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Application of green clover manure in winter wheat growing

V.F. Petrychenko[1], V.V. Lykhochvor[2*], Y. M. Olifir[3]

[1]*Institute of Feed and Agriculture of Podillya NAAS, Vinnytsia, Ukraine*
[2]*Lviv National Agrarian University, Dublyany, Ukraine,*
[3]*Institute of Agriculture of the Carpathian Region NAAS, Obroshyne, Ukraine*
**Corresponding author Email: lykhochvor@ukr.net*
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The field experiment studied the value of precursors for winter wheat (*Triticum aestivum*) on dark gray podzolic light loam soil, in particular the possibility of replacing some mineral fertilizers with green manures. We found that the highest grain yield (6.89 t/ha) of winter wheat of the Yulia variety was obtained in the variant with plowing down of the green mass of the first mowing of meadow clover (*Trifolium pratense*) in June. The yield (6.64 t/ha) of winter wheat was also high in the variant with the plowing down of the second mowing of the green clover mass in August. The yield of winter wheat decreased to 6.42 t/ha in the variant with mowing the green mass on one mowing and semi-steam tillage and 6.32 t/ha with clover application for two mowings, i.e., removal of biomass from the field. The results showed that the impact on the yield of winter wheat, the placement of wheat after clover with the plowing down of the first mowing of clover on green manure is equivalent to the application of mineral fertilizers at the rate $N_{90}P_{30}K_{60}$; thus, clover as a precursor is an essential factor in biologization of cultivation technology. Yields decreased for winter wheat sowing after winter rape to 6.01 t/ha and after soybeans to 5.79 t/ha. These two precursors are valuable for wheat, but the yield decreased by 0.88 t/ha and 1.1 t/ha, respectively, compared to tillage at the first mowing of clover. It was the lowest for placement after unwanted precursors. Thus, sowing of wheat on wheat led to a drop of the yield to 5.24 t / ha, and after corn for grain - to 4.89 t/ha. The increase of yield from the choice of the best precursor (clover with plowing down of the first mowing) compared with the worst precursor (corn for grain) is 2.0 t/ha. Simultaneously, the increase of the rate of application of mineral fertilizers from $N_{60}P_{30}K_{40}$ (N_{60}) to $N_{150}P_{60}K_{100}$ (N_{60} + N_{60} + N_{30}) caused the increase of yield by only 1.25 t/ha.
Keywords: biologization, meadow clover, winter wheat, precursor, yield.

Introduction

Perennial legumes are the most accessible factor in the biologization of technologies for growing and restoring soil fertility. They can fix nitrogen from the air that remains in plant remains and the soil. The organic matter of clover is a source of nutrients that improves the physical and mechanical properties of the soil, its structure. According to various data, from 70-80 to 200-300 kg/ha of biological nitrogen remains in the soil after legumes (Petrichenko & Likhochvor, 2020). It is proved that the application of meadow clover as a precursor for winter wheat provides the formation of an excellent state of agrophytocenosis and the highest yield (Zabarna, 2019). After meadow clover, winter wheat forms the highest yield and is dominated by other perennial legumes (Razanov & Tkachuk, 2018). The best conditions for the soil's biological activity are formed by placing winter wheat after clover for one mowing (Tsyuk et al., 2018).

Crop rotations with leguminous precursors had a better nitrogen supply than crop rotations with pure steam and corn for silage (Kudrya, 2020). In the conditions of Pidkarpattya, the growing of legumes on sod-podzolic soils improved soil fertility; in particular, the content of alkaline hydrolyzed nitrogen increased by 3.9%, mobile phosphorus by 5%, metabolic potassium by 14% (Karbivska et al., 2019). The technology of optimizing the bulk mass of the soil by selecting leguminous perennial grasses at the level of 1.13–1.18 g/cm^3 has been developed (Tkachuk, 2020). Green fertilizers contribute to the more efficient use of renewable resources, particularly the accumulation of organic matter due to solar energy, biological nitrogen as a result of the activity of tubers bacteria. Replenishment of the soil with the organic matter due to green manure leads to an increase in the soil biological activity (Chmel et al., 2019)

Mostly clover as a precursor of winter wheat was used after harvesting green mass for fodder purposes. The issue of plowing down green mass as a green fertilizer has hardly been studied. At high prices for mineral fertilizers, this becomes very economically relevant, especially in connection with solving critical environmental problems.

