The Features of the Yield Formation for Spring Rapeseed Herbage of Different Varieties in the Conditions of Non-Chernozem Zone

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Abstract. The herbage of rapeseed is a valuable feed with a high protein content, as in legumes. It is widely used in the green conveyor system, as a silage crop and for grazing when regrowing after mowing. In many countries with developed agriculture, there is a tendency to increase the area occupied by rapeseed. The correct selection of spring rapeseed varieties is crucial for their successful cultivation. According to the results of our research, the Oredezh 4 rapeseed variety showed itself to be fast-growing, and its mowing ripeness came on the 37th day. A higher yield compared to other varieties on average for two years of research provided a variety of spring rapeseed Oredezh 2.

1. Introduction
Rapeseed is a valuable high-protein crop that is widely used for animal feed. 1 kg of rapeseed herbage in terms of dry matter contains more than 10 MJ of exchange energy. Rapeseed surpasses many agricultural crops in terms of food and feed value.

The herbage of rapeseed is a valuable feed, which in terms of protein content is not inferior to legumes, and contains 1 kg of 0.16 caloricity units and up to 35 g of protein, and this is significantly higher than the herbage of corn and sunflower. Green food is characterized by juiciness, good digestibility, and low fiber content [1].

Rapeseed is widely used in the green conveyor as a postharvest crop. In our zone, if there is enough moisture in the soil, it can give two mows of green mass per season.

After mowing with intensive regrowth, rapeseed crops can be used for grazing animals. Under irrigation, the productivity of the green mass of rapeseed is significantly higher, by more than one-third [2].

Rapeseed is easily silaged and is a good preservative for other feeds. Mixed with other crops, it is used to prepare high-quality nutritional silage. If you compare it with corn silage, it is richer not only in protein, but also in carotene.

Rapeseed straw is added when laying silage from other crops, as well as for feeding animals in prepared form.

Rapeseed is also of considerable interest as a good early honey plant, which can produce up to 90 kg of honey per 1 hectare. The yield of rapeseed seeds increases from bee pollination of its crops.
Rapeseed is a good precursor for all cereals. It creates positive agrotechnical conditions for subsequent crops in the crop rotation, helps to improve the structure of the soil and increase its fertility. It leaves up to 2 times more root residues per hectare than even clover [3].

Moreover, the content of nutrients in them is equal to 15-20 tons of manure. Many more are found in straw and crop residues. The rapeseed herbage can also be used as a green fertilizer or green manure. When cultivating rapeseed, crop rotation productivity increases by 10-15%.

Rapeseed is a multi-sided forage crop, because both green mass and flour from seeds, cake, protein concentrates, and meal are used for animal feed.

Many countries with developed agriculture are actively increasing the production of rapeseed. The introduction by breeders of new varieties with a low content of erucic acid and glucosinolates in seeds contributed to the widespread use of rapeseed in these countries. Seed cake and protein meal obtained during processing of seeds of non-erucic and low-glucosinolate varieties are used for feeding farm animals without special restrictions [4].

Different varieties of rapeseed are cultivated in different soil and climate zones of the Russian Federation.

The right choice of spring rapeseed varieties is important for stable high yield. Thanks to the work of breeders, the genetically possible yield, economically valuable characteristics of varieties are constantly increased, their suitability for cultivation in local conditions is improved, as well as their resistance to diseases and pests and adaptive factors [5].

Breeding progress based on the wide application of the latest methods of biotechnology and genetic engineering will accelerate in the future, which will allow farms to widely use its results for regular variety exchange and variety renewal.

2. Objects and methods of research

For feed purposes, you can use almost any rapeseed variety. Many varieties do not respond equally to the prevailing weather conditions, even if they belong to the same group of ripeness, so an additional reserve for crop stabilization can be seeding a mixture of varieties in forage crops.In the North-Western zone, the leading breeding institution is the Federal State Funded Research Institution Leningrad Research Institute of Agriculture “Belogorka”, which has created such varieties of spring rapeseed as Oredezh 1, Oredezh 2, Oredezh 4, Oredezh 5. The purpose of our research was an agrobiological assessment of promising varieties of spring rape in the conditions of the Novgorod region to identify early-maturing and yielding green mass, which have an advantage in a number of other characteristics.

In accordance with the purpose of the research, the following tasks were set:
1. to study the agrobiological features of promising varieties of spring rapeseed.
2. to identify the features of the formation of the green mass crop depending on the variety of spring rapeseed.

The experiments were laid and conducted at a pilot site in the Novgorodsky District of the Novgorod Region in 2015-2016 [6].

