysvětlují rozpory, které až dosud existovaly v literatuře, pokud jde o obsah fosforu ve svinutkových rostlinách.

Porovnáme-li změny v obsahu jednotlivých frakcí fosforu u nemocných rostlin, pozorujeme tendenci k zvyšování obsahu nízkomolekulárních frakcí. Mezi různými frakcemi fosforu bylo možno najít jeden společný rys u všech vyšetřovaných odrůd a to výrazné zvýšení obsahu rozpustného organicky vázaného fosforu v osách svinutkových rostlin.

МАРИЕ УЛЬРИХОВА, Й ЛИМБЕРК, Отдел фитопатологии, Институт экспериментальной ботаники ЧСАН, Прага, Чехословакия: **Нарушения метаболизма фосфора у растений картофеля, зараженных вирусом скручивания листьев картофеля.** — Biol Plant. **10** 311 до 317, 1968

Вирус скручивания листьев картофеля вызывает сильные нарушения метаболизма фосфора у зараженных растений. В зависимости от чувствительности сорта к вирусу скручивания листьев картофеля и также в зависимости от вегетационного периода каждый сорт реагирует на инфекцию до определенной степени по-разному. Сорта сильно чувствительные к вирусу скручивания листьев картофеля, как напр Apta (ULRYCHOVÁ LIMBERK 1967) и Sieglinde, реагируют на инфекцию понижением количества общего фосфора. У слабо чувствительного сорта Krasava содержание количества общего фосфора практически не изменяется. Однако, осенью можно наблюдать незначительное понижение количества общего фосфора и у средне чувствительного сорта Tatranka и слабо чувствительного сорта Krasava. Результаты нашей работы объясняют противоречия, которые до сих пор существовали в литературе по содержанию фосфора в листьях картофеля, зараженных вирусом скручивания.

Сравнивая изменения в содержании отдельных фракций фосфора у больных растений можно наблюдать стремление к повышению содержания низкомолекулярных фракций. Среди отдельных фракций фосфора возможно найти одну общую черту у всех испытываемых сортов. выразительное повышение содержания растворимого органически связанного фосфора в стеблях зараженных растений.