Influence of trace elements on soybean yield in grassland-swamp soils

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Abstract. This article presents the results of experiments conducted in the conditions of meadow-swamp soils of Tashkent region. The study of the effect of various norms of trace elements sulphur, manganese and iron on the growth, development and yield of early maturing varieties of soybeans was studied. Positive results were obtained from moderate levels of sulphur and manganese, and low levels of iron. Macro and micronutrients had a positive effect on soy yield. An additional 7.6 quintals (q)/ha was harvested in exchange for macro fertilizer. Compared to the background variant, the yield was 4.6-8.3 q/ha for sulphur and 4.9-9.8 q/ha for manganese. The yield of the iron element was lower than that of the background variant. Grain quality has changed in exchange for macro and micronutrients. In exchange for mineral fertilizers, this figure increased by 2.4%. In exchange for the element sulphur, the protein increased by 3.1-5.8%; an increase of 4.4-8.4% was observed in exchange for the element manganese. It was noted that the protein increased by 7.9-8.7% in exchange for the element iron.

1. Introduction

Nowadays, when protein deficiency is prevalent all over the world, the protein richness of soybeans, the presence of all the amino acids useful for humans in the protein content, is of particular importance, further increasing the nutritional value of soybeans [1]. It should be noted that the advantage of soy can be compared with a number of foods in terms of richness in lysine, methionine, arginine, leucine and other essential amino acids [2].

In many countries where soybeans are grown, this crop is the only source of protein, which also provides livestock with nutritious food and increases its productivity. Soybeans contain 30-52% protein, 17-27% fat and 20% carbohydrate water. The prevalence of soybean crop on earth is related to the quality of grain and protein [2, 3].

Based on the positive biological properties of soybeans in the country, it is necessary to study the norms of micronutrients on the background of mineral fertilizers, to determine the optimal ones in the creation and improvement of technology for growing soybeans as a primary and secondary crop [3].

Soy is a plant demanding to nutrients. 124 kg of nitrogen, 22 kg of phosphorus, 102 kg of potassium, 34 kg of calcium, 23 kg of sulphur, 191 g of zinc, 18 kg of magnesium, 187 g of manganese, 865 g of iron and 75 g of copper are extracted from the soil at a yield of 24 quintals (q)/ha [4]. This shows that in addition to macronutrients, micronutrients are also necessary for the growth and development of shade.
Micronutrients optimize plant nutrition [5], increase resistance to stress, stimulate growth [6]. Such cases are also observed in the shade plant [7]. According to the biological potential of modern soybean varieties, it is possible to grow 3.5-4.4 t/ha of seeds, but in practice this is very difficult to achieve [8].

Sulphur promotes the formation of certain amino acids, namely protein. sulphur is involved in the formation of chlorophyll, and soy absorbs a lot of sulphur during this period. Sulphur in the seeds yields 27–66% relative to the total amount. Kazakh scientists have studied the importance of sulphur and recommended the use of sulphur-containing nanopreparations to increase the germination of soybean seeds and increase the overall yield and quality. Among the various drugs, a good result was obtained from the dry nanopreparation [9].

Micronutrients are less absorbed by the soybean plant than nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. Nevertheless, their importance is not small, the lack of trace elements in the soil slows down the growth rate of the plant, and the yield is reduced.

Zinc activates enzymes, participates in plant nitrogen metabolism and protein formation. Iron is a component of chlorophyll and is important in respiration and photosynthesis. Symptoms of calcium deficiency: slow development of meristem tissue of the stem, leaf and root tips. Due to the slow mobility of calcium, its deficiency is first seen in young leaves and growth points. Manganese, barium, and molybdenum do not form seeds in legumes unless they are sufficient [10]. At the beginning of the application period, molybdenum and barium have a positive effect on the plant [1]. Magnesium deficiency begins with yellowing of the veins of aged leaves. The yellowing of the leaves begins at the bottom and reaches the young leaves as the deficiency intensifies. Symptoms of magnesium deficiency are similar to those of potassium, iron, or manganese [5, 6].

In iron deficiency, chlorophyll production stops abruptly [4, 7]. The interstices of young leaves could turn yellow. As the deficit increases, the leaf veins also turn yellow and the leaf turns completely white. Brown spots appear on the edges of the leaves. Iron deficiency is common in soils with a soil environment pH greater than 7 [2, 5]. Shade varieties have different approaches to iron deficiency. In resistant varieties, iron assimilation begins in the root system, while in the developed root system; iron is assimilated from various root wastes [6]. As the pH of the soil increases, the absorption of manganese becomes more difficult [1, 2].

