Productivity of seed peas Nemchinovsky 50 in mixed crops with cereals

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Abstracts. Peas is the best-known annual legume forage crop. Creation of a new variety of seed peas Nemchinovsky 50 is a breeding approach to solve the problem of vegetable protein and the production of high-quality feed with a high protein content in grain and in concentrated feed with a high content of essential amino acids (lysine, tryptophan). The analysis of long-term data showed that under various agrometeorological conditions of environmental testing, the variety was characterized by resistance to lodging and major diseases, good productivity in comparison with the previously bred variety Nemchinovsky 100. The increase in yield was facilitated by its high productivity (laying of fertile nodes), the number of seeds in a pod (4-5 pieces), the mass of 1000 seeds is at the level of 180-190 g with a protein content in the grain about 26-28%.

1. Introduction
In 2019, the seed pea variety Nemchinovsky 50 was included in the State Register of Breeding Achievements of the Russian Federation and approved for use in the North-West region. A patent No. 10111 of November 27, 2019 was received for it. Provided that the technology of cultivation, storage and processing of grain are followed, the new variety guarantees production of high-quality raw materials for the feed industry [1, 2].

Modern pea varieties, in particular Nemchinovsky 50, are sown both in pure form for grain and in mixed crops with cereals for the production of concentrated feed for animal husbandry. When sowing seed peas with cereals (wheat, barley, oat), it is necessary to take into account the purpose for which these crops will be used. When sowing for the production of food grains and grain feed, the ratio of the sown crops should be 70% of the cereal component (3.5 million) and 30% of legumes (0.5 million). For the production of concentrated feed, silage and haylage, the share of the legume component can be increased to 50% (0.7-0.8 million). With its increase in mixed crops with cereals, the yield of metabolic energy (ME) and the collection of dry matter (DM) from an area unit increases [3]. It is necessary to take into account in which direction these crops will be used.

When choosing varieties of peas and cereals for mixed crops, it is necessary to take into account the compatibility of varieties regarding the length of the growing season, because mismatch in time of their biological maturity can lead to significant complications during harvesting, including loss of yield and deterioration of its quality during harvesting for grain fodder [4].
2. Materials and methods

The work on the creation of a peas variety adapted to the zonal conditions Nemchinovsky 50 was carried out by methods of traditional plant breeding according to the complete scheme of the breeding process. Phenological observations, measurements and records were carried out according to the State Commission for Selection Achievements Test and Protection [5, 6].

The material for the research were varieties created in Federal Research Center "Nemchinovka": seed peas Nemchinovsky 50, spring wheat Lisa, barley Moskovsky 86 and oat Zalp. The task of the research was to obtain the maximum harvest of grain and green mass in mixed crops.

The research was conducted in 2018-2020. The experiment was laid with the seeding rate of 1.2 million grains of peas in pure form and in mix sowing; of 3 million cereal grains in mix sowing and 5 million grains in single-species sowing.

The experiment was laid in the breeding crop rotation of the Federal Research Center "Nemchinovka". The soil of the experimental site is sod-podzolic medium loamy. After harvesting the predecessors, the arable (0-20 cm) layer contained: humus 1.5-1.7%, P2O5 and K2O (0.2 HCl according to Kirsanov) 160-300 and 130-220 mg/kg, respectively, pH KCl - 5.3-6.7, Ng (according to Kappen-Gilkovits) - 0.94-2.62 mEq/100 g. The soil is well cultivated, NPK mineral fertilizers were applied for sowing at the dose of 48 kg of active matter per 1 hectare. Plot area amounted to 10 m² in 4-fold replication. The sowing was carried out at the end of April with a portioned device of the SSK-6-10 seeder. The tillage system is generally accepted for the region. Harvesting was carried out at full maturity of the plants by using a Xege-125 harvester.

The meteorological conditions over the years of research (2018-2020) differed significantly both in temperature and in the amount of precipitation, which significantly affected the volumes of the yield of aboveground biomass and grain [7, 8].

