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# The pattern of stolon growth, onset of bulking, and time-span of stolonisation and tuberisation by cv. Pierwiosnek, an early potato variety

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Abstract

Experiments were performed to check the course of stolonisation growth of the stolons and of the tuberisation in three experiments in which the plants of an early potato cv. Pierwiosnek grew under different conditions, including different lengths of the day. The following were inwestigated: the rate of stolon emergence, stolon growth, differences of the pattern of stolon growth, time-span of stolonisation and of tuber initiation, frequency of particular patterns of stolon growth in relation to the time of stolon emergence, intensity of terminal and laterel tuberisation, and of the branching of the stolons.

The differences in the growth conditions in each of the three experiments enabled us to check the of variability of the particular features during the development of the stolons.

## INTRODUCTION

The stolons of the potato represent modified lateral shoots, which arise from nods at the base of the shoot system. Kumar and Wareing (1972) demonstrated that axillaries are potentially capable of developing as stolons or as leafy shoots.

This process depends upon auxin and cytokinin interaction. Normally stolons develop only from axillaries located below the soil surface. Darkness and a moist atmophere favour stolon emergence.

The time span of stolonisation is longer than of tuberisation. Tuberisation under normal field conditions is relatively short (Buhr 1960) — no longer than 2-3 weeks, however, large intervarietal differences are observed. The time span of tuberisation can be extended by manipulations e.g. of the nitrogen level in the nutrient solution. Heyland

(1963) pointed out that short deficiency period, before flowering, followed, by a supply of NPK after flowering acted like a trigger, stimulating and lengthening the time span of tuber initiation. The rise in number of the tubers could be the result of more intensive initiation of new stolons, or of more intensive branching. Few experiments have hitherto been performed on the development of stolons and the time span of stolon emergence. L o v e l l and B o o t h (1963) studied the pattern of stolon growth and of stolon branching.

Plants of cv. Majestic were grown in water and 1/5 or 1/20 concentration of Arnon solution. The stolon production stopped in water after 14 days, with an average number of 7.5 stolons per plant, but continued in solution (average number 13.7 and 11.0). The pattern of stolon elongation was similar in that there was an initial lag phase followed by one of rapid elongation. Considerable variation was found.

Frequently individual stolons ceased to grow and remained in this phase for days or weeks, before resuming active growth. Different stolons may grow at different rates.

K r a u s s and M a r s c h n e r (1971) investigated the growth of the stolons and of the root system, then the time of tuberisation depending on the level of nutrients and on the size of the pots (volumes 15 l. and 125 l.). In the 125 l. pots an aproximately unlimited growth of the roots was noted. Also stolons grew longer. Especially in big pots the average stolons length was fivefold greater than in small pots. After 100 days no sign of tuberisation could be observed. Tuberisation took place only when nitrogen was cut off. In the small pots, stolon initiation began 27 days after planting tuberisation after 45 days — independent of the concentration of the nutrient solution. In a stable "middle" nitrogen level stolons showed a continuous pattern of growth. When the nitrogen level was varied — 3.5 m val $NO_3$ l. during the first 35 days, and 70 m val $NO_3$ l for the next 45 days, then nitrogen was cut off, the stolons showed a pattern of growth of two or three phases. In the second phase of higher nitrogen content in solution, stolons ceased to grow. The authors assumed that this stagnative phase is parallel to the period of a very intensive growth of the haulm. At least in our experiment (L i s t o w s k i and L i s 1973) we found that the rate of stolon growth and their final length was very variable, many stolons showed a 3-phasic pattern of growth: two phases of growth were separated by a shorter or longer interphase of growth stagnation.

## MATERIAL AND METHODS

Our experiments were carried out with the cv. Pierwiosnek, stored at 2° and then presprouted. Pierwiosnek is an early variety, its dormancy period is short lasting no longer than until the first part of December. Tubers of equal size with only one apical sprout were planted in pots partly filled with a mixture of peat, soil, and sand (in proportion 1:2:1). Each covered by a plastic disc, which had one hole for the stem. The dark space (8 cm height) between the soil surface and the disc was formed and filled with moist nylon cotton (Fig. 1).

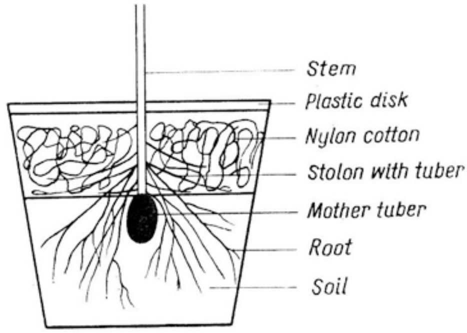


Fig. 1 Scheme of pot in which potato plants were cultivated

The roots dived into soil, but the stolons grew mostly horizontally in the space above the soil. This enabled the observation of the behavior of each stolon and made it possible to check:

— the final length of each stolon,
— the growth rate and the pattern of growth of the stolons,
— the onset of terminal tuberisation,
— the branching rate and the initiation of lateral tubers.

All stolons were marked (with a coloured thread) and measured every 3-4 days from the time of emergence (when the stolons were no longer than 0.4-0.5 cm length) to the onset of tuberisation. A slight swelling of the stolon tip was recognised as the "mark" of the tuber initiation. A part of the stolons did not form tubers. Such stolons were measured until the end of the experiment.

