AgroLife Scientific Journal - Volume 13, Number 1, 2024
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

JUSTIFICATION OF ORGANIC AGRICULTURE PARAMETERS IN POTATO GROWING WITH ECONOMIC AND MARKETING EVALUATION

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Abstract

During research, positive influence of organic farming elements on economic efficiency of potato growing has been revealed. Combination of post-harvest oil radish siderate and deep tillage provided the highest yield of potato tubers - 35.4 t ha^{-1} and starch isolation - 4.03 t ha^{-1}. Weather conditions in research years influenced yield of potatoes greatly - the influence share was 74.6%. The use of green manure increases stress resistance of potato crops to limiting weather factors. On sidereal background, zone of optimum average daily temperatures during potato vegetation period increased from 19^{0}C to 20-21^{0}C, and optimum of precipitation amount decreased from 300 mm to 280 mm. Application of post-harvest oil radish siderate under conditions of unstable moisture in the Left Bank Forest Steppe and carrying out deep tillage of typical black soil at a depth of 28-30 cm for its covering, provides the highest economic yield - 1615 € ha^{-1} and profitability level of potato growing - 77.6% at the lowest cost price of tubers - 68.68 € t^{-1}.

Key words*: green manure, yield, economic efficiency, soil tillage, crude protein, fertilization backgrounds.*

INTRODUCTION

Modern global agriculture tends to introduce regenerative agricultural measures aimed at preserving and improving soil fertility indices when growing potatoes. Thanks to restoration of soil fertility, farmers can obtain high and stable yields of potato tubers with high quality at relatively low production costs, which ensures competitiveness and strong economic attractiveness of organic agricultural technologies (Woźniak, 2019; Sumbul et al., 2020; Kvitko et al., 2021; Karpenko et al., 2022; Mishchenko et al., 2022a; Sobko et al., 2023; Hryhoriv et al., 2023).

In the conditions of Ukraine, fertility of black soils suffers from lack of organic fertilizers and excessive tillage of the soil. To ensure favourable conditions for growing potatoes on soils with lost optimal fertility parameters, farmers are forced to invest significant financial resources in application of mineral fertilizers, growth stimulants, pesticides and additional soil loosening. As a result, the product loses its quality indices, and its economic recoupment and, accordingly, sale price become quite high (Murtić et al., 2021; Tonkha et al., 2021; Tanchyk et al., 2021; Tsyuk et al., 2022; Karbivska et al., 2023).

Restoration of economic attractiveness of growing potatoes on black soils of Ukraine is quite possible with introduction of intermediate sideration and tillage without ploughing (Abby, 2016; Bondarchuk et al., 2018; Hryhoriv et al., 2022b). After all, post-harvest period in recent years of climate warming tends to lengthen, which makes it possible to grow a high yield of oil radish phytomass for siderate. Growing of siderate and enrichment of soil with its phytomass contributes to intensification of microbiological activity (Möller et al., 2022; Hryhoriv et al., 2022c; Karbivska et al., 2022) and biological loosening, which ensures longer preservation of optimal density of soil composition, compared to mechanical ploughing. Combination of intermediate sideration with tillage ensures preservation and restoration of agrophysical properties of soil

(Mooleki et al., 2016; Hryhoriv et al., 2021; Mishchenko et al., 2022b), its phytosanitary state (Mishchenko & Masyk, 2017; Tall & Meyling, 2018; Mishchenko, 2019) and water regime, which reduces the need for intensive loosening of soil when growing potatoes (Litvinov et al., 2020; Eid et al., 2021; Tykhonova et al., 2021; Yakupoglu et al., 2021; Hryhoriv et al., 2022a; Radchenko et al., 2022). This application of low-cost agricultural measures for preservation and restoration of organic matter of the soil - intermediate siderate and tillage without ploughing ensures high economic profitability of potato growing. Therefore, adaptation of organic farming elements to soil and climatic conditions of Ukraine is an actual scientific direction nowadays.

MATERIALS AND METHODS

Our research included the task of identifying the most effective method of covering post-harvest siderate of oil radish to obtain high and quality harvest of potato tubers.