We studied the varieties of spring rape Oredezh 1, Oredezh 2, Oredezh 4 and compared them with one of the old varieties of Forum – st., which is used in farms. The research was carried out on plots of 40 m² (accounting area of 24 m²) in 4 repetitions, the placement of plots is randomized. Phenological observations of the growth and development of rapeseed plants and accounting for the yield of green mass of rapeseed varieties were carried out.

3. Results and discussion

When sowing in early spring, depending on the temperature and humidity of the soil, as well as the depth of seeding, spring rapeseed seedlings appear on the 4-7th day. With the emergence of seedlings, the growth and development of rapeseed is not the same. During the first growing season, it grows slowly, forming a powerful root system and rosette leaves. In the future, there is a more intensive growth. After the beginning of sprouting, there is an intensive growth of vegetative mass. From the beginning
of shoots to flowering in spring rape takes 40-48 days. The duration of flowering, depending on weather conditions, ranges from 20 to 30 days.

In our research, rape seed seedlings appeared on the 4th-5th day after sowing. This is due to the fact that the seed was sown in the allowed time, the temperature and humidity of the soil were optimal for germination of spring rape seeds, and the air temperature was 7.8-11 °C. To get a high yield of green mass, it is necessary that spring rape plants grow in sufficiently moist soil and at optimal humidity.

The onset of the budding phase in the years of research depended on the availability of moisture and heat. In 2015, budding was observed on the 20-22 day after germination (in the Forum variety-art. on the 30 day), this is due to a lack of moisture in the soil and high air temperatures. In 2016, the period from germination to budding was stretched from 23 to 36 days, the average monthly air temperature during this period was below the annual average of 14.5 °C, and the amount of precipitation exceeded the annual average (table 1).

Rapeseed is moisture-loving. The greatest need for moisture is required during flowering and seed filling. Weather conditions in 2016 had a more favorable effect on spring rape plants, the period from budding to the flowering phase was on average 11 days (for the Forum-st. variety – 14 days), and in 2015 this period lasted 11-14 days.

| Variety   | Seeding – sproutings | Sproutings - budding | Budding – flowering |
|-----------|----------------------|----------------------|---------------------|
| 2015      | 2016                 | 2015                 | 2016               |
| Forum-st. | 4                    | 5                    | 30                  | 36                  | 14 | 14 |
| Oredez 1  | 5                    | 5                    | 22                  | 26                  | 11 | 12 |
| Oredez 2  | 5                    | 5                    | 22                  | 26                  | 11 | 12 |
| Oredez 4  | 4                    | 5                    | 20                  | 23                  | 11 | 11 |

Among the studied varieties, the rapeseed variety Oredez 4 was distinguished by its precocity, the period of mowing ripeness came in 2015 on the 35th day, in 2016-on the 39th day (table 2).

| Variety | Vegetation period |
|---------|------------------|
|         | 2015 | 2016 | Average per 2 years |
| Forum-st. | 48   | 55   | 51                       |
| Oredez 1  | 38   | 43   | 40                       |
| Oredez 2  | 38   | 43   | 30                       |
| Oredez 4  | 35   | 39   | 37                       |

The Oredez 4 rapeseed variety has emerged as a precocious variety over the years of research. Varieties Oredez 1 and Oredez 2 in 2015 also showed themselves as precocious and the period of mowing ripeness came for them on day 38, and in 2016 these varieties belonged to the group of medium-ripened (43 days). The period of mowing ripeness in 2015 in the variety Forum-st. it was 48 days, while in 2016 the period of mowing ripeness was 55 days and it belongs to the group of late-maturing.

Analyzing the growth of spring rapeseed plants, we can draw the following conclusions: in the period from June to July, spring rapeseed plants grew at an intensity of 1.65 – 2.09 cm/day, rapeseed of the Oredez 4 variety grew more intensively in 2015 (2.04 cm/day) and in 2016, the Oredez 2 variety grew at a rate of 2.09 (table 3).
Table 3. Growth rate of spring rapeseed over 2 years of research (cm per day).

| Variety   | June, 15–July, 21 | July, 21–August, 22 |
|-----------|-------------------|---------------------|
|           | 2015   | 2016   | 2015   | 2016   |
| Forum-st. | 1.83   | 1.82   | 0.68   | 0.72   |
| Oredezh 1 | 1.88   | 1.89   | 0.90   | 0.94   |
| Oredezh 2 | 1.88   | 2.09   | 1.13   | 0.65   |
| Oredezh 4 | 2.04   | 1.65   | 0.86   | 1.38   |

When analyzing data for the dynamics of rapeseed plant growth over two years of research, the length of the stem was distinguished by rapeseed varieties Oredezh 2:1.27 m, the shortest-stemmed plants were those of the Forum-St. (1.09 m), and plants of the Oredezh 1 and Oredezh 4 varieties were almost at the same level (1.23-1.21 m) (figure 1, table 4).