In experiments I and II we used plastic pots 22 cm heigh, 22 cm in diameter, the soil layer was 13 cm. Plants were kept in a green house of north exposure. In experiment I tubers stored at 2° presprouted, dived in a perlite layer in the dark (from January 23 to February 13). The time of observation was from February 13 to April 10. Temperature conditions were more or less stable (20°C at day, 15°C at night). The day length increased from 10 to 13 h.

In experiment II tubers stored at 2° up to the 8th of May were presprouted in light in 4 weeks, then were kept in a perlite layer in the dark from June 7 to June 20. On the 20th June they were planted in pots. Observation time was from June 20 to September 4.

The day length decreased from 17 h to 13 h 40 min. Temperature was variable (according to change of the outer temperature). In experiment III tubers stored at 2° to April 6 were presprouted in light to up to May 4, then in the dark (the perlite layer was made deeper) from May 4- May 21. Then they were planted in pots 18 cm high, 17 cm in diameter, soil layer was 11 cm deep and plants were kept in an open greenhouse. The observation time was from May 21 to July 31. Temperature was variable according to the natural outer conditions. The day length increased from 16 h to 17 h 10 min then decreased to 15 h 30 min.

The physiological age of the tubers used in experiment I and II and III was not the same. It was found (Rozier-Vinot 1971) that physiological age influenced upon the apical dominance and the growth rate of the sprout. Since in our experiments only terminal sprout was left on the mother tuber, one can assume that differences in physiological age did not influence the development of the plants.

There are differences in outer conditions in all three experiments, especially in the light conditions — length of the day and light intensity. The general conditions for an intensive elongation growth of the haulm contrary to experiment III, were profitable for the plants in Exp. I and II.

Plants in the Exp. III grew in poorer conditions (less soil, larger variability of soil moisture conditions, higher temperature, higher light

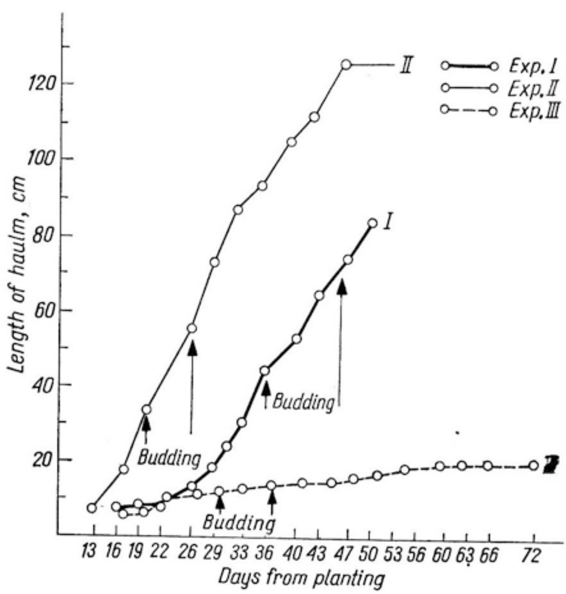


Fig. 2 The growth of the haulm

intensity). Generally speaking there were stress conditions which gave as result a slow growth of the haulm and the hastening of the senescence process (Fig. 2).

## RESULTS

### The pattern of stolon growth

The time span of stolon emergence is relatively long — 30 days on the average per plant in Exp. I, 59 days in Exp. II and 49 days in Exp. III. More than 50% of all stolons emerged in the early growth phase (Table 3).

The growth rate of all stolons was nearly equal at the beginning but soon differentiated. Taking into account the whole period of the stolon development 4 patterns of growth could be described: (Fig. 3).

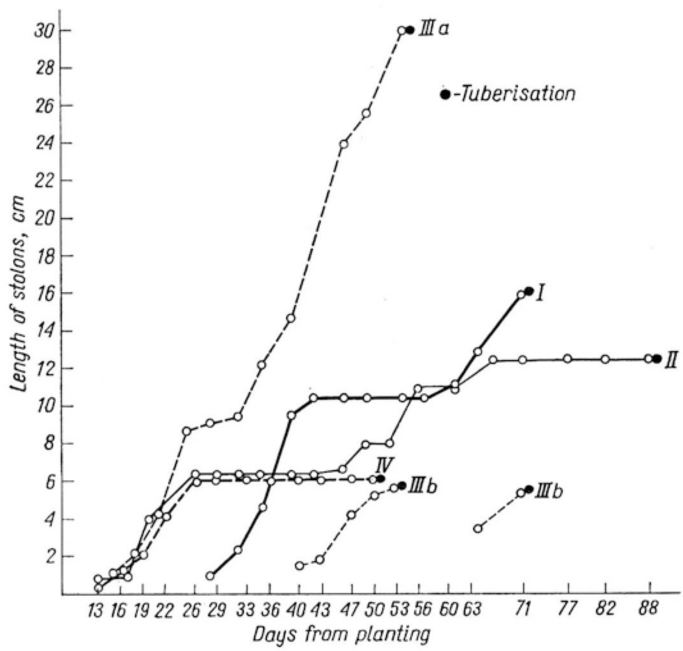


Fig. 3 Pattern of stolons growth. (Types: I, II, III a, III b, and IV)

Type I — threephasic — a shorter or longer stagnative period separates two phases of active growth — at the beginning, and before tuberisation.

