# Phosphorus Uptake by Oat Studied with $P^{32}$ under Various Soil-, Water- and Nutrient Conditions

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A complicated relation exists between the water and nutrient uptake by plants and also between the water and nutrient supply. This appears in the fact that on the one hand water utilization or the amount of water required for a unit of dry matter production depends upon the natural or artificial nutrient supply of the soil and, on the other hand the effectivenes of soil nutrients and nutrients given as fertilizers is significantly influenced by soil moisture.

Soil, as the permanent source of water and nutrients, continuously affects all life processes of the plant — first of all the water and nutrient uptake — through the roots. Water and mineral ion uptake is only partly a passive physical process, it is much more an active life process, that is, it is related to the respiratory metabolism (PETINOV [6]). The effect of soil moisture on the physiological processes in plants — among others also upon the nutrient uptake — depends on the effect of soil moisture's surface tension, on the suction of plants and indirectly on the operation of stomata and all these are influenced by transpiration.

The study of the existing correlation between transpiration and nutrient uptake is important both from theoretical and practical points of view. The role of transpiration in the ion uptake by roots has been debated since the turn of the century. In the last decades TIMIRJAZEV's views about the independent processes of transpiration and nutrient uptake were widely proved (PETERBURGSKI [5], FEDOROVSKI [4], SUTCLIFFE [10]). But this correlation is not of the same proportion for each cation and anion.

Nutrient uptake by plants should be regarded as a manifestation of active interaction between the plant and its environment [7]. The plant which develops on a soil supplied well with nutrients slows down its growth if the available water is insufficient and contains relatively more nutrients than a plant that does not suffer from water stress [8].

SHAW [8] quoting others points out that as a result of water stress P-ions can accumulate, but also decrease in plants. FAWCETT and QUIRK [3] concluded from the results of pot experiments that the phosphorus content of wheat was independent of soil moisture. Similar results were obtained by BEATON and READ [1]. SIMPSON [9] used $^{32}P$ in his potato experiment in which the decreasing moisture tension (increasing soil moisture) increased the phosphorus uptake from fertilizer in the soil having a lower as well as a higher phosphorus content.

From the above mentioned literature review — which was taken from our theme documentation [2] — one can see that these theoretical questions are not yet clarified, though they are closely related to irrigated farming.

## Discussion

Experiments conducted so far prove, that the nutrient and water supply of plants is the limiting factor of high yields. The correlation of these two factors and the often appearing interaction — especially in the nutrient uptake of plants — is influenced by a third one, the soil, its natural nutrient content, its physical, water economic and chemical characteristics. This is especially true for the utilization of phosphorus fertilizers, that is, for the uptake of phosphoric acid. The effectiveness of the fertilizer and the differentiation of total phosphorus — originating from soil and from fertilizer — taken up by the plant can be determined mainly by radioactive labelling. This means among other things, that by using isotope method the transformation of soil phosphates, the quantitative change in the expectable P-availability resulting from soil moisture can be studied.

To study these questions pot experiments were conducted with oat using $^{32}P$ labelled phosphorus fertilizer in 1965 and in 1967.

## Experimental procedure

In the experiment pots (6 kg) were used with a closed bottom. In 1965 the pots were located in a greenhouse (between 1 February and 4 June) and in 1967 in a growth house (between 13 April and 20 July).

$^{32}P$ labelled superphosphate was prepared in the isotope laboratory of ÖRKI, with the chemical method in 1965 and in water suspension in 1967. Total activity used was 405 $\mu c$ per pot (at the start) for each dose, thus the specific activity varied in the treatments.

**The amount of nutrients (active ingredient), mg/pot**

| | Ammonium nitrate | Superphosphate (17,5) | Potassium (40%) |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Ø | — | — | — |
| 2 NK | 600 | — | 600 |
| 1 NPK | 300 | 300 | 300 |
| 2 NPK | 600 | 600 | 600 |
| 3 NPK | 900 | 900 | 900 |
| 4 NPK | 1200 | 1200 | 1200 |

Besides the 4 nutrient levels 2 soil moisture levels were maintained — 45 or 40 and 70% of the soil's maximum water capacity. This moisture content was maintained by daily weighing and watering. This made possible also the simultaneous study of water consumption by plants. Number of replications: 3. Yield data evaluation was made by variance analysis.

