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Pea Growth and Ion Accumulation at Varying Seed Density

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Abstract. Decreased accumulation of elements, particularly of nitrogen, had in dense stand a negative influence on the plants, in spite of the supply of fresh solution and the control of the concentration of nutrients in the pots. The fresh weight and the dry matter of one plant were reduced substantially with rising stand density (from 5 to 10, 20, 40 and 80 plants per 450 sq. cm); the RGR value, the relative absorption rate I_M, the content of all tested elements calculated per one plant, the chlorophyll content in the overground parts of one plant, and the distribution index decrease. Qualitatively the same influence is caused by deficiency of nutrients. Plant dying and self-thinning of the culture occurred in denser stand in the course of cultivation. The root-weight ratio rose with stand densification, particularly at the end of the experiment. The net assimilation rate (NAR) related to chlorophyll dropped with stand density; NAR at density "80" rose slightly from the 22nd day of cultivation and did so at further lower densities. Almost all NAR values lie over the control value at the last measurement. The chlorophyll content in mg g^{-1} dry matter of the overground parts rose with stand density to density "40" (41% more than at density "5"); afterwards it dropped. The accumulation (in mg g^{-1} d.m.) of phosphorus ions was higher in the plants from dense cultures compared with density "5", particularly in the roots. The accumulation of potassium was near to the control value ("5"), while that of nitrogen was lower. The utilization quotients of phosphorus and potassium in denser stands were the same or negligibly lower than at density "5". They were a little higher in nitrogen than in the controls. Also the ratio RGR/I_M was a little higher than in denser stands. The root-weight ratio, the accumulation of elements in mg g^{-1} d.m., the chlorophyll content in mg g^{-1} d.m., NAR_{ch}, the utilization quotient, and the ratio RGR/I_M differed qualitatively by the densification of the culture (with complete mineral nutrition) from the influence of element deficiency (at the same stand density).

In studying the factors influencing the dry matter production of plants, great attention was paid to light intensity and processes directly dependent on it. The dry matter production of one plant, NAR, and RGR dropped with decreasing light intensity obtained experimentally, *e.g.* through the reduction of the distances between plants (density), (HODÁŇOVÁ 1967, BIRKE 1963, BLACKMAN and BLACK 1959, IWAKI 1958, WATSON 1958, BLACKMAN and WILSON 1951 and others).

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Most experiments, however, were carried out under conditions where it was not possible to follow or to exclude, respectively, the influence of a further no less important factor, *i.e.* the mineral nutrient. It is obvious that the increasing mutual shading of plants as well as the deficiency of elements lower the dry matter production, *i.e.* they have the same final effect. BLACKMAN and WILSON (1951 earliest date), found a dependence of RGR and NAR on the quantity of nutrients. Individual elements taking part in production decrease with various intensity (WATSON 1947); the deficiency of these elements directly influencing the formation of the products of photosynthesis manifests itself very intensively and quickly (SCHILLING 1963, BISWAS and SEN 1959, NIČIPOROVIČ and ČEN IN 1959). There are also specific features of the influence of the two factors, excluding the similar effects of the influence of nutrient deficiency and mutual shading of plants (*e.g.* BROUWER 1965).

The present paper reports a study on the growth of pea plants, cultivated hydroponically with replenished nutrition, and their uptake, accumulation, distribution, and utilization of nitrogen, phosphorus, and potassium at varying stand density.

Material and Methods

Plant Material and Cultivation Technique

For the experiments we used peas (*Pisum sativum* L. cv. Stupický zelený), one seed of which weighed 225 mg on the average and contained 1008 mg-atoms of nitrogen, 50 mg-atoms of phosphorus, and 84 mg-atoms of potassium. The peas germinated five days in a germinating pot (from April 19, 1967), whereupon the germinating plants were put into water culture at varying density: I variant 5 plants on 450 sq. cm (marked "5"), II — 10 plants ("10"), III — 20 plants ("20"), IV — 40 plants ("40"), V — 80 plants ("80"). The mean weight of the dry matter of a germinating sprout was 6·5 mg, of the root 7·5 mg. Planting was carried out so that in each variant of each harvest there were four reproductions, thus making a total of twenty reproductions.