Type II — a second stagnative phase (before tuberisation).

Type III — continuous growth.

Taking into account the emergence time of the given stolons one can speak of two different sub-types:

III-a when the stolons emerge early. Stolons are long, and have a long span of development till tuberisation.

III-b stolons emerge late. They are short and quickly tuberise.

Type IV — stolons with a very long stagnative phase, after a short period of active growth.

All the above described types of stolon growth can be observed on the same plant, however with variable frequency (Tables 1, 2). As

Table 1

The frequency of several pattern of stolons growth

| Number of exp. | Date of stolon emergence | Pattern of growth | | | | |
|---|---|---|---|---|---|---|
| | | % of stolons | | | | |
| | | I | II | IIIa | IIIb | IV |
| I | 15 II-8 III | 45.9 | 21.3 | 19.6 | — | 13.1 |
| | 8 III-10 IV | 8.7 | — | — | 71.6 | 15.2 |
| II | 20 VI-26 VII | 50.0 | 18.5 | 31.3 | — | — |
| | 26 VII-28 VIII | 7.7 | — | — | 92.3 | — |
| III | 21 V-10 VI | 45.7 | — | 37.1 | — | 17.1 |
| | 14 VI-31 VII | 8.3 | — | — | 79.2 | 12.5 |

Table 2

Percent of stolons in which growth or stagnative phase precede tuberisation

| Number of exp. | Percent of stolons | |
|---|---|---|
| | growth before tuberisation (I i III) | stagnation before tuberisation (II, IV) |
| I | 72.9 | 27.1 |
| II | 80.0 | 20.0 |
| III | 80.4 | 19.6 |

an exemple, on Fig. 4-8, we presented growth spectra of all stolons of 5 plants. The threephasic type is the prevailing type of growth among early formed stolons (Table 1). One can assume that type I represents the basic growth pattern of the stolons. Other types (II. IIIa, IV) are devations from the threephasic model of growth. It is very difficult to give an answer to the question, why one stolon showed a type IV or II and another stolon a type III or I pattern of growth. Of course one can speak of competitive processes between the elongation rate of the haulm and the differentiation and elongation of the stolons, and at least between the stolons themselves. But interacting relations are not simple here and we could the character of the stagnative phase of adjacent stolons.

## The rate of stolon emergence

The rate of stolon emergence is summarized in Table 3. A part of the earlier formed stolons was falling out (being rotten or damaged),

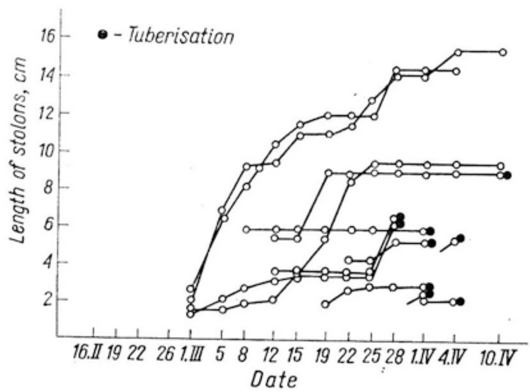


Fig. 4 The growth of the stolons. (The first plant)

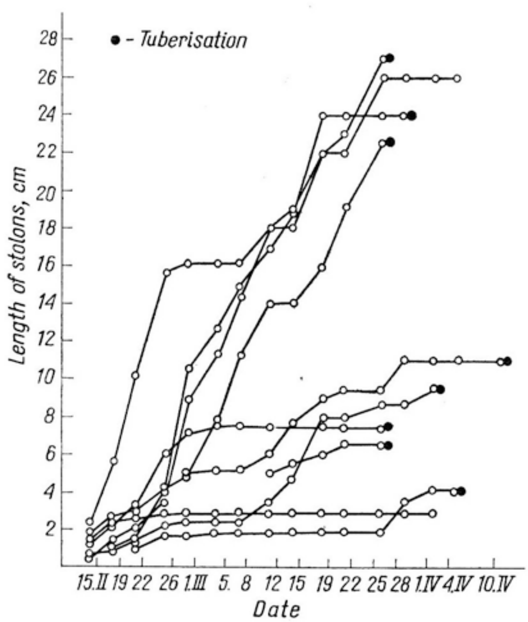


Fig. 5 The growth of the stolons. (The second plant)

during the course of development, therefore the final number of stolons was of course less than the number of formed ones.

As we have mentioned a major part of the stolons emerge in an early phase of growth of the sprout (Table 2 and 3) However they emerge later also. The time of stolonisation is relatively long especially in long day conditions (see Table 7).

