

Influence of Sodium Humate and Nutritive Conditions on the Content of Nucleic Acids, Particularly on the Ribosomal Ribonucleic Acid in Wheat Roots

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Abstract. Changes in the nucleic acid (NA) content were studied in roots of young wheat plants cultivated under various nutritive conditions, namely in a nutrient solution, in distilled water and in a solution of sodium humate in distilled water. Changes in the ribosomal ribonucleic acid (RNA) in particular and their connection with growth rate were investigated. The amount of the NA fraction investigated (more than 90 per cent of which is represented by the ribosomal RNA) changed substantially under the cultivation conditions studied. In roots of one plant cultivated in water the content of the NA fraction investigated was at the most about 25 μg and it began to decrease as early as from the second day of cultivation. After 12 days of cultivation it decreased to 15 μg . When cultivated in Na-humate the roots contained at the most 33 μg NA, between the 5th—7th day, followed by an intensive decrease after 12 days, to 17 μg . The content of the fraction investigated in wheat plants cultivated in a nutrient solution was about double the value in comparison to these two cases with the maximal value about 60 μg between the 7th—9th day. After 12 days this amount decreased to 45 μg .

The ratio between the growth rate and the NA content presented positive values only when plants were cultivated in a nutrient solution and in Na-humate until the day when the NA content ceased to increase. In the case of Na-humate this took place on the 6th day and in the case of a nutrient solution on the 9th day. Under conditions favourable for growth (in a nutrient solution and in field conditions) the precultivation of wheat plants in Na-humate resulted in a more intensive growth of roots in comparison with the root growth of plants precultivated in distilled water. In plants precultivated in distilled water for 4 days the growth rate continuously increased under favourable nutrition conditions in contrast to plants transferred from distilled water as late as on the 6th day. Their growth stopped after the transplantation and was restored only after a 2 day lag phase. On the other hand, in plants precultivated in Na-humate the transfer to favourable nutritive conditions resulted in both cases in a short term cessation of growth.

In a considerable number of papers concerning effects of humus substances on plants a favourable influence has been proved. This is evidenced most clearly macroscopically by an intensive growth of plants. Though the influence of humus substances on plant metabolism has been studied very extensively the nature of their action is not fully understood.

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In the recent years the connection between NA metabolism and growth has been studied in a series of papers, and it has been found that the growth rate is closely connected with the amount of RNA. This was proved both with microorganisms, particularly in microbes and yeasts (CASPERSSON and BRANDT 1941, JEENER and BRACHET 1944 and others as cited by KEDROVSKY 1951, MAALOE 1960, WILLIAMSON and SCOPES 1961, KJELGARD 1963 and others) and in algae (HERRMANN and SCHMIDT 1965, POGO et al. 1966 and others) and with higher plants (HEYES 1960, WOODSTOCK and SKOOG 1960, 1962, SITNIK and MUSATENKO 1963, SITNIK 1964, INGLE and HAGE-ANN 1964, BROWN 1964, GILES and MAYERS 1964, KEY 1964, MUSATENKO and DZYUBENKO 1964, WALTON 1965 and others).

On the basis of other papers (ALI-ZADE 1959, BARKER and HOLLONSHEAD 1964, BARSKAYA and OKNINA 1959, MARCUS and FEELEY 1962, HOLDGATE and GOODWIN 1965 and others) one can draw a general conclusion, that a high content of RNA is accompanied by an intensive growth throughout the ontogenesis of plants, while cells and tissues with a low vital activity possess a low content of RNA.

The correlation between the growth rate and the RNA content probably concerns only the ribosomal RNA (NEIDHARDT and MAGASANIK 1960).

We made this finding the basis of our study concerning the influence of humic acid on NA metabolism and therefore we paid our attention especially to the ribosomal RNA. A similar connection has not yet been studied. The influence of humic substances on NA metabolism was investigated by CHRISTYEVA (1963) who compared it to the action of other physiologically active substances. Recently CHRISTYEVA et al. (1967) have studied especially the effect on DNA metabolism. They found that after treatment with humic substances both the intensity of the DNA synthesis and its content in the nucleus increase as well as the protein content in the cell. These changes also become evident in subsequent generations, although to a less extent.

As follows from our previous experiments (FIALOVÁ and ŠMÍDOVÁ, unpublished data) the preparation of humic acid used has various effects on the growth of wheat plants, depending on whether it is applied as Na-humate or as K-humate. Besides this the growth effect was also dependent upon the presence of mineral nutrients in the cultivation medium. In their presence growth was only slightly affected by both forms of humate. On the other hand when plants were grown in a solution of humates in distilled water only (in a concentration of 100 mg humic acid per liter), K-humate (4×10^{-4} M potassium) slightly stimulated the growth of shoots and roots of wheat plants, while Na-humate (4×10^{-4} M sodium) considerably accelerated the growth of roots.