To support and activate physiological processes in the development of soybeans, it is recommended to feed soybean varieties with micronutrients in the period of deficiency of micronutrients outside the root (chelate feeding). In their experiments in 2018-2020, the authors found that when micronutrients affected soybean crops, micronutrients affected soybean height, leaf, root development, tuber formation, grain quality, and yield.

2. Materials and Methods

2.1 Study area

The research was conducted in the experimental fields of the Rice Research Institute for 2018-2020. The Rice Research Institute is located in the south-eastern part of the Tashkent region, in the Chirchik oasis, 15 km from Tashkent, on the left bank of the Chirchik River. In terms of geographical location, the coordinates of the institute are bounded on the Greenwich scale by 69°18 east longitude and 41°20 north latitude. The topography of the area is flat, the soil in the experimental fields corresponds to the soil of the riverside areas, and the soil layer of the area consists of meadow-swampy soil. The reason for the emergence of this type of soil is mainly that the lands attached to the institute are located close to the banks of the Chirchik River, the surrounding farms are also engaged in rice cultivation, and there is an excess of moisture in the soil.

The soil layer in the experiment area is meadow-swamp, loamy sandy soil. It is known that gray soils are less stratified and are characterized by a lack of humus, which is also evident from the specific color that occurs in meadow-swamp soils. The driving layer of the experimental farm of the Rice Research Institute is 0-30 and 0-40 cm, below the driving layer is a layer of gel 30-40 cm thick, at a depth of 60-70 cm there is a layer of sand and small stones (Table 1).
Table 1. Agrochemical composition of the soil in the driving layer

| Year | Humus, % | Total, % | Mobile forms, mg/kg |
|------|----------|----------|---------------------|
|      |          | N        | P       | K       | N-NH₄  | P₂O₅  | K₂O   |
| 2018 | 1.63     | 0.30     | 0.21    | 0.76    | 26.30  | 35.6  | 188.6 |
| 2019 | 1.77     | 0.23     | 0.19    | 0.71    | 29.60  | 43.0  | 198.3 |
| 2020 | 1.95     | 0.27     | 0.17    | 0.72    | 17.53  | 38.6  | 183.0 |

The soil in the experimental farm was not saline (pH 7.1-7.3). According to its mechanical composition, heavy sand belongs to the soil type. The amount of physical mud in the driving layer was 40-60%.

The amount of humus in the driving layer was 1.63-1.95%, total nitrogen was 0.27-0.30%, phosphorus 0.17-0.21%, potassium 0.71-0.76%.

There are no mineral salts due to the partial slope of the experimental area, the fact that the bottom layer of the soil is composed of sand and pebbles, and the groundwater flows from the northeast to the southwest. Groundwater varies at a depth of 0.5-1.0 meters during periods when rice paddies are flooded. When the rice is not filled with water, the groundwater begins to deepen, which lasts until February at a depth of 1.5-1.6 m.

2.2 Experimental part

The experiments were conducted in an area free of rice. Field experiments showed that in 4 turns the piles were 20 m long, 2.4 m wide, 4 rows, the total area of each pile was 48.0 m², including 2 rows in the middle and 2 rows of protection rows at the edges. The options are placed by the randomization method.

Conducting field calculations, calculations and observations were carried out on the basis of "Methodological manual of the State Commission for Variety Testing of Agricultural Crops", "Methods of field experiments" and "Methodology of field experiment" [8, 9]. Leaf level is determined by the method of A.A. Nichiporovich, by leaf cuttings, the number of stems and weight were determined by the method of G.S. Posypanov [10]. To determine the weight of the roots, a monolith measuring 60x5x30 cm was dug, the roots were washed and weighed both wet and dry. Biometric measurements were performed on the counted plants prior to harvest. The plant height, branching, number and weight of pods, number and weight of grains, weight of 1,000 grains were determined. To determine the yield, the pods were collected, crushed, and pulled from the accounted area of the stalks. Yield was determined by converting the yield per hectare using the number of bushes per hectare. The results of the study were analyzed by variance according to the method of B.A. Dospekhov [10].