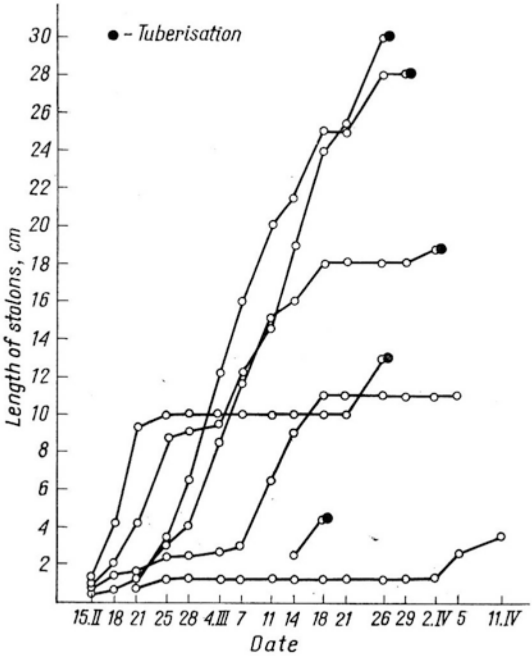


Fig. 6 The growth of the stolons. (The third plant)

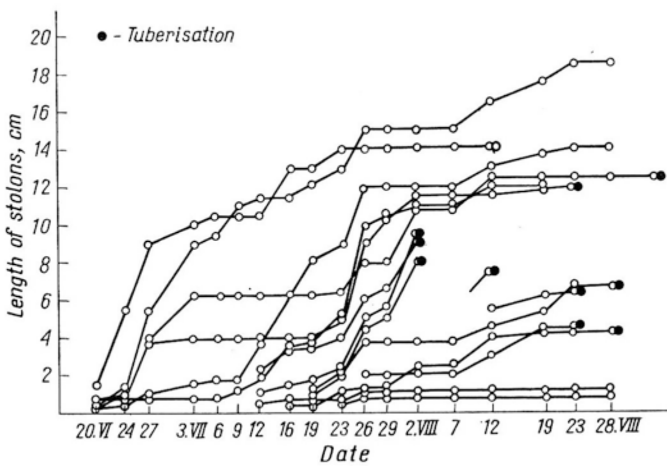


Fig. 7 The growth of the stolons. (The fourth plant)

Table 3

The rate of stolons emergence
(The number of stolons as % of their end amount)

| Number of exp. | | to 13 II (0) | to 22 II (9) [1] | to 28 III (15) | to 8 III (23) | to 15 III (30) | to 19 III (34) | to 29 III (44) | to 2 IV (49) | to 5 IV (52) | Sum of stolons |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1 | 12.6 | 46.0 | 63.8 | 70.1 | 79.5 | 88.0 | 90.4 | 98.4 | 100 | 265 |
| | 2 | 9.0 | 32.8 | 50.0 | 58.5 | 70.0 | 75.0 | 84.7 | 97,5 | 100 | 167 |
| II | | to 19 IV (0) | to 26 IV (7) | to 9 VII (20) | to 16 VII (27) | to 26 VII (37) | to 12 VIII (54) | to 28 VIII (70) | | | sum of stolons |
| | 1 | 30.0 | 48.3 | 58.3 | 83.0 | 91,0 | 97.8 | 100 | | | 182 |
| | 2 | 26.2 | 38.0 | 47.4 | 75.2 | 94.7 | 97.8 | 100 | | | 137 |
| III | | to 21 V (0) | to 31 V (10) | to 10 VI (20) | to 21 VI (31) | to 5 VII (45) | to 19 VII (59) | | | | sum of stolons |
| | 1 | 22.5 | 35.4 | 59.1 | 71.8 | 92.3 | 100 | | | | 220 |
| | 2 | 19.9 | 30.1 | 53.8 | 67.2 | 91.4 | 100 | | | | 186 |

In the course of these experiments a part of the stolons were excised; therefore the end amount is gives as: 1 — the sum of formed stolons, 2 — the sum of tuberising and steril stolons at the end of the experiments.

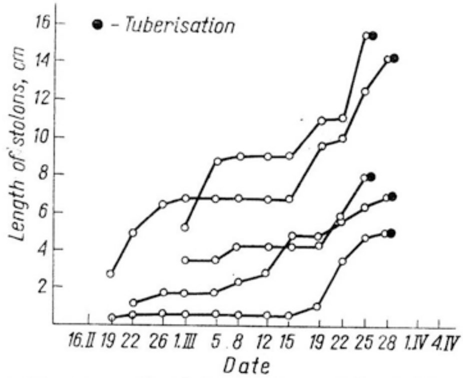

Fig. 8 The growth of the stolons. (The fifth plant)

Table 4

The mean rate stolons emergence per plant

| Number of exp. | Number of stolons | 13 II-1 III | 1 III-19 III | 19 III-5 IV | $\Sigma$ |
|---|---|---|---|---|---|
| I | a | 8.9 | 3.0 | 2.1 | 14.0 |
| | b | 4.5 | 2.1 | 2.1 | 8.7 |
| | | 20 VI-6 VII | 12 VII-2 VIII | 7 VIII-28 VIII | |
| II | a | 11.3 | 8.0 | 0.9 | 20.2 |
| | b | 6.8 | 7.5 | 0.9 | 15.2 |
| | | 21 V-31 V | 1 VI-10 VI | 18 VI-9 VII | |
| III | a | 8.0 | 5.5 | 1.1 | 14.6 |
| | b | 6.1 | 5.3 | 1.1 | 12.5 |

a — mean number of stolons emerged per plant, b — mean number of tuberising and steril stolons.

One must discern between the stolons which emerge late, from the so called "Middle group". The late stolons begin to emerge when the growth rate of the haulm diminishes, or the growth is completely arrested. At that time, many of the earlier formed stolons showed terminal swelling or remained in a long stagnative phase.