Economic efficiency of growing potatoes with usage of post-harvest siderate of oil radish and soil tillage methods without ploughing was determined under conditions of the Left-Bank Forest-Steppe of Ukraine during 2017-2022 by conducting field experiment using method of split plots according to the scheme:

Area of sowing plot was 96 m^2, the accounting area was 60 m^2. The research was carried out on typical deep low-humus medium loam black soil with a humus content of 3.9% - in a layer of 0-30 cm and a pH of 6.7; provision of lightly hydrolysed nitrogen was 101 mg kg^{-1} (according to Kornfield), mobile phosphorus - 135 mg kg^{-1} of soil, and potassium - 117 mg kg^{-1} of soil (according to Chyrykov) (Horodnyi, 2005). Soil of experimental plot in a layer of 0-30 cm had structure coefficient of 2.38, a density of complexity - 1.20 g/cm^3, total porosity of 51.16%, and the lowest moisture content - 28.27%.

Post-harvest siderate of oil radish was sown in the first decade of August, and covering of its phytomass was carried out at the end of the third decade of October using different tillage methods. In the research, potato variety Slovianka was used. It was grown after predecessor of winter wheat according to generally accepted technology for this growing zone.

Economic efficiency of covering methods for post-harvest siderate of oil radish was determined using a system of calculation indices that indicated profitability or unprofitability of the crop growing technology (Pivovar, 2013).

RESULTS AND DISCUSSIONS

According to results of research, the variant with application of oil radish siderate and its covering by the method of tillage without ploughing to the depth of 28-30 cm provided the highest yield of potato - 30.3 t ha^{-1} (Figure 1).

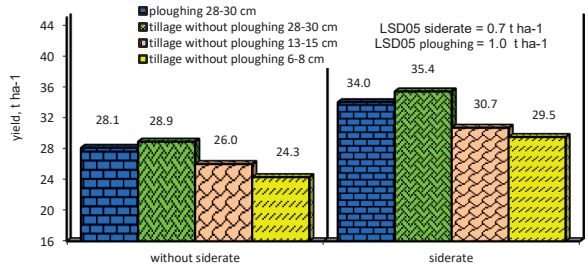

Figure 1. Influence of siderate and main soil tillage on potato yield, t ha^{-1}

When covering oil radish siderate, yield of potato was lower and significantly varied - by 1.8 t ha^{-1}. Variants of ploughing and deep soil tillage without ploughing did not significantly differ in terms of yield on a non-sideral background.

In terms of potato tuber yield, on both backgrounds, soil ploughing was significantly superior to tillage without ploughing to a depth of 13-15 cm - by 2.1-3.3 t ha^{-1} and 6-8 cm - by 23.8-4.5 t ha^{-1}.

Reducing depth of tillage without ploughing from 28-30 cm to 13-15, and to 6-8 cm significantly reduced yield of potato both on background with siderate and without one - by 1.8-5.1 t of potato per ha. Among themselves, the variants of tillage without ploughing to a depth of 13-15 and 6-8 cm also differed significantly in yield levels - by 1.0-1.4 t ha^{-1} when growing potatoes.

Application of post-harvest green manure, compared to non-sideral background, significantly increased potato yield on all

variants of soil tillage methods - by 3.9-6.2 t ha^{-1}.

Weather conditions of research years had a big influence on potato yield - the share of their influence was 74.6%. Increase of average daily air temperature during vegetation period of potato growing in all tillage variants negatively affected tuber yield. This is proved by reverse correlation between potato yield and average daily air temperature during growing period of the crop, which was of medium strength on the background with siderate - r = -0.48, and without siderate - strong - r = -0.74 (Figure 2).

On a non-sidereal background, inhibitory zone of falling line showing response of the yield to average daily temperature during potato vegetation period is clearly evident after 19^{0}C. On the background of covering oil radish siderate, negative impact of increase in average daily temperatures appears out of optimum zone of 20-21^{0}C. This regularity proves that application of green fertilizer increases stress resistance of the crops to negative impact of average daily air temperatures during vegetation period, which explains higher yield of the crop.