These intensively growing roots of wheat plants cultivated in aqueous solution of Na-humate became a suitable material for studying the changes in the NA metabolism induced by humic acid. From the values of the relationship between the amount of RNA and the growth rate it would be possible to draw conclusions about the mode of action of humic acid on NA metabolism and in growth processes. For comparison the same relations were investigated in roots of wheat plants cultivated in a nutrient solution, the growth intensity of which was almost identical to that of a solution of Na-humate, as well as in roots of wheat plants cultivated in distilled water, growing

about half as rapidly as in a nutrient solution and in Na-humate. This comparison appeared to be necessary for the reason that Na-humate was applied in an aqueous solution, so that plants probably grew under insufficient nutrient conditions. The influence of nutrient conditions on NA metabolism was studied in a series of papers and it was found that starvation either from a deficiency in nutrients or light brings about considerable changes in the NA content (ASEYEVA and BELOZERSKY 1957, KONAREV 1953, 1954 and oth.). An extremely unfavourable effect was proved to result from a deficiency in nitrogen (CASPERSSON and BRANDT 1941, JEENER and BRACHET 1944 and others as referred to by KEDROVSKY 1951, TURKOVA and MESHCHERYAKOVA 1964 and others), but also in boron (SHKOLNIK et al. 1963, ALBERT 1965) and in zinc (KESSLER and MONSELISE 1959) and other elements. The NA content decreases also in young seedlings after removing their reserve tissues (HOCQUETTE et al. 1952 and oth.).

In order to choose a convenient method for the estimation of NA several methods of NA isolation and determination were thoroughly examined in our laboratory (FIALOVÁ 1968). With regard to the intention of our work requiring specifically estimation of RNA it was proved impossible to employ those methods in which besides NA's a considerable amount of oricine-positive or UV-light-absorbing substances was released. The most suitable method was that of KERN (1960), by means of which it is possible to isolate the RNA fraction which is represented probably by a substantial amount of the ribosomal RNA from the root tissue analysed. Owing to the fact that this RNA fraction was not contaminated by UV-light-absorbing substances it was possible to estimate it spectrophotometrically.

Material and Methods

Seedlings of wheat *Triticum aestivum* L., cv. Pyšelka served as experimental plants.

Wheat grains were allowed to soak for 12 hours in distilled water at 20° C. Grains of an approximately identical size and degree of germination were further cultivated in appropriate cultivation media in Petri dishes for 48 hours in an incubator at 25° C in the dark. Seedlings of an approximately identical size (length of coleoptile about 2 cm, length of roots 4.5 cm.) were transplanted in lots of 15 plantlets into glass cultivation pots containing 250 ml of the same cultivation solution in which grains were allowed to germinate. The cultivation pots were provided with dark covers. Plants were further grown under artificial and controlled conditions at about 20° C, at 50–65 per cent relative air humidity and at a 16 hour illumination having an intensity of 900 lx on the level of leaves. White fluorescent tubes of 40 W were used for this purpose. In some experiments, when long term artificial cultivation conditions would result in etiolation, plants were grown in the garden (in June). According to growth curves the 2nd, 5th, 7th and 12th day after planting the grains in Petri dishes were chosen as suitable dates for the collection and analysis of plants.

The cultivation solutions.

1. Knop's nutrient solution containing in millimoles: 4.87 Ca²⁺; 4.79 K⁺; 0.81 Mg²⁺; 1.47 H₂PO₄⁻; 11.72 NO₃⁻; 1.53 Cl⁻; 0.81 SO₄²⁻; 0.062 Fe³⁺ per liter distilled water. Chemicals purchased by the firm "Lachema" were used in this work. The nutrient solution was used diluted with water, namely with 3 parts (quarter nutrient solution) or with 1 part (half nutrient solution) of distilled water per 1 part of the nutrient solution.
2. Glass-distilled water. The electrical conductivity varied in the range of values 4.5—6.4 × 10⁻⁶ Ω⁻¹cm⁻¹.
3. Solution of Na-humate in distilled water (100 mg humic acid dissolved in 2 ml 0.2 N NaOH and made up with distilled water to 1000 ml). The humic acid originated from the preparation "Humussäure", Riedel & de Haen, Hannover. The solution contained 4 × 10⁻⁴ M sodium.

The influence of cultivation conditions on growth was evaluated from the length of the primary root, from the fresh weight of the entire root system and from its dry weight. The results were statistically evaluated using t-test. In plants cultivated in distilled water and in a solution of Na-humate the distribution of nitrogen among the shoot, root and remainder of the grain was also estimated.

