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EFFECTS OF SYSTEMATIC MINERAL FERTILIZATION ON THE UPTAKE, DISTRIBUTION AND REMOVAL OF SOIL COPPER BY SUNFLOWER PLANTS

N. MITREVA and V. ILIEV
(Bulgaria)

Voluminous amount of literature has been published on the uptake of microelements considering the soil type and the geographical provinces. According to us, the studies on the influence of cultural treatments and fertilizers (as they also take part in the nutrition of plants with microelements) are very few.

It is well known (2) that fertilization with microelements and particularly when in great doses, not only enriches the soil with these elements but results in a series of changes in the availability of other marco and microelements.

It is also important to know the need of plants for microelements during the different phases, the distribution of microelements in different organs, as well as their quantity coming from the soil for the intensive plant growing and for finding the parameters of the expected yields.

Cooper is an indispensable nutritive element of high physiological importance for the plants. Being a component of oxidizing ferments, this element increases the activity of peroxidase influencing this way the synthesis of protein, carbohydrates, and fats.

In this study we publish one-year data of uptake and distribution dynamics of cooper from soil into sunflower plants during their ontogenetic development and the quantity of the extracted copper in the cases of differently graded fertilization.

MATERIALS AND METHODS

We carried out a field experiment with systematic fertilization on slightly leached chernozem in 1973 in the Agricultural Research Institute near General Toshevo. The experiment was performed in the block-method in four replications and consisted of the following fertilization variants :

1. Non-fertilized (check) variant.

2. Phosphorus fertilized variant — doses of 0, 4, 8, 16, 32 kg/per 1000 square metres of P_2O_5 on two degrees of fertilization. Peredovik variety was included in the crop rotation of wheat, maize, wheat and sunflower. Data were recorded on 7 dates during the following phases of development of sunflower plants :

1st date — 3—4 pairs of leaves ;
2nd date — 8—10 pairs of leaves ;
3rd date — beginning of bud formation ;
4th date — beginning of blossom ;
5th date — end of blossom ;
6th date — seed maturation ;
7th date — complete ripeness of seeds.

Copper content in plants was determined spectrophotometrically (SP — 90) in HCl extract after dry burning and oil — EDTA extract.

RESULTS

Table 1 shows the copper concentration in different organs and its variations depending on fertilization and plant development. The highest concentration was in leaves and heads and the lowest (about 1/4 in comparison with blades) — in the petioles. Copper concentration in stems was medium. The higher copper quantity in organs of the most active metabolic processes confirms the physiological role of copper.

Changes in the concentration of copper connected with plant age were observed in all organs but they were the faintest in leaves and seem to be connected with fertilization. In variants with no phosphorous fertilizers there could be traced a tendency of decrease at the end of vegetation. In all variants the concentration of copper in petioles decreased with the age of plant. An increase of concentration was observed in phase 3 in leaves and stems and in some of the variants and in phase 5 in all variants compared with the other development phases. Copper concentration in stems during the last days of vegetation decreases 4 to 5 times compared with the first phase. In heads, phase 6, the concentration is twice as less as in phase 3 but during ripening it increases again. Mineral fertilizers have affected copper concentration in plants. Nitrogen fertilizers increase its concentration in all parts of the plants while phosphorous fertilizers have the opposite effect, better observed in the vegetative organs.

Figure 1 shows the copper distribution in organs for each particular phase in percentage of the total quantity of copper in the plant. It depends first of all on the relative proportion of organs in the total mass of the plant. Changes in copper distribution in organs connected with the age are also submitted to changes in the relative part of each organ in the whole mass of the plant. In the first phase, for example, 70—80 per cent from the copper quantity in the whole plant is concen-