Table 2. Scheme of the experiment

| #  | Options | Norms of micronutrients, kg/ha | Period                      |
|----|---------|--------------------------------|-----------------------------|
| 1  | Control |                                |                             |
| 2  | BC-N₂₀P₁₀₀K₇₀ |                              |                             |
| 3  | BC+S    | 1.07; 2.14; 3.21                | During blooming; at the end of the flowering period |
| 4  | BC+Mn   | 1.8; 3.6; 5.4                   |                             |
| 5  | BC+Fe   | 1.8; 3.6; 5.4                   |                             |

‘Orzu’ is an early maturing variety, it takes 35-40 days from sowing to flowering, 110-120 days before ripening, and the stem is branched. The stem grows upright, the stem is hollow, and the height
of the stem can be up to 50-70 cm. The leaves are three-lobed, large, light green. The leaves of the plant are moderate, the leaves are symmetrical. The length of the leaf band is 10 cm. When fully ripe, 75% of the leaves fall off. The flower is white, with 2-7 flowers in the inflorescence. Beans are gray, small, 2.4 cm to 4.0 cm long. The pods do not crack when ripe, forming an average of about 40 pods per bush. On average, the weight of 1000 grains is 120-130 g of grain yield on irrigated lands, 32 q/ha. When sown as a secondary crop, 10-20 q of grain is obtained. The grain contains 25% fat and 36-38% protein.

In Tashkent province, the technology of cultivation of meadow-swamp soils has been implemented. After the land was prepared, the experimental field was divided into piles based on a working program. The method of sowing was wide, 60 cm between rows, 5 cm between bushes. ‘Orzu’ variety was planted on May 7. 500,000 seeds (62.5 kg / ha) of ‘Orzu’ variety were sown at a depth of 4-5 cm per hectare. Before planting, a background of mineral fertilizers was established in the program, using 50 kg of nitrogen, 100 kg of phosphorus and 70 kg of potassium. The experimental field was irrigated 4 times and cultivated 3 times during the application period. According to the program, at the beginning of the mowing period (or when 5-6 true leaves develop and the end of the flowering period begins to germinate) micronutrients were fed in 3 different doses, extra-root shade, suspension was used.

3. Results and Discussion

According to the average 3-year data, at the beginning of the validity period, the number of bushes in the control variant of the variety ‘Orzu’ was 471.2 thousand bushes. When mineral fertilizers were applied, the number was 477.0 thousand. The micronutrients did not affect the number of bushes of the plant at the beginning of the application period, as the micronutrients were only applied during the application period at the end of the flowering and flowering period. At the beginning of the growing season, the number of sprouted grasses was 94.2-96.2% of the sown seeds. At the end of the operation period, the number of preserved plants relative to the number of lawns was 90.9-95.0%. It was observed that the degree of storage of the number of bushes in soybean varieties was high. In the control variant it was found to be 90.7-91.1%, which is 1.0-4.6% higher than in the control when using micro-fertilizers.

Micronutrients influenced the development of soybean plants against the background of macronutrients. The mowing period was 11 days in all variants. The germination period was 22-27 days, the flowering period was 14-16 days, the legume period was 16-20 days, and the ripening period was 42-47 days. The application period was the same in the variants where control and mineral fertilizers were applied. In the variant where sulphur was applied to the control, the validity period was extended by 1-5 days. It was observed that manganese was prolonged for 2-4 days. In general, it was observed that in the variants using sulphur and manganese from micronutrients, the shelf life was extended by 1-5 days compared to the control.

According to the data obtained for an average of 3 years, it was observed that the growth of the soybean variety ‘Orzu’ was influenced by macro and micro fertilizers. Only in exchange for mineral fertilizers it was found that the height of the stem was 0.8-2.4 cm higher than in the control option. It was noted that no micro-fertilizers were used during the branching period, the difference in options was only slightly changed due to mineral fertilizers, and the stem height was between 13.7-16.1 cm. During the flowering period, the height of the stem in the control variant was 47.0 cm. In the variant where mineral and micro fertilizers were applied, the stem height was 48.4-50.9 cm, which was 0.7-3.0 cm higher than the control; the 9-11 options are an exception, as it was observed that the stem height was lower than the control option when the steel element was used. High rates were observed when sulphur and manganese were used in moderate amounts. The stem of ‘Orzu’ variety increased by 4.45% due to macronutrients and by 2.78-6.30% due to microelements (Table 3).