The nitrogen content was determined using Kjeldhal's technique (Dvořák et al. 1955).

Nucleic acids were isolated and estimated according to KERN's procedure (1960) as referred to in our previous paper (FIALOVÁ 1968). For technical reasons either roots of plants cultivated in distilled water and in Na-humate or roots of plants grown in distilled water and in a nutrient solution were analysed simultaneously. In the first case roots of 255 plants grown in distilled water and 193 plants grown in Na-humate were processed in one analysis, in the second case roots of 135—165 plants grown in water and 105—135 plants grown in a nutrient solution. In addition 75 plants were cultivated in each variant for characterization of growth.

The NA content was estimated from spectrophotometric measurements using an MOM spectrophotometer and measuring tubes of 1 cm. It was calculated according to Chargraff's procedure as referred to by KEIL and ŠORMOVÁ (1959). Since the specific phosphorus content of NA from wheat roots was not known, for εP the average value was introduced from εP given by the authors mentioned, viz. 7500. The calculated amount was expressed per root system of one plant analysed.

Results

The growth character of experimental plants in connection with the cultivation conditions is given in Table 1. When growing wheat plants in an aqueous solution of Na-humate the growth rate of roots is significantly increased. The elongation growth is influenced to the highest extent, it is about twice as rapid as the elongation growth of roots from distilled water.

The fresh weight of roots increases by 70 per cent, the dry weight by about 50 per cent. On the other hand, no significant differences could be found either in the total nitrogen content or in its distribution among individual organs in comparison with organs of plants cultivated in distilled water (Fig. 1).

The elongation growth and the fresh weight increase of roots of wheat plants cultivated in an aqueous solution of Na-humate is of about the same intensity as when cultivating them in a diluted (quarter) nutrient solution. On the other hand the increase in dry weight of plant roots grown in a nutrient solution are lower than in Na-humate and only slightly and insignificantly higher in comparison with the variant with distilled water. The roots of wheat plants grown in a nutrient solution increased in their length and

Table 1

Root growth of wheat plants cultivated in distilled water, in a solution of sodium humate and in a nutrient solution (number of repetitions given in Table 2)

A — Root length in cm

| Age of plants in days | H ₂ O $\bar{x} \pm s\bar{x}$ | Na — humate $\bar{x} \pm s\bar{x}$ | \bar{d} % to H ₂ O | Signifi- cance | Nutrient solution (1/4) $\bar{x} \pm s\bar{x}$ | \bar{d} % to H ₂ O | Signifi- cance |
|-----------------------|--|---------------------------------------|---------------------------------------|-------------------|--|---------------------------------------|-------------------|
| 2 | 4.7 ± 0.238 | 4.7 ± 0.296 | 0 | — | 4.7 ± 0.685 | 0 | — |
| 5 | 8.0 ± 0.506 | 11.7 ± 0.311 | + 46 | +++ | 9.5 ± 0.350 | + 18 | — |
| 7 | 8.4 ± 0.271 | 15.2 ± 0.321 | + 80 | +++ | 12.9 ± 0.268 | + 53 | ++ |
| 9 | 9.0 ± 0.407 | 18.1 ± 0.083 | +105 | +++ | 14.9 ± 0.670 | + 65 | +++ |
| 12 | 9.7 ± 0.814 | 18.1 ± 1.210 | + 97 | ++ | 19.4 ± 0.500 | +100 | +++ |

B — Fresh weight of roots of 1 plant in mg

| | | | | | | | |
|----|-------------|-------------|------|-----|--------------|------|-----|
| 2 | 32.4 ± 1.44 | 29.7 ± 3.48 | — 5 | — | 30.0 ± 0.500 | — 8 | — |
| 5 | 52.3 ± 0.85 | 69.3 ± 1.43 | + 32 | +++ | 55.9 ± 2.920 | + 6 | — |
| 7 | 54.0 ± 1.39 | 84.3 ± 2.48 | + 56 | +++ | 80.7 ± 0.894 | + 50 | +++ |
| 9 | 55.7 ± 1.12 | 88.9 ± 2.90 | + 73 | +++ | 86.2 ± 2.080 | + 58 | +++ |
| 12 | 57.1 ± 4.24 | 86.6 ± 4.49 | + 52 | ++ | 96.8 ± 3.560 | + 69 | +++ |