*Table 1*

**Some agrochemical data of soils (0—25 cm)**

| Soil types | No. of stickiness | Max. water capacity | Humus | Total N | Easily available nutrients mg/100 g soil | | pH in $H_2O$ |
|---|---|---|---|---|---|---|---|
| | | % | | | (Egner) $P_2O_5$ | (Nehring) $K_2O$ | |
| I | 56 | 44,0 | 2,18 | 0,21 | 12,5 | 20,3 | 7,8 |
| II | 60 | 48,0 | 2,33 | 0,21 | 7,0 | 22,5 | 6,4 |
| III | 27 | 29,8 | 1,18 | 0,06 | 7,0 | 10,4 | 8,3 |
| IV | 43 | 44,0 | 1,65 | 0,09 | 5,1 | 18,1 | 8,2 |

Soils used in the experiment: I. Solonetz meadow soil (Szarvas), 1965 and 1967; II. Meadow alluvial soil (Szarvas), 1967; III. Sandy meadow chernozem (Izsák), 1967; IV. Brown forest soil with carbonate remnants (Szekszárd), 1965 and 1967. All four types were collected at places where fertilization field experiments were carried out. Their main characteristics are presented in Table 1.

## Discussion of the results

To characterize the dry matter yield increase the *grain yields* of pots are given in Table 2.

When comparing the data of the 2 years one should take into account that while in 1965 the experiment was carried out in a greenhouse under less favourable light and temperature conditions, in 1967 a growth house having natural environment was used. Irrigation effect depends on the soil types. Oat in the meadow alluvial soil reacted best to the better water supply and this was not significantly affected even by fertilization. This inference is true also for solonetz meadow soil and partly for the sandy meadow chernozem. On the other hand there was no watering effect in either year on unfertilized brown forest soil, that is, the increase of watering effect by fertilization was significant. These statements are well represented in Figs. 1 and 2.

Fertilization effect on soils containing more nutrients, irrespectively of water supply, is very small, even in the grain weight there is often a depression. Concerning the weight of the whole plant a certain positive effect is observed also on these soils. On the nutrient deficient brown forest soil, however, the fertilizer effect is always significant and it is directly proportional to the NPK dose. In both years the interaction between nutrients and water supply was positive.

In Table 3 the relative *phosphorus content* of oat is presented. It can be seen that, as a result of better water supply, the $P_2O_5$ % in *grain* increases that is, phosphorus uptake from the dry soil is lower. But this can be counterbalanced, especially on meadow and meadow-alluvial soils. There is no essential difference in the relative phosphorus content of grain (in controls) cropped on different soils, especially at optimal soil moisture.

In the relative $P_2O_5$ content of *straw* similar phenomena are observed with the remark that on all soils, except on the solonetz meadow soil, the

