Effect of Mineral Fertilizers on the Growth and Nutrient Uptake of Maize Plants

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According to A. A. J. DE 'SIGMOND, one of the main tasks of agricultural chemistry is to study the nutrition of cultivated plants. About the turn of the century he carried on intensive research work in this field, studying the dry matter accumulation and nutrient uptake of some agricultural crops.

He suggested to consider the nutrient requirement of a certain plant to be equal with the nutrient amount taken up during the vegetation period. This quantity, however, depends to a great extent on the genetic background of the plant and on the environmental conditions (soil, climate, etc.), too.

His detailed studies on the development and nutrient uptake of maize and some other crops provide very valuable data for agricultural science and serve as a useful guide for fertilization practices [9—13].

'SIGMOND found the experimental results to be in accordance with experiential observations. They can be summarized in a general physiological theory which sets a course for new directions of research, requiring the study — in accurate and practical experiments — of the effect of every factor (soil, fertilization, cultivation, etc.) influencing the development and nutrient uptake of plants.

From among the above-mentioned factors we must emphasize the effect of fertilizers, especially nowadays, when the fertilizer amounts per unit area are increasing considerably.

An understanding of crop morphology in relation to growth and nutrient uptake is fundamental to the development of more effective fertilization practices.

'SIGMOND's theory was proved by the numerous scientific results published thereafter.

A review of NELSON [8], incorporating results obtained by several researchers, notes that the curve for N accumulation as a function of time in the whole maize plant slightly precedes the curve for dry matter production until shortly after tasselling and silking.

Accumulation of dry matter is accompanied in maize plants by N, P and K accumulation. The absolute N, P and K contents of the whole plants increase up to harvest time. HANWAY [1] found a characteristic distribution of N in the different parts of maize plants irrespective of cropping system and fertilizer treatment. Nitrogen accumulated in each plant part as it grew with little translocation from one part to another until grain formation began, when

N was translocated from all other plant parts to the grain. HANWAY observed that translocation of N from cob, husk and stalk preceded that from the leaves and that by silking time the plant had taken up 65 per cent of the total crop accumulation of N. At maturity 2/3 of the crop's total above-ground N content was concentrated in the grain and half of this amount appeared to have been translocated from other above-ground parts.

We also studied for several years the dry matter accumulation and nutrient uptake of maize plants in field and pot experiments. The aim was primarily to examine the changes due to mineral, especially N and P fertilization. The use of isotope indication made it possible to study directly the uptake of the different plant nutrients. This method helped us to gain more information about the time and ways of uptake and utilization of P and N from fertilizers by maize plants.

In the following the summarized results of our experiments on dry matter accumulation and nutrient uptake of maize are presented. The methods used and the conditions of the experiments are described in some previous publications [2 – 7].

Effect of fertilizers on growth, development and nutrient uptake of maize

Fig. 1 shows the dry matter accumulation in maize plants at the different stages of growth. It can be seen that dry matter production was going on till harvest, though the rate of accumulation was rather uneven. Up to the time of the appearance of 3 – 5 leaves, dry matter production was very slow, not reaching 1 per cent of the maximum dry weight. At the time of shoot elongation it amounted to 8 – 10 per cent. It was during the period from tasselling to silking that dry matter accumulation was the most rapid, resulting in the production of 50 – 60 per cent of the maximum dry weight. After silking the increase was still going on, though to a lesser extent than in the previous vegetation period.

Dry matter accumulation in the various plant parts during the successive growth stages was also different. Before the time of shoot elongation the leaves accounted for the greatest part of the dry matter content. At silking, the dry weight of the stalk increased to a considerable extent, surpassing that of the leaves. The dry weight of the ear was relatively not high yet and that of the tassel remained negligible. Thereafter, the dry weights, especially those of the ears, continued to increase with a gradual decrease in the relative weight of the leaves, stalk and tassel.

Fig. 1 shows the increase of the dry matter content in maize plants as affected by fertilization (with 50 kg/ha N, P_2O_5 and K_2O, expressed in active agent). The differences observed in the various treatments were due to the proportional increase in the dry weight of the plant parts, i.e. at the beginning of growth in that of the leaves and stems and later in the dry weight of the ears.