Materials and methods

Field research was conducted during 2018-2020 in Lviv National Agrarian University's research field on dark gray podzolic soil. Eight variants of precursors for winter wheat were studied (Table 1). In the meadow clover's variant, the green mass was mowed on one mowing in June and used for haymaking. Subsequently, semi-steam tillage was carried out: disking, plowing, pre-sowing tillage. In the second variant, meadow clover formed a second mowing, which was mowed in August. That is, two mowings of green mass were alienated from the field. After mowing, the field was plowed and prepared for sowing. At the beginning of clover flowering in June, the green mass was plowed as green manure in the third variant. In the fourth variant, the first mowing was used for hay, and the green mass of the second mowing was plowed on green manure in August.

The total area of the elementary plot was 60 m^2, the estimated area of the plots was 50 m^2, the experiment was repeated three times, and the location of the plots was systematized. Winter wheat was grown according to intensive technology. Julia variety was

sown with a sowing rate of 4 million/ha. The sowing date is October 4. Depth of seed wrapping – 3 cm. Fertilizer application rates were set considering the removal of 1 centner of grain ($N_3P_1K_2$) and recalculation of correction factors depending on the content of nutrients in the soil. Nitrogen fertilizers in the form of ammonium nitrate (N_{34}) were applied in the following terms: first application in early spring in the tillering phase (BBCH 25), second application at the beginning of stalking (BBCH 30), 3rd in the earing phase (BBCH 59). Phosphorus and potassium fertilizers were applied under plowing. Crop care included protection against lodging, three fungicides applications to control diseases, and two sprays of fungicides.
Weather conditions in the years of research were quite contrasting and differed from the average long-term data in the amount of precipitation and temperature. During the year in 2018 fell 760 mm, in 2019 – 818 mm, in 2020 – 710 mm with a long-term average of 615 mm. Precipitation in June 2018 and in May 2019. created conditions of excessive moisture, which led to reduced yields. Air temperature during the years of research was not a limiting factor in yield growth. In 2018, the average monthly temperature was 8.8 °C, in 2019 – 9.1 °C, in 2020 – 9.4 °C, with a long-term average of 7.8 °C.
Mathematical and statistical processing of research results was carried out by variance and correlation-regression method using Microsoft Excel and Statistica 6.0. The tables' data are presented as the arithmetic mean with standard deviation (x ± SD).

Results and discussion

We found that sowing after meadow clover on one mowing and two mowings gives almost the same results - on average on all backgrounds of fertilizers, respectively, 6.42 t/ha and 6.32 t/ha (Table 1). The effect of semi-steam tillage after clover on one mowing is estimated by a slight increase in the grain – 0.1 t/ha.

Table 1. The yield of winter wheat variety Julia depending on the precursor and fertilizer rate, t/ha (x ± SD, n = 6).

Predecessors	Fertilizer rate				Average for precursors
	$N_{60}P_{30}K_{40}$ (N_{60})	$N_{90}P_{40}K_{60}$ ($N_{45}+N_{45}$)	$N_{120}P_{50}K_{80}$ ($N_{60}+N_{60}$)	$N_{150}P_{60}K_{100}$ ($N_{60}+N_{60}+N_{30}$)	
Meadow clover on 1 mowing	5.73 ± 0.10	6.23 ± 0.12	6.70 ± 0.14	7.02 ± 0.15	6.42 ± 0.12
Meadow clover on 2 mowings	5.67 ± 0.12	6.15 ± 0.10	6.57 ± 0.12	6.88 ± 0.11	6.32 ± 0.15
Meadow clover with plowing of the 1st mowing	6.38 ± 0.10	6.74 ± 0.14	7.15 ± 0.16	7.30 ± 0.14	6.89 ± 0.13
Meadow clover with plowing of the 2nd mowing	6.01 ± 0.13	6.50 ± 0.16	6.93 ± 0.11	7.12 ± 0.12	6.64 ± 0.11
Winter rape	5.27 ± 0.09	5.89 ± 0.10	6.31 ± 0.13	6.58 ± 0.10	6.01 ± 0.14
Soybean	5.02 ± 0.11	5.60 ± 0.12	6.18 ± 0.10	6.35 ± 0.15	5.79 ± 0.10
Winter wheat	4.48 ± 0.13	5.07 ± 0.09	5.54 ± 0.14	5.88 ± 0.10	5.24 ± 0.13
Maize (corn)	4.17 ± 0.10	4.65 ± 0.14	5.18 ± 0.11	5.57 ± 0.13	4.89 ± 0.11
Average on the background of fertilizers	5.34 ± 0.11	5.85 ± 0.13	6.32 ± 0.12	6.59 ± 0.14	