Cultivation proceeded in Richter's nutrient solution with microelements and iron added, as reported for the concentration 1·0 in LAŠTŮVKA and MINÁŘ (1967, 1970a). The solution was stirred, aerated, and maintained at the initial concentration ($\pm 5\%$). The cultivation pots were put in a greenhouse (LAŠTŮVKA 1968), the temperature of the air varying between $+18°$ and $+28°$, that of the solution between $+19°$ and $+25°$.

One certain density was always present in all reproductions to preserve certain conditions in the individual growths, the outsides being planted with a protective zone of the same plants.

Experimental Procedures

A part of the plants was harvested and weighed after 17, 22, 28, 35 and 42 days from planting in water culture, and the content of nitrogen, phosphorus, potassium (MINÁŘ and LAŠTŮVKA 1966) and chlorophyll were determined spectrophotometrically according to the method described by ŠESTÁK (1966), the calculation by MacKinney — Arnon, cited by ŠESTÁK *et al.* (1966).

Characters Evaluated

We give the dry matter production per plant, the root-weight ratio (RWR, % basis dry matter), the relative growth rate (RGR), the net assimilation rate (NAR), the chlorophyll content in mg per g of dry matter of the overground parts and in mg per entire overground parts of the plant; furthermore, the relative absorption rate (I_M), the accumulation of N, P, K in mg per g of dry matter in mg-atoms per plant, the distribution index (%, basis dry matter), the quotient of utilization (basis dry matter), and the ratio RGR/I_M.

The calculation of I_M is given by LONERAGAN and ASHER (1967); RGR by ASHER and LONERAGAN (1967); the calculation of the two values is always understood from the beginning of cultivation to the day of sampling, the respective curves being marked with the relevant day. The calculation of NAR (chlorophyll) is given by the equation

$$2 \cdot \frac{(W_2 - W_1)}{(A_2 + A_1) \cdot (t_2 - t_1)},$$

at intervals of 1 to 17, 17 to 22, 22 to 28, 28 to 35, 35 to 42 days of cultivation; the corresponding curves are always marked with the last day of the interval. The calculation of NAR, the terminology, and the symbols are taken from the paper by NEČAS *et al.* (1966). The evaluation of the differences of some results was carried out with the aid of the t-test.

Results

The results are given in Tables 1—7 and in Figures 1—5.

Higher densities did not even reach, at first sampling, the assumed value, although only viable plants were used. The densities in the individual samplings were: at density "5" and "10" the number of plants did not change; at"20" in the last sampling there were only 19 plants; at "40" in the first sampling 38 plants, furthermore, 37, 33, 33, and finally, in the last sampling 32 plants; at "80" in the first sampling 70, furthermore, 64, 61, 54, and, finally 43 plants on 450 sq.cm.

In the course of growth the ratio of accumulated ions at the individual densities changed very little. At the beginning the P:N:K: ratio is approximately 1 : 11 : 3·5 at all densities; at the end it is 1 : 15 : 3·5 at density "5", at further densities the accumulation of nitrogen drops relatively more, while that of potassium only insignificantly, namely 1:12:3·3.

This experiment also demonstrated that in the first phases of growth nitrogen and nitrogen substances, respectively, are eliminated into the medium, this being due to stand densification.

