Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2020, 10(3), 124-130, doi: 10.15421/2020_145

ORIGINAL ARTICLE

Effect of fertilization on *Solanum tuberosum* L. productivity in Ukrainian Polissya

T.V. Klymenko[1], S.V. Fedorchuk[1], O.I. Trembitska[1], S.V. Zhuravel[1], V.G.Radko[1], I.Y. Derebon [1], M.M. Lisovyy[2], O.O. Didur [3], Y.V. Lykholat[3]

[1]Polissia National University, 7 Staryy bulvar, Zhytomyr, 10008, Ukraine
[2]National University of Life and Environmental Sciences of Ukraine, 13 b.4 Heroev Oborony St, Kyiv, 03041, Ukraine [3]Oles Honchar Dnipro National University, 72 Gagarin Ave, Dnipro, 49010, Ukraine

**Corresponding author E-mail: lisova106@ukr.net*

Received: 21.06.2020. Accepted 22.07.2020

We selected an effective variant in the potato fertilizer application system, which could provide the predicted yield in areas with an optimal cultivation balance in heat and moisture. We used a fertilization that contained organic, mineral variants and their compositions (control, green manures with straw, $N_{50}P_{40}K_{70}$, 25 t ha^{-1} of manure with $N_{25}P_{20}K_{35}$, 50 t ha^{-1} of manure per crop rotation area, 37.5 t ha^{-1}t of manure with $N_{12.5}P_{10}K_{17.5}$). We registered that the most effective was the application of 35.7 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$, which provides the highest yield of tubers (34.93 ± 0.77 t ha^{-1}) compared to the control (20.43 ± 0.47 tha^{-1}). We proved the positive effect of the same variant of the fertilizer system at almost all critical stages of potato development (stage of booting, budding, and flowering) by the estimation of height and weight of potato plants, moisture reserves in the soil under potatoes. The composition of green manures with straw increased the yield of potato by 15% comparing to the control towards 35.7 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$, where the increase of the yield was the largest and comprised 65.8% regards the control.

Keywords: Potato production; Potato fertilizer system; Yield of tubers

Introduction

One of the main problems both of Ukraine and the whole world is providing the population with food of high quality and sufficient amount. Among the main crops preference is given to cereals, in particular wheat (Nazarenko & Lykholat, 2018; Nazarenko et al., 2018, 2019), hybrid of corn (Khromykh et al., 2018) and fruit plants (Shcherbyna et al., 2017; Khromykh et al., 2018*a*, 2018*b*; Lykholat et al., 2018, 2019), comprehensive research on the stability of which is currently being conducted by the scientists from all the regions of Ukraine. Considerable attention is paid to potato, which is considered the "second bread". The global problem of growing potato, particularly in Ukraine, is to increase its yield and quality of tubers, as it still remains the most popular vegetable food, technical raw materials and feed for the livestock industry. Ukraine grows more than 5% of the world harvest, where the area of potato plantations is 1.6 million hectares with the yield of only 13–14 t ha^{-1}, while in Western Europe the yield is 30–40 t ha^{-1} (Kravchenko et al., 2010; Olifir et al., 2012; Shuvar et al., 2016; Volkohon et al., 2018). Therefore, the priority in the field of potato growing in Ukraine is to increase the yield of tubers and improve their taste. The solution of such a problem is impossible without the use of fertilizers and taking into account the peculiarities of the climate of a particular region. However, in recent years, a sharp decline in manure production in farms located in northern Ukraine and covering the territory of Polissya lowland (Polissya), and the high cost of mineral fertilizers do not allow to apply their recommended doses, and lead to the search for effective potato fertilizers and alternative sources of organic matter into the ground. This would help not only to obtain high yields, but also increase soil fertility (Bovsunovskyi et al., 2009; Behei et al., 2012). In this regard, there is a need to find effective fertilizer for potato in Polissya during its cultivation on agro-soil, which was formed under conditions of intensive agricultural cultivation within the distribution of zonal soil – light gray podzolic soil, which is suitable for growing potato (Kravchenko et al., 2010).

At the present stage, the development of agriculture is considered and evaluated through the prism of environmental problems, where the optimal combination of the ecological state of the agro-landscape and the technology of growing crops are taken into account (Znamenskyi et al., 2009; Sereda et al., 2013; Zlenko, 2014). In recent decades, the intensification of degradation processes in agro-ecosystems has caused the unbalanced anthropogenic load on natural resources, namely the high agricultural development of northern Ukraine, including Zhytomyr region (52.8%) and its plowing (40.5%). As a result, there is a widespread decrease in humus content in soils, caused by the imbalance between the entry of organic matter into the soil and its removal with the crops, which leads to deterioration of physical, physicochemical properties of soils, reduction of crop yields (Munoz et al., 2010; Brurberg et al., 2011; Hudz et al., 2011; Karpishchenko et al., 2013; Petcu et al., 2014).

It is known that a powerful reserve to increase soil fertility and potato yield are organic fertilizers, namely manure. However, due to the sharp decline in livestock in recent years, the number of production and application of organic fertilizers to the soil has decreased accordingly (Saidak et al., 2014). In order to reach the appropriate levels of productivity of agro-ecosystems, it is necessary to achieve a positive balance of nutrients both through its own production and imports in the required quantity and

range. The use of by-products of cereals – straw, as well as green manures – green fertilizers can also be of some importance in this regard (Hudz et al., 2010; Volkohon et al., 2014). To enrich the soil with organic matter, and, accordingly, the water and nutrient regimes of the soil green manure crops are used, the plant mass of which is wrapped in soil at the place of cultivation. The decay products of the green mass should be used directly by the next crops, and this can be achieved by plowing the green manure in late autumn (Bunchak, 2010; Bedernichek et al., 2014). To date, the issue of the impact of such fertilizers on soil moisture reserves and yield of potato tubers has not been sufficiently studied (Kalenska et al., 2012; Kucherenko, 2012; Dehodiuk et al., 2015).