Our investigations revealed that the N and P uptake by maize was going on up to harvest time, showing the maximum at the time of shoot elongation and silking. The rate of K uptake was the highest at the time of leaf and stalk development, then it decreased and remained essentially unchanged until harvesting. As a response to N and NPK fertilization, the N and P amounts taken up by the plant were considerably higher.

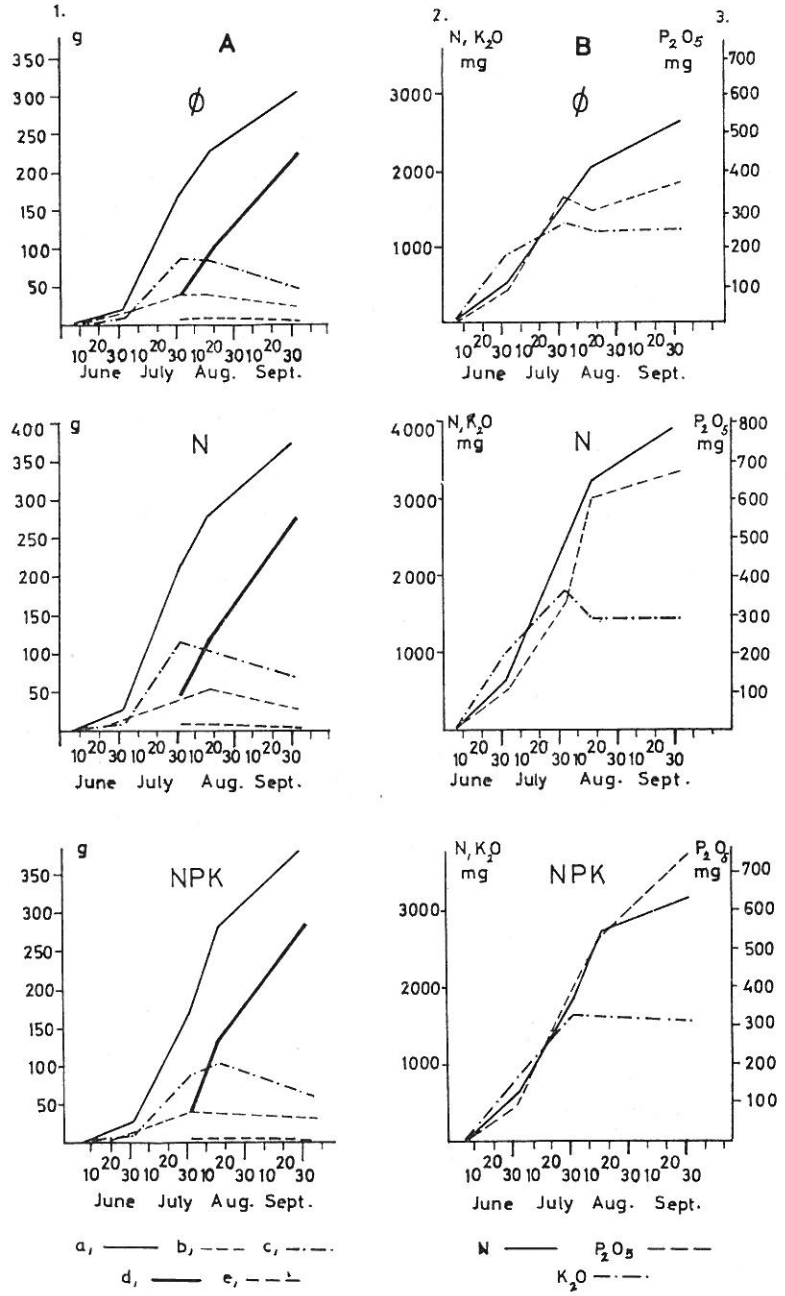

Fig. 1

Dry matter accumulation and nutrient uptake by maize. Vertical axes: 1. dry matter, g; 2. N, K_2O uptake, mg; 3. P_2O_5 uptake, mg

