Green fertilizers as a way to preserve fertility of ordinary chernozem

E V Kravtsova and L V Rudakova

Azov-Black Sea Engineering Institute of the FSBEI HE «Don State Agrarian University», 21, Lenin st., Zernograd, Rostov region, 347740, Russia

E-mail: lena.le2011na.kravtsova@mail.ru

Abstract. The effectiveness of green fertilizers depends on the type, productivity and method of using green manure crops. The more and better the green mass of manure crops, the better the effect. In our studies, such green manure crops as sainfoin, rapeseed, white mustard, chickpeas and a mixture of legumes (spring barley + peas) were used. During the beginning of flowering, they were planted. The maximum content of the biomass of air-dry matter for sainfoin and a legume mixture was 5.85 and 5.61 t/ha, respectively. The highest rates of green mass for sainfoin was 3.74 t/ha. For other green manure crops, the differences varied from 1.19 to 3.12 t/ha. Analysis of nutrients in the soil showed that after planting green manure in the arable layer, the amount of mobile phosphorus and exchangeable potassium increased. The highest content of nutritional elements was for nitrate nitrogen after sainfoin, mobile phosphorus and exchangeable potassium after rapeseed. Green manure crops (chickpea, rapeseed and white mustard) have a beneficial effect about content agronomically valuable units 10.0... 0.25 mm in soil layer of 0 ... 30 cm and improve soil structure. Thus, it was found that siderates enrich the soil with organic matter and basic nutrients, which improves the nutrition of grain crops at the initial stages of development and preserves the soil fertility of ordinary chernozem.

1. Introduction
In the majority of regions of the Russian Federation, the removal of nutrients with agricultural crops exceeds their input into the soil, which leads to an uncompensated consumption of resources and decreases the fertility of arable soils. In conditions of insufficient production and application of organic (about 50 million tons per year, or less than 1 t/ha of sown area) and mineral fertilizers (on average 36 kg/ha), the task of intensifying the use of renewable biological resources that support self-regulation mechanisms is urgent [1].

One of the most pressing issues of modern farming is the conservation and maintenance of organic matter in the soil. The increased use of chernozems leads to a strong mineralization process, which causes humification not only of humus, but also of fresh organic residues in the soil [2].

The effectiveness of green fertilizers depends on the type, productivity and method of using green manure crops. The more and better the green mass of green manure crops, the higher the effect [3].

It is known that without fertilizers, about 15 ... 20% of the main nutrients of plants return to the soil, and the humus is restored only by 20 ... 30% of the soils, i.e. agricultural works has a negative balance. To ensure its deficit-free balance and the preservation of basic nutrients, it is necessary to contribute at least 4 ... 8 t of manure and 30 kg of mineral fertilizers per hectare annually. Due to a
sharp drop in livestock production, the yield of manure and high-cost mineral fertilizers decreased, unfortunately, they began to be used in small quantities [4].

One of the main solutions to this problem is the use of sideral cultures. Cheaper, affordable and effective green fertilizers can become an unlimited, reproducible basis for organic matter. When filling green mass, the soil is enriched not only with nitrogen, phosphorus, potassium, calcium, magnesium, but also with other nutrient elements. Green fertilizers giving a large amount of organic matter, improve physical and chemical properties of soil.

The mass of green fertilizers serves as a good source of humus, where the vital activity of microorganisms increases and the water, air, heat and nutritional regimes of the soil improve [5, 6].

Green fertilization has two effects: it supplies crops with nutrients and improves the soil quality. Green manure is not inferior to manure [5, 6]. The green manure contributes to an increase in soil organic matter, which is equivalent to the introduction of 20 ... 30 tons of manure per one hectare at a lower (2 ... 3 times) cost [7, 8].

The organic matter gives the topsoil a certain color. Its surface consists of 1 ... 6% organic matter, which decreases with depth. The dark top layer of the soil corresponds to the high content of organic matter. The content of organic matter is important for soil fertility, since it provides it with required nutrients [9].

Therefore, the purpose of our work is to use green fertilizers as a way to preserve the fertility of ordinary chernozem.

2. Materials and methods

Studies were carried out through field experiments and using the state variety method crop testing [10, 11].

