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Optimization of norms of fertilizers for predicted productivity of grain of soya bean (*Glycine max* L. Merr.)

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The purpose. To optimize norms of fertilizers for predicted productivity of soya bean at the level of 3 – 4 t/hectare. **Methods.** Balance method of removal of nutrients with predicted yield and their return to soil in view of biological nitrogen. **Results.** Optimum norms of fertilizers for predicted productivity of soya bean are calculated: 3; 3,6; and 4 t/hectare. **Conclusions.** Assortment of fertilizers for soya bean, as well as forms, time and methods of their application are specified.

Key words: *soya bean, predicted productivity, biological nitrogen, norms, assortment, method of applications of fertilizers.*

The soya is an important food culture in Ukraine. Originating from China and owing to its high nutritional value, the soya has eventually spread all over the world. The soybean contains 35 to 52% protein, 17 to 27% oil, 18 to 25% carbohydrates, a complex set of vitamins and biologically active substances (such as phosphatides, isoflavones, saponins, etc.) used for medicinal purposes [1].

In Ukraine, the soya crop was cultivated on limited plots.

In 2001, the total soya-crop area and yield indices made up to 137.430 ha and 1.3 t/ ha, respectively.

By 2016, the soya-cultivation area increased to 1.853.400 hectares, with up to 2.31 t/ha yielding capacity [2].

Remarkable yields of soybean were recorded in Zaporizzha, Zakarpattya and Kherson oblast areas (3.63, 3.68 and 3.63 t/ ha, correspondingly).

In most of other regions (Chernihiv, Poltava, Odessa areas etc.), the soybean yields were about or somewhat over 2.0 t/ha.

Up to date, the leading scientific institutes of the National Academy of Agricultural Sciences of Ukraine(*) have created a lot of high-score varieties of soya species featured with over 3.0 - 4,0 t/ha yielding- index.

The soya is generally a crop that demands specific growing conditions. Its high yields may be expected upon well-structurized soils of neutral (or near-neutral, i.e., pH 6.5 to 7.5) reaction of soil solution.

Soya is very demanding for favorable thermal and water regimes, and availability of soil-abundant mobile macro- and micro- nutrients as well.

Regarding macro-nutrients, first and foremost need is for nitrogen, phosphorus, potassium, calcium, magnesium and sulfur.

Among trace elements, molybdenum, manganese, zinc and copper are the most needed.

Optimization of plants' nutrition regimes is feasible at the expence of: (i) nutrient substances from soil, and (ii) application of organic and mineral fertilizers.

Owing to symbiosis with tuberous bacteria, soya as a leguminous culture has an ability to assimilate atmospheric nitrogen.

(*) NOTE: (such as (i) Selection- Genetic Institute "The National Center for Seeds and Plants Studies", (ii) The Podillya Institute of Forage and Agriculture, (iii) The V.Yu. Yuryev Institute of Plant- Breeding, etc.)

An influence of various factors (biological plants' properties; degree of nutrients' availability in soil; nitrogen assimilation from the air) on forecast soybean yielding capacity makes calculations for mineral fertilizers' rates (especially nitrogen) very difficult.

Up to date, several methodology approaches are known to calculate the rates of nitrogen fertilizer inputs for soya: (i) to rid off nitrogen-based fertilizers' application at all; (ii) to apply mineral N- fertilizers in limited (20 to 30 kg /ha) amounts, - as start-off rates before initial symbiotic nitrogen- fixation in soil; (iii) to input medium- averaged rates of nitrogen (40 to 60 kg/ha); (iv) to input elevated (over 90 kg/ha) rates of nitrogen, with no account of atmospheric N-intake [1].

Such a discrepancy of recommendations requires a proper selection amomg existing methodological approaches to mineral fertilizers rates' calculations for forecast soya yield.

The Goal of the Study: to optimize mineral fertilizers' input- rate per forecast- estimated yielding capacity (3.0 to 4.0 t/ha) of soybean.

Methodology of the Study: The most popular way of calculating fertilizer- rates is the **balance method** that accounts for (i) amount of post- harvest withdrawal of nutrients (at forecast crop-yield-estimations), and (ii) their comeback into soil from various sources [3].

As an example, calculation of mineral fertilizers' rates per forecast soya yielding capacity (3 t/ha) included:

- a forecast yielding capacity of soybean: 3.0 t/ha;
- nutrients content in 1 ton of soybean: 52.6 kg nitrogen; 11.1 kg phosphorus; 14.8 kg potassium;
- demand for nutrients at 3 t/ha soybean- yield formation makes up 157.8 kg/ha (3.0 by 52.6 kg) nitrogen; 33.3 kg (3.0 by 11.1) phosphorus (whereby conversion to P2O5 makes up 76.3 kg/ha (33.3 by 2,291); as well as 44.4 kg/ha (3.0 by 14.8) potassium; and 53.5 kg/ha (44.4 kg/ha by 1,205) at conversion to K2O;
- calculated rates of fertilizers (157.8 kg/ha nitrogen; 76.3 kg/ha phosphorus; 53.5 kg/ha potassium) undergo correction per content of mobile compounds of nitrogen, phosphorus and potassium in soil.