The growing seasons 2018-2020 were distinguished by the aridity in the beginning of the growing season (Figure 1). But, during the active growth of pure and mixed crops of leguminous crops with the participation of peas in 2018 the deficit of precipitation in the first half of it was accompanied by lower air temperatures, which reduced evaporation and did not lead to a noticeable decrease in biomass accumulation, and did not worsen the conditions for grain formation. In 2019 a more pronounced lack of precipitation at significantly higher average daily air temperatures, as will be shown below, markedly reduced nitrogen fixation and with it the yield of aboveground mass and grain. In the third decade of 2020, a large amount of precipitation took place, which led to partial flooding of crops. Also, throughout the growing season during 2020, there was a large amount of precipitation, sometimes heavy rainfall, which led to excessive waterlogging of the soil. Only in August 2020, the amount of precipitation decreased, which allowed the plants to lose excess moisture in the grain for harvesting period (Figure 2).

The growing seasons 2018-2020 were distinguished by the Hydrothermal Humidity Coefficient (HHC). The average monthly HHC values during May-August in average annual terms under the conditions of 2018 were 0.66-0.87 and 1.99-0.51, respectively by periods, and in 2019 varied in the range of 1.04-0.76, gradually decreasing from the beginning until the end of the growing season. On average, during the growing season, the HHC were 1.96, 1.00 and 0.84, respectively over the years (at a norm of 1.52). In 2020, the HHC increased from the third decade of May to the first decade of August and amounted to 3.47 and 2.63 (Figure 3).
Figure 1. Average daily temperature, °C 2018-2020.

Figure 2. Amount of precipitation 2018-2020.
3. Results and discussion

At present, the compatibility of varieties for production of cereals grain fodder (oat, spring barley, wheat) and leguminous crops, primarily seed peas, remains an urgent task. The creation of new varieties of cereals and leguminous crops is aimed primarily at increasing grain yields in order to obtain balanced feed in protein and essential amino acids. The creation of sustainable agroecologies allows to increase the balanced feed base for farm animals.

When choosing support cultures and varieties, it is necessary to strive to ensure that the harvesting ripeness occurs simultaneously for both components. Mixed sowing facilitates mechanized harvesting and provides seeds with high sowing quality. It is necessary to combine the number of plants of each component per area unit to obtain the optimal leaf surface area and did not cause a negative effect of competition for light, moisture and nutrients when selecting components for mixed agrophytocenosis.

Table 1 presents data on a number of plants, height and lateral development in single-species and mixed crops.

In terms of the number of cereal plants, mixed crops with barley and oats varieties stand out for all three years of research. This is due to the better lateral development compared to spring wheat. The best lateral development for cereals was shown in 2020 for oat Zalp and barley Moskovsky 86 with the indicators of 1.6 and 1.9 plants. Over the two previous years, productivity was lower due to poor soil moisture supply during the tillering period. For 3 years of research Zalp oat stands out on plant height and, accordingly, on the accumulation of green mass of plants, both in single-species and in mixed sowing with peas. The height of oat plants in the single-species crops averaged 76.3 cm and 66.7 cm when mixed with peas.

Along with this, the height of plants also increases with the increase in moisture supply for peas Nemchinovsky 50 and oat Zalp, both in single-species and in mixed crops. The best result of research over the years on plant height is observed in peas Nemchinovsky 50 in the variant with oat and in pure form in 202, which amounts 71 cm and 79 cm. This figure is 89 cm in oat plants, both in pure form and mixed sowing with peas.
Table 1. Number of plants, height and lateral development in single-species and mixed crops 2018-2020.

| Variety                          | 2018     | 2019     | 2020     |
|----------------------------------|----------|----------|----------|
|                                  | Number of plants pcs/m² | Lateral development, pcs | Heigt, cm | Number of plants pcs/m² | Lateral development, pcs | Heigt, cm | Number of plants pcs/m² | Lateral development, pcs | Heigt, cm |
| Seed peas Nemchinovsky 50        | 299      | ---      | 59       | 350      | ---      | 50       | 288      | ---      | 79       |
| Spring wheat Lisa               | 154      | 1.5      | 58       | 174      | 1.2      | 56       | 332      | 1.3      | 68       |
| Oats Zalp                       | 259      | 1.4      | 65       | 263      | 1.4      | 75       | 246      | 1.6      | 89       |
| Barley Moskovsky 86             | 280      | 1.7      | 56       | 221      | 1.4      | 65       | 313      | 1.9      | 66       |
| Spring wheat Lisa + seed peas   | mix      | 233      | ---      | 165      | ---      | 265      | ---      | ---      | ---      |
| Nemchinovsky 50                 | cereal   | 161      | 1.2      | 66       | 51       | 1.2      | 53       | 1.2      | 66       |
|                                 | peas     | 114      | ---      | 58       | 114      | ---      | 50       | 122      | ---      | 73       |
| Barley Moskovsky 86 + peas      | mix      | 242      | ---      | 316      | ---      | 322      | ---      | ---      | ---      |
| Nemchinovsky 50                 | cereal   | 119      | 2.3      | 62       | 188      | 1.4      | 59       | 1.5      | 62       |
|                                 | peas     | 123      | ---      | 62       | 128      | ---      | 49       | 162      | ---      | 74       |
| Oats Zalp + Nemchinovsky 50     | mix      | 301      | ---      | 245      | ---      | 231      | ---      | ---      | ---      |
|                                 | cereal   | 182      | 1.6      | 50       | 149      | 1.3      | 69       | 1.6      | 89       |
|                                 | peas     | 119      | ---      | 68       | 96       | ---      | 46       | 89       | ---      | 71       |