The leaf surface of the shade varied considerably in options in exchange for the minerals and micronutrients applied. In the variant of macro and micronutrients not applied during the branching of
the ‘Orzu’ variety, the leaf surface was 17.3 thousand m²/ha when applying mineral fertilizers was 18.1-19.0 thousand m²/ha. No trace elements were used during this period.

| #  | Options       | Days | Stem height, cm | Leaf surface, thousand m²/ha | Root weight, q/ha | Branching, pieces/plant |
|----|---------------|------|-----------------|-----------------------------|-------------------|-------------------------|
| 1  | Control       | 111  | 103.3           | 38.8                        | 25.9              | 2.4                     |
| 2  | BC-N₉P₁₀K₇₀ | 111  | 107.9           | 43.3                        | 28.3              | 2.6                     |
| 3  | BC+S₁₅        | 115  | 110.9           | 45.6                        | 28.9              | 2.7                     |
| 4  | BC+S₃₀        | 116  | 112.5           | 49.1                        | 29.1              | 3.1                     |
| 5  | BC+S₄₅        | 112  | 114.7           | 47.4                        | 29.6              | 2.5                     |
| 6  | BC+Mn₂₅      | 113  | 112.8           | 45.5                        | 28.7              | 2.7                     |
| 7  | BC+Mn₅₀      | 116  | 114.5           | 47.8                        | 29.3              | 2.9                     |
| 8  | BC+Mn₇₅      | 116  | 111.2           | 47.1                        | 29.5              | 2.8                     |
| 9  | BC+Fe₂₅      | 111  | 110.9           | 42.9                        | 27.2              | 2.5                     |
| 10 | BC+Fe₅₀      | 112  | 107.5           | 39.9                        | 26.2              | 2.4                     |
| 11 | BC+Fe₇₅      | 111  | 101.5           | 30.7                        | 24.5              | 2.2                     |

During the flowering period, the leaf surface was well developed and, according to the options, was 46.6-53.0 thousand m²/ha. Until the flowering period, soybean varieties were fed vegetatively once with micronutrients. Feeding was repeated for the second time at the end of the flowering period and at the beginning of the period of legume formation. The effect of this was observed in the variants. Due to the fertilizer background, the leaf area increased by 8.2 thousand m²/ha. 4.0 compared to the leaf surface control option in exchange for sulphur; 6.0 and 5.2 thousand m²/ha, respectively. The highest value was obtained at medium and high levels of sulphur. The leaf surface relative to the control option in exchange for the manganese element is 3.0 by the manganese standard; 6.4 and 6.2 thousand m²/ha, respectively. 3.3 compared to the leaf surface control option in exchange for the iron element; 4.8 and 3.8 thousand m²/ha, respectively.

According to the average data, in the control variant of ‘Orzu’ variety, the root mass was 26.2 q/ha. In exchange for mineral fertilizers, the root mass increased by 1.7 q/ha or 6.5%. It was found that when using the elements of sulphur and manganese, the root mass increased by 2.4-3.5 q/ha or 9.1-13.3%.

During the period of budding, the number of branches in the control variant of the variety ‘Orzu’ was 2.4, which increased by 0.2 against the background of mineral fertilizers. In exchange for sulphur, the number of horns increased by 0.3-0.5 compared to the background variant; the number of branches increased by 0.1-0.3 against the background due to the element manganese; it was found that the number of horns in all variants using iron was lower than in the background variant.

In our experiment, the weight of 1000 grains in the background version of the variety ‘Orzu’ was 155.7 grams. When sulphur was added to the background of mineral fertilizers was 155.8-163.1 grams. At all rates of sulphur applied, it was found that the absolute weight of the grain was higher than the background variant. When manganese fertilizer was applied, it was 156.3-162.0 above the background variant in all norms. When the iron element was used, it was found to be inferior to the background option by all standards. The weight of 1000 grains of ‘Orzu’ variety increased by 11.5 or 8.4% due to mineral fertilizers; against the background of mineral fertilizers increased by 11.6-15.3 g or 8.4-11.1% in exchange for micronutrients. It was observed that the performance was lower than the control when the iron element was used.
The yield of ‘Orzu’ variety in the control variant was 19.1 q/ha. Yield increased by 5.5 q/ha in the case of mineral fertilizers, 27.0 q/ha in the case of low sulphur application in the background variant, which was 7.9 q/ha higher than in the control, 2.4 q/ha higher than in the background variant.