C — Dry weight of roots of 1 plant in mg

| | | | | | | | |
|----|--------------|--------------|------|-----|--------------|------|---|
| 2 | 2.14 ± 0.212 | 1.95 ± 0.192 | — 10 | — | 1.92 ± 0.040 | — 7 | — |
| 5 | 4.16 ± 0.108 | 4.95 ± 1.050 | + 19 | — | 3.70 ± 0.173 | — 11 | — |
| 7 | 4.40 ± 0.155 | 6.00 ± 0.195 | + 36 | +++ | 5.13 ± 0.236 | + 17 | — |
| 9 | 4.53 ± 0.256 | 6.80 ± 0.387 | + 43 | +++ | 5.30 ± 0.152 | + 13 | — |
| 12 | 4.62 ± 0.360 | 6.70 ± 0.000 | + 46 | +++ | 6.03 ± 0.145 | + 31 | + |

— = insignificant $P < 5\%$

+ = on the level of significance $P > 5\%$

++ = significant $P > 1\%$

+++ = highly significant $P > 0.1\%$

Fig. 1

Fig. 2

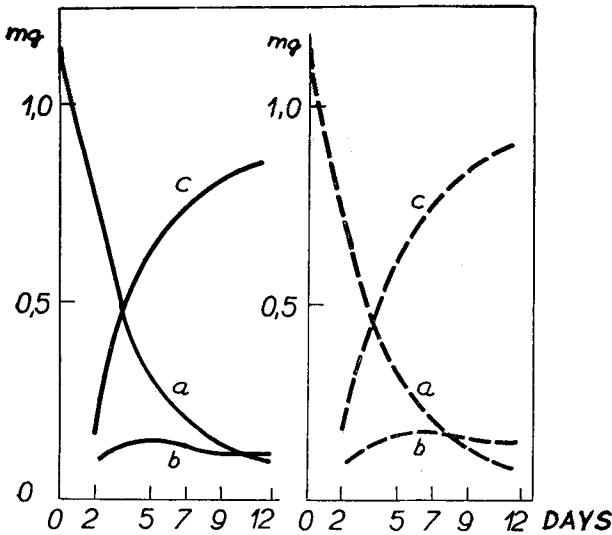


Fig. 1. Distribution of nitrogen between the grain residue (a), root (b) and shoot (c) of wheat plants cultivated in distilled water (—) and in sodium humate (---).

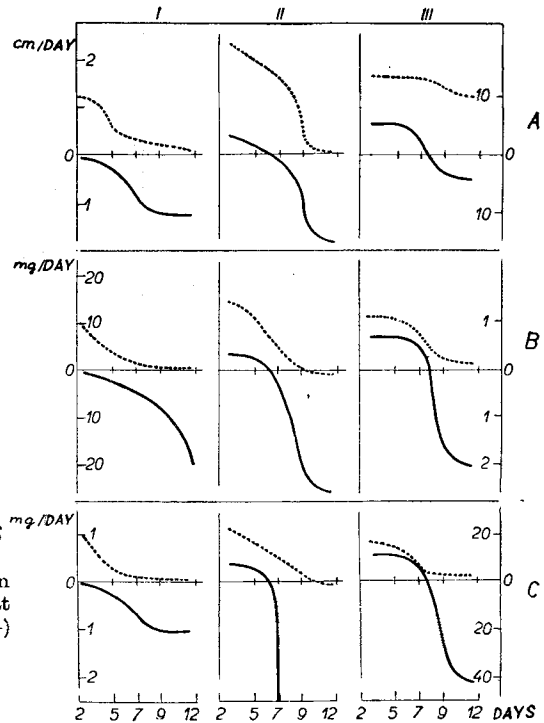


Fig. 2. Correlation between the rate of the NA accumulation in roots of wheat and their increases in length (A), fresh weight (B) and dry weight (C) during cultivation in distilled water (I), in sodium humate (II) and in a nutrient solution (III).

Abscissa: age of plants in days.

Ordinata: left — growth rate (.....)

right — ratio between the growth and NA content (—)

Table 2
Changes in the NA content of the nucleoprotein fraction (ribosomal RNA) from roots of wheat plants cultivated in distilled water, in sodium humate and in a nutrient solution
 \bar{x} is given in μg per 1 plant