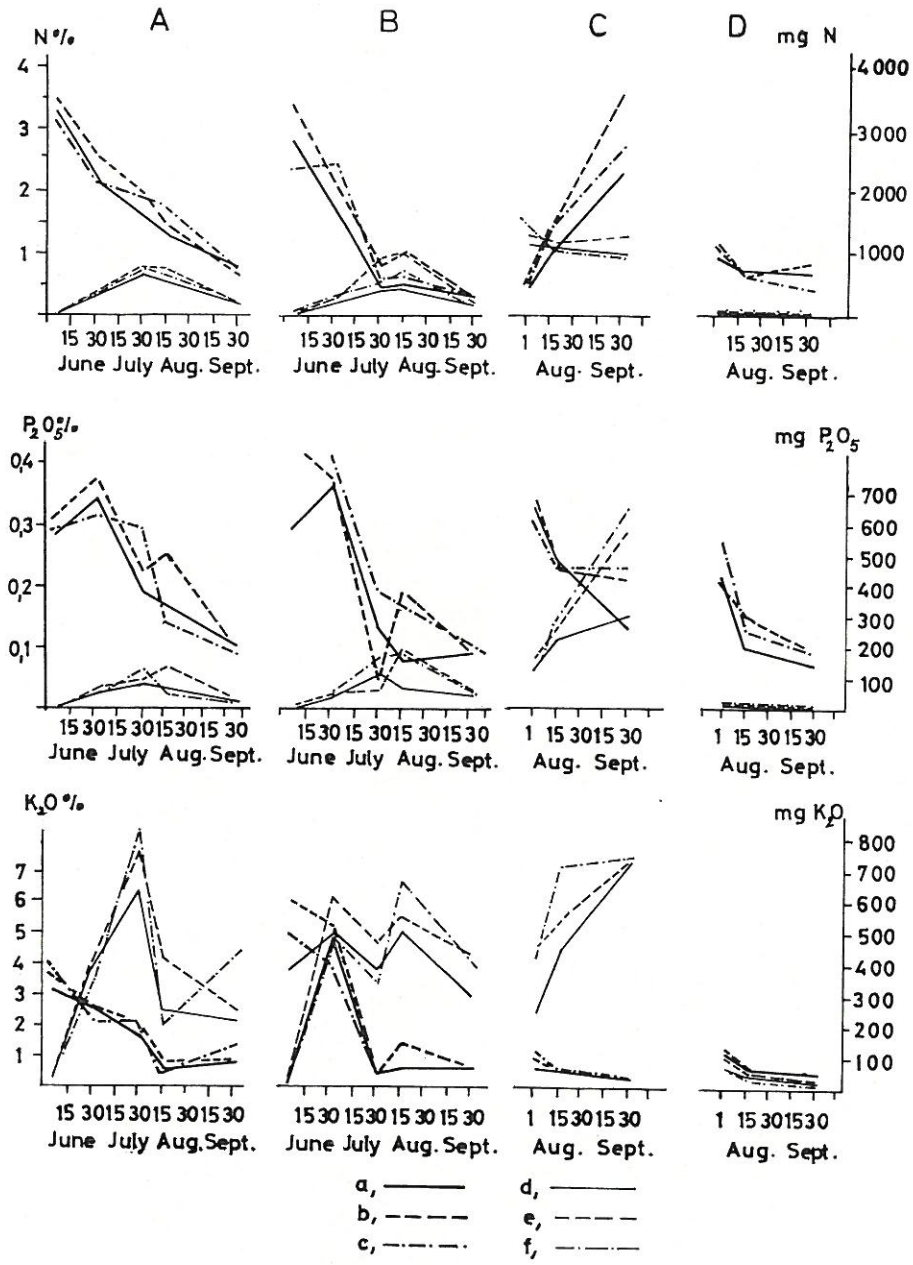

Fig. 2

The N, P and K contents of the different plant parts as affected by the treatments. A — Leaf; B — Stalk; C — Cob; D — Tassel. Vertical axes: (left) nutrient content, %. a. control; b. N treatment; c. NPK treatment. (right) nutrient content, mg. d. control; e. N treatment; f. NPK treatment

The data obtained for the N, P and K contents (given in per cent) and nutrient amounts (in mg) in the different vegetative organs are shown in Fig. 2. The N, P and K dynamics of the above-ground parts of maize reflect the physiological processes in the plant. Before silking and grain formation the mineral nutrients were accumulated in the leaves and in the stalk. After the development of the generative organs, the N, P and K contents in all the plant parts decreased with the exception of the ears in which there was an increase until harvesting. Most part of the nutrients in the plant organs was translocated into the ears.