In almost all agricultural enterprises of the Polissya zone, excess straw is formed, which is proposed to be applied into the soil to replace manure. To avoid the additional costs of scattering straw in the field, it is applied into the soil in crushed form at the same time as harvesting cereals. To ensure the fermentation of straw and improve nitrogen nutrition of plants it is necessary to apply 8-10 kg of nitrogen fertilizers in the active substance per 1 ton of straw (Dehodiuk et al., 2010; Baliuk et al., 2010; Bengtsson et al., 2014; Hamaiunova et al., 2016).

The aim of the research is to determine the most effective potato fertilizer system which will provide the predicted yield of it. The tasks of the research are the following: to determine the moisture reserves in the soil depending on the fertilizer variant, to study the dynamics of growth and development of potato plants, to determine the productivity of potato tubers depending on the use of organic and mineral fertilizers and their compositions. The joint application of cereal straw and green fertilizers – green manures was used as one of the search variants for alternative fertilizers.

Materials and Methods

The research region is located in the north of Ukraine on the territory of Ukrainian Polissya. According to the physical and geographical zoning, Polissya covers the south-western part of a large area of mixed forests of the East European Plain. Total area of Ukrainian Polissya is 113.5 thousand km^2 (19% of the territory of Ukraine). This is the territory of intensive agricultural production and mainly the territory of development of summer types of health and cognitive recreation. The formation and development of forest-steppe landscapes are determined by the optimal balance of heat and moisture (evaporation of moisture during the growing season of plants is almost equal to the amount of precipitation), as well as the widespread distribution of loess. Thus, the annual rainfall in Polissya is 500–600 mm, the majority (70%) falls from April to October. In wet years it reaches 850–950 mm, and in dry about of 300–400 mm. Evaporation does not exceed 400–450 mm. The coefficient of moisture (the ratio of precipitation to evaporation) is 1.9–2.8 (Dehodiuk et al., 2010).

The testing site of the research is an experimental agricultural field of Zhytomyr National Agro-ecological University (Zhytomyr region) (Figure 1). The source soil under the arable land, transformed into agro-soil, is a light gray podzolic loess loam on fluvial-glacial deposits. The upper layer of agro-soil (0–20 cm) is characterized by the following agrochemical parameters: humus content – 1.22–1.35%, medium acid soil acidity (pH_{aqua} 4.8–4.9), the amount of absorbed bases and the degree of saturation of soil bases are low and are respectively 1.80–2.07 mmol-eq 100 g^{-1} of soil and 46.5–53.2%, the content of mobile forms of nitrogen and phosphorus is medium, potassium – low.

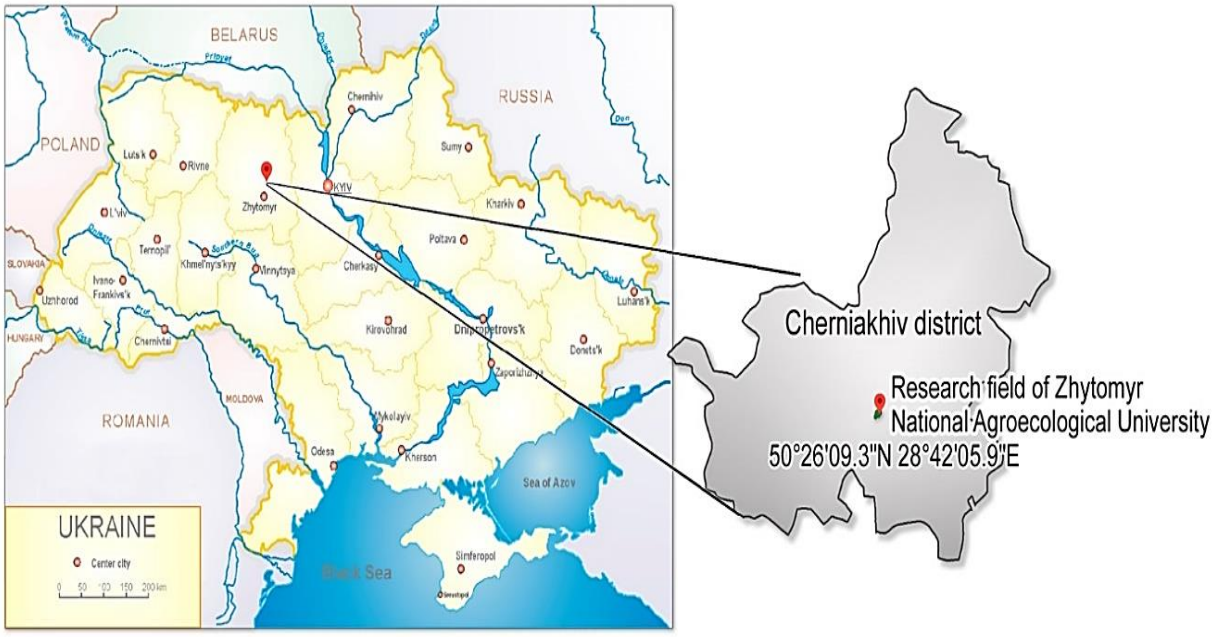

Figure 1. Localization of the testing site.

Object of the research is the dynamics of growth and development of potato plants, yield accumulation depending on the use of different fertilizer schemes. The preceding crop to potato is winter rye. The main tillage was based on tillage without rotation of the chunk with heavy disc harrows (model BDT-3) to a depth of 16–18 cm. The fertilizer system included the use of by-products of the preceding crop – straw (3 t ha^{-1}), green fertilizer – oil radish (12 t ha^{-1}), manure and mineral fertilizers (nitrogen – ammonium nitrate, phosphorus – simple granular superphosphate, potassium – potassium salt). Fertilizers were applied in a scattering manner.

During the experiment, such a potato fertilizer system was used which included control (variant without fertilizers), application of organic fertilizers (manure, joint application of green manures and straw), inorganic fertilizers ($N_{50}P_{40}K_{70}$) and joint application of compositions of organic and inorganic fertilizers (Figure 2).