1st application of nitrogen BBCH 25; the second – BBCH 30; third – BBCH 59

We suggested that it is possible to increase the yield of winter wheat through the use of green manures. The highest yield on average in the background (6.89 t/ha) is provided by plowing the first mowing of meadow clover's biomass. This is higher than the variant in which the green mass of the first mowing was alienated from the field by 0.47 t/ha. Plowing the second mowing increases yield compared to the clover variant on two mowings by 0.32 t/ha, which is less than the first mowing plowing by 0.25 t/ha. This can be explained by the fact that during the summer plowing down the green mass has more time for mineralization. Mineralization processes are faster and more intense as they occur at optimal temperatures.

Placement of winter wheat after other precursors led to a significant reduction in yield compared to sowing options after clover. Thus, after winter rape, the background's average yield decreased by 0.31 – 0.88 t/ha. After soybean, wheat yield decreased by 0.53 – 1.10 t/ha. This can be explained by the fact that soybeans use nitrogen fixed from the atmosphere to form high-protein grains and less nitrogen enters the soil than after clover. The lowest yield, as expected, was obtained with monoculture cultivation of wheat (5.24 t/ha) and sowing it after corn for grain (4.89 t/ha). The reason for this is the deterioration of phytosanitary conditions. The decrease in the yield level for sowing wheat after corn compared to its placement after clover with the plowing down of the first mowing is quite significant and averages 2.00 t/ha.

The analysis of Table 1 shows that when sowing winter wheat after wheat and corn on the variant with the application of the maximum amount of fertilizers, $N_{150}P_{60}K_{100}$ yields were obtained, respectively, 5.57 and 5.88 t/ha. The exact yield level was for the wheat placement after clover on one (5.73 t/ha) and two mowings (5.67 t/ha), but at the lowest rate of fertilizer - $N_{60}P_{30}K_{40}$. To form a yield of 6.38 t/ha after clover with plowing down of the second mowing, it is necessary to apply only $N_{60}P_{30}K_{40}$, and when placing after soybeans to form the same level of yield (6.35 t/ha), the rate of mineral fertilizers should be increased to $N_{150}P_{60}K_{100}$. When sowing wheat after wheat and corn, it is impossible to reach the level of 6.38 t/ha, even at the maximum rate of fertilizers in our research. In terms of the impact on the grain yield of winter wheat of the Yulia variety, the placement of wheat after clover with the plowing down of the first clover mowing on green manure is equivalent to the application of mineral fertilizers at least $N_{90}P_{30}K_{60}$ ($N_{150}P_{60}K_{100}$ – $N_{60}P_{30}K_{40}$).

Based on the correlation-regression analysis results, mathematical models were built, and the dependences of the yield of winter wheat of Julia variety placed after meadow clover on the total number of NPK, which reflect the equations presented in Table 2.

Table 2. The equation of the dependence of the yield of winter wheat variety Julia on the total number of NPK.

Precursor	Equation	Multiple Correlation Coefficient, R	Determination Coefficient. D
Meadow clover on 1 mowing	$Y = 2.481-0.003X+0.276X^{0.5}$	0.998	99.6
Meadow clover on 2 mowing	$Y = 2.411-0.004X+0.284X^{0.5}$	0.999	99.80
Meadow clover with plowing down of the 1st mowing	$Y = 2.701-0.007X+0.354X^{0.5}$	0.997	99.40
Meadow clover with plowing down of the 2nd mowing	$Y = 2.609-0.005X+0.312X^{0.5}$	0.999	99.80

Note: Y - yield, t/ha; X- is the total number of NPK.

The calculated mathematical models are 95% reliable according to Fisher's criterion and Student's criterion. They make it possible to predict the grain yield of winter wheat depending on the total dose of mineral fertilizers after these precursors. It should be noted that the yield of winter wheat is closer to the total amount of mineral fertilizers placed after meadow clover on two mowings and after plowing the second mowing (R = 0.999) compared to sowing wheat after meadow clover on the first slope (R = 0.997-0.998).

Conclusion

If meadow clover is used for fodder production, it is advisable to place winter wheat on two mowings after clover. The use of green clover mass as green manure provides a significant increase in yield (0.32 t/ha and 0.47 t/ha) compared to options where the green mass of clover was used for forage harvesting, i.e., alienated from the field. Plowing down the first clover mowing on green manure is equivalent in terms of the impact on yield to the application of mineral fertilizers at the rate of $N_{90}P_{30}K_{60}$.

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