Table 1

Copper concentration in sunflower organs in mg/kg dry substance

Degree of fertilization	P_2O_5	Leaves							Petioles							Stems							Heads					Seeds	
		Date of sampling																											
		I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	VII	III	IV	V	VI	VII	VI	VII
Check		25	22	25	16	24	25	17	12	13	9	8	9	10	10	21	17	13	14	11	5	4	25	25	11	11	8	16	17
$N_{12}K_8$	0	24	27	33	28	29	33	36	14	16	11	15	18	19	14	20	22	36	14	26	5	8	27	28	25	18	23	22	17
	4	17	19	21	18	17	18	15	12	13	8	8	12	7	7	19	14	14	13	23	6	4	26	24	17	12	22	22	20
	8	13	16	14	9	16	16	11	8	10	7	7	8	8	6	12	11	13	10	14	4	4	21	17	14	11	14	17	21
	16	9	13	12	8	10	12	8	4	7	5	6	4	3	5	6	8	9	9	13	7	2	14	17	13	8	16	17	16
$N_{18}K_{12}$	0	23	25	30	25	25	35	28	18	19	16	19	21	14	11	16	21	25	19	27	7	8	19	28	16	14	23	26	20
	8	14	14	16	11	16	16	10	11	10	7	7	8	4	5	10	10	16	12	21	4	3	14	19	13	10	23	20	19
	16	9	11	11	10	11	16	6	10	7	5	6	6	3	5	8	8	9	12	17	4	2	13	14	11	7	19	17	15
	32	9	10	10	9	8	7	5	9	7	4	5	4	3	5	7	8	6	8	8	4	2	12	12	10	5	13	12	13

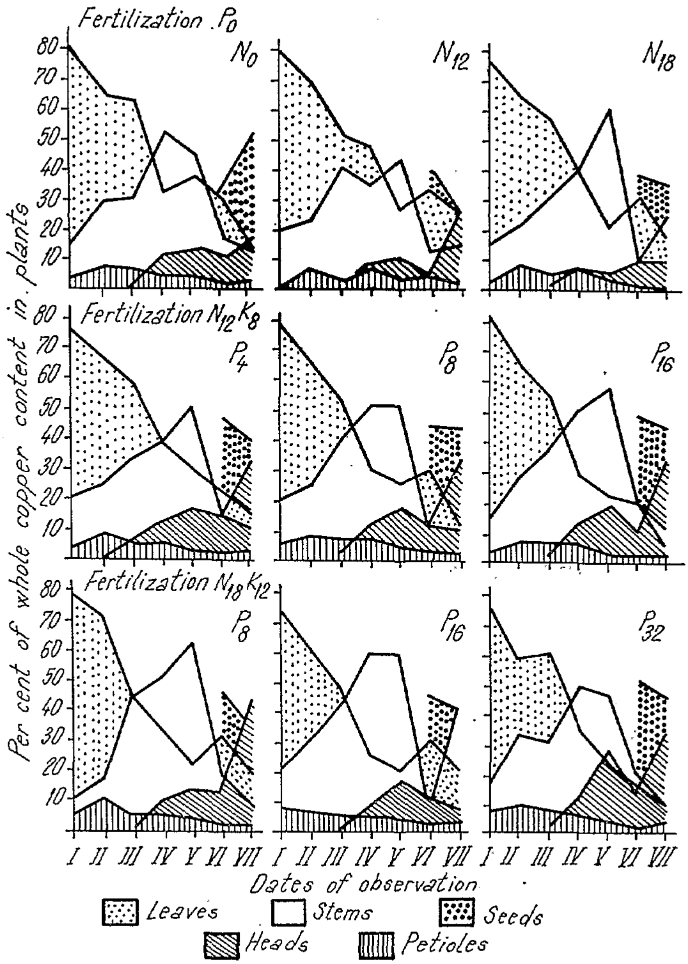

Fig. 1 — Copper uptake by different sunflower organs.

trated in leaves while in phase 7 only 8—20 per cent copper of the whole quantity in the plant are present there.

Four to eight per cent are concentrated in petioles but at the end of vegetation the percentage is 1.4 to 2.7. Stems contain 16—21 per cent at the beginning and at the end of vegetation 7—16 per cent. The relative proportion of the head in the total mass of the plant increases during the process of ripening and if at the beginning of its formation the copper content ranges between 0.5—2.7%, during ripening it represents 15—44% of the total quantity entering the plant.

Fertilization appreciably influences the distribution of the assimilated copper in different organs. Nitrogen fertilizers stimulate copper accumulation in leaves, while phosphorous fertilizers favour the accumulation of copper in heads and seeds.