The height of spring rape plants in 2015 did not differ much (lower by 0.1–0.2%) from the height of rapeseed plants in 2016.

When comparing the indicators of the conducted field experience and data from literature sources, we can conclude that the height of rapeseed plants in 2015 and 2016 was low, this is due to adverse weather conditions, lack of moisture during the growing season in 2015, and excessive soil moisture and low air temperatures in 2016.

Despite adverse weather conditions, spring rape of the Oredezh 2 variety gave good prerequisites for the herbage formation.

Table 4. Spring rapeseed plants height, m, per 2015–2016.

| Variety   | June, 15 | July, 21 | August, 22 | Average height |
|-----------|----------|----------|------------|---------------|
|           | 2015     | 2016     | 2015       | 2016          |
| Oredezh 1 | 0.20     | 0.20     | 0.90       | 0.90          | 1.21          |
| Oredezh 2 | 0.21     | 0.26     | 0.29       | 1.04          | 1.29          | 1.25          | 1.27          |
| Oredezh 4 | 0.17     | 0.18     | 0.93       | 0.79          | 1.21          | 1.24          | 1.23          |
| Forum-st. | 0.19     | 0.18     | 0.87       | 0.85          | 1.09          | 1.09          | 1.09          |

Figure 1. Spring rapeseed plants height graph (per 2 years).

The analysis of spring rapeseed plants morphological structure was carried out during the bean formation phase, on 10 plants from each plot.

After analyzing the research data for two years, we can draw the following conclusions: the main mass of spring rape plants is made up of stems (57.2–62.9%), the share of leaves falls from 23.6 to
20.45%. The percentage of the flowers weight from the plant mass is 6.55-4.15%, roots – 9.4-7.5%, and beans – 2.6-8.15%.

During the years of research, the morphological structure was different, and it also differed between varieties of spring rape (table 5).

For example, in 2015, the percentage of leaves in plants of the Oredezh 2 and Oredezh 4 varieties (15.8-17.5%) was lower compared to other studied varieties (Oredezh 1-25.7%, Forum-st. – 21.3%), as well as in 2016. The percentage of leaves in plants of Oredezh 1 and Forum-st. varieties in 2015 was lower than in 2016 by 4.2-1.7%.

**Table 5. Spring rapeseed morphological structure.**

| Variety      | leaves weight, % | caules weight, % | flowers weight, % |
|--------------|------------------|------------------|-------------------|
|              | 2015 average     | 2015 average     | 2016 average     |
| Oredezh 1    | 25.7             | 21.5             | 32.6             |
|              | 53.8             | 60.6             | 57.2             |
|              | 4.2              | 4.1              | 4.15             |
| Oredezh 2    | 17.5             | 19.6             | 18.55            |
|              | 31.6             | 60.4             | 60.9             |
|              | 4.5              | 5.4              | 4.95             |
| Oredezh 4    | 15.8             | 16.9             | 16.36            |
|              | 62.07            | 62.9             | 62.48            |
|              | 5.03             | 5.6              | 5.31             |
| Forum-st.    | 21.3             | 19.6             | 20.45            |
|              | 62.2             | 63.6             | 62.9             |
|              | 6.3              | 6.8              | 6.55             |

The percentage of caules from the total weight of spring rapeseed plants in 2016 in the studied varieties was higher than in 2015 by 0.83-7.8%, as well as the percentage of flower weight. In the Forum-st. variety, the percentage of flower weight was higher than in other varieties in both 2016 (6.8%) and 2015 (6.3%).

During the growing season, the proportion of leaves decreases, and the generative organs increase.

Spring rapeseed is a promising forage crop for the non-chernozem region. The significance of rapeseed feed is determined by a sufficient protein content and low fiber content. The rapeseed herbage contains 0.12-0.16 caloricity units, 20-30g of digestible protein, up to 31% protein per absolutely dry substance, a lot of vitamins and mineral salts, and the composition of trace elements green mass of spring rapeseed herbage is equal to the vetch-oat mixture. The green mass of rapeseed is used as a green feed and for preparing silage.

In the years of research (2015-2016), two mowing of the green mass was carried out, and based on the results of these data; we can conclude that the meteorological conditions in 2016 were more favorable for obtaining the green mass of spring rapeseed. In 2015, the first mowing was carried out during the flowering phase - the formation of beans, the highest yield of green mass was obtained from the Oredezh 2 variety (2.96 tpha), the yield indicators of the Forum-st. and Oredezh 1 were almost at the same level (2.17-2.18 tpha), Oredezh 3 occupied the second position-2.40 tpha. The second mowing was carried out 45 days after the first mowing, as in the first mowing, the highest yield was in rapeseed of the Oredezh 2 variety, the Oredezh 1 variety was more productive (0.91 t/ha) of the Oredezh 4 variety (0.86 tpha).Rapeseed variety Forum-art. it did not show high yield results (0.56 tpha) (table 6).