*Table 2*

**Weight of oat grain, g/pot**

| Treatments | I. Solonetz meadow soil | | | | IV. Brown forest soil with carbonate remnants | | | | III. Sandy meadow chernozem | | II. Meadow-alluvial soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1965 | 1967 | Average | D | 1965 | 1967 | Average | D | 1967 | D | 1967 | D |
| *45% (1965)—40% (1967) water capacity* | | | | | | | | | | | | |
| ∅ | 8,1 | 4,2 | 6,1 | — | 4,5 | 7,4 | 5,9 | — | 8,1 | — | 5,3 | — |
| 2 NK | 12,2 | 5,1 | 8,6 | 2,5 | 6,9 | 9,5 | 8,2 | 2,3 | 5,6 | −2,5 | 5,3 | +0,2 |
| 1 NPK | 13,5 | 3,5 | 8,5 | 2,4 | 8,3 | 6,7 | 7,5 | 1,6 | 7,1 | −1,0 | 5,6 | +0,3 |
| 2 NPK | 14,3 | 4,2 | 9,2 | 3,1 | 10,6 | 7,7 | 9,1 | 3,2 | 7,9 | −0,2 | 4,4 | −0,9 |
| 3 NPK | 16,5 | 4,3 | 10,4 | 4,3 | 11,0 | 8,0 | 9,5 | 3,6 | 8,2 | +0,1 | 4,3 | −1,0 |
| *70% water capacity* | | | | | | | | | | | | |
| ∅ | 9,2 | 16,9 | 13,0 | — | 4,4 | 8,4 | 6,4 | — | 14,3 | — | 20,9 | — |
| 2 NK | 17,3 | 20,7 | 19,0 | 6,0 | 13,6 | 20,6 | 17,1 | 10,7 | 13,7 | −0,6 | 22,2 | +1,3 |
| 1 NPK | 15,5 | 17,3 | 16,4 | 3,4 | 12,9 | 14,8 | 13,8 | 7,4 | 13,6 | −0,7 | 22,6 | +1,7 |
| 2 NPK | 16,7 | 19,0 | 17,8 | 4,8 | 15,0 | 19,1 | 17,0 | 10,6 | 17,3 | +3,0 | 18,8 | −2,1 |
| 3 NPK | 18,5 | 18,5 | 18,5 | 5,5 | 17,5 | 24,2 | 20,8 | 14,4 | 18,8 | +4,5 | 17,8 | −3,1 |
| 4 NPK | 16,8 | 19,0 | 17,9 | 4,9 | 14,6 | 28,0 | 21,3 | 14,9 | 19,3 | +5,0 | 1,92 | −1,7 |
| *Increase at 70% water capacity as compared to the 40% water capacity* | | | | | | | | | | | | |
| | g | g | g | % | g | g | g | % | g | % | g | % |
| ∅ | 1,1 | 12,7 | 6,9 | 113 | −0,1 | 1,0 | 0,5 | 8 | 6,2 | 76 | 15,6 | 294 |
| 2 NK | 5,1 | 15,6 | 10,4 | 121 | 6,7 | 11,1 | 8,9 | 108 | 8,1 | 145 | 16,7 | 304 |
| 1 NPK | 2,0 | 13,8 | 7,9 | 93 | 4,6 | 8,1 | 6,3 | 84 | 6,5 | 92 | 17,0 | 304 |
| 2 NPK | 2,4 | 14,8 | 8,6 | 94 | 4,4 | 11,4 | 7,9 | 87 | 9,4 | 119 | 14,4 | 328 |
| 3 NPK | 2,0 | 14,2 | 8,1 | 76 | 6,5 | 16,2 | 11,3 | 119 | 10,6 | 129 | 13,5 | 314 |
| $LSD_{5\%}$ Watering effect (a) | | 1,62 | | | | 1,50 | | | 1,63 | | 1,81 | |
| Fertilization effect (b) | | 1,02 | | | | 0,95 | | | 1,03 | | 1,15 | |

increased superphosphate dose proportionally increases the phosphorus per cent. The relative phosphorus content of *roots* is contrary to that said above, that is, in drier soils the phosphorus per cent is higher on all soil types. It is conspicuous that also the fertilization effect can be observed in this case and at a better water supply it is almost the same in all treatments. This phenomenon could be explained by the possible transformation of soil phosphorus into available form, due to the more favourable moisture conditions. This phosphorus is sensed mainly by the roots and thus they do not require the artificially supplied nutrients.

Table 4 presents the *distribution of phosphorus taken up* by plants in mg and Table 5 in per cent.

Radio isotope technics makes possible the separation of phosphorus taken up by plant in such a way that one can determine the amount of phosphorus originating from fertilizer and also the available phosphorus of soil utilized by the plant. It can be stated, that at an optimal water supply, in absolute numbers, in average, the amount of phosphorus taken up from the fertilizer as well as from the soil is more than twofold. At the same time, in relative numbers (Table 5), there is no difference between the two moisture