Sideric cultures were taken as an object for the experiment: sainfoin, rapeseed, white mustard, chickpeas, cereal beans mixture (spring barley + peas, ratio of 2:1, i.e. 47% of spring barley and 53% of peas in mass ratio). The area of the registration area is 364 m2, repeat four times. The number of test variants studied was 10 (for winter wheat - sainfoin, rapeseed, white mustard, chickpeas and a mixture of cereals; analogue of spring barley). The predecessors of green manure crops were cereals - in 2014, winter rye, in 2015 - spring barley, and in 2016 - winter wheat. A two-factor stationary field experiment was conducted according to the scheme: 5A × 3B, where factor A - green manure crops, factor B – research years.

The soil of the experimental site is ordinary chernozem, carbonate, granulometric composition of the soil is heavy loamy. The power of the humus horizon is 40 ... 60 cm, the content of the gumusa is low - 2.58 ... 3.07%. The agrochemical properties of the soil were characterized by a low supply of nitrate nitrogen, an average supply of phosphorus and an increased supply of exchangeable potassium; the pH was slightly alkaline. The granulometric (structural) composition of the soil was dominated by the middle blocky fraction, according to the content of 0 ... 30 cm from agronomically valuable aggregates in the arable layer of soil, 10.0 ... 0.25 mm in size (according to the method of dry sieving by N.I. Savvinov).

Green manure crops that reached the flowering phase were planted into the soil of BDP-4 in two tracks with an interval of one month. Green manure crops decompose faster than those that have reached a coarser stem.

3. Research results

During the studies (2014 ... 2016), air-dry matter in the biomass of different variants of the experiment formed in different ways. The highest values were observed in 2014. In 2015, there was a decrease in biomass, and in 2016, there was an increase in biomass.

On average, the maximum biomass of air-dry matter was 5.85 t / ha for sainfoin, 5.61 t / ha – for cereal-legume mixture, 1.98 t / ha - for chickpea at HCP05 (A) = 0.75 t / ha (Table 1).
Table 1. Air-dry matter in the biomass of different green manure crops, t/ha (2014 ... 2016)

| Sideral crop, Α | Agricultural year, B | HCP05 (Α) = 0.75 |
|-----------------|----------------------|------------------|
|                 | 2014 | 2015 | 2016 |                   |
| Sainfoin        | 9.28 | 4.48 | 3.80 | 5.85              |
| Rape            | 5.29 | 3.33 | 3.40 | 4.01              |
| White mustard   | 3.93 | 3.03 | 4.80 | 3.92              |
| Chickpea        | 2.65 | 1.23 | 2.20 | 1.98              |
| Cereal mixture  | 5.49 | 5.93 | 5.40 | 5.61              |
| Average         | 5.33 | 3.60 | 3.92 | 4.28              |

HCP05 = 1.29
HCP05 (B, AB) = 0.59

Green manure crops (sainfoin, sweet clover and others) have a deep penetrating root system capable of extracting nutrients from the lower soil layers and redistributing them in the arable layer. This allows sainfoin and other green manure to form a large vegetative mass with a high fertilizing value of up to 50 ... 60 t/ha [12].

M.V. Fedorov (1954), M.M. Kononov (1963), M.I. Sidorov and N.I. Zezyukov (1981, 1988) pointed out “the enormous importance of plant residues in the formation of soil fertility.” Organic material entering the soil has a positive effect on diet [13].

When planting green mass of green manure crops in 2014, the maximum input of green organic matter into the soil was 3.30 t/ha.

Comparing green manure crops, the highest rates of green mass entering the soil were observed for sainfoin – 3.74 t/ha. For the rest of green manure crops, the differences were insignificant: from 1.19 to 2.16 t/ha.

An analysis of variance of the results showed that the input of green mass of sideral crops is reliable for sainfoin (3.74 t/ha) and cereal-legume mixture (3.12 t/ha) with HCP05 (Α) = 0.06 t/ha) (Table 2).

