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Second Interregional Fertilizer Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item VIII/11

PRODUCTION AND APPLICATION OF FERTILIZERS WITH MICROELEMENTS IN THE UKRAINIAN SSR[1/]

by

P.A. Vlasyuk

Plant Physiology Research Institute
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SUMMARY

PRODUCTION AND APPLICATION OF FERTILIZERS WITH MICROELEMENTS IN THE UKRAINIAN SSR[1/]

by

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Research carried out over many years in scientific and higher educational institutions in the Ukraine has shown that various amounts of trace elements such as manganese, zinc, molybdenum, lithium, etc., which are very important for the structure and functions of plants, are localized in the cells individual organoids, tissues and organs of the plants. These trace elements form complexes of varying stability with the organic ligands present in the cells, tissues and organs of plants. A lack of trace elements in the soil, nutrient solution or seeds produces pathological changes in the plant organism, which are the result of disturbances in the exchange of nucleinic acids, proteins, lipids, physiologically active substances and so on, caused by the lack of one element or another.

Trace elements prevent the occurrence of functional disorders, increase the resistance of plants to various unfavourable conditions in the environment and to fungoid and bacterial diseases, and also increase the plants' productivity. The effectiveness of fertilizers and preparations containing trace elements depends on the content of available forms of such elements in the soil, the biological and varietal characteristics of

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the crops, the soil and climatic conditions, the form, dose and method of application and, in addition the amounts of trace elements in the seeds of the plants under cultivation.

In order to provide a basis for the most effective use of trace elements in Ukrainian agriculture and to plan for their supply and distribution to different zones, districts, and collective and State farms, charts have been drawn up showing the content of available forms of trace elements in the main varieties of soil in the republic.

In order to bring micro-nutrients into wider use in agriculture in addition to the use of trace element salts and preparations for seed dressing and for the enrichment of superphosphate fertilizers such nutrients should be introduced into the composition of concentrated mixed and complex mineral fertilizers. In order to establish the technology for producing mixed and complex fertilizers containing trace elements, the optimum doses of manganese, molybdenum zinc, lithium and boron in these fertilizers are determined, the best ratios of macro and micro-nutrients are selected, and tests are carried out with the new fertilizers on different agricultural crops in different soils and climatic zones of the Ukraine, taking into account the existing content of available forms of the various trace elements.

The Significance of Microelements For Plants

Despite the vast amount of information that is annually received on the effectiveness of different types of micro ferlitizers and the significance of microelements for the existence of living organisms, the disclosure of the essence and diversity of their effect and action on separate stages of metabolism during the growth processes, the development and formation of harvests and the quality of agricultural produce is by far incomplete.

At the present time, due to the utilisation of up-to-date methods and technical research equipment, physiologists and biochemists are confidently passing from the study of changes which take place during the presence or absence of this or that microelement in general integral processes of metabolism (respiration, photosynthesis, etc.) to more profound research conducted on the level of a cell, separate organoids and molecules.

In recent years, Ukrainian scientists occupied with the study of the biological role of microelements in the life of plants have centered most of their attention on investigating the physiological and biochemical essence of the action of separate microelements on the one hand, and on the other - on creating and studying the effectiveness of new types of fertilizers containing microelements in various soil and climatic conditions on basic agricultural crops.

Research has shown that a cell and separate organoids contain different amounts of microelements of manganese, molybdenum, zinc and boron which are very important to their structure and functions. It has been found that molybdenum and zinc, which comprise a number of enzymes taking part in nitrogen metabolism, are in noticeable amounts localized in ribobodies and cytoplasm, while manganese and iron which regulate the reduction-oxidation processes of photosynthesis are found in chloroplasts and cytoplasm. A co siderable amou t of boron, which favourably influences the processes of photosynthetic phosphorylation, is also found in chloroplasts (Vlasiuk and others, 1963, 1971; Kibalenko, 1965, 1966; Vlasiuk, Ivchenko, 1967). By using the method of electronic microscopy, it has been established that a shortage of microelements results in pathological changes in the ultra-structure of cellular organoids and the disturbance of functional activity (Silayeva, Uzenbayeva, Shirayev, Ostrovskaya, 1967; Timashov, 1968; Zaitseva, Ostrovskaya, 1968; Kibalenko, 1969; Zakharchishina, Kluchko, 1970; Pilipenko, 1970). By using the methods of ion-exchange chromatography, infrared spectroscopy and electronic paramagnetic resonance, it has been established that microelements are formed by complexes of varied stability containing nearly all the organic addenda found in a cell - proteins, nucleic acids, amino acids, sugars, polyphenols, organic acids and substances of the cell membrane (Vlasiuk and others, 1969; Kibalenko, 1968; Vlasiuk, Klimovitskaya, Bidzilya, 1970; Rudakova, Rizhikova, 1968; Rastorguyeva, Ostrovskaya, 1970). The character and stability of the tie between the microelements and addenda depend on the level of their presence in the organs, tissues and cells, as well as on the concentration of addenda and the physiological state of the plants.