Reliable direct correlation of medium strength was established between potato yield and precipitation amount during vegetation period on a non-sideral background r = 0.62. According to variants of main tillage, effect of precipitation on potato yield on the background of green manure decreased to r = 0.37; on this background, the response curve shows emergence of a stationary region after 280 mm of precipitation, which indicates a lower need for amount of precipitation to obtain high tuber yields. Growing curve of yield response to precipitation amount in the variant without siderates does not go from limited zone to stationary zone at 300 mm of precipitation.

In critical period of potato growth and development (budding-flowering phase), yield level had a negative dependence on average daily air temperature r = -0.62-0.68, and a positive - with precipitation amount r = 0.41-0.48.

Potato yield was suppressed with increase of air temperature during critical period of development. However, under the same weather conditions, in the variants with main soil tillage were obtained higher yields on the background with oil radish siderate than without one.

On the background with green manure application, the highest yield of potato was received with smaller amount of precipitation during its flowering, as optimal zone of yield response curve was within 110-130 mm of precipitation.

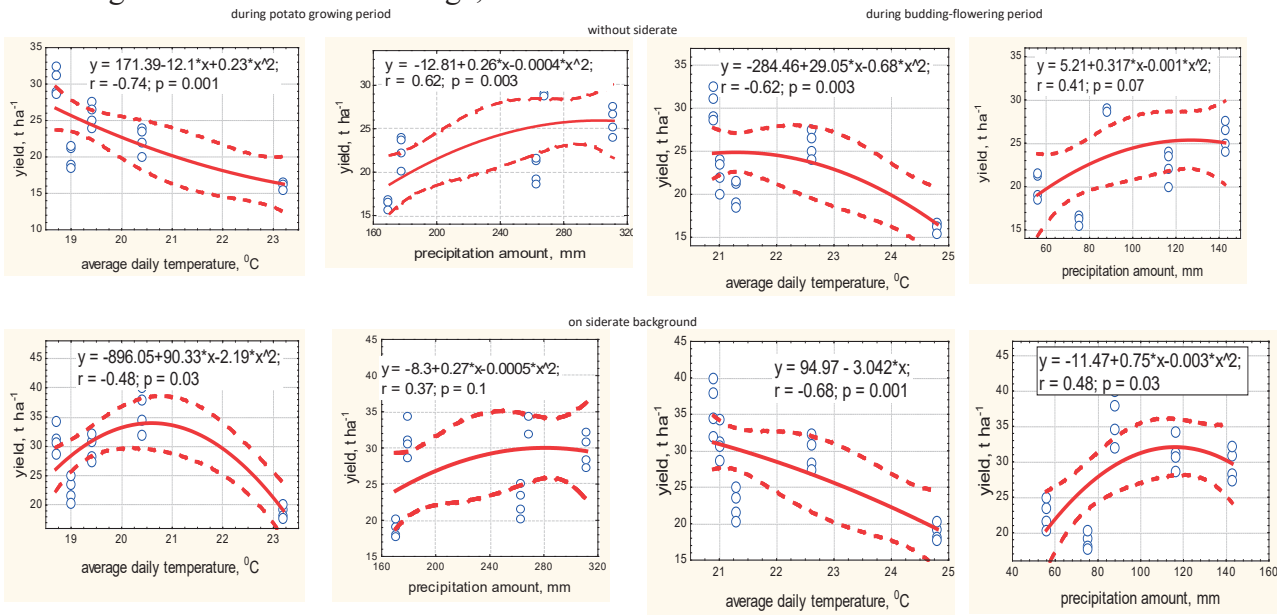

Figure 2. Correlation dependencies between weather elements and potato yield

On a non-sideral background, optimal zone for obtaining maximum yield of potato tubers shifted along response curve to higher indices of precipitation amount - 120-140 mm. Data of response curve indicate that application of green fertilizer increases stress resistance of potato crops to such a limiting factor as content of productive moisture, due to its insufficient replenishment because of unstable precipitation during flowering period of the crop.

