

## Nutritive regimen of leached chernozem at use of different fertilizer systems for sugar beet cultivation

Ivanina V.<sup>1</sup>, Pavuk I.<sup>2</sup>, Mazur H.<sup>3</sup>

<sup>1</sup> Institute of biopower crops and sugar beet of NAAS, Klinichna Str., 25, Kyiv, 03141, Ukraine; <sup>2</sup> Vinnytsia national agrarian university, Soniachna Str., 3, Vinnytsia, 21008, Ukraine; <sup>3</sup> Uladovo-Liulinetsk selection station of the Institute of biopower crops and sugar beet of NAAS, Uladovske, Kalynivskyyi region, Vinnytsia oblast, 22412, Ukraine; e-mail: <sup>1</sup> v\_ivanina@meta.ua, <sup>2</sup> matematiks@gmail.com, <sup>3</sup> selekstanciya@gmail.com

**The purpose.** To study efficiency of traditional and alternative organic-and-mineral fertilizer systems in formation of nutritive regimen of sandy loam leached chernozem. **Methods.** Short-term field, laboratory-analytical, mathematical processing of the gained results. **Results.** Dynamics of the content in soil of movable joints of nitrogen, phosphorus and potassium is shown at application for cultivation of sugar beet of traditional and alternative fertilizer systems. **Conclusions.** The alternative fertilizer system ( $N_{90}P_{60}K_{90}$  + straw + green manure crop) is recognized to be more efficient for improvement of nutritive regimen of leached chernozem. On the beginning of vegetation the content of mineral nitrogen at its application has increased up to 30–35 kg/hectare with flushing out of nitrate nitrogen to the depth of 0–90 cm, and of ammonium nitrogen — to 0–60 cm. During the vegetation period nitrate nitrogen of soil was used by plants on 70–90%, and ammonium nitrogen — on 10–40%. The content of movable joints of phosphorus and potassium at alternative fertilizer system increased mainly in arable layer of soil (0–30 cm) on 20 and 10 mg/kg of soil accordingly (60 and 30 kg/hectare) and preserved relative stability during vegetation.

**Key words:** nutritive regimen, leached chernozem, fertilizer system.

**Introduction.** Achievement of high productivity of beet sugar is possible for the creation of a favorable soil nutrition regime for growth and development of plants [1], [2], [3]. Research of Ya.P. Tsvey [4] testify that by the organic-mineral systems of fertilizers it is formed a special trophic environment in the soil as a result of the transformation of the organic-mineral substrate of fertilizers, which ensures the stability of the organic colloidal complex, maximizing its saturation with exchangeable forms of nutrients. Under such conditions, a large amount of nutrients accumulate in the soil in water-soluble and exchangeable forms, the soil moisture is better stored and more economically used, which, in aggregate of these factors, creates conditions for a stable mineral nutrition regime in time [5], [6], [7].

The use of alternative systems of fertilizers with the application of winter wheat straw and green mass of green manure crops under sugar beet deserves attention. Research of O.M. Berdnikov, Yu.A. Nymytiuk [8], V.M. Poliovyi [9], G.I. Parfeniuk [10] show that the application of straw under sugar beet is capable to provide the soil with an organic substance in volumes equivalent to 30 t/ha of manure. The alternative organic fertilizer stabilizes the organic matter of the soil, improves its structure, water regime and nutrition conditions of the plants.

**Research purpose** was to study the efficiency of traditional and alternative organic-mineral systems of fertilizers in the formation of nutrition regime of leached black soil, easy texture.

**Materials and research methods.** The research was carried out in the conditions of the stationary field experiment (2015-2017) of the Uladovo-Liulinetska research-breeding station, the zone of sufficient moisture of the Forest-Steppe of Ukraine.

Drilling area – 100 m<sup>2</sup>, accounting area – 50 m<sup>2</sup>, placement of the variants in experiments - systematic consistent, repetition of the experiment is four times. The sugar beet hybrid – “Bulava”, cultivation agrotechnic is generally accepted for the Forest-Steppe Zone.