The cultivation of plants in extreme conditions of microelemental sufficiency has shown that manganese, boron and molybdenum increase the fraction of transport RNA (when fractionating the total preparation of nucleic acids on columns of methylized albumin in kieselguhr), which is proof of the intensification of its adaptory properties when transporting amino acids and biosynthesizing proteins. A shortage of zinc, molybdenum and boron in plants results in the degradation of the fraction of light RNA and the increased heterogeneity of DNA which fully corresponds with the growing activity of ribonuclease and desoxyribonuclease frequently noticed in those plants (Timashov, 1966; Vlasiuk and others, 1969, 1969 a; Kibalenko, Sidorshina, Demchenko, 1970; Ivchenko, Krasina, Karabchuk, 1970).

The elimination of boron from the nutrient mixture brings about a complete stoppage of the DNA synthesis in most of the cells in the root tips of peas, and also reduces the RNA synthesis in the merismatic and transitional zone (Timashov, 1970; Rapota, 1970).

The disturbance of nucleic acid metabolism in plants cultivated with a shortage of this or that microelement is most likely the result of their influence on stabilizing the structure of DNA and RNA and forming DNA-RNA hybrids which are less subject to the attack of nuclease enzymes. The similar effect of microelements having different chemical properties and physiological significance is explained by the fact that all of them can complex with nucleic acids due to phosphate groups. Besides, a specific correlation is indicated between each microelement and other functional groups of nucleic acids; for example, between zinc and molybdate ions and nitrous bases, and between borate and ribose groups (Vlasiuk and others, 1969, 1970, 1970 a; Kibalenko and others 1970).

The lithium microelement has had a favourable effect on the respiratory intensiveness of tomato plants and aubergine, as well as on the value of the respiratory coefficient which is the qualitative index of the process. During the entire ontogenisis, the plants cultivated on a nutrient mixture containing lithium have a higher respiratory coefficient than standard ones, which shows that they consume more oxided organic compounds as a respiratory substrate, primarily sugars which considerably rise in content under the influence of lithium (Okhrimenko, Uyazdovskaya, 1970).

Rubidium, nickle and cesium increases the respiratory activity of germinating seeds of winter wheat and corn, while titanium inhibites the process.

The intensiveness with which organic acids are formed is closely connected with the reduction-oxidation processes and the energic level of the cell which changes under the influence of microelements.

It has been shown that nickle and cesium reduce the total quantity of organic acids in 3-day-old germs of winter wheat as compared with 2-day-old germs, which can be explained by their active inclusion in the metabolic processes of the young plants. A chromatographic separation of organic acids shows the presence of oxalic, tartaric, malic, alpha-ketoglutaric and aconitic acids, and at the same time establishes that tartaric acid is accumulated in relatively large quantitites in the germs. Under the influence of microelements, the content of organic acids changes to various degrees, but in the main correlates with the activity of corresponding dehydrogenase (Vlasiuk and others, 1970).

It was specified that lithium caused the accumulation of tartaric and especially malic organic acids in the leaves of tomato plants, while the content of citric acid altered slightly.

Presowing Enrichment of Seeds with Microelements

The Institute of Plant Physiology of the Ukrainian Academy of Sciences has worked out and extensively introduced into agriculture a method of presowing enrichment of seeds (with microelements) by dusting them with a mixture of microelement salts and talc, simultaneously carrying out disinfection (Vlasiuk, Darmenko, 1965).

Research has repeatedly shown a noticeable increase (2, 3-fold) in the activity of enzymes (protease, anylase, lipase) of the germinating seeds enriched with the microelement salts of manganese, boron, zinc and molybdenum. This causes a rapid disintegration of reserve nutrients and a change in the products of metabolism. It was also indicated that the overall quantity of thiamine, riboflavin and ascorbic acid increased under the influence of molybdenum and vanadium, noticeably increasing the content of vitamins related to proteins in the prosthetic groups of enzymes, which was of utmost importance (Vlasiuk, Kuznetsova, 1967).

When the seeds of wheat are enriched with rubidium, there is a considerable increase of lipase; 36 hours after they begin germinating, the activity of lipase is six times greater, while it increases only 2.4 times when the seeds are enriched with manganese Seventy-two hours after they begin germinating, the activity of lipase becomes even greater under the influence of rubidium and manganese. The same occurs when the seeds of corn are enriched with rubidium.