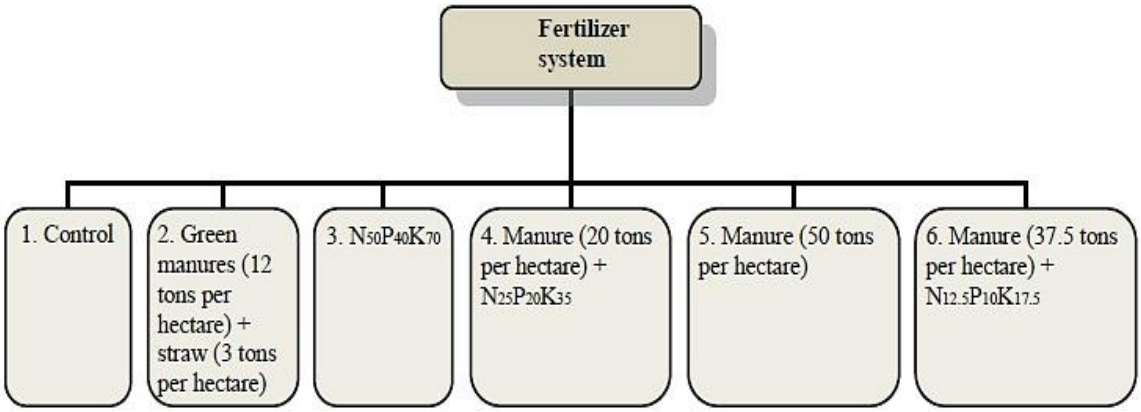

Figure 2. Potato fertilizing pattern.

Potato has high requirements for soil and air moisture. Potato due to weak cuticle and low osmotic pressure is a plant of hydrophilic type, i.e., more adapted to humid conditions. As a result it is very sensitive to sudden changes in humidity. There are two critical periods of moisture consumption (when moisture deficiency causes irreversible processes in plant development): the growth of stolons and the formation of tubers and the active growth of tubers. The first critical period coincides with the budding phase and lasts until flowering (Olifir et al., 2012). Lack of moisture at this time is not very noticeable on the outside part of the plant, but it leads to the fact that the organic matter formed in the leaves almost does not pass into the tubers and is used to grow the tops. Drought at the beginning of tuber formation leads to a decrease in the number of tubers and to a delay in their formation. Therefore, it reduces the yield significantly. Due to this circumstance, the moisture reserves in the experiments were determined during the budding phase. During the same phase, the height and weight of potato plants were determined.

Early Bellarosa potato of German selection was used in the experiments. The variety is high-yielding. The tuber is oval-round, the eyes are small. The skin is slightly rough, red. The flesh is light yellow. The weight of the marketable tuber is 117–207 grams. Some tubers reach 800 g or more. The yield of marketable tubers is 82–99%, shelf life is 93%. The starch content is 12.6–15.7%. Taste qualities according to a five-point scale is 4.8. The maximum yield is 38.5 t ha^{-1}. Potato variety Bellarosa is resistant to the pathogen of potato cancer, golden potato nematode, bacterial rot, scab, weakly affected by late blight and has high resistance to viruses (Brurberg et al., 2011). Bellarosa potatoes can be harvested in 2 months, one can even dig them up and eat them 45 days after germination. During culinary heat treatment, the tubers retain their shape and do not crumble.

In the experiments the conventional methods for measuring linear dimensions (using a ruler), weight of potato plants, weight of tubers (weighing on scales), soil moisture reserves (thermostatic-weight method) were used, and the conventional wide-range (70 cm) agricultural techniques for growing potato (planting tubers in the ridges (55 thousand pieces per hectare), wrapping plants before closing the rows) were used. Such elements of agricultural technologies make it possible to obtain a higher yield on the soils of the Polissya zone in comparison with the Dutch, German and other intensive regional technologies of potato cultivation used on high quality soils. Statistical processing of the experimental material was carried out using the procedure of descriptive statistics, as well as one-way analysis of variance (Mcdonald, 2014). To correctly compare the average values of soil moisture, the characteristics of the aboveground vegetative part and the potato yield obtained in control with other variants using fertilizers, one of the varieties of a posteriori multiple comparison test of group averages – Tukey's test was chosen (Zar, 2014). A posteriori comparisons are pairwise comparisons of the studied groups for identification of the differences between them. The differences in the mean was found statistically significant with a confidence probability of P≥95%. For the mean value, the standard error was calculated. The data in Tables presented like means and standard errors.

Results

Moisture reserves as a component of agro-ecological potential of potato productivity

The agro-ecological condition of the soil and plant productivity are significantly influenced by tillage, fertilizer application, as well as the supply of productive moisture throughout the growth and development of plants, which together lead to high potato yields. Consider the results of determining moisture reserves in the upper soil layer (0–20 cm and 0–50 cm, where the bulk of the root system of plants is located) of experimental areas with different fertilization schemes in the budding phase of potatoes and during its harvesting (Table 1).

Table 1. Soil moisture reserve values (mm) vs. potato fertilizer systems (n = 3, 2016–2018).

Period	Control	Green manures and straw	$N_{50}P_{40}K_{70}$	37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$
Budding stage:				
soil layer 0–20 cm	33.4 ± 0.38^{a}	37.6 ± 0.64^{b}	34.9 ± 0.78^{abc}	40.3 ± 0.52^{bd}
soil layer 0–50 cm	104.7 ± 0.76^{a}	110.4 ± 1.54^{ab}	113.6 ± 2.69^{abc}	127.3 ± 2.43^{d}
Harvesting:				
soil layer 0–20 cm	23.6 ± 0.36^{a}	21.7 ± 0.57^{ab}	20.8 ± 0.35^{bc}	25.3 ± 0.50^{ad}
soil layer 0–50 cm	78.5 ± 1.17^{a}	76.3 ± 0.87^{ab}	81.1 ± 1.55^{abc}	86.4 ± 0.75^{d}

* here and then the same Latin letters are statistically insignificant differences in the compared pair means by Tukey's test (HSD), P < 0.05.