Among methods of soil tillage, the strongest inverse correlation dependence of the yield on average daily air temperature when growing potato, was obtained with deep ploughing - r = -0.52 (Figure 3).

Potato crops suffered a little less from increase in average daily air temperature with soil tillage without ploughing at a depth of 13-15 and 6-8 cm - r = -0.51. The highest resistance of crops to increase in air temperature was provided by deep soil tillage without ploughing by 28-30 cm, which is indicated by correlation coefficient r = -0.5.

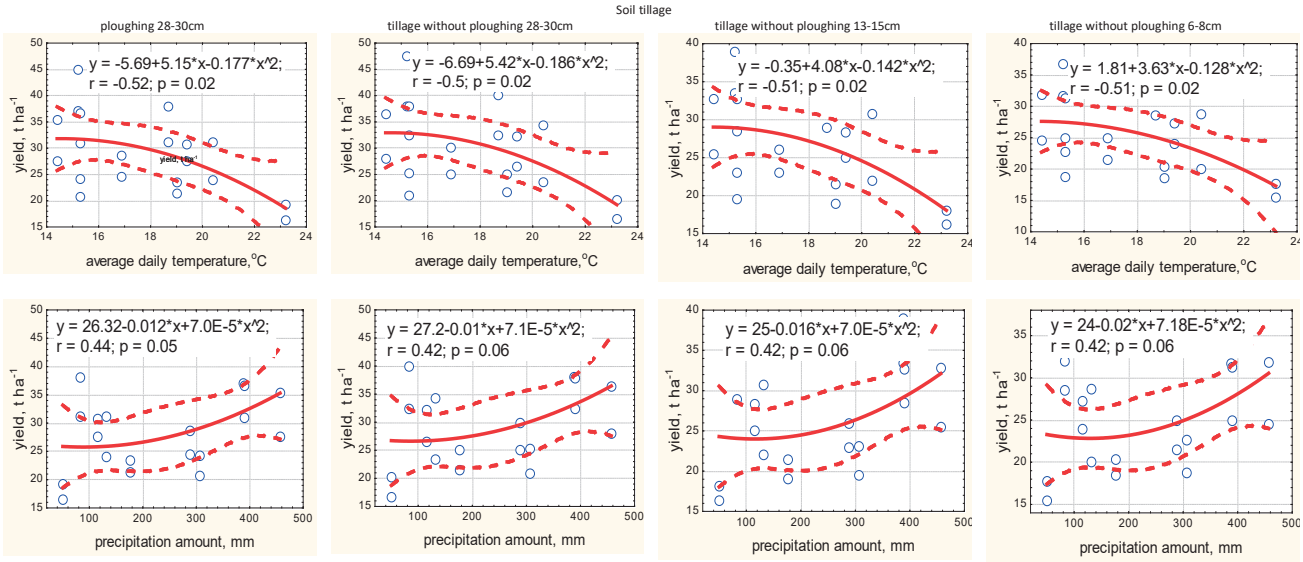

Figure 3. Correlation dependencies of potato yield on weather elements

Variant of ploughing contributed to a higher dependence of yield formation on amount of precipitation during vegetation period, which is evidenced by the highest direct correlation coefficient r = 0.44. With non-ploughing methods of tillage, formation of potato yield level depends to a lesser extent on amount of precipitation during vegetation period r = 0.42.

Improvement of technological indices of potato quality was facilitated by application of sideral background - by 0.2-0.3%, and implementation of non-ploughing soil tillage instead of ploughing - by 0.2-0.4% (Table 1).

Thus starch, content in potato tubers on background without siderate by the variants of main soil tillage ranged from 12.9 to 13.2%, and on siderate background - from 13.1 to 13.5%.

The largest collection of starch was obtained with application of green manure - oil radish under tillage without ploughing in a depth of 28-30 cm - 4.03 t ha^{-1}, which was 0.3 t ha^{-1} more than under ploughing.