The differencial curve of copper assimilation in sunflower during its ontogenetic development for each of the variants is shown in figure 2. The basic part, about 65 per cent of the copper needed for the yield formation is assimilated from the soil during the period between bud

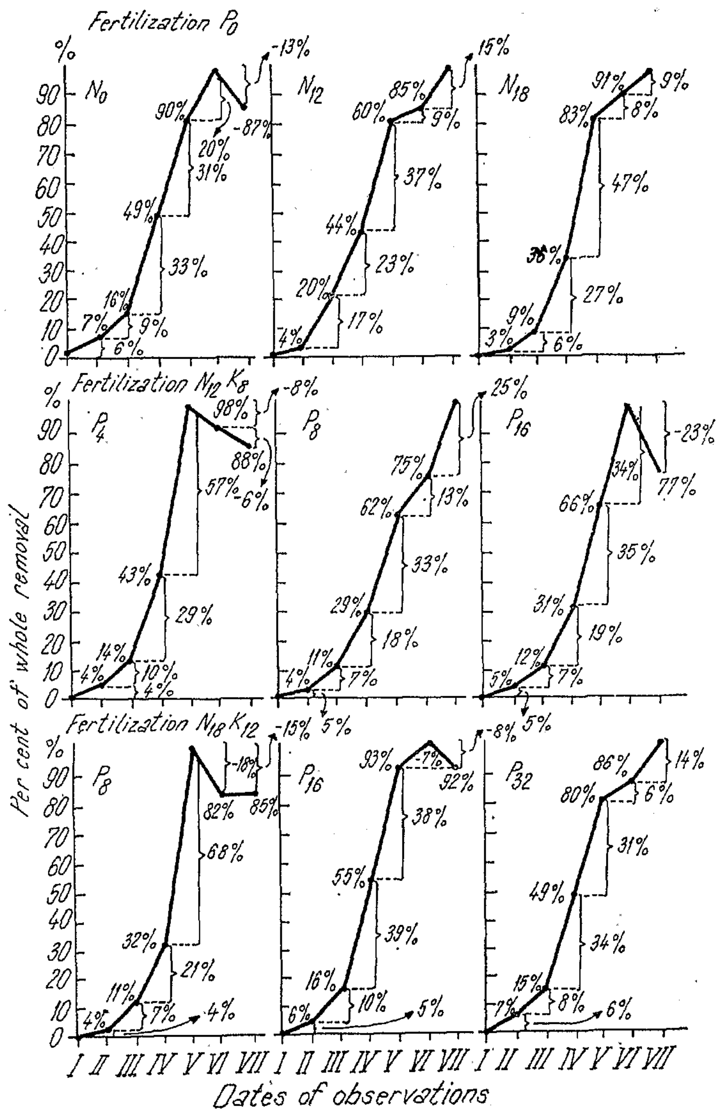

Fig. 2 — Copper assimilation in sunflower during its ontogenetic development.

formation and complete flowering. 10—15 per cent of the needed amount of copper is assimilated till phase 3 and after phase 5, about 20 per cent.

In variants with phosphorous fertilizers, in most cases the maximum assimilation of copper appeared to come and cease earlier, i.o., the maximum of assimilated copper din not coincide with the phase of complete maturity of seeds. In some variants the copper content at maturity significantly decreased (3—23 per cent in comparison with the maximum amount of this element in the plant).

The highest percentage of losses were determined in leaves and stems, while the lowest in seeds.

Data for copper removal in different organs are analogous to the distribution data for the same organs at the end of vegetation (figure 3).