"Late" stolons are short, do not develop any branches or lateral bulbs (Tables 8-9) and show the IIIb pattern of growth.

Their "life time", in other words the time span between their emergence and terminal tuberisation, is very short (Table 6). "Early" stolons are much longer (Table 5) often branched, with lateral tubers (Tables 8a, 9). On the contrary to the relative stability of the percentage of early stolons in relation to all stolons — the number of late stolons is variable, much higher in Exp. I (25% of all stolons) lower in others. But the

Table 5

The length of the stolon with terminal tuberisation in dependence of the time of their emergence

| Number of exp. | | | |
|---|---|---|---|
| | 13 II-1 III | 2 III-19 III | 22 III-4 IV |
| I | 11.8 | 7.9 | 5.3 |
| | 20 VI-6 VII | 12 VII-2 VIII | 7 VIII-28 VIII |
| II | 9.2 | 5.0 | 4.0 |
| | 21 V-31 V | 1 VI-10 VI | 18 VI-9 VII |
| III | 8.4 | 5.7 | 3.6 |

number of stolons of the "middle time group" are lower in the Exp. I and higher in the Exp. II. One can suppose that the so called "middle time group" of stolons are in respect to their origin, "new" stolons or "restitutive" stolons. The later are stolons, which emerged in the vicinity of a stolon which was removed. The existence of a inhibitive zone around each active meristemoid or organoid (Bünning 1953) prevents any activation of another meristemoid in such a zone. But it is possible when the stolon is removed.

The former are the results of an expansion of the stolon — forming activity. Long-day conditions seemed to stimulate the development of the "new middle" stolons. Therefore in Exp. II (also in Exp. III) there are more "middle" stolons in relation to „late" than in Exp. I. In such conditions not only more stolons are formed but the trend of their emergence showed equalisation.

## The onset of tubers

In Table 6 and 7, we gave information about the time span of terminal tuberisation, and about the relation between the time of stolon emergence of the given stolon and its tuberisation time.

The time span for tuberisation is much shorter than the time scale for stolonisation. This is known and such conclusions could be drawn from many field experiments, but exact data were lacking. The relation between the onset of terminal tuberisation and the time of stolon emergence and their pattern of growth is very distinct. This time is as shorter as later the given stolon emerges, lasting by many "late" stolons only a few days.

Table 6

Relation between the time of stolon emergence and the number of days to tuberisation

| Number of exp. | to 13 II | 13-22 II (0-9)* | 22 II-5 III (9-20) | 5-12 III (20-27) | 12-19 III (27-34) | 19-29 III (34-44) | 29 III-5 IV (44-52) |
|---|---|---|---|---|---|---|---|
| I | 39 | 39 | 32 | 20 | 13 | 7 | 4 |
| | to 19 VI | 19-26 VI (0-7) | 26 VI-8 VII (7-19) | 8-16 VII (19-27) | 16-29 VII (27-40) | 29 VII--12 VIII (40-55) | 12-28 VII (55-71) |
| II | 65 | 57 | 46 | 31 | 26 | 8 | 7 |
| | to 21 V | 21 V-3 VI (0-13) | 3-10 VI (13-20) | 10-24 VI (20-34) | 28 VI-9 VII (34-49) | | |
| III | 42 | 42 | 37 | 10 | 8 | | |

* In brackets number of days since the first measurement.

Table 7

Time-span of stolonisation and tuberisation

| Number of exp. | Time-span of stolonisation | | | Time-span of tuberisation | |
|---|---|---|---|---|---|
| | for whole experiment | mean per plant a | mean per plant b | for whole experiment | mean per plant |
| I | 51.0 (13 II-4 IV) * | 31.5 | 38.0 | 27.0 (15 III-11 IV) | 8.8 |
| II | 70.0 (20 VI-28 VIII) | 49.0 | 51.0 | 32.0 (2 VIII-31 X) | 16.0 |
| III | 59.0 (21 V-19 VII) | 49.0 | 49.0 | 43.0 (6 VI-19 VII) | 11.0 |

* In brackets dates of the stolonisation and tuberisation time-span.
a — tuberising and steril stolons, b — all emerged stolons.

## The intensity of branching and the onset of lateral tubers

The data about branching of stolons and emergence of lateral tubers are given in Table 8 and 9. The "late" stolons did not show any tendency to branch. Branched stolons and lateral bulbs are a feature only of the early or "middle-time" developed stolons. It is understood that the development of lateral tubers is often the result of the damaging of the terminal point of growth. But very often one can observe branching and lateral tubers an stolons with an intact terminal apex. The lateral tubers appeared after terminal tuberisation however seldom also before tuberisation. One can observe stolons with both terminal and lateral

Table 8

Percent of branched stolons in relation to the sum of the steril and tuberising stolons

| Number of exp. | % of stolons with terminal tuberisation | % of branched stolons | | % of stolons with lateral tubers | |
|---|---|---|---|---|---|
| | | a | b | c | d |
| I | 85.3 | 54.0 | 54.2 | 41.0 | 44.4 |
| II | 33.3 | 47.2 | 49.0 | 30.4 | 26.7 |
| III | 32.0 | 37.1 | 55.8 | 18.8 | 36.5 |

a — branched stolons as % of sum of the stolons with terminal tubers and steril, b — branched stolons as % of sum of the stolons with terminal tubers, c — stolons with lateral tubers as % of sum of the stolons with terminal tubers and steril, d — stolons with later tubers % of sum of the stolons with terminal tubers.