The greatest need for moisture for potato plants is during budding. According to the research results, the moisture reserves in the agro-soil during the years of research were sufficient for potato plants, because during the potato growing season the moisture reserve in the arable layer of the soil is more than 15 mm (Table 1). At this stage of potato development, the soil (layer of 0–20 cm), to which green manures were added compared to the control, was more moist (33.4 ± 0.38 mm and 37.6 ± 0.64 mm accordingly), and the soil to which manure with $N_{12.5}P_{10}K_{17.5}$ was added (37.5 t ha^{-1}) had maximum moisture reserves (40.3 ± 0.52 mm). Moisture reserves in the soil layer of 0-20 cm in the variant with the application of green manures and straw are not statistically different from the variant with the application of mineral fertilizer ($N_{50}P_{40}K_{70}$) and the variant with the combined application of organic and inorganic fertilizers (37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$). Regarding the moisture reserves in the layer of 0-50 cm, depending on the different fertilizer application variants, at the stage of potato budding the soil to which manure was added (37.5 t ha^{-1}) with $N_{12.5}P_{10}K_{17.5}$ compared to the control had higher moisture reserves (104.7 ± 0.76 mm and 127.3 ± 2.43 mm, respectively). Their averages are statistically significantly different from each other. Other variants (green manures with straw; $N_{50}P_{40}K_{70}$) showed worse results. Therefore, the application of manure (37.5 t ha^{-1}) with $N_{12.5}P_{10}K_{17.5}$ compared to the control affects the soil moisture content more effectively for both the soil layer of 0–20 cm and for the layer of 0-50 cm (relative increase is 20.7% and 21.6%, respectively). Consider the effect of different variants for applying fertilizers to moisture content in the soil at the stage of harvesting potatoes (Table 1). Average moisture reserves in the soil layer of 0-20 cm in the variant with the application of green manures and straw (21.7 ± 0.57 mm) and the variant with the application of organic and inorganic fertilizers (37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$) (20.8 ± 0.35 mm) do not differ statistically from the control (23.6 ± 0.36 mm), and the variant with introduction $N_{50}P_{40}K_{70}$ into the soil showed smaller result than in the control (20.8 ± 0.35 mm and 23.6 ± 0.36, respectively). Regarding the moisture reserves in the layer of 0–50 cm, depending on the different variants for fertilizing, at the stage of harvesting potatoes, the soil to which was added 37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$ compared to the control had higher moisture reserves by 10.0% . Their averages are statistically significantly different (86.4 ± 0.75 mm and 78.5 ± 1.17, respectively). Other variants (green manures with straw; $N_{50}P_{40}K_{70}$) compared to the control showed less effective results.

Therefore, the joint application of 37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$ in comparison with the control has positive effect on moisture retention in the soil layer of 0–50 cm. The variant with the application of green manures and straw statistically differs from the variant of application of manure with $N_{12.5}P_{10}K_{17.5}$ (37.5 t ha^{-1}) and the value of moisture reserves is inferior to the latter (76.3 ± 0.87 mm and 86.4 ± 0.75 mm of water, respectively).

Thus, the use of a composition of organic and mineral fertilizers (37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$) contributed to the retention of moisture in the soil layer of 0–50 cm, which improved the water-physical properties of agro-soil and, as a consequence, had positive effect on further growth and development of potato plants and crop formation in general.

Development of aboveground vegetative part (height, weight) of potato

It is known that the height of potato stems depends on environmental conditions, cultivation technology and variety, the maximum height is reached during flowering. The agro-technological methods of increasing the productivity of agricultural crops include, in particular, the application of fertilizers to the soil. The results of the evaluation of fertilizer efficiency show that the height of potato stems depends on the type of fertilizer (organic, inorganic, joint use of organic and inorganic fertilizers) and their application dose (Table 2). If in the control variant the average height of plants in the phase of intensive growth was 17.5 ± 0.4 cm, then due to the application of fertilizers the height of plants increased statistically significantly to 20–26.5 cm, exceeding the control by 14–51% (Table 2). In the flowering phase, plant development reached its maximum height. In the control variant, the average height of the plants was 31.0 ± 0.7 cm, and in the fertilized variants it ranged from 38.0 ± 0.8 cm to 56.0 ± 0.9 cm, exceeding the control by 23–81% (Table 2). There was a statistically significant dependence of the positive effect on the stems on the introduction of straw and green manures into the soil. Their use increased plant height by 23% compared to the control. Due to only mineral fertilizers, the height of the stems increased by 40%. The joint application of organic and mineral fertilizers showed the statistically significant increase in the stem height by 47–81% relatively to the control. The maximum increase in the height of potato plants compared to the control was obtained in the 37.5 t ha^{-1} of manure and mineral fertilizers – by 81% (31.0 ± 0.7 cm and 56.0 ± 0.9 cm).

Table 2. The fertilizer system vs. potato plant height (cm per bush, n = 50).

Stage	Control	Green manures and straw	$N_{50}P_{40}K_{70}$	25 t ha^{-1} of manure and $N_{25}P_{20}K_{35}$	50 t ha^{-1} of manure per crop rotation area	37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$
Stalking	17.5 ± 0.4^{a}	20.0 ± 0.4^{b}	22.0 ± 0.5^{bc}	25.0 ± 0.5^{d}	23.0 ± 0.6^{dce}	26.5 ± 0.8^{df}
Per cent before control	100	114.3	125.7	142.9	131.4	151.4
Budding	31.0 ± 0.7^{a}	38.0 ± 0.8^{b}	43.5 ± 0.7^{c}	49.0 ± 0.9^{d}	45.5 ± 1.0^{ce}	56.0 ± 0.9^{f}
Per cent before control	100	122.6	140.3	158.1	146.8	180.6
Wilting of the tops	26.0 ± 0.8^{a}	31.5 ± 0.6^{b}	33.0 ± 0.6^{bc}	40.0 ± 0.6^{d}	34.5 ± 0.5^{ce}	49.0 ± 0.8^{f}
Per cent before control	100	121.2	126.9	153.8	132.7	188.5