Seeds and heads remove almost twice as much as stems and leaves do. Copper removal by 100 kg of seed and its corresponding vegetative

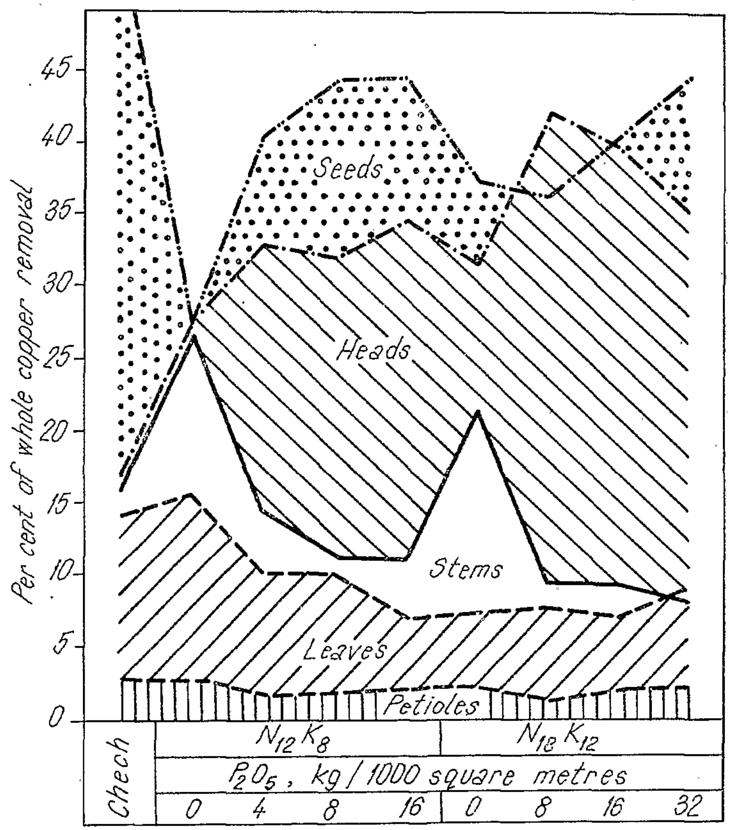

Fig. 3 — Copper distribution in sunilower organs during the phase of full maturity.

mass (table 2) vary from 2.9 to 6.3 g and shows to be tightly conected with the nitrogen and phosphorous fertilizers. Nitrogen fertilizers stimulated assimilation and copper removal with the yield while phosphorous fertilizers had the opposite effect. In highest yield (365 kg per 1000 square metres from variant $N_{12}P_{16}K_8$) copper removal with 100 kg was 3.58 g.

Table 2

Copper removal by 100 kg of seed and its corresponding vegetative mass (in grammes)

Degree of fertilization	P_2O_5				
	0	4	8	16	32
$N_{12}K_8$	6.346	4.957	4.768	3.584	—
$N_{18}K_{12}$	5.819	—	4.360	3.636	2.919

Check — 3.245 g.

DISCUSSION

Data obtained in this study show that copper concentration in sunflower largely varies depending on the phase of development and fertilization, being specific for the different organs in respect to copper enrichment as well as to changes in age. In stems and petioles copper concentration appeares to be disposed to changes with age, larger than that of leaves, which is an index for a higher copper mobility in these organs. The lower concentration in plants from variants with phosphorous fertilizers is obviously connected with a mobility decrease of copper in soil, (possible deposition of the phosphorous ion) and in variants with higher rate of phosphorus — with the dilution effect which becomes manifest during the synthesis of a large sunflower organic mass.

Copper accumulation in leaves and heads is connected with the intensive oxido-reducing processes in these organs. Analogous data were obtained by S a e n k o and others (1968) for zink, copper, manganese and iron in the organs of four different species.

The difference observed in copper concentration, distribution and removal with yield in the variants are connected with the changes in copper availability in soil under the influence of nitrogen and phosphorous fertilizers. According to the published data (1), copper availability depends to a great extent on soil acidity. Hence, physiologically acid fertilizers will favour the copper assimilation by plants. Data of pH and Cu in soil (table 3) and the high copper content in the check non-fertilized variant show that copper mobility in soil is originally high. The ten-year systematic mineral fertilization had influenced the soil acidity. A more considerable change in soil acidity occurred under the influence of nitrogen fertilizers (a decrease of soil pH with almost 0.8)

Table 3

Content of labile nutritive substances in the tilled soil layer (phase of complete maturity)