Soil of the research plot is leached black soil which characterized by the following agrochemical properties: organic matter content by Turin – 4.1-4.2%, pH salt solution – 5.9-6.5, hydrolytic acid (Hg) by Kappen – 1.18-1.30 mg-equ./100 g of soil, sum of absorbed bases (S) by Kappen-Gilkovits – 24.4-27.6 mg-

equ./100 g of soil, alkaline hydrolyzed nitrogen at Cornfield – 130-140 mg/kg of soil, mobile phosphoric and potassium by Chirikov – 140-160 and 75-80 mg/kg of soil.

Fertilizers were applied in the form of ammonium nitrate, simple granular superphosphate and potassium chloride. Organic fertilizers were applied in the form of manure and alternative sources of organic matter – the green mass of the after harvesting green manure crop of mustard white (average yield – 24.6 t/ha) and by-products of winter wheat.

Ammonium and nitrate nitrogen in the soil were determined according to DSTU 4729-2007, a mobile phosphorus and potassium – by Chirikov in accordance with DSTU 4115-2002.

**Research results and their discussion.** Studies have shown that at the beginning of the vegetation of sugar beet it is accumulated a significant reserves of nutrients in mobile forms in the leached black soil, which creates favorable conditions for the initial growth and development of plants. Thus, in the control without fertilizers during the formation of plants density, the content of nitrate nitrogen in the layer 0-30 cm was 16.4 mg/kg, 30-60 cm – 14.1, 60-90 cm – 11.3 mg/kg of soil; with the volumes of their accumulation in the layer 0-90 cm – 125 kg/ha (table 1).

**Table 1. Dynamics of nitrate nitrogen in leached black soil for different fertilization systems, average 2015-2017, mg/kg of the soil**

№ var.	Variant	May			July			September		
		0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
1	Without fertilizers (control)	16,4	14,1	11,3	14,6	11,0	7,7	2,3	1,1	0,8
2	N <sub>60</sub> P <sub>30</sub> K <sub>60</sub>	18,9	15,0	12,0	15,8	11,6	8,5	2,0	0,9	0,7
3	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub>	20,5	16,4	12,2	16,2	11,7	8,0	2,4	1,2	0,7
4	N <sub>120</sub> P <sub>90</sub> K <sub>120</sub>	21,2	16,6	12,1	16,3	12,2	8,6	2,2	1,5	0,9
5	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 40 t/ha manure	23,4	17,8	13,4	18,6	14,5	9,5	2,8	1,1	0,7
11	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + legume (mustard white)	20,8	16,3	12,1	16,3	12,3	8,1	2,3	0,9	0,8
12	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 5 t/ha straw of winter wheat + legume	20,0	16,2	11,8	15,9	12,7	8,7	2,5	0,8	0,9
NIR <sub>0,05</sub>		1,2	0,8	0,6	1,0	0,5	0,4	0,1	0,1	0,1
P, %		1,7	2,0	1,7	1,9	1,8	2,2	2,3	1,8	1,8

Application of nitrogen fertilizers increased the content of nitrate nitrogen in all 0-90 cm layer of soil with preferential growth in a layer 0-30 cm. For doses of nitrogen fertilizers of 60-120 kg/ha in the total mineral fertilizer, the content of nitrate nitrogen in arable 0-30 cm layer at the beginning of the vegetation was increased by 2.5-4.8 mg/kg compared with the control without fertilizers and amounted to 18.9-21.2 mg/kg of soil. An increase in the dose of nitrogen fertilizers was accompanied by a rise in the content of nitrate nitrogen in the soil.