Table 2 shows the yield data for single-species crops of peas and cereals for 3 years. The data presented in Table 2 indicate that oats Zalp stands out for the indicator of an average yield of grain at 3.1 t/ha and green mass – 29.9 t/ha. Further, with the yield data for grain and green mass, there are barley Moskovsky 86 and peas Nemchinovsky 50 – 2.15 t/ha, 1.93 t/ha and 22.25 t/ha, 24.15 t/ha, respectively.

Spring wheat Liza did not declare itself during three years of research due to contrasting meteorological conditions. The grain yield of spring wheat averaged 1.44 t/ha with a yield of green mass of 12.7 t/ha. The low yield of grain and green mass of spring wheat can be explained by the fact that the moisture reserve in 2018 and 2019 during the tillering period was critically small for the growth and development of plants.
Wheat plants were unable to fully pass the tillering phase and to establish a good number of productive stems at the low level of total tillering. The grain content of cereals was low. The plants formed a small number of grains in the ear and panicle, but the grains were filled well. This is evidenced by the data of the mass of 1000 grains for each presented culture.

The mass of 1000 pea grains averaged 155.2 g, which is a low figure for this variety. With good moisture supply of soil and average indicators of the temperature regime in summer, this indicator usually is 185-190 g.

### Table 2. Productivity of seed peas and cereals in single-species crops 2018-2020.

| Culture, variety       | Single-species, t/ha | Productivity of green mass, t/ha | Mass of 1000 grain, g | Protein content in grain, % |
|------------------------|----------------------|----------------------------------|-----------------------|----------------------------|
|                        | 2018 | 2019 | 2020 | 2018 | 2019 | 2020 |                      |
| Seed peas Nemchinovsky 50 | 1.65 | 1.63 | 2.51 | ---  | 18.0 | 30.3 | 155.2 | 27.5 |
| Spring wheat Lisa      | 1.53 | 1.51 | 1.28 | ---  | 8.0  | 17.4 | 40.6  | 14.1 |
| Barley Moskovsky 86    | 2.23 | 2.53 | 1.70 | ---  | 21.0 | 23.5 | 52.3  | 14.3 |
| Oat Zalp               | 1.48 | 3.53 | 4.29 | ---  | 25.5 | 34.2 | 36.5  | 13.0 |

Table 3 shows the yield of grain and green mass of seed peas Nemchinovsky 50 for 2018-2020 in mixed sowing with cereals.

### Table 3. Grain yield of seed peas Nemchinovsky 50 mixed with varieties of cereals.

| Variant                        | Grain yield, t/ha | Yield of green mass, t/ha |
|--------------------------------|------------------|---------------------------|
|                                | 2018 | 2019 | 2020 | 2019 | 2020 |
|                                | mix  | mix  | mix  | peas | cereal | peas | cereal |
| Seed peas Nemchinovsky 50 +    | 2.09 | 1.84 | 3.14 | 2.01 | 19.0   | 1.5  | 6.30   | 31.2 |
| Spring wheat Lisa              | 2.56 | 1.65 | 3.40 | 1.91 | 8.5    | 10.5 | 7.20   | 34.9 |
| Seed peas Nemchinovsky 50      | 2.65 | 2.29 | 3.40 | 1.91 | 8.5    | 10.5 | 7.20   | 34.9 |
| Barley Moskovsky 86            | 2.45 | 1.18 | 3.40 | 1.91 | 8.5    | 10.5 | 7.20   | 34.9 |
| Seed peas Nemchinovsky 50 +    | 2.01 | 1.6  | 3.26 | 0.80 | 5.01   | 1.24 | 11.0   | 22.8 |
| Oats Zalp                      | 3.26 | 0.80 | 5.01 | 1.24 | 11.0   | 15.0 | 15.30  | 22.8 |

The numerator is the grain mixture yield; denominator is pea yield.