When sulphur was used in moderation, the yield was 30.0 q/ha, which was 10.9 q/ha higher than the control variant and 5.4 q/ha higher than the background variant. When high doses of sulphur were used, the yield was slightly lower than in the previous variant, but an additional yield of 8.9 q compared to the control variant and 3.4 q compared to the background variant.

When the element manganese was added to the background variant in small amounts, the grain yield was 26.8 q. The yield was 7.7 q more than the control and 2.2 q more than the background variant.

When manganese was used in moderation, the grain yield was 29.2, 10.1 q/ha higher than the control variant and 4.6 q/ha higher than the background variant. When manganese was used at the highest rate, the yield was reduced by 1.6 q/ha compared to the previous variant, but by 18.5 and 3.0 q/ha, respectively, compared to the control and background variants.

Table 4. Yield formation under the influence of trace elements (average between 2018-2020)

| #  | Options          | Weight of 1000 grains, g | Grain yield, ts/ha | Protein content, % | Oil content, % |
|----|------------------|--------------------------|--------------------|-------------------|----------------|
| 1  | Control          | 137.7                    | 19.1               | -                 | -              |
| 2  | BC-N_P_K         | 149.2                    | 24.6               | 38.8              | 19.3           |
| 3  | BC+S_1.5         | 149.3                    | 27.0               | 40.4              | 18.8           |
| 4  | BC+S_3.0         | 153.0                    | 30.0               | 41.9              | 18.5           |
| 5  | BC+S_4.5         | 151.5                    | 28.0               | 44.6              | 19.1           |
| 6  | BC+Mn_2.5        | 149.5                    | 26.8               | 43.2              | 18.8           |
| 7  | BC+Mn_3.0        | 151.0                    | 29.2               | 45.1              | 18.6           |
| 8  | BC+Mn_7.5        | 150.4                    | 27.6               | 47.2              | 18.6           |
| 9  | BC+Fe_2.5        | 131.0                    | 25.3               | 46.3              | 19.0           |
| 10 | BC+Fe_5.0        | 129.2                    | 20.8               | 47.4              | 19.0           |
| 11 | BC+Fe_7.5        | 126.7                    | 19.2               | 48.5              | 18.6           |

When the iron element was used in small quantities, the yield was 25.7 q/ha. An additional yield of 6.7 q/ha was obtained compared to this control. Yield was 1.2 q/ha relative to the control when used at the moderate dose, while it was observed that the yield was equal to the control option when used at the high dose. It was noted that the yield decreased compared to the background option.

The protein content of the ‘Orzu’ variety was 38.8% in the control variant. In exchange for mineral fertilizers, this figure increased by 2.4%. In exchange for the element sulphur, the protein increased by 3.1-5.8%; an increase of 4.4-8.4% was observed in exchange for the element manganese. It was noted that the protein increased by 7.9-8.7% in exchange for the element iron. Of the trace elements studied in grain quality, the greatest effect was shown by the element iron.

4. Conclusions

1. Micronutrients on the basis of micronutrients prolonged the shelf life of the ‘Orzu’ variety by 4-5 days for sulphur and 2-4 days for manganese;
2. Macro and micronutrients affected the growth of soybeans, the stems were higher by 4.45% due to macronutrients and 2.78-6.30% due to micronutrients.
3. Micronutrients have a positive effect on the development of the leaf surface, and in accordance with the applied standards, the leaf surface in exchange for sulphur is 4.0-6.0 thousand m²/ha; manganese-3.0-6.6 and iron element-3.3-4.8 thousand m²/ha higher than the control.

4. The weight of 1,000 grains of ‘Orzu’ variety increased by 11.5 or 8.4% due to mineral fertilizers; against the background of mineral fertilizers increased by 11.6-15.3 g or 8.4-11.1% in exchange for micronutrients. It was observed that the performance was lower than the control when the iron element was used.

5. Macro and micronutrients had a positive effect on soy yield. An additional 7.6 q/ha was harvested in exchange for macro fertilizer. Compared to the background variant, the yield was 4.6-8.3 q/ha due to sulphur and 4.9-9.8 q/ha due to manganese. The yield of the iron element was lower than that of the background variant.

6. Grain quality has changed due to macro and micronutrients. In exchange for mineral fertilizers, this figure increased by 2.4%. In exchange for the element sulphur, the protein increased by 3.1-5.8%; an increase of 4.4-8.4% was observed in exchange for the element manganese. It was noted that the protein increased by 7.9-8.7% in exchange for the element iron.

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