| Age of plants in days | Distilled water | | Sodium humate | | \bar{d} % to H_2O | Signifi- cance | Nutrient solution (1/4) | | \bar{d} % to H_2O | Signifi- cance | | | |
|--------------------------|------------------------|---|---------------------------------|---|--|-------------------|-------------------------|------------------|--|-------------------|---------------------------------|-----|-----|
| | $\bar{x} \pm s\bar{x}$ | n | $s\bar{x}$ in % \bar{x} | n | | | $\bar{x} \pm s\bar{x}$ | n | | | $s\bar{x}$ in % \bar{x} | | |
| 2 | 24.7 ± 1.480 | 7 | 6.1 | 4 | 19.4 ± 0.550 | 4 | 2.8 | 22.5 ± 1.990 | 3 | 8.8 | — | 9 | — |
| 5 | 22.4 ± 0.682 | 7 | 3.0 | 4 | 32.5 ± 1.700 | 4 | 5.2 | 45.3 ± 0.575 | 3 | 1.3 | + | 103 | +++ |
| 7 | 19.5 ± 0.416 | 9 | 2.1 | 6 | 32.8 ± 2.420 | 6 | 7.3 | 59.7 ± 0.447 | 3 | 0.8 | + | 207 | +++ |
| 9 | 16.9 ± 0.428 | 6 | 2.6 | 3 | 24.4 ± 1.070 | 3 | 4.4 | 56.6 ± 0.670 | 3 | 1.2 | + | 235 | +++ |
| 12 | 14.8 ± 0.807 | 6 | 5.4 | 3 | 17.6 ± 1.840 | 3 | 10.0 | 43.3 ± 0.914 | 3 | 2.1 | + | 192 | +++ |

both fresh and dry weight throughout the cultivation period, while when cultivating them in Na-humate the root growth was very intensive at first and after about nine days suddenly stopped. The fresh and dry weight presented a decrease after this date which was not statistically significant owing to the dispersion of the values. In distilled water the growth of roots slowed down very soon and almost ceased beginning from the seventh day.

The content of the NA fraction supposedly identical to the ribosomal RNA, considerably changed during a 12-day cultivation in a nutrient solution, Na-humate or in distilled water (Table 2).

As seen from the ratio between the NA content and the growth rate determined at 24 hour intervals, the positive values are represented by roots of plants cultivated in a nutrient solution up to the ninth day and by that cultivated in Na-humate for a shorter period (up to the sixth day). In contrast, when plants were grown in distilled water the ratio between the NA content and the growth rate had negative values. (Fig. 2).

These results would indicate that the ratio between the NA content and the growth rate is considerably influenced by nutrition and can be found only under favourable nutritive conditions. When cultivating plants in solutions of Na-humate and in distilled water, which results in an early growth suppression, this relationship certainly cannot be demonstrated. Therefore we tried to examine how the content of NA's accumulated during a short term precultivation in distilled water and in solution of Na-humate would be influenced by the transfer of plants into conditions favourable for growth. The data given in Table 2 served as initial values in this experiment. They show that the maximal differences between both variants could be found 5—7 days from the beginning of cultivation. At this period differences between the two variants were apparent, not only as to NA content, but also to character. When cultivating plants in distilled water the NA content decreases while cultivation in a solution of Na-humate causes a reversion from an intensive increase to a decrease between the 7th—9th day. On the basis of these results one portion of plants (330) was transferred on the fifth day and another (330) on the sixth day of the precultivation into a diluted nutrient solution (half nutrient solution). At the same time plants were

Fig. 3

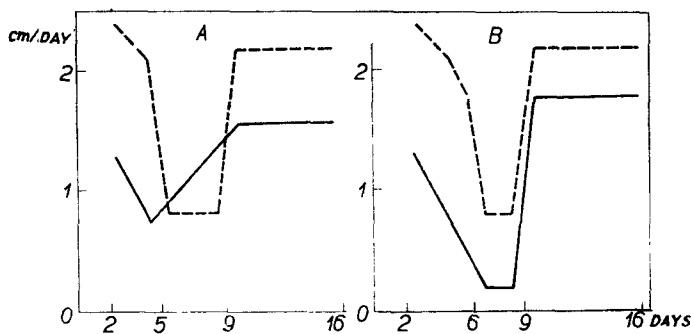


Fig. 3. Diurnal increases in root length of wheat plants precultivated in distilled water (—) and sodium humate (---) and transplanted on the 5th day (A) and 6th day (B) into a nutrient solution.

transferred from artificial cultivation conditions, which were not suitable for further cultivation of wheat plants because of the low light intensity (900 lx), to the experimental garden. Experiments were carried out in June.

In this experiment the length and fresh and dry weight of roots was determined partly from plants on the day of transplantation (from each variant 90 plants were collected), partly from 9 and 16 day-old plants (120

Fig. 4

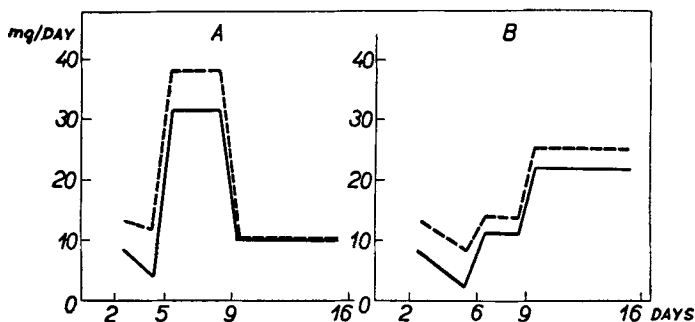


Fig. 4. Diurnal increases in fresh weight of roots of wheat plants precultivated in distilled water (—) and sodium humate (---) and transplanted on the 5th day (A) and the 6th day (B) into a nutrient solution.