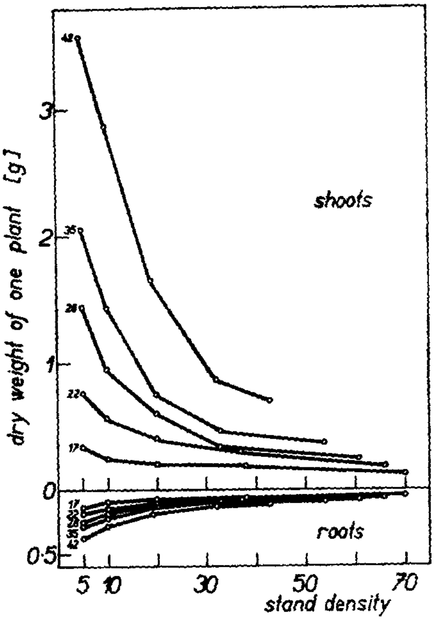


Fig. 1. Dry matter of one plant (n = 4). Abscissa: the stand density. Ordinate: dry weight of one plant in g, above: shoots, below: roots. Significant differences between density "5" and the others are designated: ● ($P < 0{\cdot}001$). The days are marked with the day of sampling.

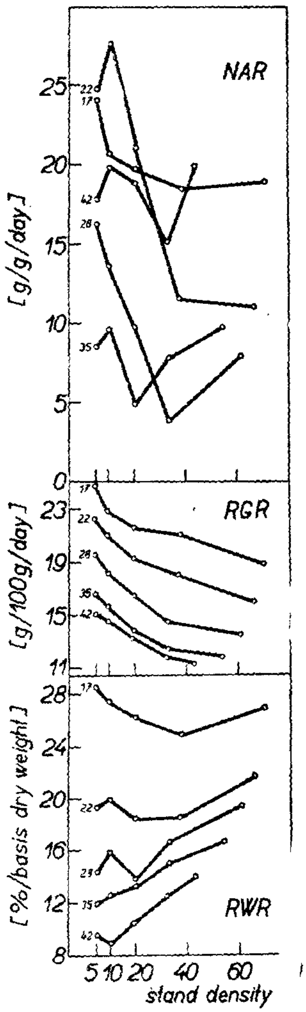


Fig. 2. Net assimilation rate (NAR = g g^{-1} day^{-1}), relative growth rate (RGR = g 100 $g^{-1}day^{-1}$), root weight ratio (RWR = %/basis dry weight). Abscissa: the stand density. The curves are marked with the day of sampling.

Table 1

Content of chlorophyll a and b in mg g^{-1} dry weight of the top of a plant

Days of cultivation	Stand density									
	5		10		20		40			
	a	b	a	b	a	b	a	b	a	b
17	5·254	1·351	5·645	1·852	5·717	1·925	5·807	2·151	5·66	2·088
22	5·234	1·693	4·643	1·486	4·801	1·605	6·140	2·100	4·70	1·786
28	5·331	1·642	5·312	1·757	5·629	1·847	5·184	1·837	5·14	1·836
35	4·273	1·495	4·360	1·537	5·416	1·927	5·366	1·836	4·6[illegible]	1·756
42	2·865	1·073	3·343	1·212	4·249	1·460	4·042	1·518	3·1[illegible]	1·158

Values are means of 4 replications.

Discussion

The results of the regular measurements of the concentration of the solution flowing out of the cultivation vessels convinced us that the concentration of the nutrients varied within minimal limits (100% ± 5%). An analysis of the results, however, showed that in dense stands either the stirring of

TABLE 2

CONTENT OF CHLOROPHYLL (a + b) in the top of one plant (mg)

Days of cultivation	Stand density				
	5	10	20	40	80
17	2·252	1·882	1·567	1·528	0·984
22	5·293	3·530	2·588	2·497	1·190
28	10·104	6·779	4·530	2·345	1·702
35	11·882	8·515	5·581	3·406	2·360
42	14·098	13·082	9·511	4·837	3·070

the solution was not sufficient to remove the concentration gradient round the roots, or what is more probable, the elimination of ions or substances, respectively, by the root system negatively influenced accumulation (mg g^{-1} d.m.), especially that of nitrogen. This, of course, influenced the results in an undesirable manner, because the very reserve of nitrogen in the tissue plays a major role (BROUWER 1963) Simultaneously with this experiment we followed under practically the same conditions the influence of the concentration of the nutrient solution on pea growth, the growth density, however, being the same ("10") LAŠTŮVKA and MINÁŘ 1969a, b). The results of this experiment where mineral nutrients play a major role in