Table 1. Scheme of the experiment

Basic fertilization (factor A)	Basic soil tillage (factor B)
Post-harvest remains of winter wheat 5.2 t ha^{-1} – background (control)	Ploughing tillage to the depth of 28–30 cm (control)
	Soil tillage without ploughing to the depth of 28–30 cm
	Soil tillage without ploughing to the depth of 13–15 cm
	Soil tillage without ploughing to the depth of 6–8 cm
Background + post-harvest siderate of oil radish 29.7 t ha^{-1}	Ploughing tillage to the depth of 28–30 cm (control)
	Soil tillage without ploughing to the depth of 28–30 cm
	Soil tillage without ploughing to the depth of 13–15 cm
	Soil tillage without ploughing to the depth of 6–8 cm

Lowering of tillage depth to 13-15 and 6-8 cm provided lower starch yield - by 0.17 and 0.33 t ha^{-1} correspondingly, comparing with the control variant (Table 2).

Starch content in potato tubers ranged from 12.7 to 13.2%, it was significantly lower (by 0.4%) comparing with the control, with application of mineral fertilizer $N_{125}P_{63}K_{150}$. With organic fertilization, increase in starch content in tubers was greater than the control without siderate by 0.1%, largely due to green fertilizer of buckwheat.

Table 2. Influence of basic tillage method and sideral background on technological indices of potato

Background	Basic soil tillage			
	Ploughing 28-30 cm	Without ploughing 28-30 cm	Without ploughing 13-15 cm	Without ploughing 6-8 m
starch content, %				
Without siderate	12.9	13.1	13.2	13.2
Siderate	13.1	13.3	13.4	13.5
starch collection, t ha^{-1}				
Without siderate	3.11	3.16	2.94	2.81
Siderate	3.73	4.03	3.56	3.40

Starch collection in all fertilization backgrounds was significantly higher than in the control without siderate, except for buckwheat siderate. The share of fertilizer influence on starch collection was 52%, year weather conditions - 42%, and other factors - 6%.

So, application of sideral background and deep tillage without ploughing contributed to formation of potato tuber yield with the best quality.

Based on yield data of our research, were calculated indices of economic attractiveness of potato growing. In general, green fertilizer of oil radish significantly increased potato value - by 18-25% for all methods of soil tillage comparing with background without siderate, Among the methods of covering oil radish, the highest value of potato - 3475.6 € ha^{-1} was obtained for non-ploughing tillage to a depth of 28-30 cm (Table 3).

Table 3. Technological indices of potato quality for different fertilization backgrounds

Technological indices	Variant						LSD$_{05}$
	Without siderate (control	postharvest siderate				$N_{125}P_{63}K_{150}$	
		oil radish	phacelia	buckwheat	manure 25 t ha^{-1}		
Starch content, %	13.1	13.2	13.2	13.1	13.2	12.7	0.14
Starch collection, t ha^{-1}	3.25	4.08	3.87	3.37	3.92	3.71	0.25

Cowering of green manure provided 6.3% reduction in the cost of potato - to the level of 2939.0 € ha^{-1} (Table 4). The cost of potato grown in the variant with shallow (13-15 cm) covering of siderate by tillage without ploughing was by 6.7% lower than the cost of potato grown with ploughing, and by 11.6% than the cost of potato grown with surface tillage (6-8 cm).

Production costs on siderate background have been determined as the highest when growing potato - 2091.7 € ha^{-1}. Replacing ploughing with surface tillage contributed to reduction costs of basic tillage by 1-3% due to reduction of costs for fuel and oil materials.