Table 9

Relation between the time of stolons emergence and branching and tuberisation of lateral stolons

| Number of exp. | 13 II-1 III | | 1 III-19 III | | 20 III-5 IV | |
|---|---|---|---|---|---|---|
| | % of branched stolons | % of stolons with lateral tubers | % of branched stolons | % of stolons with lateral tubers | % of branched stolons | % of stolons with lateral tubers |
| I | 85.0 (3.8) [1] | 70.0 (2.6) [2] | 44.8 (1.7) | 27.3 (0.8) | 21.6 (0.6) | 13.5 (0.2) |
| | 20 VI-6 VII | | 6 VII-2 VIII | | 2 VIII-28 VIII | |
| II | 92.8 (4.7) | 71.4 (1.6) | 33.3 (1.0) | 9.5 (0.1) | 20.0 (0.5) | 0.0 (0.0) |
| | 21 V-31 V | | 1 VI-10 VI | | 14 VI-19 VII | |
| III | 76.0 (3.2) | 59.0 (1.1) | 64.0 (3.2) | 42.0 (0.7) | 30.0 (0.5) | 6.0 (0.1) |

1 — mean number of lateral stolons per one main stolon, 2 — mean number of lateral tubers per one main stolon.

tubers as well as stolons which remained sterile. What are the causes of such differences in development? Perhaps very small differences in the rate of the growth between stolons acted as selective factor.

## CONCLUSIONS AND DISCUSSION

Conditions in which plants have developed in each of the three series of experiments, not only clearly differed but were not optimal from the view of a harmonious growth.

There were especially good conditions for elongation growth of the haulm in the two first experiments, in contrast in the third the growth was to a great degree inhibited (Fig. 2). Such variability in external conditions gives the possibility to judge the degree of steadiness or of fluctuation of processes like stolonisation, growth of the stolons and tuberisation which were observed during the experiment. One can suggest that this variability can be due to two reasons:

a) External conditions influence the growth process of the haulm, the development and growth of the leaves and their photosynthetic activity and therefore it indirectly act on the growth of the stolons and the onset of tubers and in this way on the relation between the part of the plant above and beneath the surface of the soil.

b) The same external factors directly influence the processes of stolon emergence, stolon growth and onset of the tubers.

It seems that the range of a far reaching steadiness is great and embraces the following features and properties of developmental characters:

1) Described types of growth of stolons which were observed in all three experiments. Type I dominated in early stolons (50% of all stolons) (Table 1). Type II was observed only in early developed stolons and Type III in the late developed ones. The percent of type III is varied. This variability perhaps could be explained by differences of the inflow of assimilates — lower in Exp. I and higher in Exp. II, in spite of intensive growth of the haulm in both experiments.

2) Late and early developed stolons are higly stable in respect to their morphology. Late stolons — are short, not branching, show a continuous pattern of growth and tuberise only terminally. The early developed ones were longer, often branched and often also developed lateral tubers.

3) Most of the stolons emerged in very early phases of the development of the sproots. It seems that setting of these stolons is to a high degree independent of the inflow of assimilates and of mineral substances. The determination of the trend of development of an axillary bud into a stolon depends on the relation between IAA and cytokinin

(Kumar and Wareing 1972). A lack of light is indispensable. The stablility of the rate of growth in this early phase of growth of the stolons shows that their supply of assimilates is more than adequate and therefore there is no competition between the growing shoot and stolons and among the stolons themselves. Competition appears somewhat later and it seems that this is the cause of differences in the pattern of the growth, changes in speed of stolonisation, and at last it explains why a part of the stolons do not tuberise.

4) The process of the emergence of stolons as well as the stolon growth at its initial phase, are very likely under control of hormonal mechanisms — perhaps of inductive nature and to a high degree autonomous, that is, independent from external factors like temperature, soil moisture, also light intensity and length of the day.

The number of stolons emerging in later phase is less numerous, but in the Exp. I one can observe a rise of intensity of formation of the so called "late stolons". Taking into acount the restitutive stolonisation, the *de novo* development of stolons in the middle phase of formation of stolons is very small (Table 4). I the two other experiments (II and III) late stolonisation is in general weak, but the emergence of stolons in the middle phase is relatively more intensive.

The differences as it seems, are the result of various lengths of the day. Experiment I was performed, when the day length was increasing, the experiment II during a period when it was decreasing, and experiment III was performed when the days were still long during the whole experiment. In the conditions of long day the stolonisation is more intensive and therefore, more stolons are formed. When the day gets shorter, the time of stolon emergence becomes also shorter (similarly to the time span of tuberisation), but when the day length increases a secondary phase of the so called late stolonisation begins.