TABLE 3

CONTENT OF NITROGEN in mg g^{-1} dry matter. Values are means of 4 replications

Days of cultivation	Stand density									
	5		10		20		40		80	
	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots
17	47·00	27·80	+ 50·93	++ 44·40	++ 42·40	++ 47·20	+ 44·00	++ 46·73	++ 51·87	++ 45·80
22	50·00	39·00	51·87	++ 45·80	++ 46·27	38·07	50·93	+ 41·80	49·07	+ 41·33
28	44·40	43·53	43·47	43·53	++ 36·00	44·40	44·50	44·20	45·33	41·80
35	38·13	42·67	++ 33·40	+ 46·87	39·20	41·80	+ 42·67	++ 36·20	++ 22·67	++ 38·07
42	44·40	44·40	++ 27·80	43·07	++ 38·53	44·40	++ 36·20	++ 39·00	++ 37·13	++ 39·00

Significant differences between density "5" and the others are designated: $P < 0·01$ +, $P < 0·001$ ++.

TABLE 4

CONTENT OF PHOSPHORUS in mg g^{-1} dry matter. Otherwise as Table 3

Days of cultivation	Stand density									
	5		10		20		40		80	
	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots
17	7·32	9·00	+ 7·78	++ 7·31	++ 7·88	++ 16·20	++ 7·88	++ 17·73	++ 8·38	++ 18·24
22	6·09	13·58	+ 7·00	+ 13·80	+ 6·76	+ 15·13	++ 7·55	++ 17·27	++ 8·35	++ 18·86
28	6·22	13·80	5·96	+ 15·24	5·96	++ 15·37	++ 7·12	++ 17·27	++ 7·75	++ 20·80
35	5·60	18·60	5·20	++ 16·42	+ 5·20	+ 17·87	++ 6·36	++ 19·79	++ 6·56	++ 20·40
42	5·72	14·13	5·20	14·69	5·84	+ 15·38	5·20	++ 16·31	5·20	++ 18·24

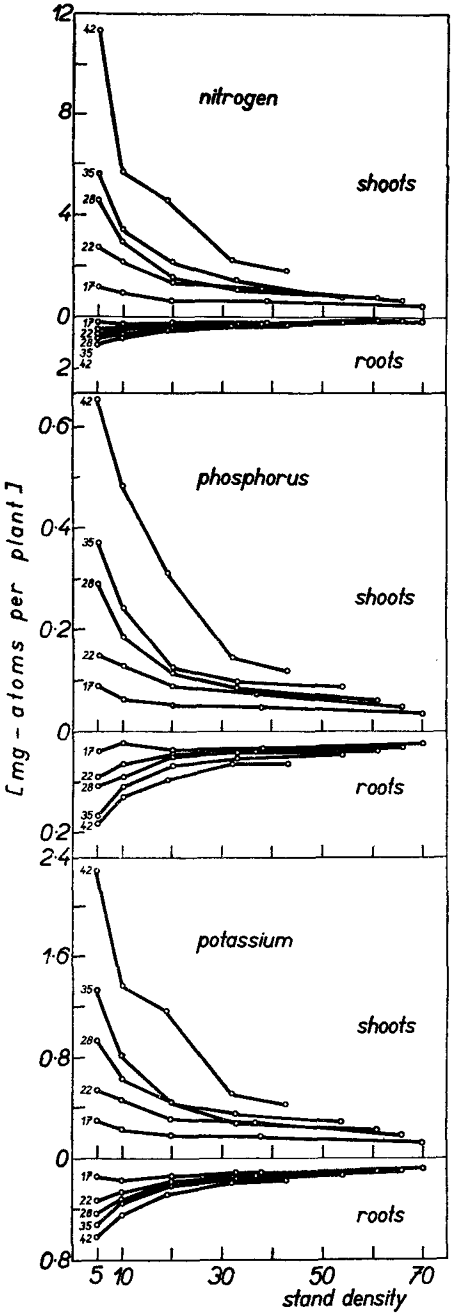
growth and in the accumulation of ions, permit us to draw a comparison with the results described in the present paper. They make it possible to determine approximately the intensity of the influence of nutrient deficiency in dense cultures and the specific reaction of the plants to the whole complex of factors associated with the densification of the culture.