At the beginning of the wilting of the tops, the height of the plants naturally decreased compared to the flowering phase and in average was 26 ± 0.8 cm in the control (Table 2). The fertilizer application variants used in the study had a statistically significant positive effect on the height of potato plants: the height of plants in this phase ranged from 31.5 ± 0.6 cm to 49.0 ± 0.8 cm, exceeding the control by 23-81% (Table 2). Thus, on the experimental testing site under the climate conditions of Polissya in the case of application in agro-soils such fertilizers as green manures and straw, $N_{50}P_{40}K_{70}$, manure complex 25 tons per hectare and $N_{25}P_{20}K_{35}$, manure (50 t / ha of crop rotation area), manure complex (35 tons per hectare) and $N_{12.5}P_{10}K_{17.5,}$ the height of potato plants at such stages of potato development as budding, flowering and wilting of the tops was statistically significantly higher than the height of potato plants at the respective stages in the control (Table 2). Simultaneous application of green manures and straw has a positive stimulating effect (114.3–122.6% of the control), the greatest effect is observed from the combined use of manure (37.5 tons per hectare) and $N_{12.5}P_{10}K_{17.5}$ (151.4–188.5% of the control). In the formation of the yield of potato tubers an important role is played by the accumulation of vegetative mass of plants, which is closely related to the size of the leaf surface of potatoes. Therefore, under optimal conditions for the development of potato culture, the increase in aboveground mass is associated with the

increase in the photosynthetically active surface, and therefore, it is logical to assume a probable increase in its yield. The results of evaluating the effectiveness of the fertilizer system show that the accumulation of aboveground vegetative mass (as well as height) of potato plants depends on the fertilizer system: type of fertilizer (organic, inorganic, joint use of organic and inorganic fertilizers) and its application doses (Table 3).

Table 3. Fertilizer system vs. potato vegetative mass, g per bush (n = 50).

Stage	Control	Green manures and straw	$N_{50}P_{40}K_{70}$	25 t ha^{-1} of manure and $N_{25}P_{20}K_{35}$	50 t ha^{-1} of manure per crop rotation area	37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$
Stalking	28.4 ± 0.4^{a}	72.4 ± 0.9^{b}	100.3 ± 1.4^{c}	110.3 ± 2.7^{d}	104.0 ± 1.6^{cde}	157.8 ± 3.0^{f}
Percent before control	100	254.9	352.5	396.5	368.0	555.6
Budding	110.5 ± 2.2^{a}	218.8 ± 2.2^{b}	273.5 ± 4.0^{c}	303.5 ± 2.8^{d}	297.0 ± 3.4^{de}	387.3 ± 5.1^{f}
Percent before control	100	198.0	247.5	274.7	268.8	350.5
Wilting of the tops	123.3 ± 2.7^{a}	260.6 ± 3.8^{b}	359.5 ± 2.4^{c}	330.9 ± 3.0^{d}	304.8 ± 2.6^{e}	409.5 ± 2.4^{f}
Percent before control	100	211.4	291.6	268.4	247.2	332.1

At all the studied stages of development of the potato bush (stalking, flowering, wilting of the tops), its average weight in the control is statistically significantly less than those plants that have been exposed to fertilizers. The process of increasing biomass by potato bushes during the test of the entire fertilizer system is more intense at the stage of stalking than at other stages (Table 3). Thus, at this stage the excess of control is 2.5 times for the variant with the application of green manures and straw, for other variants – from 3.5 to 5.6 times. At the stages of flowering and wilting of the tops, these relative indicators change more slowly, which indicates the significant contribution to the growth of the potato bush biomass from the joint application of organic and mineral fertilizers and their high efficiency. Greater accumulation of mass is observed at the studied stages of development of the potato bush from the use of joint application of manure and mineral fertilizers with different doses.

Productivity of tubers

Among the important factors that increase the productivity of tubers are fertilizers. According to the results of our own research in the control, the yield of potato tubers was the lowest and comprised 204.3 hundred kilograms per hectare (Table 4). In the series of increase of potato yields using different fertilizer variants, its minimum yield is predicted in the case of green manures and straw, the maximum – in the case of a composition of manure 37.5 tons per hectare and $N_{12.5}P_{10}K_{17.5}$.

Table 4. The average potato yield vs. the fertilizer system (hundred kilograms per hectare, n = 3).

Marker	Control	Green manures and straw	$N_{50}P_{40}K_{70}$	25 t ha^{-1} of manure and $N_{25}P_{20}K_{35}$	50 t ha^{-1} of manure per crop rotation area	37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$
Yield of potato tubers	204.3 ± 4.7^{a}	239.0 ± 6.4^{b}	312.0 ± 0^{c}	330.3 ± 6.2^{cd}	296.3 ± 7.2^{cde}	349.3 ± 7.7^{df}
Per cent before control	100	115.0	148.1	156.8	140.7	165.8

The results of statistical processing of the data show that the yield of potato tubers in the control is statistically significantly different from other variants for applying both organic and mineral fertilizers (Table 4). Therefore, fertilizer application is the best way to increase potato yield. Thus, in studies on the use of straw and green manures compared with the control there was a statistically significant increase in tuber yield by 34.7 c ha^{-1}. In the experiment using only mineral fertilizers, there was an increase in yield of potato tubers by 107.7 c ha^{-1}. This indicates that the provision of potato with the basic elements of mineral nutrition allows to obtain a significant increase in yield. In the case of manure (50 t ha^{-1}), the yield of potato tubers increased by 92 c ha^{-1}. The experiments also obtained a significant increase in yield in the case of application of manure compositions (25 t ha^{-1}) and moderate doses of mineral fertilizers ($N_{25}P_{20}K_{35}$). The difference in yield compared to control was 126 c ha^{-1}. The highest yield of potato tubers in the experiments was obtained in the case of applying to the soil a composition of manure at a dose of 37.5 t ha^{-1} and moderate doses of mineral fertilizers ($N_{12.5}P_{10}K_{17.5}$). In this variant the increase in yield compared to the control is quite significant and amounted to 145 c ha^{-1}.