Table 4. Economic efficiency of growing potato on different fertilization backgrounds and various methods of soil tillage

Index	Soil tillage							
	ploughing 28-30cm		Without ploughing на 28-30 cm		Without ploughing на 13-15 cm		Without ploughing на 6-8 cm	
	without siderate	post-harvest siderate	without siderate	post-harvest siderate	without siderate	post-harvest siderate	without siderate	post-harvest siderate
Yield, t ha^{-1}	24.1	28.5	24.12	30.3	22.3	26.6	21.3	25.2
Sale price, € ha^{-1}	121.95	121.95	121.95	121.95	121.95	121.95	121.95	121.95
Value of products, € ha^{-1}	2939.0	3475.6	2941.5	3695.1	2719.5	3243.9	2597.6	3073.2
Cost of production, € ha^{-1}	2036.8	2091.7	2016.6	2080.1	1992.7	2049.3	1984.7	2040.6
Including main tillage, € ha^{-1}	52.9	52.9	32.49	32.49	20.1	20.1	18.9	18.9
Application of siderate € ha^{-1}	0	23.6	0	23.6	0	23.6	0	23.6
Net income € ha^{-1}	902.2	1383.9	924.8	1615.0	726.8	1194.6	612.8	1032.6
Additional income (loss) € ha^{-1}	x	481.7	22.6	712.8	-175.4	292.4	-289.4	130.4
Prime cost 1 t, €.	84.5	73.4	83.6	68.6	89.4	77.0	93.2	80.9
Level of recoupment, %	44.3	66.2	45.9	77.6	36.5	58.3	30.9	50.6

Application of post-harvest siderate of oil radish increased the costs of crop growing by 1.2% - 23.63 € ha^{-1}, and the use of tillage without ploughing instead of ploughing provided savings in production costs within 1.0-1.7% - by 20.4-34.0 € ha^{-1}.

Net profit of potato growing technologies varied twice. The highest result was obtained for covering post-harvest siderate of oil radish by tillage without ploughing on a depth of 28-30 cm under potato - 1615.0 € ha^{-1}, additional profit, comparing with the control, increased by 712.85 € ha^{-1}. With covering siderate by ploughing, was received a smaller additional profit when growing potatoes - 481.7 € ha^{-1}, which was 48% less than growing with deep tillage loosening. Lowering depth of tillage from 28-30 cm to 13-15 and 6-8 cm reduced the level of additional income when growing potato on sideral background more than twice - to 11989 and 130.4 € ha^{-1}.

Conducting tillage without ploughing to a depth of 13-15 and 6-8 cm on a background without siderate was unprofitable comparing with ploughing.

Covering green manure of oil radish helped to increase profitability of potato crop growing in the range of 53-75% and reduce their prime cost in the range of 13-18%, comparing with background without siderate. The lowest prime cost of growing potato was obtained when covering oil radish by tillage without ploughing to a depth of 28-30 cm - 68.7 € t^{-1}, which was cheaper than ploughing by 4.73 € t^{-1}. With shallow covering of siderate by tillage without ploughing to a depth of 13-15 cm the prime cost of potato growing was higher by 5% than with ploughing, and with surface (6-8 cm) covering of siderate - by 10% than with ploughing.

Profitability of growing potato varied between the variants within 47%. Sidereal background provided increase in profitability of the crop growing - within 20-32%. The highest profitability of potato growing has been determined for deep covering of oil radish siderate by tillage without ploughing to a depth of 28-30 cm - 77.6%. For ploughing profitability was lower by 11.5%. Covering of siderate by tillage without ploughing to a depth of 13-15 and 6-8 cm was inferior to ploughing in terms of potato profitability by 7.9 and 15.6%.

CONCLUSIONS

Application of post-harvest siderate of oil radish and its covering by tillage without ploughing to a depth of 28-30 cm on typical black soil contributes to obtaining higher and better potato yields under conditions of unstable moisture in the North-Eastern Forest-Steppe of Ukraine.

When growing potato on the background of post-harvest oil radish siderate and with soil tillage without ploughing, lack of precipitation and high average daily temperatures had smaller effect on limiting yield level of the crop.

Growing of post-harvest siderate of oil radish is a low-cost agricultural measure, and its covering by the method of tillage without ploughing provides saving of financial resources, comparing with ploughing. Covering of post-harvest oil radish siderate by tillage without ploughing to a depth of 28-30 cm, when growing potato, provided the lowest prime cost of potato tubers - 68.7 € t^{-1}, and the highest profit indices - 1615.0 € ha^{-1} with profitability level of 77.6%.

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