*Table 3*

**Phosphorus uptake by oat**
**Phosphorus content of oat in per cent of air dry matter**

| Soil type | Year | Ø 40 | Ø 70 | 1 NPK 40 | 1 NPK 70 | 2 NPK 40 | 2 NPK 70 | 3 NPK 40 | 3 NPK 70 |
|---|---|---|---|---|---|---|---|---|---|
| *Grain* $P_2O_5$% | | | | | | | | | |
| I. Solonetz meadow soil | 1965 | 0,67 | 0,77 | 0,79 | 0,83 | 0,72 | 0,80 | 0,83 | 0,76 |
| I. Solonetz meadow soil | 1967 | 0,68 | 0,90 | 0,85 | 0,90 | 0,99 | 0,90 | 1,08 | 0,84 |
| II. Meadow-alluvial soil | 1967 | 0,77 | 0,80 | 0,74 | 0,76 | 0,98 | 0,78 | 1,06 | 0,88 |
| III. Sandy meadow chernozem | 1967 | 0,50 | 0,57 | 0,73 | 0,86 | 0,73 | 0,85 | 0,64 | 0,96 |
| IV. Brown forest soil with carbonate remnants | 1965 | 0,70 | 0,73 | 0,59 | 0,70 | 0,59 | 0,73 | 0,65 | 0,78 |
| IV. Brown forest soil with carbonate remnants | 1967 | 0,74 | 0,80 | 0,65 | 0,75 | 0,74 | 0,74 | 0,68 | 0,67 |
| Average | | 0,67 | 0,76 | 0,72 | 0,80 | 0,79 | 0,80 | 0,82 | 0,81 |
| *Straw* $P_2O_5$% | | | | | | | | | |
| I. Solonetz meadow soil | 1965 | 0,37 | 0,54 | 0,25 | 0,32 | 0,20 | 0,38 | 0,34 | 0,34 |
| I. Solonetz meadow soil | 1967 | 0,19 | 0,21 | 0,24 | 0,23 | 0,32 | 0,21 | 0,30 | 0,20 |
| II. Meadow-alluvial soil | 1967 | 0,15 | 0,12 | 0,17 | 0,19 | 0,32 | 0,24 | 0,42 | 0,24 |
| III. Sandy meadow chernozem | 1967 | 0,10 | 0,08 | 0,14 | 0,25 | 0,20 | 0,32 | 0,19 | 0,24 |
| IV. Brown forest soil with carbonate remnants | 1965 | 0,06 | 0,25 | 0,06 | 0,18 | 0,10 | 0 18 | 0,10 | 0,21 |
| IV. Brown forest soil with carbonate remnants | 1967 | 0,11 | 0,23 | 0,13 | 0,19 | 0,17 | 0,21 | 0,19 | 0,19 |
| Average | | 0,16 | 0,24 | 0,16 | 0,23 | 0,22 | 0,26 | 0,26 | 0,24 |
| *Roots* $P_2O_5$% (1967) | | | | | | | | | |
| I. Solonetz meadow soil | | 0,38 | 0,24 | 0,46 | 0,29 | 0,58 | 0,31 | 0,57 | 0,28 |
| II Meadow-alluvial soil | | 0,28 | 0,30 | 0,30 | 0,23 | 0,50 | 0,25 | 0,60 | 0,32 |
| III. Sandy meadow chernozem | | 0,39 | 0,33 | 0,39 | 0,33 | 0,41 | 0,32 | 0,46 | 0,29 |
| IV. Brown forest soil with carbonate remnants | | 0,27 | 0,26 | 0,34 | 0,28 | 0,40 | 0,25 | 0,42 | 0,26 |
| Average | | 0,33 | 0,26 | 0,37 | 0,28 | 0,47 | 0,28 | 0,51 | 0,29 |

In 1965 45% water capacity

*Table 4*

**Distribution of phosphorus taken up by plant ($P_2O_5$ mg/pot)**

| Soil | Year | 1 NPK | | 2 NPK | | 3 NPK | | 4 NPK |
|---|---|---|---|---|---|---|---|---|
| | | 40 | 70 | 40 | 70 | 40 | 70 | 70 |
| *Originating from fertilizer* | | | | | | | | |
| I. Solonetz meadow soil | 1965 | 34,0 | 40,6 | 57,3 | 62,2 | 80,6 | 84,7 | — |
| I. Solonetz meadow soil | 1965 | 17,6 | 45,1 | 30,9 | 82,4 | 44,0 | 96,2 | 150,5 |
| II. Meadow-alluvial soil | 1967 | 29,3 | 81,4 | 58,7 | 115,9 | 79,8 | 173,0 | 228,8 |
| III. Sandy meadow chernozem | 1967 | 40,9 | 124,4 | 83,1 | 201,7 | 83,5 | 242,8 | 269,7 |
| IV. Brown forest soil with carbonate remnants | 1965 | 30,6 | 54,5 | 48,4 | 84,6 | 50,0 | 87,6 | — |
| IV. Brown forest soil with carbonate remnants | 1967 | 28,5 | 80,4 | 56,4 | 152,7 | 61,7 | 213,3 | 262,0 |
| Average | | 30,1 | 71,1 | 55,8 | 116,6 | 66,6 | 149,6 | — |
| *Originating from soil* | | | | | | | | |
| I. Solonetz meadow soil | 1965 | 107,7 | 155,1 | 98,5 | 150,7 | 124,5 | 136,6 | — |
| I. Solonetz meadow soil | 1967 | 67,0 | 235,8 | 79,6 | 218,7 | 62,0 | 167,7 | 158,5 |
| II. Meadow-alluvial soil | 1967 | 54,5 | 203,5 | 58,5 | 124,3 | 57,8 | 128,4 | 162,0 |
| III. Sandy meadow chernozem | 1967 | 58,7 | 119,3 | 56,1 | 114,0 | 42,6 | 129,1 | 76,9 |
| IV. Brown forest soil with carbonate remnants | 1965 | 35,4 | 66,1 | 37,3 | 71,7 | 44,4 | 99,4 | — |
| IV. Brown forest soil with carbonate remnants | 1967 | 50,8 | 141,7 | 55,9 | 131,1 | 48,8 | 101,6 | 105,5 |
| Average | | 62,3 | 153,6 | 64,3 | 135,1 | 63,3 | 127,1 | — |
| *Total $P_2O_5$ taken up* | | | | | | | | |
| In the average of 6 experiments | | 92,4 | 224,7 | 120,1 | 251,7 | 129,9 | 276,7 | — |