A study of the effect of microelements on protein metabolism has shown that presowing enrichment of corn and wheat seeds with microelements has a noticeable effect on the quantity of proteins of different fractions. For instance, under the influence of nickle and rubidium on corn germs and of rubidium, nickle and cesium on wheat germs, there is a considerable growth in the consumption of reserve proteins - prolamines, which are reserve nitric substances due to their high content of glutamic acid, amides and proline. The active conversion of reserve proteins of the endosperm of germinating seeds is correlated with the growth of the hydrolytic activity of proteolytic enzymes under the influence of microelement enrichment of seeds.

According to our data, the increased activity of reduction - oxidation and proteolytic enzymes, as well as the lipase in germinating seeds of wheat and corn under the influence of rubidium, cesium and nickle, is accompanied by the accumulation of albumin and globulin. All these changes in cellular metabolism confirm the profound transformations that occur in the structures of nuclei in earlier (starting) periods of germination under the influence of microelements, as mentioned above, and the result of which is speedier germination and growth of seeds. (Vlasiuk, 1970).

The Effect of Microelements on the Stability of Plants

The work of Soviet Ukrainian researchers has shown that with the help of microelements one can boost the resistance of plants to unfavourable growth conditions (Vlasiuk, 1968) and fungi diseases (Yaroshenko, 1969; Pidoplichko, Kaznachei, Kononko, 1968; Kuznetsova, 1970), as well as cure various functional diseases such as rosette-microphyly in apple trees (N.P.Kholodon, 1968) and chlorosis in fruit crops (Ostrovskaya, 1965).

It has been established that rosette-microphyly in apple trees grown in the Ukraine is caused by both the direct shortage of zinc in light soil (which has a low content of zinc) and the indirect or "physiological" deficiency found in trees grown on calcareous or leached chernozem, which is probably due not to the shortage of zinc, as in the first case, but to the consumption of the available zinc by complex metabolically inactive compounds. This results in the disturbance of processes which would normally require zinc; this is especially true of the biosynthetical processes regulating growth, in connection with which the portion of inhibitors, mainly floridzin, increases among the free growth regulators in the leaves of the diseased trees (Vlasiuk and others, 1969, 1970; Karakis, 1968). The use of zinc salts during a period of 1 - 2 years (injections in the trunk or skeleton branches, early outside root fertilization when buds are dormant and the spraying of vegetating apple trees) improved the overall state of the trees and partially or completely eliminated rosette-microphyly, thus increasing the harvests (Kholoden, 1964).

The study of another functional disease, carbonate chlorosis, which in the Ukraine affects apple, pear and cherry trees, grapes, oil-yielding roses and hops, has shown that the cause of the disease is the discrepancy arising between the great necessity of the plants for iron as a complexon for an organism of physiologically active compounds on the one hand, and the possibility of providing the requirement level when there is a considerable reduction in the solubility of iron in soil with a high pH content, saturated with calcium carbonate, on the other (Ostrovskaya, 1965).

One of the effective ways of modifying the symptoms of chlorosis or completely curing the disease is to use iron chelate compounds which have a number of advantages over mineral compounds of this element.

The experiments carried out in different soil and climatic zones (Kiev, Zaporozhian and Crimean regions) with apple, pear and cherry trees, grapes, oil-yielding roses and hops have shown that both application to the soil and, to a large extent, outside root application of fertilizer DTPU and PPPU are effective ways of curing chlorosis (Vedebura, 1965; Karabanov, Kulko, 1965; Makarova, Khilik, Ostrovskaya, 1965; Petrenko, 1964; Polischuk, 1967; Richter, 1967; Khilik, 1966).

For instance, in the late-ripening and early varieties of apple trees, the harvest increase when DTPU is applied to the soil is observed three years later. They give quick profits and are highly effective when the recommended amount of fertilizer is applied. Experiments on the Renet Bauman variety of apples cleared an average annual profit of over 165. roubles per hectare when 600 gr. of DTPU was applied to each tree (Zaporozhian region). With outside root application of fertilizer to different varieties of apple trees (0.2-0.5% solutions of iron compound twice or three times), the harvest increase amounted to 6-210% (depending on the degree of chlorosis), averaging a yearly profit of 165.-794. roubles per hectare.

Fertilizers and Preparations Containing Microelements

Ukrainian scientists in their early research relating to the 1930's (Vlasiuk, 1924) studied the different waste products of industrial enterprises, which could be used as microfertilizers. Such was manganic slime containing 14-22% manganese oxide and 1.5-5% manganese carbonate.

It has been ascertained that for sugar beet, winter wheat, millet and especially corn the best type of manganese fertilizers are the industrial by-products which would raise harvests and improve the quality of agricultural produce (Vlasiuk, 1962).