During the period before silking the nutrient content of the leaves and stalks increased considerably due to N and NPK fertilization. At harvesting, however, the effect of the treatments was observable primarily in the N and P contents of the ears.

Nitrogen uptake by maize plants from ^{15}N labelled fertilizer

A field experiment was conducted on a brown forest soil on loess with ^{15}N labelled ammonium nitrate, using 90 kg N/ha. During the growing season the nutrient content and uptake of the crops and the recovery of ^{15}N from ammonium nitrate were studied under field conditions.

Table 1 summarizes the data on the N percentage of the different plant parts. It can be observed that, due to fertilization, there was a significant increase in the N contents at the time of the different samplings and in the average of the samplings. It may also be seen that both on the untreated and on the N-fertilized plots there was a reliable decrease in the N percentages of the leaves and tassels during the whole vegetation period, whereas the N content of the stalks decreased only before silking and then it remained essentially unchanged.

In Fig. 3 the amounts of N taken up by maize are represented for each plant part. It can be clearly seen that the N content of the different plant parts increased considerably due to N fertilization, and that 45—54 per cent of the total N amount derived from the applied fertilizers. It was proved that due to the effect of the treatments, the N amount taken up by the plants increased significantly during the vegetation period. The labelled fertilizers were utilized to 40.8 per cent under the given conditions.

Uptake and utilization of phosphorus and nitrogen by young maize plants from ^{32}P and ^{15}N labelled fertilizers

As proved by the chemical analyses of maize samples grown in field experiments and collected during the growing period, the uptake of nutrients already began at an early stage of plant development. This fact indicates the importance of this stage from the point of view of plant nutrition and growth. For this reason, primarily the N and P uptake by young maize plants was studied in pot experiments.

The seasonal uptake of phosphate was studied by using ^{32}P superphosphate in a brown forest soil with low available phosphorus content. The superphosphate was mixed into the soil. After emergence the plants were cut weekly for 10 weeks. The above-ground parts of the plants were used both for

Table 1

Effect of N fertilization on the N content of the different plant parts (%)

Plant parts and sampling dates	Ø	N	N – Ø	$LSD_{5\%}$	Average
Leaf					
29 July	1.57	2.43	0.86	0.15	2.00
16 August	1.11	1.95	0.84	0.21	1.53
14 Sept.	1.00	1.15	0.15	0.20	1.07
21 Oct.	0.68	0.89	0.21	0.11	0.78
$LSD_{5\%}$	0.04		0.06		0.03
Average	1.09	1.60	0.51*	0.02	1.34
Stalk					
29 July	0.67	0.89	0.22	0.15	0.78
16 August	0.34	0.42	0.08	0.21	0.38
14 Sept.	0.31	0.33	0.02	0.20	0.32
21 Oct.	0.34	0.34	—	0.11	0.34
$LSD_{5\%}$	0.04		0.06		0.03
Average	0.41	0.49	0.08*	0.02	0.45
Tassel					
29 July	2.02	2.53	0.51	0.15	2.27
16 August	1.07	1.00	–0.07	0.21	1.03
14 Sept.	0.79	0.99	0.20	0.20	0.89
21 Oct.	0.68	0.71	0.03	0.11	0.69
$LSD_{5\%}$	0.04		0.06		0.03
Average	1.14	1.30	0.16*	0.02	1.22

chemical and radiochemical analyses. The results indicated that in the first week after emergence the young seedlings were supplied mainly with the original nutrients of the grain. Afterwards, the nutrient sources of the soil were utilized. The dry weight, as well as the amounts of total and fertilizer P were significantly increased by the applied P. It could be established that half of the total assimilated P amount derived from superphosphate.

Further, the efficiency of P fertilization, as affected by the applied N rates, was studied.