Table 2. Input of green mass of green manure crops to the soil, t/ha (2014 ... 2016)

| Sideral crop, Α | Agricultural year, B | HCP05 (Α) = 0.06 |
|-----------------|----------------------|------------------|
|                 | 2014 | 2015 | 2016 |                   |
| Sainfoin        | 6.06 | 2.81 | 2.33 | 3.74              |
| Rape            | 3.33 | 1.46 | 1.69 | 2.16              |
| White mustard   | 2.77 | 1.16 | 2.44 | 2.12              |
| Chickpea        | 1.54 | 0.66 | 1.36 | 1.19              |
| Cereal mixture  | 2.81 | 3.34 | 3.24 | 3.12              |
| Average         | 3.30 | 1.89 | 2.21 | 2.47              |

HCP05 = 0.11
HCP05 (B, AB) = 0.05

It is known that green fertilizers enrich the soil with nitrogen and other chemicals.

One ton of green manure crops contains 4.5 ... 7.7 kg nitrogen, 0.5 ... 1.2 kg phosphorus, 1.8 ... 2.0 kg potassium, which is equivalent to the introduction of 6 ... 7 c/ha of expensive ammonium nitrate, and 30 ... 40 tons of manure [14].

The chemical composition of plants affects from phase of development during plowing into the soil.

The main advantage of green manure crops is an increase in nutrients and organic matter in the soil [15]. Organic matter is an important source for soil fertility [16].

The green mass causes rapid decomposition of saprophytic microflora, which accelerates the mineralization of plant residues - the main substrate where pathogens of root rot, snow mold and others
develop. In addition, when plowing green mass, the number of actinomycetes, which are soil phyto-pathogenic, increases several times [17].

After planting green manure crops, in the soil layer of 0 ... 30 cm, organic matter ranged from 3.91 to 4.33%.

No significant differences in the content of organic matter in the topsoil were observed.

An analysis of variance of the results showed that significant content of organic matter in the arable soil layer was observed only after rapeseed (4.33%), the rest of crops, except for chickpea (3.91%), were at the middle level at HCP05 (A) = 0.08% (Table 3).

Table 3. Content of organic matter in the soil layer of 0 ... 30 cm before sowing winter wheat after green manure crops, %

| Sideral crop, A       | Agricultural year, B | HCP05 (A) = 0.08 |
|-----------------------|----------------------|------------------|
|                       | 2014 | 2015 | 2016 |       |
| Sainfoin              | 4.03 | 4.19 | 3.81 | 4.01  |
| Rape                  | 4.17 | 4.60 | 4.22 | 4.33  |
| White mustard         | 3.84 | 4.63 | 3.81 | 4.09  |
| Chickpea              | 3.85 | 4.26 | 3.61 | 3.91  |
| Cereal mixture        | 3.94 | 4.45 | 3.70 | 4.03  |
| Average               | 3.97 | 4.43 | 3.83 | 4.07  |
| HCP05 (A) = 0.14      |      |      |      |       |
| HCP05 (B, AB) = 0.06  |      |      |      |       |

The filling of green fertilizer helps to preserve and increase the fertility of the soil, in it the main elements of nutrition are improved. Before sowing winter wheat, the content of basic nutrients is able to provide plants with nutrients and get good shoots.

According to our studies, the largest content of nitrate nitrogen was provided by sainfoin 37.2 mg / kg and cereal mixture 27.9 mg / kg. No significant differences were observed after rapeseed, white mustard and chickpea (Table 4).

Table 4. Content of nitrate nitrogen in the soil layer of 0.30 cm before sowing winter wheat after sideral crops, mg / kg

| Sideral crop, A       | Agricultural year, B | HCP05 (A) = 1.82 |
|-----------------------|----------------------|------------------|
|                       | 2014 | 2015 | 2016 |       |
| Sainfoin              | 40.7 | 33.7 | 37.2 | 37.2  |
| Rape                  | 24.6 | 15.4 | 30.4 | 23.5  |
| White mustard         | 27.3 | 13.3 | 28.5 | 23.0  |
| Chickpea              | 26.2 | 14.1 | 23.4 | 21.2  |
| Cereal mixture        | 28.7 | 25.2 | 29.4 | 27.9  |
| Average               | 29.5 | 20.3 | 29.8 | 26.5  |
| HCP05 (A) = 3.17      |      |      |      |       |
| HCP05 (B, AB) = 1.41  |      |      |      |       |

The differences between green manure crops were significant. An analysis of variance made it possible to establish a significant effect of nitrate nitrogen after sainfoin (37.2 mg / kg) at HCP05 (A) = 1.82 mg / kg.