**Table 6. Herbage yield of spring rapeseed, average per 2015–2016 (tpha).**

| Variety      | Mowing 1 | Mowing 2 | During vegetation period |
|--------------|----------|----------|--------------------------|
|              | 2015     | 2016     |                          |
| Oredezh 1    | 2.18     | 0.91     | 3.09                     |
| Oredezh 2    | 2.96     | 1.04     | 4.00                     |
| Oredezh 4    | 2.40     | 0.89     | 3.26                     |
| Forum-st.    | 2.17     | 0.56     | 2.73                     |

|              | 2016     |          |                          |
|--------------|----------|----------|--------------------------|
| Oredezh 1    | 3.45     | 0.36     | 3.81                     |
| Oredezh 2    | 3.91     | 0.45     | 4.36                     |
| Oredezh 4    | 3.49     | 0.42     | 3.91                     |
| Forum-st.    | 2.44     | 0.39     | 2.83                     |
The yield of spring rapeseed herbage in 2016 was significantly higher than the 2015th crop. This becomes noticeable when comparing data from the first mowing. Variety Oredezh 2, as in 2015, was the most productive - 3.91 t/ha, and the yield of the Forum variety-art. it was also low - 2.44 t/ha, the yield of varieties Oredezh 1 and Oredezh 4 was almost the same (3.45-3.49 t/ha). The second mowing in 2016 was lower than the second mowing in 2015, and the yield of green mass was almost the same (0.36-0.45 t/ha).

Analyzing the mowing data for two years we can note the following: the most productive variety for the years of research on green mass was Oredezh 2, it gave stable and high yields of green mass (table 7). The weight of the green mass of spring rape in the Oredezh 1 variety (3.45 t/ha) was slightly inferior to the Oredezh 4 variety (3.58 t/ha), the variety Forum-st. was the worst-yielding – 2.78 t/ha (figure 2).

| Variety   | 2015  | 2016  | Average |
|-----------|-------|-------|---------|
| Oredezh 1 | 3.09  | 3.81  | 3.45    |
| Oredezh 2 | 4.00  | 4.36  | 4.18    |
| Oredezh 4 | 3.26  | 3.91  | 3.58    |
| Forum-st. | 2.73  | 2.83  | 2.78    |

Figure 2. Herbage yield of spring rapeseed over the years of research (average per 2015-2016).

The main indicators that determine the productivity of the rapeseed varieties herbage are: plant height (109.7-127.4), % ratio of leaf weight (16.36 - 21.5%) and caules weight (57.2-62.4%).

In single-species crops, Oredezh 2 rapeseed (41.8 t/ha) provided a higher yield of herbage compared to other varieties, on average for two years of research.

4. Conclusion
In order to make conclusions about the research, it should be noted that spring rapeseed is a promising high-protein crop of universal use for the development of the non-chernozem zone forage base. For its successful cultivation, certain conditions must be met, including the use of precocious crop varieties.

According to the results of our research, the Oredezh 4 rapeseed variety showed itself as a precocious variety and the period of mowing ripeness came on its 37th day. Varieties of rapeseed Oredezh 1 and Oredezh 2 showed themselves as precocious and the period of mowing ripeness came to them on the 40th day.
When analyzing data on the height of rapeseed plants for two years of research, Oredezh 2 – 1.27 m rapeseed was distinguished by the length of the caules. The plants with the shortest caules were Forum-st. 1.09 m.

After analyzing the research data for both years on the morphological structure, we can conclude that the main mass of spring rape plants is made up of stems (57.2–62.9%), the share of leaves falls from 23.6 to 20.45%. The percentage of flower weight from the mass of the plant is 6.55–4.15%.

A high yield of green mass after the first mowing was obtained from the Oredezh 2 variety (2.96 tpha) in 2015, the yield indicators of the Forum-st. and Oredezh 1 were almost at the same level (2.17-2.18 tpha). The second mowing was carried out 45 days after the first and the highest yield were also for Oredezh 2 rapeseed - 1.04 tpha. The yield of spring rapeseed herbage in 2016 was significantly higher than the 2015<sup>th</sup> crop. The Oredezh 2 rapeseed variety was the most productive-3.91 tpha, the yield of Oredezh 1 and Oredezh 4 varieties was almost the same (3.45-3.49 tpha).

The most productive variety for years of research on the herbage was Oredezh 2, it gave stable and high yields of herbage. The yield of rapeseed herbage the spring variety Oredezh 1 (3.45 tpha) was slightly inferior to the Oredezh 4 (3.58 tpha), the Forum-st. variety was the most unsuccessful – 2.78 tpha.

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