The yield of the peas-cereal mixture in 2018 was lower compared to 2019 due to the May drought during the germination and tillering of the cereal component and seedlings, which formed 3-5 true leaves of seed peas. This was reflected in the overall productivity of crops by the time of harvesting. The lowest yield demonstrated mix of peas with spring wheat Liza and oat Zalp in 2018 at the level of 2.09 t/ha and 2.01 t/ha respectively. Due to the low bushiness and the number of productive stems, the yield of wheat
and oat was low amounting 0.41 t/ha and 0.25 t/ha. The grain yield of cereal crops was also, affected by the drought during the period of grain filling, which affected the mass of grain from the ear.

The meteorological conditions in 2019 were also accompanied by a drought in May, but later, during the period of flowering and the formation of beans in peas and grain filling in wheat, the moisture supply of crops was at the level of average long-term values with a slight excess in temperature. As the result, the grain yield of spring wheat Liza and barley amounted to 2.56 t/ha and 2.45 t/ha. The yield of peas Nemchinovsky 50 and oat Zalp exceeded the mixed crops with wheat and barley and amounted to 3.26 t/ha.

In 2020, the yield of grain of peas and cereal mix was significantly higher and ranged from 3.14 t/ha with spring wheat Lisa to 5.01 t/ha in the variant with oats Zalp. The yield growth was at the expense of cereal crops in all the variants – due to better bushiness and good moisture supply in the phase of tillering, flowering and grain filling. Yields of peas by variants and years ranged from 1.6 t/ha to 2.01 t/ha except for the variant with oats in 2019, where it was 0.80 tons per hectare.

The output of the grain received in 2019 was significantly different from 2018. Thus, the greatest ratio of legumes - cereals component was in the version with barley according to the 2018 data. The grain ratio was almost 50:50 in a mixed crop of peas and barley in 2019. In the variant with oats, the ratio of the grain of peas and oats was 1:3 and amounted to 0.8 t/ha of peas and 2.46 t/ha of oats. The ratio of pea grain and wheat was 40:60 in the variant with spring wheat.

Because of the different lateral development of the cereal component in the mixture with peas, the percentage of legumes - cereal mixture in the green mass varied significantly. Thus, the largest amount of the grain legumes component was in the version with spring wheat at 19.0/1.5. In the version with barley and oat this number was at 8.5/10.5, 11.0/15.0 and 15.3/22.8 respectively. Experiment options with barley and oat seem to be preferable to spring wheat because of the better ratio of legumes - cereal component with a high yield of raw protein, fiber, exchange energy for the harvesting of concentrated feed, silage and hay.

4. Conclusions
Meteorological conditions of the year (temperature, precipitation and HHC) significantly affect the passage of plant development phases. Lack of moisture in the initial period of plant development entails low yield of grain and green mass, low grain content in the ear.

These experiments show that mixed crops of seed pea Nemchinovsky 50 with oats and barley are preferable for the harvest of grain and green mass, preparation of concentrated feed, as well as silage and haylage. The harvested green mass is balanced by essential amino acids, especially lysine and tryptophan compared to mixed pea and spring wheat crops.

Options for sowing grain crops with seed peas Nemchinovsky 50 are suitable for seed production of this variety.

The experience of seed production of legumes with cereals is preferred because of peas lodging in poor meteorological conditions of the year: high rainfall and strong winds during flowering and grain filling pea plants lie down.

The option of seed production of barley Moskovsky 86 is the best due to the best ratio of peas and cereals in the mixture - 2:1.

On average for 2 years oats grain yield in mixed crops was 2.63 t/ha, with barley 2.50 t/ha and wheat 2.32 t/ha. When processing the harvested grain mixture into grain feed, the best option regarding nutrition and balance of essential amino acids in the prepared feeds is to sow barley with field peas. Eating and digestability of feed is better, compared to oats and spring wheat.

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