For more effective utilization of manganic slime and lower expenses on transportation and application, the Institute of Plant Physiology of the Ukrainian Academy of Sciences suggested in 1949 that manganic slime be included in superphosphate granules. For this purpose a technology was worked out for producing granulated superphosphate containing 1.6-2.5% manganese and manganized nitrophoska (0.9-1.0% manganese). Later, in 1960's, other microelements such as molybdenum (0.26%), boron (0.1-0.5%) and zinc (0.9-1.0%) were added to the superphosphate and nitrophoska.

It was proved that the effectiveness of fertilizers with microelements depended on a number of conditions, particularly on the content of active microelements in the soil, on the biological and varietal peculiarities of the plants, on the maternal reserves of microelements in the seeds, on the soil and climatic conditions of the given zone, as well as on the types, doses and means of application of macro- and microfertilizers.

Sulphuric manganese applied during autumn ploughing in a 5 kg/hectare dose along with the base fertilizer (20 tons/hectare of manure, 45 kg/hectare of nitrogen and 45 kg/hectare of RA) raised the harvests of winter wheat (Mironovka 808 variety) by on average 3.1 centners/hectare during 1965-1970 (planted after peas); manganic slime applied in a dose of 3.0 centners/hectare produced a 1.4 c/h increase, and manganized superphosphate applied in a dose of 3.0 c/h raised the harvest by 3.75 c/h with the control yield at [illegible].2 centners/hectare (P=2.9-5.6%).

Molybdenized superphosphate containing 0.26% molybdenum, when applied in a quantity of 2-3 centners/hectare during autumn ploughing, or 2 kg/hectare of ammonium molybdate used with mineral fertilizers raised the harvest of winter wheat in the same conditions by I.7-2.2 centners/hectare which coincided with the control yield. By applying a mixture of ammonium molybdate (I kg/hectare of molybdenum) and sulphuric manganese (5kg/hectare of manganese together with the base organo-mineral fertilizers in the above-mentioned proportions, the grain harvest increased by an average 3.4 centners/hectare during I966-I970.

The utilization of sulphuric manganese, manganic slime and manganized superphosphate for sugar beet along with the base fertilizers boosted the harvest of one-seeded beet roots by 47, 40 and 25 centners per hectare respectively with the control yield at 475 centners/hectare (P=2.75-5.0%).

Similar increases in the harvest of beets were obtained by using molybdenized superphosphate and ammonium molybdate, and the use of molybdenum in combinations with manganese brought the harvest increase of beets to 62 centners/hectare (equivalent to the control yield) with a significant rise in the saccharinity of beets and a 4.6 c/h increase in the sugar yield with the control yield at 70.5 c/h.

The application of manganese fertilizers to corn boosted the harvests of grain by I.7-4.4 centners/hectare; molybdenized superphosphate and ammonium molybdate raised them by 2.5-3.3 c/h, while the combination of ammonium molybdate with sulphuric manganese increased the harvests by 11.8 centners/hectare with the control yield at 61.8 centners-hectare (P=4.4-4.9). Boron, zinc, lithium and their combinations with manganese showed unstable results with corn.

During 1966-1970, the harvest increase of peas under the influence of ammonium molybdate and vanadate averaged I.I-0.8 c/h with the control yield at 25.7 c/h. Borate superphosphate raised the harvests of peas by I.0 c/h with the control yield at 2I.I centners/hectare.

Microfertilizers had no effect on barley or foxtail clover, which confirms the necessity of annually applying microfertilizers to agricultural crops in rotation, and determines the direct correlation between the effectiveness of microfertilizers and the content of their active forms in meadow-chernozem podsolized soil of the Physiology of Plants Institute station of the Ukrainian Academy of Sciences, as well as with the biological peculiarities of the cultivated crop.

Cultivation of wheat after peas and the use of molybdenized superphosphate, ammonium molybdate and its combinations with sulphuric manganese improved to almost the same extent the quality of peas as to protein content and yield per hectare.

Ammonium molybdate and its combinations with manganese proved effective on winter wheat cultivated after perennial grass.

It has been shown that in conditions of experimental stations (western forest-steppe area of the Ukraine and the Lvov region where a study was made of the effect of the pure salts of copper, boron, manganese and molybdenum applied with the base organo-mineral fertilizers), the use of boron on serozemic podzolized and soddy-calcareous soils produced an average 25 c/h increase of sugar beets during 1964-1966, the use of manganese - also a 25 c/h increase, and a combination of boron and molybdenum - an increase of 35 centners per hectare with the control yield at 360 centners/hectare.

The harvest of corn cobs on serozemic podzolized soil with the use of boron went up by II.8 c/h, with molybdenum - by 9.2 c/h, and with a combination of boron and manganese - by 2I.5 c/h, the control yield being I02.8 centners/hectare. The harvest increase of the green mass of corn on peaty soil when applying molybdenum averaged 42.6 c/h, with the use of sulphuric copper - 50.5 c/h and by applying copper mixed with boron - 60.7 c/h with the control yield at 490 centners/hectare (Gilis, Radchenko, 1967).