Research results. Soya is cultivated in all soil-climatic zones of Ukraine characterized by varieties of soil cover. Differently podzolized and gleyified soddy-podzolic soils, as well as meadowy, boggy-marsh and peaty lowland soils are common in Polissia;

light-grey and grey forest soils, dark-grey podzolized soils; typical and podzolized chernozems are characteristic in the Forest-Steppe areal;

- typical and southern chernozems, as well as dark-chestnut and chestnut solonets soils are common throughout the Steppe zone;

meadow-brownish-podzolic surfacially-gleyified soils are typical for Transcarpathia.

Soils are inherited with mobile nutrients to various extents.

A degree of each land plot's supply with nutrients is determined by results of latest agrochemical certification of agricultural-purpose land sites.

Main document after agrochemical survey is a "Land Plot Agrochemical Certificate" based on (i) results of soil solution reaction analysis (pH of saline and clear water solutions); (ii) content of humus and alkali-hydrolyzed nitrogen (the Cornfield method); (iii) content of mobile nutrient compounds (phosphorus, potassium, sulfur), (iv) content of trace elements [4].

Thus calculated mineral fertilizers rates per forecast soybean yield (3.0 t/ha) are adjusted via correction coefficients for content of mobile compounds of nitrogen, phosphorus and potassium in soil (Tables 1,2,3).

Generally accepted average content of mobile nutrients per each element is assumed as 1.0.

Soya is planned for cultivation preferably on typical medium loamy chernozems with either neutral reaction of soil solution and low nitrogen content(*); or with medium phosphorus content(**), or with elevated potassium content(**).

NOTES: (*) after Cornfield method; (**) after Chirikov method.

Table 1. Correction factors per content of mobile nitrogen compounds in soil

Degree of nitrogen availability in soil	Content of alkaline-hydrolyzable nitrogen (after Cornfield method), mg/kg soil	(*)Mineral nitrogen content (NH4 + NO3), mg/kg soil	Hydrolyzable nitrogen content(**) (after Tyurin-Kononova method), mg/kg	Correction factor
low	<101	<15	<40	1.2
medium	101 to 150	16 to 24	41 to 50	1.0
elevated	151 to 200	25 to 30	51 to 70	0.9
high	>200	>30	>70	0.8

NOTES: (*) At determining an amount of mineral or hydrolyzed nitrogen in soil.

(**) Correction factor for low (80 mg/kg soil) nitrogen content after Cornfield method is 1.2, whereby the nitrogen rate rises from 157.8 to 189.4 kg/ha (i.e.,157.8 is multiplied by 1.2).

Correction factors in other methods of nitrogen analysis in soil are calculated in the same way.

Correction factors for adjustment of phosphate fertilizers' rates per content of mobile phosphorus compounds in soil were elaborated for: (i) Kirsanov method (soils with acidic reaction of soil solution), (ii) Chirikov method (neutral or near-neutral reaction), and (iii) Machigin method (alkaline reaction), Table 2.

Since the mobile phosphorus compounds content in typical chernozem is of medium size (70 mg/kg after Chirikov method), the correction factor is 1.0 and the phosphorus rate remains the same at 76.3 kg/ha (76.3 by 1.0).

Table 2. Correction factors per mobile phosphorus compounds' content in soil

Degree of phosphorus availability in soil	According to methods after:			Correction factor
	Kirsanov	Chirikov	Machigin	
	Content of phosphorus compounds, mg/kg of soil			
low	<51	<51	<15	1.1
medium	51 to 100	51 to 100	16 to 30	1.0
elevated	101 to 150	101 to 150	31 to 45	0.9
high	>150	>150	>45	0.8

Correction factors in other methods of phosporus analysis of soil are calculated in the same way.

The correction factors for adjustment of potassium fertilizers' rates per content of potassium mobile compounds in soil were elaborated for methods by: (i) Kirsanov (i.e., acidic reaction of soil solution); (ii) Chirikov (neutral or near- neutral soil reaction); and (iii) Machigin (alkaline reaction), Table 3.

Since mobile potassium compounds content in typical chernozem is elevated (130 mg/kg after Chirikov method), the correction factor is 0.8 and the potassium rate decreases to 42.8 kg (53.5 by 0.8).

Correction factors in other methods of potassium analysis in soil are determined in the same way.

Table 3. Correction factors for potassium mobile compounds' content in soil

Degree of potassium availability in soil	According to methods after:			Correction factor
	Kirsanov	Chirikov	Machigin	
	Content of potassium compounds, mg/kg of soil			
low	<81	<81	<101	1.2
medium	81 to 120	81 to 120	101 to 200	1.0
elevated	121 to 170	121 to 180	201 to 300	0.8
high	>170	>180	>300	0.7

After adjustment for the nutrients’ content in soil, rates of mineral fertilizers are: 189.4 kg/ha nitrogen, 76.3 kg/ha phosphorus, and 42.8 kg/ha potassium.