It was established that the application of N promoted the utilization of P fertilizers in the early stage of development (Fig. 4). In samples taken from plots without N-treatment it was only 5.9 per cent of the total P amount assimilated by the plant that derived from the fertilizer, whereas after N fertilization this quantity reached 28.2 per cent in the average of the N-treatments. The effect of N fertilization was observable also in the later growing periods. Without N, only 56.4 per cent of the total P content of the seven-week-old maize plants derived from the added fertilizer, in contrast with the 68.9 per cent established in the average of the N-treatments. As for the utilization of P fertilizers, these values were 27 and 35.4 per cent, respectively.

The advantages of the isotope method were the greatest in the case of the simultaneous labelling of several nutrients. Experiments were carried out

in nutrient-free sand cultures using ^{32}P labelled superphosphate and ^{15}N labelled calcium ammonium nitrate to study the P and N uptake of the young maize plants, as well as to investigate the interactions of these two nutrients.

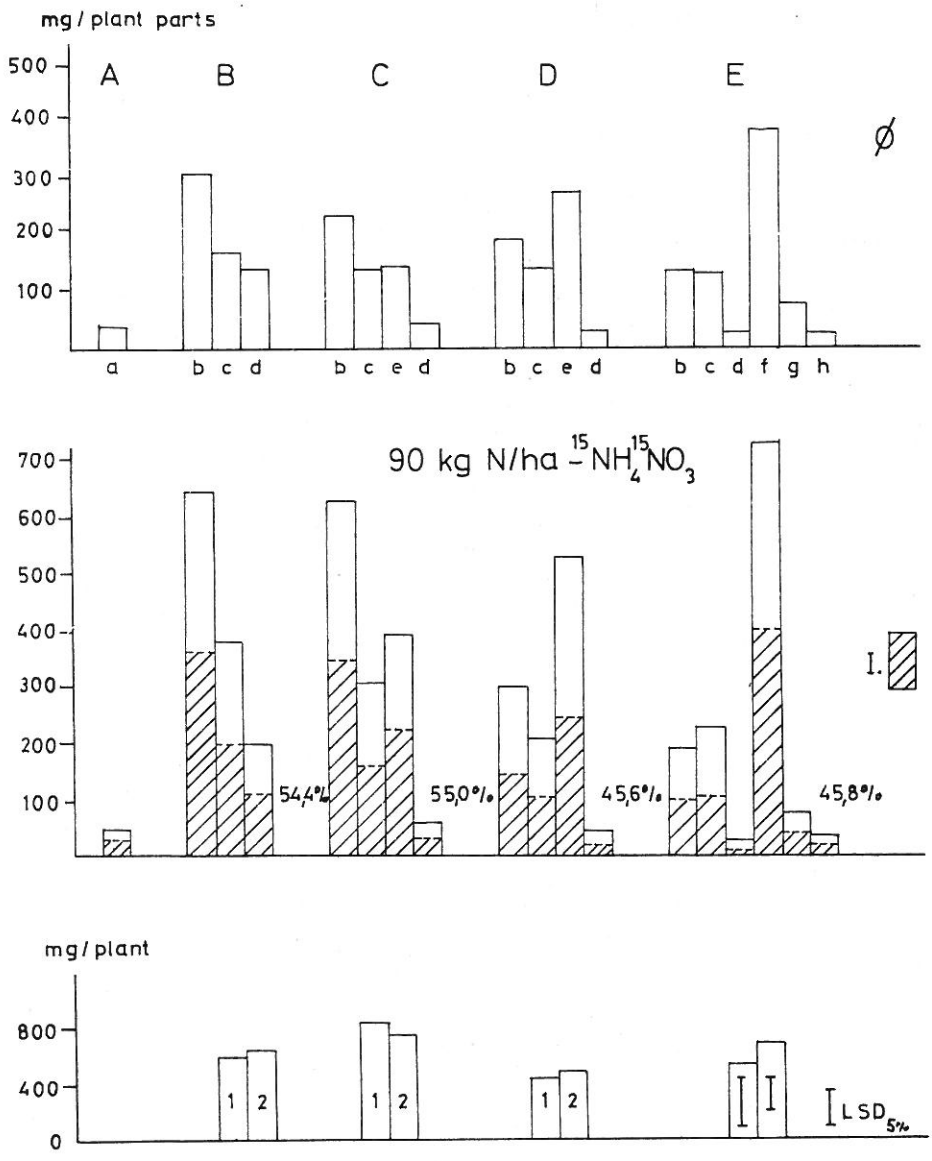

Fig. 3

Nitrogen uptake by plants at the different stages of growth as affected by N fertilizing. A — Emergence; B — Tasseling; C — Silking; D — Milky ripeness; E — Harvest. a. seedling; b. leaves; c. stalk; d. tassel; e. cob; f. grain; g. corn cob; h. husk. I. N derived from the fertilizer. Column diagram at the bottom: N surplus due to the effect of treatment. 1. calculated with the method of difference; 2. on the basis of isotope dilution