The most substantially the content of nitrate nitrogen in the soil was raised by the traditional organic-mineral system of fertilizers (N90P60K90 + 40 t/ha manure). Thus, at the beginning of the vegetation, its content in the layer 0-30 cm was 23.4 mg/kg, 30-60 cm – 17.8, 60-90 cm – 13.4 mg/kg of soil, which exceeded control without fertilizers – respectively per 7.0, 3.7 and 2.1 mg/kg of soil. By the traditional organic-mineral system of fertilizers, the reserves of nitrate nitrogen in the 0-90 cm layer of leached black soil extracted during the formation of the density of shoots were higher compared to the control without fertilizers per 38 kg/ha.

Applying instead of manure a green mass of mustard white (N90P60K90 + green manure) or its combination with the adding of 5 t/ha straw (N90P60K90 + straw + green manure) was not accompanied by a significant increase of nitrate nitrogen content in the soil at the beginning of the vegetation, and was marked by a lower its migration to the deep soil layers. The content of nitrate nitrogen in the layer 0-30 cm of

these variants was respectively 20.8 and 20.0 mg/kg of soil. Reduction of nitrogen content in the soil as compared with manure may be due to its enhanced immobilization.

During the growing season, the content of nitrate nitrogen in the soil layer 0-90 cm has been decreased, and at the harvesting period of sugar beet was in the range of 0.7-2.8 mg/kg of soil. Significant differences of its content between the experimental variants were not observed. Significant decrease in the content of nitrate nitrogen in the soil may be due to the intensive use of it by plants, the absorption by soil biota and possible losses due to washing and emissions.

Application of fertilizers increased the content of ammonium nitrogen in the soil. Thus, in the control without fertilizers during the formation of the plants density, the content of ammonium nitrogen in the layer 0-30 cm was 14.1 mg/kg, 30-60 cm – 8.0, 60-90 cm – 5.1 mg/kg of soil; with the volume of the accumulation in a layer 0-90 cm – 81 kg/ha (table 2).

For the dose of the fertilizers application N<sub>60</sub>-120P<sub>30</sub>-90K<sub>60</sub>-120, the content of ammonium nitrogen increased predominantly in layers of 0-30 cm and 30-60 cm and was respectively 15.6-16.2 and 8.7-9.2 mg/kg, which was higher per 1.5-2.1 and 0.7-1.2 mg/kg of soil compared to the control without fertilizers. In the layer of soil 60-90 cm it did not observe a significant increase of ammonium nitrogen under the use of fertilizers.

**Table 2. Dynamics of ammonium nitrogen in leached black soil for different fertilization systems, average 2015-2017, mg/kg of the soil**

№ var.	Variant	May			July			September		
		0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
1	Without fertilizers (control)	14,1	8,0	5,1	9,1	7,7	4,6	9,0	7,5	4,5
2	N <sub>60</sub> P <sub>30</sub> K <sub>60</sub>	15,6	8,7	4,9	10,1	7,9	4,6	9,7	7,7	4,6
3	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub>	16,0	8,7	5,4	10,0	8,3	4,8	9,8	7,9	4,7
4	N <sub>120</sub> P <sub>90</sub> K <sub>120</sub>	16,2	9,2	5,5	10,3	8,5	4,9	9,7	8,0	4,7
5	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 40 t/ha manure	17,5	10,6	5,7	12,4	9,7	5,0	9,9	8,4	4,8
11	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + legume (mustard white)	16,1	8,5	5,1	10,3	8,8	4,9	9,6	8,0	4,8
12	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 5 t/ha straw of winter wheat + legume	16,8	9,4	5,3	11,7	9,2	5,0	10,1	8,6	4,7
NIR <sub>0,05</sub>		0,7	0,5	0,2	0,6	0,4	0,2	0,5	0,4	0,3
P, %		1,8	2,2	1,7	2,4	2,0	1,7	1,9	2,1	2,5