The nitrogen rate (189.4 kg/ha) is compensated for from various sources. The balance method involves a case (a) of nitrogen entry into soil and a case (b) of nitrogen losses from soil:

(a) In case of entry, nitrogen penetrates the soil:

- with seed-purpose beans;
- with atmospheric precipitation;
- via non-symbiotic fixation in soil by aid of indigenously inherent micro-organisms.

(b) In case of losses, nitrogen undergoes withdrawal from soil via:

- gaseous emissions from soil and fertilizers;
- evacuation with filtration atmospheric water.

It is conventionally accepted that cases of partial nitrogen entry (a) and loss (b) are self-compensating and hence, are not accounted for at calculations.

Regarding the soya, an important case of nitrogen supply is its absorption from the air due to tuber bacteria symbiosis with plants.

Regarding the soya again, the tuberous rhizobia- bacterial strains make up a minor part of soil micro-organisms, i.e., 0.1 to 0.8% of the total number of bacteria in rhizosphere, and 0.01 to 0.14% of their biomass [5].

Availability of such bacteria populations in soil where soya was never grown before, is very scarce.

Each population is separated by its distinct boundaries, without mass reproduction upon exterior territories [6].

Hence, the soya supply with biological nitrogen is generally poor, especially where it was never rown before.

Results of decade-long studies show that under favorable conditions on typical chernozems of Forest-Steppe zone, the minimum amount of total nitrogen fixation by soya makes up to 80 kg/ha; of which a part of nitrogen is shared for crop formation, and the rest remains in soil [7].

This index is used to calculate nitrogen fertilizer rates of for soya crop.

Thus calculated nitrogen rate per forecast yielding capacity of soybean is 3.0 t/ha, with deduction of biological nitrogen (80.0 kg/ha), is [189.4 - 80.0 = 109.4 kg/ha].

The balance method assumes for not only optimization of fertilizers’ rates, but also for comeback of nutrients into soil so as to avoid its degradation.

Increasing the degree of forecast soya yielding capacity shall also increase the rates of mineral fertilizers (Table 4).

Table 4. Rates of mineral fertilizers per forecast soybean yielding capacity on typical chernozems of Ukrainian Forest-Steppe zone

Forecast estimated yielding capacity, t/ha	**Rate of mineral fertilizers, t/ha of activation substance**		
	Nitrogen	**Phosphoric**	**Potassium**
3.0	109.4	76.3	42.6
3.6	131.3	91.6	51.1
4.0	145.8	101.7	56.8

Negative factors in soils of Polissya and Transcarpathia include (i) elevated acidity of soil solutions (that requires liming), and (ii) poor nutrients supply in soil.

Across the Steppe zone, the major negative factor is poor moisture- water supply in soil, which requires provision of irrigation conditions for soya cultivation.

Via application for soya of RHIZOBOPHIT™ bacterial fertilizers (that contain symbiotic nitrogen-fixing microorganisms), the legume-rhizobial symbiosis is ever increasing.

Soybean should be rhyzo-bacterized just before the sowing, not sooner than two weeks after their treatment with fungicides [8-10].

Obtaining high yielding capacity of soya without inputs of mineral nitrogen fertilizers is practically impossible [8].

The problem of nitrogen losses from soil is mitigated by such agronomic means as choice of forms, timing regimes and methods of nitrogen fertilizers' application.

It is most expedient to use for soya the SUPERAGRO™ (N15P15K15) - a complex mineral fertilizer produced by JSC Sumykhimprom (Ukraine) containing: 15.1% nitrogen; 15.4% phosphorus (P2O5); 15.2% potassium (K2O); 10.1% sulfur (S); 0.24% CaO; 0.5% MgO; alongside Cu, Mo, Mn, Zn trace elements.

In fact, this fertilizer brand contains macro- and micro-elements needed for soya crops.

Russia- and Belarus- made nitroammophos (N16P16K16) fertilizers barely contain only three macro-elements (N, P and K).

Rates of Superagro™ brand (N15P15K15) are calculated per phosphorus (P2O5) compound, while the N-rate is supplemented with granular ammonium sulfate (20% nitrogen and 23% sulfur).

It is most efficient to input complex and simple (N15P15K15) fertilizers at spring-time, simultaneously at cultivation and sowing in rows, using 100kg/ha of physical weight.

Conclusions

The optimal rates of mineral fertilizers for the forecast yielding capacity of soybean (3.0 t / ha) on the typical chernozem of Forest-Steppe zone are: 109.4 kg/ha mineral nitrogen; 76.3 kg/ha phosphorus (P2O5); 42.6 kg/ha potassium (K2O).

With an increase in forecast yielding capacity, rates of mineral fertilizers increase, too. Thus, yield of 4.0 t/ha would require: 145.8 kg/ha mineral nitrogen; 101.7 kg/ha phosphorus (P2O5); and 56.8 kg/ha potassium (K2O), respectively.

The best fertilizers' assortment formula for soya is [Superagro™ (N15P15K15) + granulated ammonium sulfate] manufactured by Sumykhimprom. It is most efficient to input complex and simple (N15P15K15) fertilizers in spring-time, simultaneously at cultivation and sowing in rows, using 100kg/ha of physical weight.

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