TABLE 5

CONTENT OF POTASSIUM in mg g^{-1} dry matter. Otherwise as Table 3

Days of cultivation	Stand density									
	5		10		20		40		80	
	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots
17	34·20	42·53	34·93	++ 73·00	34·00	++ 77·60	35·13	++ 74·33	+ 36·27	++ 70·67
22	27·60	70·33	++ 31·13	71·67	++ 30·00	++ 73·33	++ 35·13	++ 73·60	++ 37·87	+ 72·33
28	25·33	70·00	+ 25·93	69·67	++ 28·00	72·13	++ 32·27	69·33	++ 34·80	+ 73·00
35	25·27	73·00	++ 22·00	++ 69·40	++ 22·23	++ 69·00	++ 28·40	73·00	++ 30·00	71·80
42	25·00	64·27	++ 18·65	62·80	+ 27·60	+ 60·13	+ 23·20	63·07	++ 23·33	+ 59·87

It can be said from the results and other published data (IWAKI 1958, PLHÁK 1959, 1960, TEZUKA 1960, HOGETSU *et al.* 1960, LAŠTŮVKA and MINÁŘ 1969a, b, and others) that the densification of the stand and the deficiency of nutrients contribute to the decrease of dry matter of the tops and the roots of plants. Through densification of the stand, the whole process of photosynthesis is primarily influenced and at the same time, the absorption of ions at complete nutrition with mineral nutrients continues only for a short period, the accumulation of ions in mg g^{-1} d.m. increasing; subsequently, the absorption being negatively influenced (SCHILLING 1963) and the accumulation, however, remaining high, the shift of assimilates to the roots decreases, followed by a diminution of the growth of the roots. The root-weight ratio decreases as well. (BROUWER 1965).



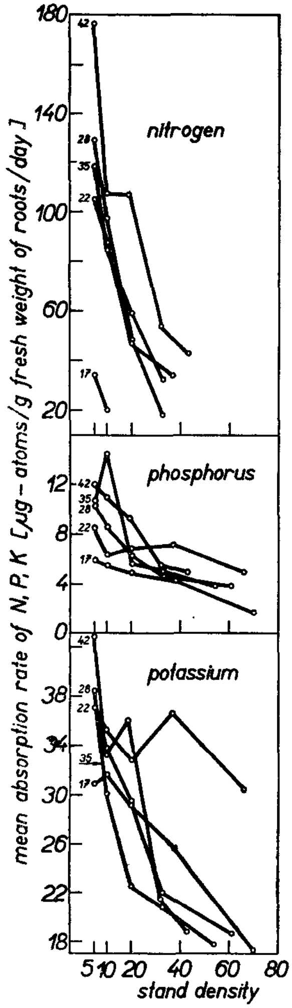


Fig. 4. Mean rate of elements N, P, K absorption per unit weight of roots in µg-atoms (g fresh weight of roots) day. Abscissa: the stand density. The curves are marked with the day of sampling.

Fig. 3. Total content of nitrogen, phosphorus and potassium, in mg-atoms per plant, above — in shoots, below — in roots. Abscissa: the stand density. The curves are marked with the day of sampling.