Indices	Check	Degree of fertilization $N_{12}K_8$				Degree of fertilization $N_{18}K_{12}$			
		P_0	P_4	P_8	P_{16}	P_0	P_8	P_{15}	P_{32}
1. pH (KCl)	5.78	5.50	5.15	5.40	5.28	5.25	5.20	5.35	5.15
2. Hydrolisic N mg/kg in soil	28.00	41.30	33.00	36.40	36.40	37.80	37.10	33.60	33.60
3. P_2O_5, mg/100 g	2.00	1.20	1.80	5.30	14.20	1.20	4.20	10.90	29.00
4. Assimileted K mg/100 g	30.00	29.00	28.00	27.00	29.00	30.00	27.00	27.00	30.00
5. Ca, mg/equivalent	20.80	19.80	18.80	18.40	18.50	18.10	22.00	17.00	21.90
6. Mg, mg/equivalent	1.90	2.70	2.60	3.40	4.00	3.80	2.90	3.60	1.60
7. Cu, mg/kg soil in EDTA	2.60	3.90	3.30	3.20	3.50	3.40	3.10	3.10	3.20

which is coordinated with the higher copper concentration in the plants of these variants. Phosphorous fertilizers had also changed the soil pH factor in the direction of higher acidity, although it was not like the rate of the nitrogen fertilizers. The lower copper concentration in sunflower tissues in variants with phosphorous fertilizers was coordinated with the higher biological yield. In varinats P_{16} and P_{32} (with higher nitrogen-potassium degree of fertilization) the lower copper concentration in tissues corresponds to a lower removal with yield. It means that copper availability for sunflower in these variants decreases, although the pH decreases in soil. In this case the reason for the lowered copper availability could be the chemical adsorbtion of the phosphate anion or some of the ballast anions in the superphosphate.

The observed maximum copper concentration in leaves and stems and the copper removal by 100 kg organic mass show the relationship with seed yield (in the bud phase $r = -0.787$ and in full blossom $r = -0.839$). This shows, that these maximums are not physiologically conditioned, i. e. that they are not the result of an increased need for copper. Their origin seems to be connected with the copper mobility in soil. Its high mobility as it is seen from our data, is a result of the nitrogen fertilizers. The high concentration of nitrate anion in soil could be obtained also under the influence of an intensive nitrification process, for which there are favourable conditions in the phases of bud formation ond flowering.

Many other investigators (5, 7, 8) have observed losses of mineral elements to the end of vegetation, compared with the maximum assimilated quantities during the earlier phases of development. Losses could be due to :

1. Rain washing.
2. Losses of mineral matter by fallen yelloy leaves, pollen anthers, etc.
3. Fluid losses — nectar secretion.
4. Gas-like losses — aromatic substances.

5. Exoosmosis — giving the nutritive substances back into the soil by roots.

In our experiment all but the second factors were possible.

It is well-known (6) that copper forms complex compounds with organic substances in plants which makes its mobility in the plant insignificant. Our data do not coincide with this point of view. Determination of copper in different organs during vegetation gave us the possibility to establish that in the period of formation of generative organs the amount of the assimilated copper undergoes a redistribution. Translocation of appreciable amounts of copper from leaves and stems towards heads could be observed. At the beginning of seed-formation copper go from the head into the seeds. Part of it returns in the head again during the phase of maturity. These copper translocations in the plant which are connected with seed-formation, confirm the opinion (3) that copper takes part in the formation of fats and proteins on the one hand and shows a significant mobility of its compounds in the plant on the other. The following conclusions could be drawn :

1. Copper concentration in sunflower vary in wide ranges-from 2 to 35 mg per 1 kg dry substance and depends on the organs, age and fertilizer, being specific for each particular organ. Highest copper concentration was determined in leaves and heads.

The copper asimilated by sunflower plants is characterized by a high mobility. During the seed formation phase, 20—50% of the copper existing in the leaves migrates into the generative organs.

2. Systematic mineral fertilization has a significant influence upon the course of uptake, concentration in tissues and distribution in organs of soil copper. Nitrogen fertilizers increase the copper mobility in soil, make the period of vegetation longer and stimulate its accumulation in the vegetative organs, while phosphorous fertilizers favour the accumulation of the assimilated copper in the reproductive organs.

3. The quantity of the copper extracted by 100 kg of yield depends on its mobility in soil, and not on the copper need of the plant for producing the highest yield.

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