The highest content of ammonium nitrogen was determined under organic-mineral system of fertilizers, when on the background of N<sub>90</sub>P<sub>60</sub>K<sub>90</sub> the 40 t/ha of manure was applied or plowed the green mass of white mustard combined with the adding of 5 t/ha of winter wheat straw into the soil. The content of ammonium nitrogen in the layer 0-30 cm under the traditional organic-mineral system of fertilizers (N<sub>90</sub>P<sub>60</sub>K<sub>90</sub> + green manure) was 17.5 mg/kg, under the alternative (N<sub>90</sub>P<sub>60</sub>K<sub>90</sub> + straw + green manure) – 16.8; in the layer 30-60 cm – respectively 10.6 and 9.4 mg/kg of soil. Compared to the control without the use of traditional and alternative organic-mineral systems of fertilizers, the reserves of ammonium nitrogen in the layer 0-90 cm were increased – respectively per 20 and 13 kg/ha.

Consequently, the use of fertilizers increased the content of nitrate nitrogen in the entire 0-90 cm layer of leached black soil, ammonium – mainly in the upper 0-30 cm and 30-60 cm layers. The highest content of mineral nitrogen in the soil was observed under the traditional organic-mineral system of fertilizers (N<sub>90</sub>P<sub>60</sub>K<sub>90</sub> + 40 t/ha manure), while the application of N<sub>90</sub>P<sub>60</sub>K<sub>90</sub> + straw + green manure increased predominantly the content of ammonium nitrogen in a layer 0-60 cm.

The intensity of the biological circle of phosphorus in agrocenoses is 4-6 times less than that of nitrogen and potassium. The sharpest need of sugar beet plants in phosphorus is observed in the initial stages of

organogenesis when it is formed the root system of plants and at the end of the vegetation, when there is place the accumulation of sugar in the roots.

Formation of sufficient phosphorus nutrition of the plants at the beginning of the vegetation determines the pace of their growth and development and forms the productive potential of plants during the harvesting period.

The study of the content of mobile phosphorus in leached black soil at the beginning of the vegetation showed that in the control without fertilizers its content in the upper 0-30 cm layer was 117 mg/kg, subsoil layer 30-40 cm – 106 mg/kg of soil. Application of fertilizers increased the content of mobile phosphorus in the layer 0-30 cm – per 0.05-0.21 mg/kg, 30-40 cm – per 0.01-0.08, which in absolute measurement value was 122-138 and 107-114 mg/kg of soil (table 3).

**Table 3. Dynamics of mobile phosphorus in leached black soil for different fertilization systems, average 2015-2017, mg/kg of the soil**

№ var.	Variant	May		July		September	
		0-30	30-40	0-30	30-40	0-30	30-40
1	Without fertilizers (control)	117	106	128	117	127	111
2	N <sub>60</sub> P <sub>30</sub> K <sub>60</sub>	122	106	134	117	131	113
3	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub>	127	107	138	120	134	114
4	N <sub>120</sub> P <sub>90</sub> K <sub>120</sub>	130	107	139	121	136	116
5	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 40 t/ha manure	138	114	147	123	140	116
11	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + legume (mustard white)	136	115	143	122	137	115
12	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 5 t/ha straw of winter wheat + legume	137	113	143	122	140	118
NIR <sub>0,05</sub>		5,5	4,6	6,0	5,7	6,0	5,4
P, %		2,4	2,0	2,2	1,9	2,3	1,9

The most significantly the content of mobile phosphorus in the soil at the beginning of vegetation has increased due to the use of traditional and alternative organic-mineral systems of fertilizers. With apply of N90P60K90 + 40 t/ha manure, the content of mobile phosphorus in the layer 0-30 cm was 138 mg/kg, 30-40 cm - 114, which exceeded the control without fertilizers – correspondingly per 0.21 and 0.08 mg/kg of soil.

Alternative systems of fertilizers (N90P60K90 + green manure and N90P60K90 + straw + green manure) have increased the content of mobile phosphorus in 0-30 cm layer at the beginning of the vegetation – reciprocally till 136 and 137 mg/kg of soil. The significant increase of mobile phosphorus in the soil may be due to the increased phosphorus mobilization by after harvesting green manure crop mustard white and rapid mineralization of the organic mass of the green manure in the soil.