Fig. 5

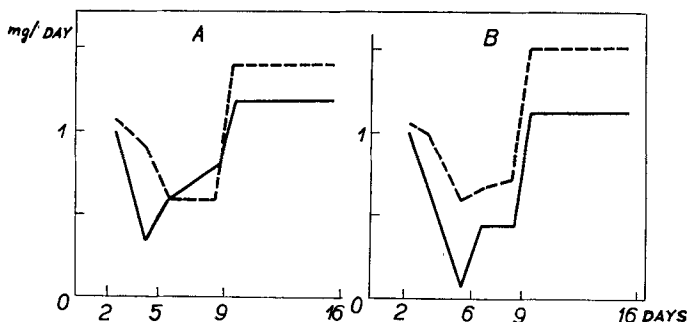


Fig. 5. Diurnal increases in dry weight of roots of wheat plants precultivated in distilled water (—) and sodium humate (---) and transplanted on the 5th day (A) and the 6th day (B) into a nutrient solution.

plants from each variant). The growth rate of roots during both means of cultivation is given in Figs. 3, 4 and 5. In all growth characters investigated the favourable effect of precultivation in Na-humate became evident. The values represent the average of two repetitions.

Discussion

The fact that humus substances accelerate the growth of plants, increasing not only elongation and fresh weight but also dry weight, indicates that these substances could also affect, among other things, NA metabolism, particularly

the RNA metabolism, which has been proved to be closely connected with growth (WOODSTOCK and SKOOG 1960, KEY 1964, INGLE and HAGEMAN 1964 and others).

Humus compounds could influence growth processes either by supplying nutrients (nitrogen, iron and others), functioning as growth regulators, or affecting the uptake and transport of substances physically as a colloid organic compound (PRÁT 1964). It is probable that these factors participate side by side in a certain ratio.

The influence of nutritive conditions on NA metabolism was investigated by some workers employing microorganisms chiefly as subjects, particularly plants and microbes (CASPERSSON and BRANDT 1941, JEENER and BRACHET 1944 as cited by KEDROVSKY 1951, and others). It follows from these studies that under insufficient nutritive conditions the RNA content is limited and proportionately the growth as well. This was found *e.g.* in yeast cultivated in distilled water. Not even after the addition of phosphorus did yeasts grow and their RNA content increase. After nitrogen was supplied both the RNA and protein contents increased and cells grew intensively. This proves a direct connection between nutrition conditions and the RNA synthesis and the connections between RNA, protein synthesis and growth. NEIDHARDT and MAGASANIK (1960) shed more light on the conception concerning the connection between the RNA amount and the rate of growth by finding that this relationship is true only for one type of RNA's, namely for the ribosomal ribonucleic acids. One can presuppose that in plants, as in simpler microorganisms, NA metabolism is dependent on nutrition. Results of works devoted to these problems give clear evidence of it. *E.g.* MARCUS and FEELEY (1962), HOLDGATE and GOODWIN (1965) and others observed that during seed germination the NA content in vegetative tissue increases and in reserve tissues decreases. Analogically ŠORMOVÁ and ŠORM (1954) found that in pea seedlings NA content increases even when seedlings were cultivated only in distilled water or even in the dark as well. But plants cultivated in a nutrient solution and in light had a higher NA content. A favourable effect of light on NA metabolism was reported also by ASEYÉVA and BELOZERSKY (1957) who found that in coleoptiles of wheat plants grown in distilled water in light the NA content increased while when growing plants in dark the NA content decreased. After removing the endosperm a considerable decrease occurred.

In contradiction to these results HOCQUETTE *et al.* (1952) observed that there was no change in the DNA content to be found in hypocotyles of bean plants cultivated in distilled water for 10 days, but the RNA content decreased even when plants were supplied with sucrose between the 8th—9th day of cultivation. Upon removal of cotyledons the RNA decrease accelerated. According to the data of INGLE and HAGEMAN (1964) in root tips of corn which germinated in a solution of CaCl_2 in dark the NA content decreased with age.

The discrepancies in these results could result not only from the fact that they were obtained using various methods, some of which have been criticized lately (HOLDGATE and GOODWIN 1965, and *oth.*) but also from the fact that young seedlings were analyzed having various amounts of reserve substances of various kinds such as carbohydrates, proteins, etc. This must

necessarily be taken into account when evaluating the results. Most of the experiments, especially those in which an intensive decrease in the NA content in vegetative tissues was found after removing the storage tissues, confirm the dependence of the NA metabolism on nutrients.