The yield of potatoes does not differ statistically between application of mineral fertilizers with high nutrient content ($N_{50}P_{40}K_{70}$) and 25 and 50 t ha^{-1} of manure with $N_{25}P_{20}K_{35}$ and 37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$ (Table 4). This can be used in agronomic practice and, if necessary, the dose of fertilizer can be changed to a lower without significant loss of yield.

The use of a composition of straw (3 t ha^{-1}) and green fertilizers – 12 t ha^{-1} of green manures in Polissya is an effective measure to improve soil fertility and slightly increase the potato yield by 15% compared to the control. The positive effect of the use of green manures under the conditions of application of a small amount of mineral fertilizers is weed control, creation of optimal phytosanitary conditions for potatoes (Loshakov, 2007).

Discussion

Under modern conditions, methods of greening agriculture are of great importance, including the rational use of manure and other organic fertilizers – sources of nutrients. There is a growing scientific and practical interest in alternative fertilizer systems based on the application of organic fertilizers and the complete abandonment of others, including mineral ones, where the main argument is the possibility of obtaining clean agricultural products and environmental protection (Dehodiuk et al., 2010). In this regard, it is relevant to obtain the characteristics of different fertilizer systems: organic, mineral ones and their compositions, to carry out the comparative study of their impact on the conservation of soil moisture, growth and weight of the crops, and their yields. Potato is a crop that is highly demanding of organic and mineral fertilizers. This is largely due to the biological characteristics of potato and, above all, poorly developed, mainly located in the upper soil layer, the root system. Rationally sound system of application of organic and mineral fertilizers for potato allows to obtain stable high yields of tubers with high quality, on the one hand, as well as to eliminate the shortcomings of both of these types of fertilizers that are applied to the soil - on the other. Since at the beginning of the growing season potato plants use nutrients from mineral compounds, and during budding – flowering before wilting of the tops mainly from mineralized organic (Shuvar, 2016), the combination of organic and mineral fertilizers in the potato fertilizer system creates a favorable nutrient regime throughout vegetation period, optimizes such ecological function of the soil as the deposition of nutrients and moisture, ensuring its overall fertility. Under favorable conditions of atmospheric and soil moisture, the productivity of any crop increases under the influence of plant nutrition. At the stage of budding of potato, the presence of the maximum amount of moisture in the soil among the proposed fertilizer system is observed during the joint application of 37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$, the minimum – during the joint application of straw (3 tons per hectare) and green manures (12 t ha^{-1}). Herewith the moisture reserves are statistically significantly different from the control (Table 1). Fertilizers are a decisive factor in significant increase of yields. Their rational use increases yields by 40–50%, and on irrigated lands - by 75% or more (Dehodiuk et al., 2010). The maximum height, weight of potato plants and its yield among the proposed fertilizer system are observed when applying the composition of 37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$, the minimum – when applying the composition of straw (3 t ha^{-1}) and green manures (12 t ha^{-1}) (Table 4). These autoecological characteristics are statistically significantly ($P \leq 0.05$) different from the control in 1.5–1.9 (Table 2), 3.3–5.5 (Table 3) and 1.7 times, respectively (Table 4). That is, under the conditions of application of 37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$ it is possible to predict a fairly high yield of potato on agro-soils in the conditions of Polissya of Ukraine.

Conclusion

We found that the best fertilizing scheme for Bellarosa potato in Ukrainian Polissya is a 37.5 t ha^{-1} of manure with $N_{12.5}P_{10}K_{17.5}$. This scheme contributes to the highest yield of tubers (34.93 ± 0.77 t ha^{-1}) compared to the control (20.43 ± 0.47 t ha^{-1}). Estimation of linear sizes, weight of potato plants and moisture reserves in the soil under potatoes demonstrates the positive effect of this fertilizer system. The composition of green manures and straw increases the yield of potato by 15% significantly compared with the control, inferior to 37.5 t ha^{-1} of manure and $N_{12.5}P_{10}K_{17.5}$, where the increase in yield was 65.8% relative to the control.

We compared the effect of different fertilizers on the productivity of potato tubers and revealed that organic fertilizers (green manures and straw) had a statistically significant yield increase, which contributed to the economic advantages. We did not register statistically different tuber yield among the case of $N_{50}P_{40}K_{70}$, the case of 25 t ha^{-1} of manure and $N_{25}P_{20}K_{35}$, and 50 tons of manure per hectare, which suggests economic/environmental necessity to abandon or accept these schems for increasing the potato yield.

References

Baliuk, S. A. Batsula, O. O., & Tymchuk, V. M. (2010). Orhanichni dobryva [Organic fertilizers]. Posibnyk ukrainskoho khliboroba – Handbook of the Ukrainian agriculturalist, 7, 128–134 (in Ukrainian).

Bedernichek, T. Y., Hamkalo, Z. H. (2014). Labilna orhanichna rechovyna gruntu: teoriia, metodolohiia, indykatorna rol [Labile soil organic matter: theory, methodology, indicator role]. Kyiv, Kondor (in Ukrainian).

Behei, S. V., & Shuvar, I. A. (2012). Ekolohichne zemlerobstvo [Ecological agriculture]. Lviv, Novyi Svit–2000. (in Ukrainian).

Bengtsson, T., Holefors, A., Witzell, J., Andreasson, E., & Liljeroth, E. (2014). Activation of defence responses to Phytophthora infestans in potato by BABA. Plant Pathol, 63(1), 193–202. https://doi.org/10.1111/ppa.12069

Bovsunovskyi, A. M. (2009). Vplyv pobichnoi produktsii ta syderatu na humusnyi stan svitlo-siroho gruntu [Effect of by-products and green manure to humus state of light gray soil]. Zemlerobstvo – Agriculture, 81, 47–51 (in Ukrainian).