5) The time span of stolonisation is distincly longer than of tuberisation (Table 7). In Exp. I the time span is the shortest (similarly the time span of tuberisation) and the percent of tuberising stolons is higher than in Exp. II and III. Both shortening of time span of stolonisation and of tuberisation, and hastening of tuber onset is in Exp. I, the result of the influence of the short length of the day. The shortening of the time of tuberisation in Exp. III is not the effect of shortening of the length of the day but the result of the stress conditions which checked growth of the haulm and of the leaves, and hastened the senescence of the plant. In Tab. 6 one can see that the later a stolon was formed the faster it reaches the stage of tuberisation.

6) Observing on the plant the time of emerging and the course of development of particular stolons, one often sees, stolons of different age tuberise nearly simultaneously. The beginning and the time of

tuberisation seems to correlate with the plant age, and so with a special stage of ontogenesis which could be called the "tuberisational ripeness". According to Madec (1959) it would be an inductive process. This tuberisational ripeness would refer not to particular stolons treated separately but to the stoloniferous zone as a whole. This would explain the later a stolon emerges the quicker it tuberises.

Some combination of external conditions influenced the process of tuberisation:

— the first whould be refered to the factors influencing the growth of the sprout. All conditions which slower the growth rate or stop the growth, act as factors which hasten the tuberisation (Milthorpe 1963). We should add that it is true when stress influencing the growth of the plant are not too detrimental.

— the second: under the same conditions of growth of the sprout a short day would hasten the tuberisation.

The first tubers on the plants appeared in Exp. I — 51 days after taking the seed — potatoes out from the store-house and setting them out to germination. This happened in Exp. II after 86 days, and in Exp. III after 61 days. Time span of tuberisation (Table 7) in the Exp. I took 8.8 days per plant, in the II — 16 days, in the III — 11 days. This hastening in Exp. I is as it seems, the effect of the short day. The delay in Exp. II is inversely the effect of a long day. We should add that in both experiments there were particularly favourable conditions for elongation growth of the stem. Differences in time of tuberisation were the reaction to various day lengths. In Exp. III a strong set back of the stem growth was observed.

According to Milthorpe (1972), in such condition a hastening of bulking should be observed. But a strong water and temperature stress — reduced the productivity of assimilation and shortened the "D" of the leaves and as result a delay in bulking.

It is known that not all stolons tuberise, that some of them remains sterile till the end when, the plants begin to get senescent (Burton 1966). In the Exp. I 89% of stolons tuberised — 85% of them terminally. In Exp. II — 54%, in Exp. III — 40.3 but respectively 33% and 32% terminally. Differences are considerable when the number of sterile stolons are compared and still more considerable when stolons which tuberise terminally are taken into consideration. These differences may also be due to the photoperiodic effect.

The short day during Exp. I in general intensified tuberisation, and especially terminal tuberisation. In the next two experiments, when plants grew under long day conditions stolonisation is enhanced but terminal tuberisation is limited. In Exp. III, moreover, early senescence of the plants which had a relatively small assimilatory surface could also be responsible for reducing the tuberisation process. The swelling of the basal part of the haulm, very often noted in plants in Exp. III, would point out to some disturbance in transport of assimilates.

In Exp. due to the long day and advantageous conditions for the elongation of the haulm, not only more stolons were formed per plant, but also more stolons remained sterile. When at the end of the experiment we cut off the top of the stem with some younger leaves — the reaction was nearly immediate, on many stolons we observed a swelling and after some days a terminal tuber formed.

Such great differences, especially in Exp. II between the number of stolons which tuberised terminally and those only with lateral tubers, would prove that different conditions are required for terminal and lateral tuberisation. This cannot be explained by the differences of the length of the day or the range of competition between intensively growing stem and the stolon zone.

The range of stability of analyzed features is wide and includes:

— relation between early formed stolons and their general number,

— percent of praticipation of type I (three-phasic pattern of development) in the group of early stolons and of type III-b in the late stolons,

— relation between the time of stolon formation and tendency to branching and formation of lateral tubers and to greater length of the stolons,

— clear relation between the time of emergence of particular stolons and time span of their growth and time of tuberisation. The later stolons emerge, the faster they tuberise,

— the time span of tuberisation is shorter and less variable than the time span of stolonisation.

A considerable number of properties and features show a comparatively great stability and are relatively independent of external conditions or of relation between the haulm and the stolon zone.

## REFERENCES

Bielińska-Czarnecka M. and Białek K., 1972. Activity of growth inhibitors in Potato tubers during vegetation and storage. Bull. Acad. Polon. Sci., Ser. Sci. Biol. 20: 809.

Buhr H., 1961. Biologie und Ökölogie der Kartoffel, [in:] R. Schick and M. Klinkowski, Die Kartoffel. Deutscher Landwirt schaftsverlag.

Bünning E., 1953. Entwic lung und Bewegungsphysiologie der Pflanzen. Springer Verlag, Berlin — Göttingen — Heidelberg.

Burton W.G., 1966. The potato. ed. Veenman and Zoonen, Wageningen.

Heyland K., 1963. Wasserkulturen mit zeitlich gestaffelten Gaben zu Kartoffeln. Z. Acker-und Pflanzenbau 118:68.