Application of fertilizers in the dose N60-120P30-90K60-120 slightly increased the content of mobile phosphorus in leached black soil compared with the control without fertilizers – per 0.05-0.10 mg/kg of soil, which was observed mainly in upper 0-30 cm layer. An increase of the dose of phosphorus fertilizers from 30 to 90 kg/ha was accompanied with only the tendency of phosphorus increase in the soil.

During the growing season, the content of mobile phosphorus in the leached black soil was highlighted with certain stability – slightly increased at the period of maximum development of the sugar beet and maintained stability until the harvest period. With applying of the fertilizers, the content of mobile phosphorus in the soil was determined to be higher compared to control without fertilizers throughout the whole period of sugar beet vegetation.

The provision of leached black soil with mobile forms of potassium was determined as an average. On the control without fertilizers, the content of mobile potassium at the beginning of the vegetation of sugar beet was in the layer 0-30 cm – 88 mg/kg, 30-40 cm – 71 mg/kg of soil. The applying of potassium fertilizers

increased the content of mobile potassium in a layer 0-30 cm – up to 93-99 mg/kg, 30-40 cm – up to 74-80 mg/kg of soil (table 4).

**Table 4. Dynamics of mobile potassium in leached black soil for different fertilization systems, average 2015-2017, mg/kg of the soil**

№ var.	Variant	May		July		September	
		0-30	30-40	0-30	30-40	0-30	30-40
1	Without fertilizers (control)	88	71	81	70	70	64
2	N <sub>60</sub> P <sub>30</sub> K <sub>60</sub>	93	74	83	71	72	67
3	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub>	93	75	87	75	74	68
4	N <sub>120</sub> P <sub>90</sub> K <sub>120</sub>	96	78	89	76	75	67
5	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 40 t/ha manure	99	78	93	77	84	72
11	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + legume (mustard white)	95	75	88	72	76	68
12	N <sub>90</sub> P <sub>60</sub> K <sub>90</sub> + 5 t/ha straw of winter wheat + legume	98	80	91	77	79	70
NIR <sub>0,05</sub>		4,6	3,4	4,0	3,0	3,3	2,7
P, %		2,0	2,2	1,8	1,8	2,3	2,4

The most significant increase of the content of mobile potassium in the soil was due to organic-mineral systems of fertilizers when fertilizers were applied in combination with 40 t/ha manure (N90P60K90 + 40 t/ha manure) or combined with winter wheat straw and green mass of mustard white (N90P60K90 + straw + green manure). At the beginning of vegetation of sugar beet, the content of mobile potassium in a layer 0-30 cm in these variants was respectively 99 and 98 mg/kg, 30-40 cm – 78 and 80, which, as compared with the control without fertilizers, was higher per 10-11 and 7- 9 mg/kg of soil. The similarity of the influence of traditional and alternative sources of organic mass on the potash stock of leached black soil may be due to the comparatively high content of potassium in these organic fertilizers and its rapid transition to soil solution.

Application of the fertilizers only in the doses N60-120P30-90K60-120 increased the content of mobile potassium in the layer 0-30 cm – up to 93-96 mg/kg, 30-40 cm – up to 74-78, which was higher compared to the control without fertilizers on 3-7 mg/kg of soil.

During the growing season, the content of mobile potassium in the upper layers of the soil decreased: at the period of maximum plants development compared with the beginning of the vegetation – per 7-9%, at harvesting time – reciprocally per 18-26%. This may be due to the use of potassium by sugar beet plants and to the processes of gradual transformation of potassium into low mobile compounds. There while, in the variants with fertilizers application, the content of mobile potassium in the soil remained higher during the entire vegetation period.