Brurberg, M. B., Elameen, A., Lea, V. H., Naerstad, R., Hermansen, A.,… Yuen, J. (2011). Genetic analysis of Phytophthora infestans populations in the Nordic European countries reveals high genetic variability. Fungal Biology, 115, 335–342. https://doi.org/10.1016/j.funbio.2011.01.003

Bunchak, O. M. (2010). Vplyv orhanichnykh dobryv universalnoi dii (ODUD) na urozhainist i yakist bulb kartopli [Influence of organic fertilizers of universal action (OFUA) on the yield and quality of potato tubers]. Zbirnyk naukovyh prac' Podilskoho derzhavnoho ahrarno-tekhnichnoho universytetu – Collection of scientific works of Podilsky State Agrarian and Technical University, 18, 140–145 (in Ukrainian).

Dehodiuk, S. E., Litvinova, O. A., & Kyrychenko, A. V. (2015). Vplyv tryvaloho zastosuvannia dobryv u sivozmini na ahrokhimichnu kharakterystyku siroho lisovoho gruntu [Influence of long-term use of fertilizers in crop rotation on the agrochemical characteristics of gray forest soil]. Peredhirne ta hirske zemlerobstvo i tvarynnytstvo – Foothills and mountain agriculture and animal husbandry, 58 (1), 84–93 (in Ukrainian).

Dehodiuk, S. E., Litvinova, O. A., Vitvitska O. I., & Bodnar Y. D. (2010). Vplyv dobryv u sivozmini na rodiuchist gruntu i produktyvnist kultur [Effect of fertilizers on crop rotation on soil fertility and crop productivity]. Zbirnyk naukovyh prac' NNTs "Instytut zemlerobstva UAAN". Collection of Scientific Papers of the National Academy of Sciences of Ukraine "Institute of Agriculture of UAAS", 4, 3–10 (in Ukrainian).

Hamaiunova, V. V., & Iskakova, O. S. (2016). Urozhainist ta yakist bulb kartopli litnoho sadinnia zalezhno vid faktoriv vyroshchuvannia [Yield and quality of tubers of summer planting depending on factors of cultivation]. Naukovyi ohliad: mizhnarodnyi naukovyi zhurnal – Scientific Review: International Scientific Journal, 3(24), 35–43 (in Ukrainian).

Hudz, V. P., Mishchenko, Y. H., Prasol, V. I., Mukha, L. V., Didora, V. H., & Kropyvnytskyi, R. B. (2011). Vplyv syderatu i sposobiv osnovnoho obrobitku gruntu na obiemnu masu ta vodospozhyvannia posiviv kartopli [Impact of green manure and methods of basic tillage on bulk weight and water consumption of potato crops]. Naukovi dopovidi NUBiP Ukrainy – Scientific reports National University of Life and Environmental Sciences of Ukraine, 1 (23). Retrieved from http://nd.nubip.edu.ua/2011-1/titul.html (in Ukrainian).

Hudz, V. P., Prymak, I. D., Budonnyi, Y. V., & Tanchyk S. P. (2010). Zemlerobstvo [Agriculture]. Kyiv, TsUL (in Ukrainian).