Table 2

N and P recovered from labelled fertilizers

Treatments	N		P_2O_5		Recovery of fertilizers, %	
	%	mg	%	mg		
	from labelled fertilizer				N	P_2O_5
^{32}P	—	—	31.9	3.5	—	19.6
$^{15}N_1$	60.1	14.1	—	—	35.2	—
$^{15}N_2$	74.7	32.6	—	—	40.7	—
$^{15}N_1$ ^{32}P	68.1	20.2	30.1	5.9	50.5	32.9
$^{15}N_2$ ^{32}P	77.3	37.0	28.3	5.9	46.2	32.5
$^{15}N_1$ ^{32}PK	62.9	17.6	29.8	4.9	44.0	27.1
$^{15}N_2$ ^{32}PK	75.6	34.5	26.9	5.8	43.1	32.1
$LSD_{5\%}$	—	7.18	—	0.76	17.9	4.2

18 mg P_2O_5, 40 and 80 mg N, resp., and 40 mg K_2O/pot.

26 days after emergence the plants were cut and the dry matter, the total phosphate and radioactive phosphate contents were determined in the above-ground part of the plants. Isotope ratio analyses of N in the plant permitted estimates of the N amount taken up from the fertilizer.

It could be established that from 60.1 to 77.3 per cent of the assimilated N amount derived from the applied N fertilizer and that from 35.2 to 50.5 per cent of the N fertilizer was utilized — depending on the treatment — during the 26 days of the experiment (Table 2).

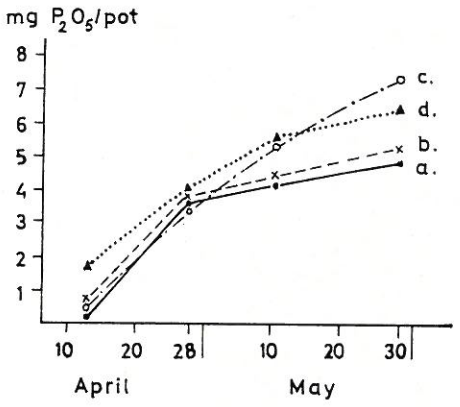

Fig. 4

P_2O_5 derived from the fertilizer, taken up by the young plant. a. control; b. 40 mg N/1 kg soil; c. 80 mg N/1 kg soil; 4. 200 mg N/1 kg soil

The data on P assimilation show that from 26.9 to 31.9 per cent of P derived from the fertilizer and the utilization percentage of P fertilizers varied between 19.6 and 32.9.

By the additional application of P and PK, the utilization of N fertilizers could be increased, though this effect was not reliable statistically. By N fertilization, however, the P uptake of the young maize plants was affected advantageously. There was a significant increase in the P amount deriving from the fertilizer and thereby a greater reliable utilization of P fertilizers was assured.

Summary

The paper reviews current knowledge and presents some new data on the effect of mineral fertilizers on the growth and nutrient uptake by maize plants.

As a response to fertilization both the dry matter content of plants and the nutrient amounts taken up by maize increased considerably.

The rate of dry matter accumulation and nutrient assimilation varied during the vegetation period and in each plant part due to the physiological processes of plant growth.

The data obtained with the isotope indication method showed that considerable amounts of N and P taken up by the plant derived from the fertilizers.

Using ^{15}N labelled fertilizers it was found that after one cropping season the utilization of N fertilizers was 40.8 per cent under field conditions. In greenhouse experiments the utilization of N fertilizers varied between 35.2 and 50.5 per cent and that of P fertilizers between 19.6—32.9 per cent.

P uptake was influenced by N fertilization, too.

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