### Conclusions

1. When sharp deficit of manure in the condition of sufficient water provision, the application of the alternative organic-mineral systems of fertilizers with the use of by-products and green mass of mustard white provides suitable conditions for nutrition of sugar beet plants. Application of N90P60K90 + straw + green manure has increased a nitrogen content in 0-90 cm layer in comparing to the control without fertilizers – per 0.5-3.6 mg/kg (19-21 kg/ha), the ammonium – predominantly in the 0-60 cm layer – per 0.6-2.7 mg/kg of soil (11-13 kg/ha). Therewith, sugar beet plants used nitrate nitrogen during the growing season from 0-90 cm layer per 70-90%, ammonium mainly from 0-60 cm layer – per 10-40%, which was accompanied by a decrease in their content at the end of the vegetation – respectively in 8-20 and 1.1-1.7 times.

2. An alternative system of fertilizers (N90P60K90 + straw + green manure) increased the content of mobile phosphorus preferably in an upper 0-30 cm layer of soil. At the beginning of the vegetation period, the

content of mobile phosphorus in the layer 0-30 cm was 137 mg/kg, 30-40 cm – 7, which is higher than the control without fertilizers – reciprocally per 20 and 7 mg/kg of soil. Significant increase in mobile phosphorus in the soil may be due to the increased phosphorus mobilization with an after harvesting crop mustard white, the organic mass of which is rapidly mineralized in the soil.

3. The use of N90P60K90 + straw + green manure created favorable conditions of potassium nutrition for the plants. The content of mobile potassium in the soil at the beginning of the vegetation under the alternative system of fertilizers, as compared to the control without fertilizers, was increased in the layer 0-30 cm – per 10 mg/kg, 30-40 cm – per 9 mg/kg of soil and was – reciprocally 98 and 80 mg/kg of soil, which was equal to the efficiency by the application of N90P60K90 + 40 t/ha manure.

### **Bibliography**

1. Ivanina V.V. (2016). Biologizatsiia udobrennia kultur u sivozminakh: monohrafiia. Kyiv: Kompyrynt. 328 p. [in Ukrainian].
2. Ivanov V.P., Prasol V.I., Mishchenko Yu.H., Kovalenko M.P. (2003). Pobichna produktsiia ta promizhni kultury yak faktor stabilizatsii rodiuchosti gruntu. *Zb. nauk. pr. IZ NAAN*. Kyiv. Spets. vyp. R. 48–51. [in Ukrainian].
3. Tsvei Ya.P., Kasianchuk F.P. (2004). Vykorystannia pozhnyvnoi hirchytsti pry vyroshchuvanni tsukrovykh buriakiv. *Tsukrovi buriaky*. № 3. P. 14-15.
4. Tsvei Ya.P. (2014). Rodiuchist gruntiv i produktyvnist sivozmin. Kyiv: Kompyrynt. 413 s. [in Ukrainian].
5. Tatur I.S., Botko A.V., Gulyaka M.I. i dr. (2016). O roli organicheskikh udobrenij v povyshenii produktivnosti saharnoj svekly i plodorodiya pochvy. *Saharnaya svekla*. № 6. P. 12-14. [in Russian].
6. Beegle D.B., Carton O.T., Bailey J.S. (2000). Nutrient management planning: justification, theory, practice. *J. Environment Quality*. 29. P. 72-79.
7. Mader P. (2004). Soil fertility in sustainable farming systems. *J. of the Royal Swedish Academy of Agriculture and Forestry*. № 1. P. 37-40.
8. Berdnikov O.M., Nymytiuk Yu.A. (2004). Rol syderatsii v suchasnomu zemlerobstvi. *Visnyk ahrarnoi nauky*. № 3. P. 12–15. [in Ukrainian].
9. Polovyi V.M. (2007). Optyimizatsiia system udobrennia u suchasnomu zemlerobstvi. Monohrafiia. Rivne: Volynski oberehy. 320 p. [in Ukrainian].
10. Parfeniuk H.I. (2002). Tsukrovi buriaky: biologizatsiia intensyvnykh tekhnolohii. *Tsukrovi buriaky*. № 6. P. 9–10. [in Ukrainian].