Kalenska, S. M., & Knap, N. V. (2012). Stan ta perspektyvy vyrobnytstva kartopli v sviti ta Ukraini [Status and outlook for potato production in the world and Ukraine]. Zbirnyk naukovyh prac' Vinnytskoho natsionalnoho ahrarnoho universytetu – Collection of scientific works of Vinnytsia National Agrarian University, 4(63), 41–47 (in Ukrainian).
Karpishchenko, O. I., & Karpishchenko, O. O. (2013). Ekoloho-ekonomichni problemy vykorystannia mineralnykh dobryv [Ecological and economic problems of using mineral fertilizers]. Visnyk Sumskoho derzhavnoho universytetu. Seriia Ekonomika – Bulletin of Sumy State University. Economy series, 2, 5–11 (in Ukrainian).
Khromykh, N., Matiukha, V., Lykholat, Y., Lisovyi, M., Nazarenko, M., & Hryhoriuk, I. (2018). Vplyv gerbicydiv na pokaznyky urozhayu gibryda kukurudzy Orzhycya 237 MV [Influence of herbicides on indexes of yield of hybrid of corn Orzhitsa 237 MV]. Bulletin of Agricultural Science. 4(781), 20–26 (in Ukrainian).
Khromykh, N. O., Lykholat, Y. V., Kovalenko, I. M., Kabar, A. M., Didur, O. O., & Nedzvetska, M. I. (2018a). Variability of the antioxidant properties of Berberis fruits depending on the plant species and conditions of habitat. Regulatory Mechanisms in Biosystems, 9(1), 56–61. https://doi.org/10.15421/021807
Khromykh, N., Lykholat, Y., Shupranova, L., Kabar, A., Didur, O., Lykholat, T., & Kulbachko, Y. (2018b). Interspecific differences of antioxidant ability of introduced Chaenomeles species with respect to adaptation to the steppe zone conditions. Biosystems Diversity, 26(2), 132–138. https://doi.org/10.15421/011821
Kravchenko, O. A., & Sharapa, M. H. (2010). Ahrotekhnichni pryiomy vyroshchuvannia vysokykh vrozhaiv kartopli v zonakh Polissia ta Lisostepu Ukrainy [Agrotechnical techniques for growing high yields of potatoes in the Polesie and Forest-Steppe zones of Ukraine]. Kartopliarstvo Ukrainy – Potato growing in Ukraine, 1–2, 20–30 (in Ukrainian).
Kucherenko, T. (2012). Kartofel v Ukraine: problemy proizvodstva i ispolzovaniya [Potatoes in Ukraine: problems of production and use]. Ovoshchevodstvo – Vegetable growing, 9 (93), 24–26 (in Russian).
Loshakov, V. G. (2007). Pozhnivnaya sideratsiya i plodorodiye dernovo-podzolistykh pochv [Crop sideration and fertility of sod-podzolic soils.]. Agriculture, 1, 11–13.
Lykholat, Y. V., Khromykh, N. O., Lykholat, T. Y., Bobrova, O. M., Didur, O. O.,.. Grygoryuk, I. P. (2019). Ukrainian Journal of Ecology, 9(4), 634-640. https://doi.org/10.15421/2019_801
Lykholat, Y. V., Khromykh, N. O., Lykholat, T. Y., Didur, O. O., Lykholat, O. A.,.. A., Grygoryuk, I. P. (2019a). Industrial characteristics and consumer properties of Chaenomeles Lindl. Fruits. Ukrainian Journal of Ecology, 9(3), 132–137. https://doi.org/10.15421/2019_720
Mcdonald, J. H. (2014). Handbook of biolological statistics, Ed. 3. Sparky House Publishing, Baltimore.
Muñoz, C., Paulino1, L., Monreal, C., & Zagal E. (2010). Greenhouse gas (CO2 and N2O) emissions from soils: a review. Chilean Journal of Agricultural Research, 70, 3, 485–497.
Nazarenko, M., Khromykh, N., Matyukha, V., Lykholat, Y., Bezus, R.,.. Shupranova, L. (2019). Chemical plant protection agents change the yield structure and the grain quality of winter wheat (Triticum aestivum L.). Bulletin of Transilvania University of Brasov – series II – Forestry, Wood Industry, Agricultural, Food Engineering, 12 (61), 2, 97–106. https://doi.org/10.31926/but.fwiafe.2019.12.61.2.8
Nazarenko, M. M., & Lykholat Y. V. (2018). Influence of relief conditions on plant growth and development. Bulletin of the University of Dnepropetrovsk. Geology, geography, 26(1), 143–149. https://doi.org/10.15421/111815
Nazarenko, M., Lykholat, Y., Grigoryuk, I., & Khromykh, N. (2018). Optimal doses and concentrations of mutagens for winter wheat breeding purposes. Part I. Grain productivity. Journal of Central European Agriculture, 19(1), 194–205. https://doi.org/10.5513/JCEA01/19.1.2037
Olifir, Y. M., Habryiel, A. Y., Kachmar, O. Y., & Ilchuk, R. V. (2012). Vplyv riznykh vydiv orhanichnykh ta orhano-mineralnykh dobryv na urozhainist, yakist bulb kartopli ta pozhyvnyi rezhym gruntu [Influence of different types of organic and organo-mineral fertilizers on yield, quality of potato tubers and soil nutritional regime]. Kartopliarstvo Ukrainy – Potato growing in Ukraine, 1–2, 30–34 (in Ukrainian).
Petcu, V., Dinca, L., & Toncea, I. (2014). The effect of crops and farming systems on soil quality. Scientific Papers. Series an Agronomy, 7, 58–63.
Saidak, R. V., & Tarariko, Y. O. (2014). Formuvannia vrozhainosti kartopli za riznykh system udobrennia zalezhno vid hidrotermichnykh umov vehetatsiinoho period [Formation of potato yield under different fertilizer systems depending on hydrothermal conditions of the growing season]. Visnyk ahrarnoi nauky – Bulletin of agrarian science, 3, 74–77 (in Ukrainian).
Sereda, L. P., & Misiulia, A. M. (2013). Doslidy na kartoplianomu poli [Experiments on a potato field]. Zbirnyk naukovyh prac' Vinnytskoho natsionalnoho ahrarnoho universytetu. Seriia: Tekhnichni nauky – Collection of scientific works of Vinnytsia National Agrarian University. Series: Technical Sciences, 12, 29–36 (in Ukrainian).
Shcherbyna, R. O., Danilchenko, D. M., Parchenko, V. V., Panasenko, O. I., Knysh, E. H., Khromykh, N. O., & Lykholat, Y. V. (2017). Studying Of 2-((5-R-4-R1-4H-1,2,4-Triazole-3-Yl)Thio)Acetic Acid Salts Influence On Growth And Progress Of Blackberries (KIOWA Variety) Propagules. Research Journal of Pharmaceutical, Biological and Chemical Science, 8, 975-979.
Shuvar, I. A., Roik, M. V., Ivanyshyn, V. V., Senderetskyi, V. M., & Tsentylo, L. V. (2016). Syderatsiia u tekhnolohiiakh suchasnoho zemlerobstva [Sideration in the technologies of modern agriculture]. I. A. Shuvara (Ed.). Ivano-Frankivsk, Symfoniia forte (in Ukrainian).
Volkohon, V., & Dimova, S. (2014). Pidvyshchuiemo urozhai [Increase the yield]. Ahrarnyi tyzhden – Agrarian Week, 7–8(283), 40–45 (in Ukrainian).
Volkohon, V. V., Pyrih, O. V., & Brytan, T. Y. (2018). Spriamovanist gruntovo-mikrobiolohichnykh protsesiv za vplyvu orhanichnykh i mineralnykh dobryv [Orientation of soil-microbiological processes under the influence of organic and mineral fertilizers]. Visnyk ahrarnoi nauky – Bulletin of agrarian science, 6, 5–11 (in Ukrainian).
Zar, J. H. (1999). Biostatistical analysis, Ed. 4. – Prentice Hall, New Jersey.
Zlenko, V. A. (2014). Analiz dynamiky vyrobnytstva ta eksportu zernovykh kultur i kartopli v Ukraini [Analysis of the dynamics of production and export of crops and potatoes in Ukraine]. Istoriia nauky i biohrafistyka – History of science and biography, 4, 11–12 (in Ukrainian).
Znamenskyi, O. P., Razkevych, M. P., & Podberezko, I. M. (2009). Perspektyvy zastosuvannia funhitsydiv ta yikh sumishei z biolohichno aktyvnymy preparatamy dlia zakhystu kartopli vid khvorob [Perspectives of the use of fungicides and their mixtures with biologically-active preparations for potato protection from diseases]. Kartopliarstvo Ukrainy – Potato growing in Ukraine, 5/6, 44–47 (in Ukrainian).

Citation:
Klymenko, T.V., Fedorchuk, S.V., Trembitska, O.I., Zhuravel, S.V., Radko, V.G., Derebon, I.Y., Lisovyy, M.M., Didur, O.O., Lykholat, Y.V. (2020). Effect of fertilization on *Solanum tuberosum* L. productivity in Ukrainian Polissya. *Ukrainian Journal of Ecology, 10*(3), 124-130.