Green manure crops of the cruciferous group — rape, mustard or rapeseed — are used to saturate the soil with phosphorus and sulfur, as well as to loosen heavy soils [18].

In the studies of V.A. Monastyrsky and A.N. Babichev, soil nutrient accumulation was investigated. When cultivating sideral crops at the beginning of vegetation in the soil layer 0 ... 20 cm nitrate content ranged from 20.6 to 22.4 mg / kg, mobile phosphorus content from 26.6 to 32.6 mg / kg and
exchange potassium content from 376 to 452 mg/kg. Analysis of the results of nutrients in the soil showed that after the filling of sideral crops into the soil at experimental sites in layer 0...20 cm, the number of nitrates increased by 10.2...15.5 mg/kg, mobile phosphorus increased by 9.4...13.6 mg/kg and exchanged potassium for 42...56 mg/kg [19].

According to our data, all the studied sideral cultures contributed to a significant increase in the concentration of phosphorus in mobile form in the soil layer 0...30 cm. The maximum amount of mobile phosphorus was obtained after rapeseed - 51.4 mg/kg (Table 5).

**Table 5.** Content of mobile phosphorus in the soil layer of 0...30 cm before sowing winter wheat after green manure crops, mg/kg

| Sideral crop, A | Agricultural year, B | HCP<sub>05</sub> (A) = 5.08 |
|----------------|----------------------|-----------------------------|
|                | 2014                 | 2015 | 2016 |          |
| Sainfoin       | 62.6                 | 18.5 | 45.3 | 42.1     |
| Rape           | 61.7                 | 36.0 | 56.6 | 51.4     |
| White mustard  | 29.4                 | 18.7 | 48.7 | 32.3     |
| Chickpea       | 40.4                 | 36.5 | 31.4 | 36.1     |
| Cereal mixture | 49.3                 | 28.6 | 39.0 | 39.0     |
| Average        | 48.7                 | 27.7 | 44.2 | 40.2     |
| HCP<sub>05</sub> = 8.79 |           |      |      |          |
| HCP<sub>05</sub> (B, AB) = 3.94 |            |      |      |          |

The minimum amount of mobile phosphorus was obtained in 2015 - 27.7 mg/kg; in 2014 and 2016, it was higher by 21.0 and 16.5 mg/kg soil, respectively.

Variance analysis of the obtained results showed that the differences between sideral rounds were substantial. A significant increase in mobile phosphorus after planting green manure was provided by rapeseed (51.4 mg/kg) at HCP<sub>05</sub> (A) = 5.08 mg/kg.

All the green manure crops did not show significant differences (HCP<sub>05</sub> (A) = 56.95 mg/kg). The highest concentration of exchangeable potassium in the 0...30 cm soil layer was provided by rapeseed - 530 mg/kg (Table 6).

**Table 6.** Content of exchangeable potassium in the soil layer of 0...30 cm before sowing winter wheat after sideral crops, mg/kg

| Sideral crop, A | Agricultural year, B | HCP<sub>05</sub> (A) = 56.95 |
|----------------|----------------------|-----------------------------|
|                | 2014                 | 2015 | 2016 |          |
| Sainfoin       | 598                  | 386  | 533  | 506      |
| Rape           | 752                  | 402  | 435  | 530      |
| White mustard  | 570                  | 452  | 512  | 511      |
| Chickpea       | 498                  | 426  | 415  | 446      |
| Cereal mixture | 476                  | 471  | 389  | 445      |
| Average        | 579                  | 427  | 457  | 488      |
| HCP<sub>05</sub> = 98.64 |           |      |      |          |
| HCP<sub>05</sub> (B, AB) = 44.11 |            |      |      |          |

The plowing of green manure crops creates a favorable background for the development of spring crops.

In summer, the plowing of green manure crops for green fertilization indicates that the content of nutrients decreases and increases nutrition for the development of spring crops (11.5 after chickpea and 3.2 mg/kg after rape); for mobile phosphorus - from 19.9 after chickpea to 24.8 mg/kg after rape; the difference turned out to be insignificant, as evidenced by the values of HCP for partial differences according to the experiment (HCP<sub>05</sub> = 0.17 mg/kg and HCP<sub>05</sub> = 0.24 mg/kg soil, respectively).
The provision of soil with exchangeable potassium was facilitated by its high content (from 427 mg/kg after chickpea to 524 mg/kg after rape), since the HCP indicator for partial differences does not exceed more than one option (HCP05 = 1.45 mg/kg).