Kraus A. und Marchner H., 1971. Einfluss der N-Ernahrung bei Kartoffeln auf Induction und Wachstumrate der Knolle. Z. Pflanzenern. Bodenk. 128:153.
Kumar D. and Wareing P.F., 1972. Factors controlling stolon development in the potato plants. New Phytol. 71:639.
Listowski A., Lis B., 1973. The influence of CCC on the stolon growth and on tuberisation of Potato. Ziemniak, 5, wyd. I.Z.
Lovell P.H. and Booth P., 1969. Stolon initiation nad development in Solanum tuberosum. New Phytol. 68:1175.
Madec P., Perennec P., 1959. Le rôle respectif du feuillage et du tubercule — mère dans la tuberisation de la pomme de terre. Eur. Potato J. 2:22.
Mauerhofer E., 1958. Die Konollenbildungperiode in die Beurteilung v. Samling und Kultursorten d. Kartoffel. Z. Pflanzenzüchtg. 40:59.
Milthorpe F.L., 1963. Some analysis of Plant Growth, in: The Growth of the Potato, ed. J.D. Ivins and F.L. Milthorpe, Butterworths, London.
Rozier-Vinot C., 1971. Quelques aspects de l'influence du tubercule de semence et du nombre de tiges sur la croissance de la plante de pomme de terre. Pot. Res. 14:29.

## Model wzrostu i tuberyzacji stolonów, czasokres stolonizacji i tuberyzacji wczesnej odmiany ziemniaka 'Pierwiosnek'

### Streszczenie

U wczesnej odmiany ziemniaka cv. Pierwiosnek przeprowadzono *in vivo* na całych roślinach obserwacje nad procesami stolonizacji, tuberyzacji oraz nad wzrostem stolonów. Każdy stolon na roślinie był oznaczony kolorową nitką, pomiary robiono co 3 dni w czasie od pojawienia się stolonu do tuberyzacji względnie przy stolonach, które nie tuberyzowały do końca doświadczenia (na rys. 4-8 podane są spektra rozwojowe stolonów dla pięciu roślin). Obserwacje prowadzone były w trzech doświadczeniach różniących się od siebie warunkami:

Doświadczenie I (styczeń-kwiecień), dzień z początku krótki o niższym natężeniu światła, wydłużający się. Korzystne warunki dla wzrostu elongacyjnego pędu;

Doświadczenie II (maj-wrzesień), dzień długi, potem skracający się. Korzystne warunki dla rozwoju pędu;

Doświadczenie III (maj-lipiec), dzień długi. Stressowe warunki dla wzrostu. Szybkie starzenie się roślin.

Analizowano: rytm i czasokres tworzenia się stolonów (tab. 3), ich liczbę (tab. 4) i długość (tab. 5). Wyróżniono 4 typy (w tym jeden w dwóch wariantach) wzrostu stolonu (rys. 2) określając częstotliwość ich występowania (tab. 1 i 2) oraz stopień rozgałęzienia się stolonów i powstawania bulwek lateralnych (tab. 8 i 9).

Przebieg tuberyzacji i związek między czasem stolonizacji a tuberyzacji przedstawiono w tabelach 6 i 7. To, iż rośliny rosły w tak różnych warunkach pozwoliło na wyróżnienie cech, czy też przebiegu procesów rozwojowych pod kątem stopnia ich stałości bądź zmienności. Do cech tych procesów o względnie dużej stałości, a więc mniej zależnych od układów warunków zewnętrznych, jak i od relacji wzrostowych między pędem a strefą stolonową, można by zaliczyć model wzrostu stolonu w powiązaniu z czasem jego powstawania.

Udział stolonów typu I wydaje się dość stały. Jest to stolon o trójfazowym typie wzrostu, tj. dwóch okresach wzrostu przedzielonych okresem dłuższej lub krótszej stagnacji wzrostowej. Ten typ wydaje się podstawowym w grupie wcześ-

niej rozwijających się stolonów, zaś typy II, III-a, IV deviacjami tego typu podstawowego. Bardzo jednolity typ III b obejmuje stolony rozwijające się późno (w fazie pączkowania, zwolnienia wzrostu pędu) — są to stolony krótkie, nie rozgałęziające się i szybko tuberyzujące, a więc o krótkim własnym okresie życia. Wcześnie założone stolony są natomiast dłuższe, często rozgałęzione i często również z lateralnymi bulwami.

Czasokres stolonizacji, choć zmienny w ilości dni, jest znacznie dłuższy od czasokresu tuberyzacji. Czasokres tuberyzacji jest ogólnie krótki, przy czym stolony o różnym własnym wieku tuberyzują często niemal jednocześnie. Wyraźny jest związek między czasem powstania stolonu a tuberyzacją. Im później powstaje, tym szybciej tuberyzuje. Zakres cech o większym stopniu stałości jest więc stosunkowo szeroki.

Zmienną jest natomiast liczba stolonów, czasokres stolonizacji liczony w dniach, intensywność tuberyzacji (a więc procent stolonów, które pozostają sterylne).

Można sądzić, że głównymi czynnikami modyfikującymi są tu:

— po pierwsze wszystkie czynniki, które wpływają silniej intensyfikując wzrost elongacyjny łodygi,

— przy zbliżonych warunkach dla wzrostu pędów będzie nim długość dnia (przede wszystkim z punktu widzenia tuberyzacji). Krótszy dzień, co jest rzeczą wiadomą z wielu prac, indukuje przyśpieszoną tuberyzację, natomiast liczba stolonów (jak i procent stolonów płonych) wzrasta na dniu długim.