The experiments conducted with sugar beet during 1961-1967 in various soil and climatic conditions of the republic have shown that when manganized superphosphate was applied to the rows, the harvest of sugar beets went up (in two experiments) by I9 c/h with the control yield at 230 centners/hectare; on serozemic podzolized soil (in 5 out of 8 experiments) it went up by 39.6 c/h with the control yield at 399 c/h; on chernozem (in 28 out of 41 experiments) - by I5.6 c/h with the control yield at 317 centners/hectare.

The application of borate superphosphate in the same conditions raised the harvest of sugar beet on soddy-calcareous soil (in 20 experiments) by I7 c/h with the control yield at 230 c/h; on serozemic podzolized soil (in 5 out of 7 experiments) - by 39.6 c/h with the control yield at 398 c/h; on chernozem (in 22 out of 33 experiments) - by I7 c/h with the control yield at 309 centners/hectare.

Molybdenized superphosphate raised the sugar beet harvest on serozemic podzolized soil (in 4 out of 8 experiments) by 33.3 c/h with the control yield at 415 c/h, and on chernozem (in I4 out of 23 experiments) - by 9.7 c/h with the control yield at 319 c/h. The effectiveness of zinc superphosphate when applied to the rows of sugar beet on serozemic soil (in 2 experiments) resulted in an increase of 15.3 c/h with the control yield at 447 c/h (Vlasiuk, I97I).

On the leached chernozem of the Zhitomir region, the application of sulphuric manganese increased the average harvest of potatoes by 20.5%, and sulphuric copper raised the harvest by I6.I% with the control yield at 202.5 c/h during I959-I963.

The application of molybdenum and boron in the same conditions had little effect (Vlasiuk, Chernishenko, I970).

On the soddy-podzolized soil of Central Polessya (Zhitomir region, Ukrainian S.S.R.), the application of microelement salts along with the base organo-mineral fertilizers to hybrid corn (Bukovinsky 3) during I963-I965 resulted in higher increases of the grain harvest when boron and molybdenum saw used and somewhat smaller increases when zinc and manganese was used (7.3, 6.4, 4.8 and 4.3 centners/hectare respectively with the control yield at 43.I centners/hectare).

Under the influence of zinc superphosphate the grain harvest of corn increased by 9.0 c/h and of millet - by I.3 c/h with the control yields at 38.8 and 30.9 centners/hectare respectively. Molybdenum helped raise the grain harvest of corn by I.5 c/h, at the same time considerably increasing the content of protein, starch and fat (Volkova, 1970).

The application of zinc superphosphate to corn on chestnut-colour soil boosted the grain harvest (in 3 experiments) by 13.1 c/h with the control yield at 60.3 c/h; on humic carbonated soil (in 2 out of 3 experiments) - by 2.0 c/h with the control yield at 56.8 c/h; and on common chernozem (in 4 experiments) - by 3.5 c/h with the control yield at 40.2 centners/hectare.

In analogous soil and climatic conditions of the Dolinsky state plant-breeding plot in the Kirovograd region the grain harvest of corn was raised by using manganized superphosphate (an average 3.6 c/h increase during 1961-1963 with the control yield at 43.3 c/h).

The "Karpovtsy" state farm, Chudnovsky district of the Zhitomir region, which cultivates hops on podzolized chernozem, averaged a 2.5 c/h increase of hop strobiles (1963-1964) by applying zinc superphosphate along with organo-mineral fertilizers, a 2.4 c/h increase by using molybdenized superphosphate, a 1.4 c/h increase by applying borate superphosphate and a 1.2 c/h increase by applying manganized superphosphate with the control yield at 11.4 c/h (Schetinina, 1967). The content of bitter substances in hop strobiles particularly increased by using borate and molybdenized superphosphates (3.5-3.4%), manganized superphosphate (2.0%) and zinc superphosphate (1.6%) with the average control content for 1963-1964 at 12.8% (G.A.Korbut); the highest yield per hectare was obtained by applying molybdenized and zinc superphosphates. Each rouble spent on these microfertilizers brought in a clear profit of 31.50-34.20 roubles. A somewhat smaller profit was gained by using manganized and borate superphosphates (27.60-27.80 roubles).

On peat-marshes of the Polessya area, Zhitomir region, the effectiveness of phosphorate-potassium fertilizers on fibre flax (M.S.Chepikov, 1968) grew when applied with boric acid (I kg. of boron per hectare) and copper (blue vitriol - 2.5 kg/h). At the same time, the harvest of fibre rose by I7.2-I2.3% (long fibre - by I5.5-I0.3%) and that of seed - by I2.5-I4.6%; the quality of fibre also improved (the actual count by I.3-I.I%) and the oil content of the seeds increased by 0.4-0.5%.