The amount of organic matter increased by 3.88-4.32% in the soil layer of 0...30 cm before sowing spring barley after the influence of green manure crops. The lowest content of organic matter was observed after chickpea 3.88%, and the remaining green manure crops differed slightly from each other (Table 7).

The highest content of organic matter in the soil layer of 0...30 cm was 4.41% in 2015; in 2014 and 2016, it was 3.99 and 3.92%, respectively.

| Sideral crop, A | Agricultural year, B | HCP05 (A) = 0.07 |
|----------------|---------------------|------------------|
|                | 2014    | 2015    | 2016 |
| Sainfoin       | 4.11    | 4.15    | 3.90 | 4.05 |
| Rape           | 4.13    | 4.62    | 4.20 | 4.32 |
| White mustard  | 4.00    | 4.59    | 4.00 | 4.20 |
| Chickpea       | 3.65    | 4.29    | 3.71 | 3.88 |
| Cereal mixture | 4.07    | 4.42    | 3.77 | 4.09 |
| Average        | 3.99    | 4.41    | 3.92 | 4.11 |
| HCP05 = 0.18   |         |         |      |      |
| HCP05 (B) = 0.11 |       |         |      |      |

An analysis of variance of the results showed that rape (4.32%) and white mustard (4.20%) with HCP05 (A) = 0.07% have a significant effect on the content of organic matter content in soil before sowing spring barley.

The soil structure was improved after chickpea, rapeseed and white mustard, since the content of agronomically valuable aggregates in the soil layer of 0...30 cm was: 85.1% after chickpea, 83.0% after rape, and 82.2% white mustard.

It was found out that chickpeas (85.1%), rapeseed (83.0%) and white mustard (82.2%) have an effect on the arable layer at HCP05 (A) = 0.06% (Table 8).

| Sideral crop, A | Agricultural year, B | HCP05 (A) = 0.06 |
|----------------|---------------------|------------------|
|                | 2014...2015 | 2015...2016 | 2016...2017 |
| Sainfoin       | 79.6          | 79.6         | 79.4        | 79.5        |
| Rape           | 82.8          | 82.8         | 83.3        | 83.0        |
| White mustard  | 82.2          | 82.2         | 82.1        | 82.2        |
| Chickpea       | 85.2          | 85.2         | 85.0        | 85.1        |
| Cereal mixture | 78.2          | 78.2         | 78.0        | 78.1        |
| Average        | 81.6          | 81.6         | 81.6        | 81.6        |
| HCP05 = 0.11   |               |               |              |
| HCP05 (B, AB)  = 0.05 |          |               |              |

Many prominent scientists have noted that sideral crops affect the soil and its fertility. In 1936, V.V. Dokuchaev taken into account: an undeniable factor is the influence of growing vegetation on the accumulation of organic matter in the soil and its qualitative composition. In 1949, P.A. Kostychev said that formation of chernozem due to herbaceous plants grown on it was a proven fact" [13]. According to A.D. Fokin in 1986: we can consider that the main components of soil organic matter are
humus substances themselves and organic residues of plant origin, which can have a significant impact on the preservation of soil fertility [8].

4. Conclusion

Thus, the use of sideral crops is an additional source of organic substance that increases the amount of nutrients in the soil, preserves and increases soil fertility. The maximum formation of the biomass of air-dry matter was observed for 5.85 t / ha of sainfoin and 5.61 t / ha of a cereal-legume mixture. Therefore, the use of sainfoin and legume mixture for green manure allows you to increase the content of organic matter.

Organic matter of green manure contributed to an increase in the content of nitrate nitrogen, mobile phosphorus and exchangeable potassium. Before sowing grain crops, the maximum content of nutrients was observed when incorporating green mass of sainfoin (nitrate nitrogen) and rapeseed (mobile phosphorus and exchange potassium).

The use of green manure crops increased the number of agronomically valuable aggregates, when using chickpeas, rapeseed and white mustard. During the observation period, an increase in agronomically valuable aggregates was observed for all green manure crops.

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