In 1965 45% water capacity

levels concerning the phosphorus uptake from the fertilizer or from the soil in per cent of total $P_2O_5$. In the case of two soils the deviations in the two years can partly be explained by the fact that in 1965 the radioactivity of straw was already too low to be measured and the roots were not taken into account.

When comparing the soils it can be seen that the largest proportion shift between phosphorus originating from fertilizer and from soil was observed on the solonetz meadow soil. More phosphorus was taken up from soil. At the same time on the sandy meadow chernozem and on the brown forest soil a larger ratio and naturally more phosphorus is taken up from the fertilizer by the plant.

It is worth-while to make a *P-balance* in the 1967 experiment from which one can see the utilization or availability of soluble phosphate supply in individual soils. To make this, we calculated at the start of the experiment the existing phosphorus supply in pots, furthermore, the amount of phosphorus taken up by the plant. We took into account the total phosphorus taken up from the soil at controls and at NK treatments. At NPK treatments the isotope method was used. (See Table 4). Thus we re ated the amount of phosphorus (mg $P_2O_5$/pot) taken up by plants from the soil to the amount of phosphorus existing in the soil (mg $P_2O_5$/pot) at the start.

*Table 5*

**$P_2O_5$ taken up by plant from fertilizer in per cent of the total phosphorus uptake**

| Soil | 1 NPK | | 2 NPK | | 3 NPK | | 4 NPK |
|---|---|---|---|---|---|---|---|
| | 40 | 70 | 40 | 70 | 40 | 70 | 70 |
| I. *On solonetz meadow soil* | | | | | | | |
| 1965 | 24,1 | 20,8 | 36,8 | 29,1 | 39,2 | 38,3 | — |
| 1967 | 20,8 | 16,0 | 28,0 | 27,4 | 41,5 | 36,4 | 48,7 |
| *II. On meadow-alluvial soil* | | | | | | | |
| 1967 | 35,0 | 28,6 | 50,1 | 48,4 | 58,0 | 57,5 | 58,6 |
| *III. On sandy meadow chernozem* | | | | | | | |
| 1967 | 41,1 | 51,2 | 59,7 | 63,6 | 66,2 | 65,4 | 78,0 |
| *IV. On brown forest soil with carbonate remnants* | | | | | | | |
| 1965 | 46,4 | 45,1 | 56,6 | 54,2 | 53,0 | 46,8 | — |
| 1967 | 35,9 | 36,2 | 50,3 | 53,8 | 56,1 | 67,6 | 71,2 |
| *In the average of 6 data* | | | | | | | |
| From fertilizer | 33,9 | 31,3 | 46,9 | 46,1 | 52,3 | 52,0 | 64,1 |
| From soil | 66,1 | 68,7 | 53,1 | 53,9 | 47,7 | 48,0 | 35,9 |

In 1965 45% water capacity.

| | 40% and 70% water capacity | | Supply in soil $P_2O_5$ mg/pot |
|---|---|---|---|
| I. Solonetz meadow soil | 10,4 | 34,8 | 690 |
| III. Alluvial-meadow soil | 16,5 | 52,2 | 357 |
| III. Sandy meadow chern. | 14,0 | 27,7 | 430 |
| IV. Brown forest soil with carbonate remnants | 26,0 | 51,8 | 265 |

In the average of treatments the following values were obtained in per cent of the supply found in the soils at the start.