From this point of view results of ŠORMOVÁ and ŠORM (1954, 1956) are of an interest with regard to some results obtained in our laboratory. In 1954 the authors mentioned found a favourable effect of nutrients and light on the NA content in young pea plantlets even when they were grown in Petri dishes with 25 ml nutrient solution for 15 days at the illumination intensity as low as 500 lx. But in their following paper published in 1956 the positive influence on the NA metabolism by nutrition conditions was disproved by the fact that plants grown in tap water after 15 days cultivation contained a higher amount of RNA than was given by the authors in 1954 for plants cultivated in a nutrient solution. Besides that plants sprouted from seeds of a higher weight had a lower NA content (1954) than plants sprouted from seeds of a lower weight (1956), which would be in disagreement with the data of CHERRY (1963).

Apart from the fact that ŠORMOVÁ and ŠORM (1954, 1956) used the method of OGUR and ROSEN which could not be reliable for such analyses (in none of the papers the spectrum of the NA hydrolysates is presented from which the NA content was calculated) a question must be considered as to whether only NA's were determined (by means of the method mentioned other UV-absorbing substances are hydrolyzed as proved in our laboratory, FIALOVÁ 1968) and whether or not only plant NA's were involved. When growing plants in Petri dishes in a small volume of the cultivation solution (25 ml), the solution must contain a relatively high concentration of organic acids and sugars secreted by roots. These organic substances could serve as a suitable nutrition medium for microorganisms. Since in some experiments the authors mentioned supplied cultivation media with chloramphenicol which has been proved to function as an inhibitor of DNA synthesis in microorganisms, one can presuppose from these results even the possibility that in the NA content estimated in plants grown in the absence of chloramphenicol the microbial NA's participated. This possibility is supported by the results of ŠEBESTA et al. (1966). They analyzed plants which were cultivated in the same way.

According to our results the RNA content in roots of wheat plants cultivated in a diluted (quarter) nutrient solution is about three times higher than that from wheat roots cultivated in distilled water. Na-humate, analogically to the nutrient solution, at first served as an activator of the RNA accumulation but this influence was of a short-term duration probably limited by the starvation of plants. This is confirmed by the fact that the RNA content after 12-day cultivation in Na-humate was of the same level as when cultivating in distilled water. If Na-humate has a nutrition effect then this is only of a short-time duration indicating that its content of nutrient is low. If it affects the NA synthesis then this probably brings about under insufficient nutrition a limitation of other metabolic pathways. Intensive NA synthesis would not be accompanied by equally intensive protein synthesis, either by the increase of the protoplasmatic matter, or by growth. In our experiments in which the growth curves were investigated an in-

dication of the fresh and dry weight decrease was apparent. But the average value of the decrease was in the range of dispersion of individual values.

Evidence in favour of the stimulative character of Na-humate effect was given by the results of our experiments when investigating the root growth of plants precultivated in distilled water and in a solution of Na-humate for several days and then transplanted into a nutrient solution and to out-door light conditions. The fifth and sixth day were chosen for the transplantation not only because at this time the difference between the NA content of roots in both variants investigated was maximal, but also for the reason that according to BOSEMARK (as cited by LINDBLAD 1959), beginning from the fifth day all reserve substances except nitrogen (probably the ergastic material) should be exhausted from the grain. On the other hand, nitrogen storage in a wheat grain should be sufficient up to the seventh day. This indicates that on the sixth day the grains were over the limit of the carbohydrate uptake and on the limit of the nitrogen uptake.

Transplantation of plants precultivated in distilled water for four days caused no disturbances of growth but its acceleration. On the other hand the transplantation of plants precultivated in distilled water for five days resulted in a growth cessation. Growth was restored only after a two-day lag phase. A quite different situation occurred with plants precultivated in Na-humate. Both the four- and five-day precultivation resulted, after transfer into more favourable nutrition conditions, in a growth retardation which was more expressive than after the five-day precultivation in distilled water. Also this result gives evidence to the fact that the long term growth of wheat in Na-humate brings about starvation of plants so that its effect appears to be mostly stimulative rather than nutritive.

Under favourable nutrition conditions the increase of the growth rate of roots was more pronounced in plants with a higher NA content, precultivated in Na-humate, in comparison with the root growth of plants with a lower NA content, precultivated in distilled water. The connection between the NA amount and the growth rate and its dependence on the nutrition conditions is thus proved.