TABLE 6

DISTRIBUTION INDEX of N, P, K elements (increase in amount of elements in plant shoots as % of total contents)

Days of cultivation	Element	Stand density				
		5	10	20	40	80
17	N	80·91	75·18	71·64	73·86	75·40
	P	66·65	74·14	57·72	57·14	55·38
	K	66·86	55·86	55·18	58·61	58·13
22	N	84·22	81·93	84·23	84·04	80·85
	P	65·07	67·10	66·24	65·54	61·19
	K	62·03	63·47	64·23	67·38	65·06
28	N	85·73	84·03	83·38	83·31	81·74
	P	72·64	67·32	70·57	67·29	61·06
	K	68·06	66·23	70·59	69·91	66·33
35	N	86·76	83·18	85·90	86·91	74·73
	P	68·82	68·74	65·40	64·41	61·52
	K	71·74	68·77	67·77	68·66	67·52
42	N	90·45	86·91	89·11	86·68	85·40
	P	79·31	78·47	76·53	69·11	63·63
	K	78·65	75·35	79·55	72·07	70·53

TABLE 7

UTILIZATION QUOTIENT of nitrogen, phosphate and potassium (g dry matter/mg-atom N, P, K)

Days of cultivation	Element	Stand density				
		5	10	20	40	80
17	N	0·337	0·285	0·321	0·313	0·279
	P	3·972	3·285	3·708	2·995	2·805
	K	1·069	0·862	0·861	0·870	0·858
22	N	0·293	0·276	0·313	0·285	0·296
	P	4·108	4·387	3·729	3·304	2·907
	K	1·090	0·996	1·028	0·924	0·861
28	N	0·316	0·322	0·377	0·316	0·314
	P	4·231	4·163	4·261	3·512	3·031
	K	1·229	1·188	1·145	1·017	0·925
35	N	0·276	0·351	0·354	0·336	0·555
	P	4·326	4·120	4·495	3·694	3·489
	K	1·261	1·229	1·369	1·113	1·057
42	N	0·317	0·480	0·362	0·383	0·375
	P	4·748	5·129	4·532	4·703	4·408
	K	1·360	1·733	1·262	1·388	1·375

The deficiency of nutrients influences negatively the whole process of the absorption of ions and of their accumulation. Moreover, photosynthesis is influenced negatively at high irradiation of the leaves, the translocation of the assimilates into the roots rises, the roots grow faster and the root-weight ratio increases (Brouwer 1963).

If only the growth density and closely connected factors without regard to mineral nutrients were observed, the decrease of dry matter production could be incorrectly attributed to the negative effects of these factors. Tezuka (1960) mentions this in his experiments concerning Iwaki's paper (1958) on buckwheat and particularly in connection with the root-weight ratio.

RWR appears to be a very good indicator for evaluating the influences of various factors. RWR rises at nutrient deficiency (Brouwer 1963, Laštůvka and Minář 1969a, b), but falls at lower light intensity and higher mutual plant shading, respectively (Bula *et al.* 1959, Brouwer 1965). Iwaki (1958) uses the ratio C/F (non-photosynthetic to photosynthetic parts) which differs more or less from RWR in the individual species of plants. This C/F ratio increased in buckwheat with densification. This is not in agreement with the influence of higher shading, but with that of nutrient deficiency. The results of our work are similar. We found a relatively lower accumulation not before the 22nd day of cultivation in the densest culture and gradually coming into play in the further stand densities. The course of the relevant curves of RWR presents a certain picture of this process.

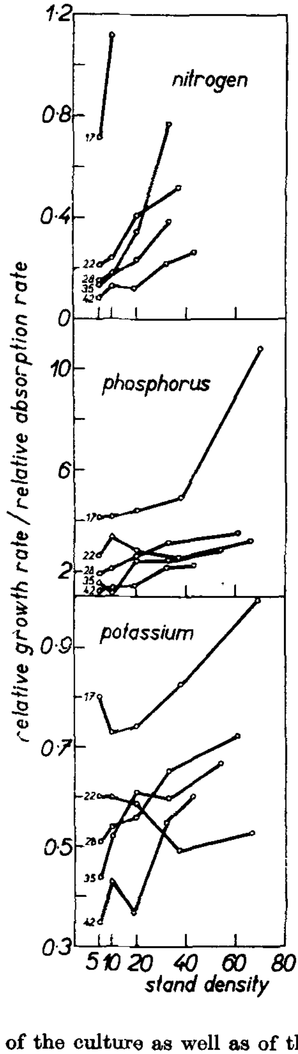


Fig. 5. The ratio between the relative growth rate (RGR) and relative absorption rate (I_M) of nitrogen, phosphorus and potassium. Abscissa: the stand density. Ordinate: values of ratio RGR/I_M. The curves are marked with the days of sampling.