The above-mentioned data indicate that fertilizers with microelements raise the harvest and quality of agricultural produce, and should therefore be used on collective and state farms of the republic. It should be pointed out that in districts with insufficient reserves of active manganic and boric forms in the soil, close to I,800,000 tons of manganized and 200,000 tons of borate superphosphates were applied during the I956-I968 period on areas of I0,000,000 and 44I,000 hectares respectively. The economic effectiveness of these fertilizers amounts to I6.00 - 60.00 roubles clear profit per hectare annually.

Copper fertilizers in the form of sulphuric by-products (pyrite cinders containing 0.2-0.5 copper) were tested on the drained, peaty, marshy and humic carbonated soils of the transitional zones of the Polessya and forest-steppe areas, Ukrainian S.S.R.

The application of pyrite cinders in a dose of 5 c/h on the drained peaty soil of the Supoi River flood plain, Rovno region, boosted the harvest of millet from 8 to 24 c/h, that of sugar beets - by 50-60 c/h (I5-20%), and potatoes - by 20%; on the "Zamglai" marsh of the Chernigov region and the "Chemirnoye" and "Yarinovka" marshes of the Rovno region, pyrite cinders raised the harvest of hemp fibre I.5 - 2-fold, of seeds - by 40-50% and of flax-fibre - by 36-40%, at the same time increasing the durability of the flax and hemp.

On the humic-carbonated soils of the "Progress" and "Pravda" collective farms in the Brodovsky district, Lvov region, the application of pyrite cinders in a dose of 5 c/h raised the grain harvest of corn by 6.3-II.0 c/h with the control yield at 53.I-97.0 c/h.

On the peaty soil of the "Oktyabr" collective farm, Volyn region, pyrite cinders produced a 90 c/h increase in the harvest of carrots, with the control yield at 699 centners/hectare.

I68,200 tons of pyrite cinders was used on more than 336,000 hectares of peaty and humic-carbonated soil during I961-I967 (Vlasiuk, Chenishenko, I969).

According to the data of scientific-research and educational establishments, the best way to use microelements at the present time is to mix them with ordinary and especially compound mineral fertilizers.

As the chemical industry is producing more and more highly-concentrated compound mineral fertilizers like nitrophoska, nitroammophoska, ammophoska, diammophos, double superphosphate and triple superphosphate which do not contain microelements, the Institute of Plant Physiology of the Ukrainian Academy of Sciences suggested that microelements be added to these fertilizers.

In 1959, an experimental consignment of nitrophoska enriched with manganese (I.0%), boron (0.25%) and zinc (0.5%) was produced at the Dneprodzerzhinsk Chemical Works.

On meadow-chernozem podzolized soil, the application of manganized and zinc-enriched nitrophoska to the rows of sugar beets raised the harvest of beet roots by I9 centners/hectare, and that enriched with boron - by 20 c/h with the control yield at 325 centners/hecrate. The saccharinity of the beet roots went up by 0.3, 0.5 and I.I% respectively. In the same conditions, when manganized nitrophoska was applied during autumn ploughing, the harvest of beet roots increased by 22.3 c/h and the saccharinity - by 0.55% with the control yield and saccharinity at 388 c/h and I9.2%.

Compound mineral fertilizers having a ratio No.PK-I:I:I, enriched with 0.I% boron increased the harvest of beet roots by 36 c/h, while those enriched with 0.2% boron raised it by 62 c/h. At the same time the saccharinity of the roots went up from I7.8 to I8.4 and I8.7% (P=I.4-5.6%).

It appears that the effect of compound nitrogen-phosphate-potash fertilizers having the ratio No.PK-I:I:I and enriched with boron is greater on sugar beet in comparison with the compound fertilizers with the No.PK-I:4:2 ratio. When the content of phosphorus in fertilizers is higher, a lower content of nitrogen is conducive to a stronger tie between the microelements and phosphates, as a result of which they are consumed more slowly by the plants and their effectiveness is reduced.

This data allows us to assume that the inclusion of microelemtents in nitrophoska, nitroammophoska and diammonitrophoska, ammophos, nitrophosphate and other compound mineral fertilizers containing, besides phosphorus and potassium, the same or greater amount of nitrogen, will make them more effective than if they were used with simple fertilizers, especially phosphorous fertilizers.

The Institute of Plant Physiology of the Ukrainian Academy of Sciences prepared experimental consignments of compound mixed fertilizers (by pressing) at the Sumy Chemical Works with different ratios No.PK (I:0, 7:I.3 for sugar beet and I:0, 7:I for winter wheat), the granules of which were coated with microelements by means of polyacrylamide. These fertilizers will be tested on sugar beet and winter wheat at the Chernivtsy, Ternopol, Vinnitsa and Sumy experimental stations in I97I.