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SVATAVA FTALOVÁ, Katedra Fisiologie rostlin a půdní biologie Přírodovědecké fakulty Karlovy university: Vliv Na-humátu a trofických podmínek na obsah nukleových kyselin, zvláště ribosomální ribonukleové kyseliny v kořenech pšenice. — Biol. Plan. 11 : 8—22. 1969.

Studovali jsme změny v obsahu nukleových kyselin (NA) v kořenech mladých rostlin pšenice pěstované v různých trofických podmínkách, a to v živném roztoku, v destilované vodě a v roztoku Na-humátu v destilované vodě. Sledovali jsme zvl. změny ribosomální ribonukleové kyseliny (RNA) a jejich souvislost s rychlostí růstu. Množství sledované frakce NA (z více jak 90% ribosomální RNA) se měnilo vlivem studovaných kultivačních podmínek dosti podstatně. V kořenech jedné rostliny pěstované v H₂O byl obsah sledované frakce NA nejvýše kolem 25 μg a zmenšoval se už asi od druhého dne stáří rostlin. Po 12 dnech kultivace poklesl na 15 μg. Při pěstování v Na-humátu obsahovaly kořeny nejvýše 33 μg NA, a to mezi 5. až 7. dnem, pak došlo

k prudkému poklesu, po 12 dnech až na 17 μg . Vzhledem k těmto dvěma případům byl obsah sledované frakce v kořenech pšenice pěstované v živném roztoku zhruba dvojnásobný, s maximální hodnotou kolem 60 μg mezi 7. až 9. dnem stáří. Po 12 dnech se toto množství zmenšilo na 45 μg .

Poměr mezi rychlostí růstu a obsahem NA vykazoval kladné hodnoty pouze při pěstování v živném roztoku a v Na-humátu, a to do dne, kdy se přestal zvyšovat obsah NA. V případě Na-humátu to bylo asi do 6. dne a v případě živného roztoku asi do 9. dne stáří rostlin. V podmínkách příznivých pro růst (v živném roztoku a ve venkovních podmínkách) se předpěstování pšenice v Na-humátu projevilo intenzivnějším růstem kořenů ve srovnání s růstem kořenů rostlin předpěstovaných v destilované vodě. U rostlin předpěstovaných v destilované vodě 4 dny se v příznivých trofických podmínkách plynule zvyšovala rychlost růstu na rozdíl od rostlin přesazených z destilované vody až 6. den. Jejich růst se po přesazení zastavil a k obnově došlo až po lag-fázi asi 2-denní. Naproti tomu se u rostlin předpěstovaných v Na-humátu projevilo přesazení do příznivých trofických podmínek krátkodobým zastavením růstu, a to v obou případech.

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Исследовались изменения содержания нуклеиновых кислот (НК) в корнях молодых растений пшеницы выращиваемых при различных условиях питания а именно, в питательном растворе, в дистиллированной воде и в растворе гумата натрия в дистиллированной воде. Мы исследовали в особенности изменения рибосомальной рибонуклеиновой кислоты (РНК) и их связь со скоростью роста. Количество исследованной фракции НК (состоящей более чем на 90 % из рибосомальной РНК) изменялось под влиянием условий культивации довольно существенно. При выращивании растений на чистой воде содержание исследованной фракции НК составляло не более 25 мкг на одно растение и снижалось уже почти от второго дня возраста растений. Спустя 12 дней от начала выращивания оно снизилось до 15 мкг. При выращивании растений на растворе гумата натрия наибольшее содержание НК в корнях, 33 мкг, отмечено в период между 5—7 днем. После этого произошло снижение до 17 мкг на 12 день. По сравнению с этими двумя вариантами растения выращиваемые на питательном растворе имели вдвое большее содержание НК с максимумом около 60 мкг на 7—9 день. В возрасте 12 дней содержание НК снизилось до 45 мкг.

Отношение между скоростью роста и содержанием НК было положительным лишь при выращивании в питательном растворе и на растворе гумата натрия до дня, когда перестало повышаться содержание НК. На растворе гумата это происходило приблизительно до 6 дня, у варианта на питательном растворе приблизительно до 9 дня возраста растений. Растения пересаженные из гумата натрия на питательный раствор имели более развитую корневую систему по сравнению с растениями выращиваемыми сперва на дистиллированной воде. У растений выращиваемых сперва 4 дня на дистиллированной воде и пересаженных на питательный раствор плавно повышалась скорость роста в благоприятных условиях питания в отличие от растений пересаженных с дистиллированной воды лишь на 6 день. Рост последних прекратился после пересадки и возобновился лишь спустя 2-х дневного лаг периода. У растений пересаженных в благоприятные условия питания с раствора гумата натрия произошла кратковременная остановка роста в обоих вариантах.