But even without this, the data clearly indicate that as a result of optimum water supply (70% water capacity), depending on the soil's phosphorus content, phosphate transformation into available form is essential, thus the ratio of the utilized phosphorus — as compared to the 40% water capacity treatment — is threefold on meadow soils, twofold on sandy and on brown forest soils. There is a considerable variation between soils under drier and under more moist conditions.

Table 6 shows the *utilization of superphosphate.*

It can be seen that the phosphoric acid utilization of the fertilizer can be increased by better water supply in most cases, that is, it can be increased by two-threefold. The utilization coefficient is the highest on sandy meadow chernozem and on brown forest soils at both moisture levels. Increased phosphorus dose decreased the utilization per cent in all cases.

*Table 6*

**Utilization per cent of superphosphate**

| $P_2O_5$ mg/pot | I. Solonetz meadow soil | | | | II. Meadow-alluvial soil | | III. Sandy meadow chernozem soil | | IV. Brown forest soil with carbonate remnants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1965 | | 1967 | | 1967 | | 1967 | | 1965 | | 1967 | |
| | 45 | 70 | 40 | 70 | 40 | 70 | 45 | 70 | 40 | 70 | 40 | 40 |
| 300 | 11,3 | 13,5 | 5,9 | 15,0 | 9,8 | 27,1 | 13,7 | 41,5 | 10,2 | 18,1 | 9,5 | 26,8 |
| 600 | 9,5 | 10,3 | 5,2 | 13,7 | 9,8 | 19,3 | 13,8 | 33,6 | 8,1 | 14,1 | 9,4 | 25,5 |
| 900 | 9,0 | 9,4 | 4,9 | 10,7 | 8,9 | 19,2 | 9,3 | 27,0 | 5,6 | 9,7 | 6,9 | 23,7 |
| 1200 | — | — | — | 12,5 | — | 19,1 | — | 22,4 | — | — | — | 21,8 |
| Average | 9,9 | 11,1 | 5,3 | 12,9 | 9,5 | 21,1 | 12,2 | 31,1 | 7,9 | 14,0 | 8,6 | 24,4 |

*Table 7*

**Total amount of phosphorus per transpired unit water**
**(mg $P_2O_5$/l litre water)**

| Treatments | Solonetz meadow soil | | Meadow-alluvial soil | Sandy meadow chernozem soil | Brown forest soil with carbonate remnants | |
|---|---|---|---|---|---|---|
| | 1965 | 1967 | 1967 | 1967 | 1965 | 1967 |
| *45% (1965)—40% (1967) water capacity* | | | | | | |
| Ø | 12,6 | 24,4 | 28,7 | 19,8 | 7,7 | 23,1 |
| NK | 12,6 | 29,3 | 26,9 | 19,8 | 8,8 | 24,4 |
| 1 NPK | 14,1 | 29,5 | 26,6 | 24,3 | 8,3 | 28,4 |
| 2 NPK | 15,5 | 28,6 | 48,8 | 34,1 | 10,7 | 36,5 |
| 3 NPK | 21,3 | 37,8 | 54,8 | 36,0 | 11,2 | 34,1 |
| Average | 15,2 | 31,1 | 37,1 | 26,8 | 9.3 | 29,3 |
| *70% water capacity* | | | | | | |
| Ø | 15,0 | 20,2 | 16,9 | 10,7 | 7,8 | 15,8 |
| NK | 15,8 | 22,3 | 17,6 | 10,9 | 8,8 | 13,0 |
| 1 NPK | 14,7 | 20,6 | 20,5 | 21,7 | 10,0 | 10,8 |
| 2 NPK | 17,1 | 20,6 | 16,5 | 25,2 | 11,1 | 12,9 |
| 3 NPK | 13,3 | 18,6 | 21,2 | 30,4 | 14,0 | 13,8 |
| 4 NPK | — | 22,1 | 27,0 | 27.1 | — | 15,4 |
| Average | 15,1 | 20,7 | 19,9 | 21,0 | 10,3 | 13,6 |

Total water used (1965) or transpired (1967) during the growing season in the average of treatments in kg:

| | | | | | | |
|---|---|---|---|---|---|---|
| 45—40% water cap. | 14,4 | 2,83 | 2,52 | 3,75 | 8,4 | 3,41 |
| 70% water cap. | 21,6 | 13,81 | 14,18 | 11,70 | 16,4 | 18,57 |

The following calculation gives us information about the existing relation between the nutrient- and water uptake (Table 7). It presents the amount of total *phosphorus* taken up from the soil and from the soil and the fertilizer *per unit of transpiration water* (1965 — evapotranspiration; 1967 transpiration).