The best doses of microelements in nitrophoska and nitroammophoska for corn cultivated on serozemic forest soil and podzolized chernozem are as follows: manganese - I.0-I.5%, molybdenum - 0.2%, boron - 0.2% and zinc - 0.5-0.75% of the weight of fertilizer; for sugar beet cultivated on podzolized and leached chernozem the requirements are: manganese - I.5-2.5%, molybdenum - 0.26%, boron - 0.2 and zinc - 0.5-1.0% of the weight of fertilizer.

This complex job is being conducted together with the Lvov, Zhitomir and Uman Agricultural Institutes and the Ukrainian Research Institute of Agriculture and Animal Breeding for Western Regions of the Ukrainian S.S.R.

By enriching nitrophoska with 2.5 kg/h of manganese, the harvest of beet roots went up by 23 centners/hectare; 5 kg/h of manganese raised it by 53 c/h; IO kg/h - by I7 c/h and 20 kg/h - by 27 c/h with the control yield at 406 centners/hectare.

Nitrophoska enriched with I kg/h of molybdenum raised the harvest of beet roots by 30 c/h; a dose of 2 kg/h of molybdenum raised it by II.0 c/h, while a combination of I kg/h molybdenum and 5 kg/h manganese boosted the harvest by 58 c/h with the control yield at 58 centners/hectare. The saccharinity of the beet roots under the influence of manganese fertilizers up from I6.75% to I7.0%, and under the influence of molybdenum fertilizers - from I7.0% to I7.56%.

Besides applying fertilizer to the soil, the above-mentioned method of presowing enrichment of seeds with microelements (manganese, molybdenum, boron, zinc, copper and others) is widely practised in the republic to assist in the germination of seeds and the rapid growth of plants, and to raise plant productivity.

In order to utilize this method in agriculture, a shop for producing I,000 tons of preparations containing manganese, boron, molybdenum, zinc and copper with talc was built at the Odessa Superphosphate Plant in I963.

3,500 tons of preparations containing microelements was used on more than 2,000,000 hectares of arable land during 1963-1970.

In order to mechanize and improve presowing enrichment of seeds, the Institute of Plant Physiology of the Ukrainian Academy of Sciences suggested that the measure be conducted together with the disinfection of seeds which is carried out in a centralized way at plants for calibrating seeds and hybrid corn.

During the 1964-1970 period, 305,969 tons of corn seeds was enriched with microelements at a calibration plants for use on more that 15,400,000 hectares.

The highest average increase in the grain harvest of corn during a 2-year period (1963-1964) was obtained by using zinc and molybdenum (7.8-8.0 c/h); boron and manganese boosted the harvest by 4.7 c/h with the control yield at 44.8 c/h.

On common chernozem of the Lugansk region the average increase in the grain harvest of corn during 1964-1966 was 5.3 c/h when the seeds were enriched with zinc, 4.8 c/h when treated with boron and 4.6 c/h when manganese was added (on completely fertilized ground); on non-fertilized ground the results were 3.2, 3.4 and 3.1 respectively with the control yield at 42.7-40.4 centners/hectare. At the same time, under the influence of microelements, the protein content of the seeds went up, the zein fraction of protein, which is of little value, decreased, and the content of fat and starch increased. The use of microelements to enrich seeds for planting in arid conditions of the Ukrainian steppe areas and on common chernozem has proved economical (Gnilitskaya, 1969).

On the soddy-podzolized soil of Central Polessya (Ukrainian S.S.R.), a combination of presowing enrichment and outside root application of manganese and boron, together with disinfection, proved more effective on the harvest of corn and horse beans (the grain harvest of corn increased by 13.4 and 3.1 c/h in 1963 and 1964 respectively, the control yield being 44.1 c/h). At the same time, the quality of the grain improved and production costs fell (Sasnuk, 1966).

In field tests on chestnut-colour salt soil at the "Rossiya" collective farm, Kherson region, the presowing dusting of rice seeds with a mixture of zinc, cobalt and molybdenum salts raised the harvest by 3.7 c/h with the control yield at 53.0 c/h (Osadcha, 1968).

The presowing enrichment of seeds with the salts of microelements mixed with talc and disinfectants, depending on the soil and climatic conditions, resulted in the following grain harvest increases during 1959-1961: winter wheat - by 1.5 - 4.5 c/h (control yield - 23-32.2 c/h); corn - by 2.0-5.0 c/h (control yield - 35-30 c/h); rice - by 4.2-5.2 c/h (control yield - 45.4 c/h; peas - by 3.5-5.3 c/h (control yield -30-40 c/h) (Vlasiuk, Chernishenko, 1969).