It is natural that RGR decreases as a result of densification of the culture as well as of the deficiency of elements. NAR is relatively insensitive to small changes of the medium, but registers a substantial change under extreme conditions (Brouwer 1963b). Its sensitivity in our opinion, can differ according to the reference value (leaf area, dry matter, chlorophyll content). In numerous experiments an unambiguous diminution of NAR values was encountered with increasing stand density and lower light intensity (Blackman and Wilson 1951, Iwaki 1958, Blackman and Black 1959, Watson 1958, Hogetsu *et al.* 1960, Sawhney *et al.* 1959, Birke 1963, Hodáňová 1967 and others). An intensive drop of NAR values can be seen in the results of our experiment; NAR, at density "80" rises from the 22nd day of cultivation; on the 42nd day of cultivation almost all NAR values are higher than the control values. In the same period the chlorophyll content is higher than the control values in almost all denser stands, the increments of dry matter, however, decreasing less markedly. This is not in agreement with the reaction to lower ion absorption (LAŠTŮVKA and MINÁŘ 1969b). The deficiency of ions exercised quite unambiguous negative influence on the chlorophyll content in mg g^{-1} d.m. of the tops, relatively more intensively than the growth. The NAR values rose sharply with nutrient deficiency (LAŠTŮVKA and MINÁŘ 1969a). We believe that another factor played a role in positively influencing the NAR values in dense stands from the 22nd day of cultivation, *i.e.* the so-called self-thinning of plants. In a certain sense this is comparable with the influence of plant thinning (WATSON 1958). We believe that the cause of self-thinning can be found in the keen competition for light; the growth differentiation, like the differentiation of the sunflower in KUROIWAS experiments (1960), starts already in the first stages of cultivation even when the germinating plants with the growth maximum balanced, with practically the same stocks in the cotyledons, were planted. In spite of these rich stocks, we found dying of plants already in the first sample.

It can be assumed that such a course as that observed with the chlorophyll content in mg g^{-1} d.m. of the tops at stand densification will also be displayed by the accumulation of ions in mg g^{-1} d.m., or, at least, the accumulation will not decrease with density, if mineral nutrients are sufficient. In addition, a relatively higher accumulation of ions in the roots can be expected, because the roots are nearest to the ion source, and thus there is also a lower distribution index and the same or lower ion utilization. The results are almost in agreement with this assumption. The phosphorus accumulation in denser cultures is in all cases higher than at density "5", being relatively higher in the roots. This is in agreement not only with the distribution index, but also with the utilization quotient. The accumulation of potassium in mg g^{-1} d.m. is very similar, but it is nearer to the values measured in the control plants. The accumulation of nitrogen, which, particularly at the end of the experiment, is lower than in the controls, is not in agreement with the stated assumption. This is confirmed by the rising value of the utilization quotient and by the ratio of accumulated ions at the end of the experiment. The distribution to the shoots decreases here with stand densification. We believe that the relatively lower accumulation of nitrogen in the experiments partly influences some processes so that they proceed as in the case of deficiency of elements (RWR, utilization). We have said that decreased absorption might be due to lower accumulation; we cannot say this with certainty, because the elimination of nitrogen and nitrogen substances, respectively, occurred in the first stages of plant growth in water culture in denser stands. The causes of this, however, could be other than those due to decreased concentration of nutrients (LAŠTŮVKA and MINÁŘ 1970b). It was a great loss for the plants and not even a proportional absorption from the solution in dense stand could compensate for this deficiency. It must be mentioned that the stocks in the cotyledons and the endosperm, respectively, are very important for plant growth not only in the period of germination, but also in further development (MINÁŘ and LAŠTŮVKA 1969).