As one can see from Table 7, there is no direct relation between the uptake of P-ions and that of water, since the application of more water does not ensure the same amount of phosphorus uptake per unit water. This refers among others to the fact, that under optimum moisture conditions — when

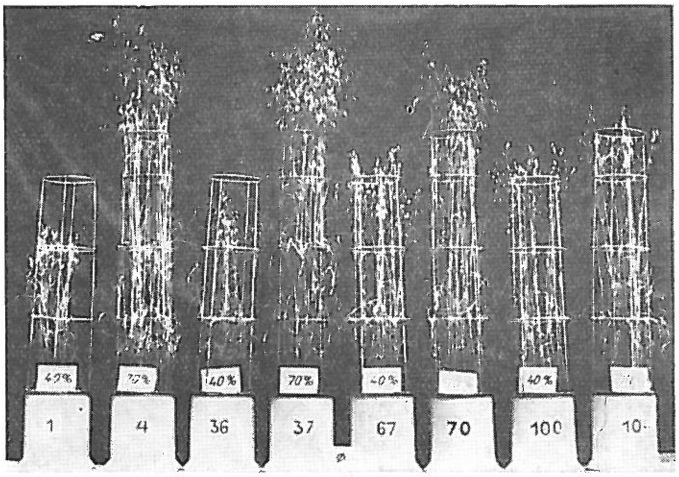


*Figure 1*

The effect of better water supply in the case of natural fertility of soil (without fertilization) 1, 4 — I soil; 36, 37 — II soil; 67, 70 — III soil; 100, 104 — IV soil

the total amount of water used is 3—5 times as high as under drier conditions — the decrease is significant. As a result of treatments, phosphorus generally increases per unit water—especially under drier growing conditions, although the amount of total water used or transpired was almost the same in the treatments.

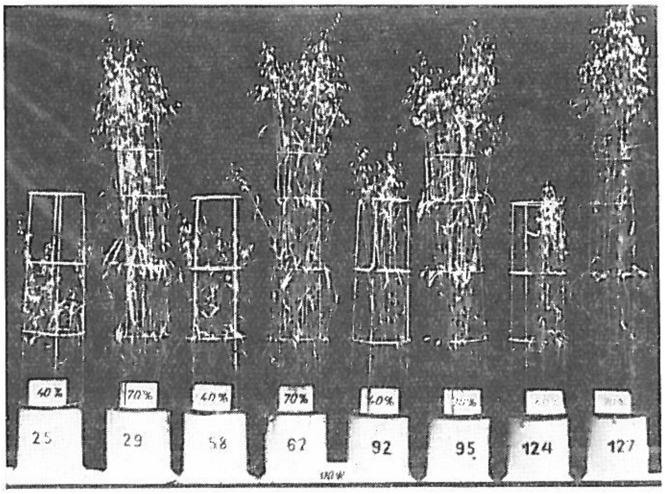


*Figure 2*

The effect of better water supply on various fertilized soils
25, 29 — I soil; 58, 62 — II soil; 92, 95 — III soil; 124, 127 — IV soil

## Summary

In pot experiments with oat the effects of natural and artificial nutrient supply of soils and of soil moisture on the dry matter weight of plants, furthermore, on phosphorus- and water uptake and utilization were studied. $^{32}P$ labelled superphosphate was used for phosphorus uptake studies.

We have concluded that in the case of soils rich in nutrient, irrigation exercises a more marked effect than fertilization. On brown forest soil containing small amount of nutrients, it is just the opposite, that is, the effect of fertilization is greater than that of irrigation or, in other words, watering is effective when the soil is also fertilized.

Relative phosphorus uptake by grain and straw is less, but by roots is more from dry soil. According to the obtained data, on solonetz meadow soil the ratio drift of fertilizer- and soil phosphorus was in favour of the latter but on sandy meadow chernozem and on brown forest soil the plant takes up phosphorus in a larger ratio and amount from fertilizer. Superphosphate utilization is most intensive on the two latter soils, but by ensuring a better water supply it can be increased on all soils. The amount of total phosphorus taken up per transpired unit water was not proportional to the amount of used and transpired water.


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