On the common chernozem soil of the Donbas, the enrichment of corn seed with a 0.02% solution of sulphuric manganese during a 12-hour period raised the grain harvest of the hybrid corn VIR -42 by an average 4.1 c/h (control yield - 32.1 c/h) in 1967-1969; the quality of the grain (the content of protein aminoacids, including lysine and tryptophan) improved, while the content of the poorly-digestible zein protein was reduced

(Belokobilsky, 1970).

On the leached chernozem of the Nosov sector of the Chernigov regional agricultural experimental station, the presowing enrichment of seeds with a 0.05% solution of sulphuric manganese raised the grain harvest of corn by an average 5.9 c/h (control yield - 64.9 c/h) during 1966-1968, and on serozemic podzolized soil of the "Desyat let Oktyabra" sector - by 4.5 c/h (control yield - 43.8 c/h) during the same period; presowing enrichment of seeds with a 0.05% solution of sulphuric zinc (same contro yields) boosted the harvests to 5.1 and 2.5 c/h respectively.

Research conducted by the department of plant physiology and biochemistry at Kiev State University showed that outside root application of manganese, boron and zinc produced more intensive metabolism, raising the productivity and frost resistance of grapes in the Kiev and Transcarpathian regions (Mininberg, 1968).

Besides a harvest increase, outside root application of manganese also improved the quality of raw material for winemaking (Rizha, 1967).

With the aim of substantiating the most effective method of utilizing microelements in Ukrainian agriculture, the Institure of Plant Physiology of the Ukrainian Academy of Sciences drew up cartograms in 1959-1961, indicating the active forms of microelements (manganese, molybdenum, boron, zinc, cobalt and copper) in the soil varieties of different arable territories in the republic.

The cartograms are drawn up on a scale of I5 km. to I cm, and have been published with recommendations as to the utilization of microelements in agriculture in I0,000 copies for all the regional and district farming managements, collective and state farms and administrative agricultural bodies.

In the ten-field grain-beet rotation conducted by the Institute of Plant Physiology of the Ukrainian Academy of Sciences in I957-I969, the microelements were applied in the form of salts and superphosphates together with organo-mineral fertilizers during autumn ploughing in the following proportions; manganese - 5, boron - 2, zinc - 3, and molybdenum - I kg/h. Superphosphates enriched with microelements were applied on the basis of phosphoric acid containing assimilable forms I8.5 - I9.7%, manganese - I.5%, molybdenum - 0.26%, boron - 0.24% and zinc - I.I% of the weight of fertilizer.

Research conducted in this field has established that the greatest quantity of manganese, molybdenum, boron and zinc was consumed by both soil and plants when the microelements were applied to the soil. The highest accumulation of zinc, manganese and boron was observed in the leaves of sugar beets, less - in the leaves of corn and the least - in the leaves of winter wheat. Molybdenum accumulated in considerable quantities in the leaves of all three crops.

The maximum consumption of boron by sugar beet leaves was observed during the opening phase of the rows; it increased in the leaves of corn towards the end of the vegetation period.

The data on removal and distribution of microelements in plant organs indicates that the most active forms of manganese and molybdenum are found in winter wheat, of boron - in sugar beets and of zinc - in corn and winter wheat.

When using superphosphates enriched with microelements, it was observed that more manganese, zinc, boron and molybdenum was consumed from the soil by harvests of sugar beets than by harvests of winter wheat.

The requirements of different agricultural crops for microelements in the soil can be judged by the removal of them by the harvests.

The common characteristic of crops cultivated in the Polessya area is a more intensive accumulation and removal of molybdenum, copper and zinc than of manganese.

On the basis of the above-mentioned facts, we can drew the following conclusions:

I) In the cells, separate organoids, tissues and organs of plants there are different reserves of microelements which are of great significance for their structures and functions.

2) A shortage of microelements in the soil and seeds causes pathological changes in the growing organism, resulting from metabolic disturbances in nucleic acids, lipids, physiological active elements, nitrogen and carbohydrates.

3) Microelements prevent the development of functional diseases and raise the productivity of garicultural crops and their resistance to unfabourable climatic conditions, fungi and bacteria.

4) The effectiveness of fertilizers and preparations containing microelements depends on the content of their active forms in the soil, on the biological and varietal peculiarities of the crops, the soil and climatic conditions, the forms, doses

and means of application, as well as on the reserves of microelements in the seeds of the cultivated plants.

5) Besides using the salts of microelements, superphosphates and nitrophoskas, enriched with microelements, and preparations for presowing enrichment of seeds, it is expediemt to include them in the composition of compound concentrated mineral fertilizers for more extensive introduction into agriculture.

6) The production of fertilizers and preparations containing microelements is carried out on an industrial basis at chemical works in previously planned aspects, forms and qualities in accordance with the content of microelements in the soil in different zones of the country.

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