The results of ion accumulation can be compared with the influence of the deficiency of nutrients (LAŠTŮVKA and MINÁŘ 1970b); the lowered concentration of nutrients decreases significantly the ion accumulation in mg g^{-1} d.m., a fall of the distribution index occuring, the utilization of elements, however, rising greatly. We completely failed to obtain the above quoted utilization quotient in the experiments with stand density, the values of nitrogen accumulation in the dense stands not being very high either, and indicating only the low, nevertheless existing, influence of this factor. Finally, the ratio RGR/I_M bears this out. This ratio in contrast to the utilization quotient, is converted from the amount of ions absorbed by the plant. In peas and other plants with supply organs, the relation between absorption and growth changes can be evaluated better than by the utilization quotient alone. If growth is limited by lower concentrations of nutrients, it continues in a restricted manner only, owing to the transport of nutrients from the supply organs, RGR/I_M rises considerably (5 times to 40 times) (Laštůvka and Minář 1970a, b). With stand density it rises two to three times, of course, substantially less; it should be balanced in the case of a sufficiency of nutrients.

The results show that the rising stand density is a major factor or complex of factors influencing the growth of plants. In dense stands, moreover, a lower accumulation of elements, particularly of nitrogen, appears. We can characterize the individual coefficients used by means of many values and of the observed dynamics of some processes in the experiment with reduced spacing of plants in the stand and in the experiment with decreased concentration of nutrients at the same spacing of plants in the stand. The fresh weight, the production of dry matter, RGR, the chlorophyll content in the shoots per plant, the accumulation of elements per plant, the absorption of ions, and the distribution index come under the progressive influence of the two factors. The specific reaction of the plants to the two factors becomes evident in the root-weight ratio, NAR (chlorophyll), in the chlorophyll content in mg g^{-1} d.m. in the utilization quotient, and in RGR/I_M. We present only processes which we have observed.

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Z. Laštůvka, J. Minář, Katedra fyziologie rostlin Přírodovědecké fakulty University J. E. Purkyně, Brno: **Růst hrachu a akumulace iontů při různé hustotě výsevu.** — Biol. Plant. **12** : 167—179, 1970.

Přes zajištění dodávky čerstvého roztoku a kontrolu koncentrace živin v nádobách, podílela se snížená akumulace prvků, především dusíku, v hustých porostech na negativním ovlivnění rostlin. Se zvyšující se hustotou porostu (5, 10, 20, 40 a 80 rostlin na 450 cm^2) byla podstatně redukována čerstvá váha a sušina jedné rostliny, klesala hodnota RGR, relativní míry absorpce I_M, obsah všech měřených prvků při přepočtu na jednu rostlinu, obsah chlorofylů na nadzemní část jedné rostliny a distribuční index. Během kultivace došlo v hustších porostech k odumírání rostlin a k samozřeďování porostů.

Zastoupení kořenů v celkové váze rostliny stoupalo, zvláště na konci pokusů. Čistá míra asimilace (NAR), vztažená na chlorofyl, s hustotou porostů klesala; od 22. dne kultivace však NAR v hustotě "80" mírně stoupne, postupně též v dalších nižších hustotách. Při posledním měření jsou téměř všechny hodnoty NAR nad kontrolní hodnotou. Akumulace (v mg g^{-1} sušiny) iontů fosforu byla vesměs vyšší v rostlinách z hustých porostů ve srovnání s hustotou "5", zvláště v kořenech. Blízká kontrole ("5") byla akumulace draslíku, nižší dusíku. Kvocient utilizace fosforu a draslíku je v hustších porostech stejný nebo nepatrně nižší než v hustotě "5". Málo vyšší než v kontrole je u dusíku. Též poměr RGR/I_M je málo vyšší v hustých porostech Zastoupení kořenů ve váze celé rostliny, akumulace prvků v mg g^{-1} sušiny, obsah chlorofylu v mg g^{-1} sušiny, NAR_{ch}, kvocient utilizace a poměr RGR/I_M kvalitativně se odlišují při zahušťování porostů (při plné minerální výživě) od vlivu deficience prvků při stejné hustotě porostu.