Prospective directions for the development of grain farming in the region, taking into account zonal features (on the example of Penza region)

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Abstract. The most important task in the sphere of agro-industrial complex management in the region is to identify new points of growth and competitive advantages of agricultural sectors, based on the rational use of available resources and minimization of the negative impact of factors constraining the development of production. An analysis of dynamics and distribution of grain crops production has shown that in view of development of industrial crops, the maintenance of stable grain production at the level of 2.7-3.0 million tons is possible due to intensification of grain and leguminous crops production and introduction of new high-yielding and demanded in the market agricultural crops into crop rotations. Intensification of grains and legumes production in Penza region must be based firstly on raising the sown areas sown with seeds of higher reproductions for providing of scientifically grounded varietal changes and variety renovation. The implementation of this task will be possible if a modern system of breeding and seed production of grain crops is established in the region. Preservation of soil fertility and reduction of the grain crop production cost can be achieved by reducing the application of nitrogen fertilizers and increasing the share of profitable leguminous crops, such as peas, lentils, and lupine, in the structure of crop rotations. Grain maize has a significant potential for diversification and increase in grain production, if agrotechnics, zoned and promising varieties and hybrids adapted to soil and climatic conditions of the region are introduced. Sustainable production of grain and leguminous crops in the region is impossible without modernization of existing and creation of new capacities on storage and processing of grain crops. Realization of complex of scientific-production and organizational-economic and program-targeted measures is of great importance.

1. Introduction
The crop farming industry in Penza region is developing dynamically, and crop rotations are characterised by maximum saturation with highly profitable crops, primarily wheat, sunflower and sugar beet. Between 2016 and 2020, the area sown with grain and legume crops increased to 850,000 ha, with gross production exceeding 3.2 million tonnes in 2020.

Instead of optimal 10-16% in the structure of crop rotations, sunflower in Vadinsk-Mokshan zone takes 20% on average, in Belinsk-Serdobsk - 24.5%, Kuznetsk-Lopatino - 20%. Further expansion of sown areas of sugar beet is limited by production capacity of sugar factories. In this connection agricultural commodity producers of the region face the problem of scientific-based structure of crop
rotations on condition of inclusion of new profitable crops, which are in demand on the market and adapted to the soil-climatic conditions of one or another zone.

2. Results
When analyzing the current state of production of grain and leguminous crops in order to determine the prospects of grain farming development it is advisable to take into account soil-climatic and economic features of 4 zones allocated in the region (Table 1).

Table 1. Natural and economic zones of Penza region.

| №  | Indicators                                      | Vadinsk-Mokshan | Belinsk-Serdobsk | Nikolsk-Gorodishche | Kuznetsk-Lopatino |
|----|------------------------------------------------|-----------------|-----------------|--------------------|-------------------|
| 1  | Number of municipal areas (units) / sown areas, thousand ha | 12 / 631.1      | 7 / 501.6       | 3 / 63.9           | 5 / 197.6         |
| 2  | Ball rating of arable land by productivity      | 29.4 to 24.2    | 37.0 to 28.7    | 19.0 to 15.0       | 25.8 to 24.0      |
| 3  | Period of active plant vegetation, days         | 136-142         | 138-144         | 135                | 138-144           |
| 4  | Number of elevators, units/thousand tonnes of single storage | 11/758          | 8/652           | 1/20               | 2/166             |

Since 2016, there has been a positive trend in the area of grain and leguminous crops, with an increase of 136 thousand ha, or 16%, in the period from 2016 to 2020. Gross grain production in 2020 was 3.2 million tonnes, the highest since 1974. Due to the intensification of cereal crops production, the average yields have increased considerably. In 2000-2009, average yields of cereals varied from 1.4 to 2.0 tons per hectare and in 2000-2009 averaged 1.56 tons per hectare; in 2011-2020 the average yields reached 2.517 tons per 1 ha or 162% of the level achieved in 2000-2009.

At the same time, a number of problems still restrain the development of the region's grain sector. The main of them are: insufficient level of development of breeding and seed production system, as a result of which more than a half of areas under grain and leguminous plants are sown with seeds of mass reproductions. In addition, with the growth of grain production in the region there is the lack of elevator capacities. Taking into account existing prerequisites for sustainable grain production in the region of 2.7-3.0 million tonnes, the shortage of modern storage and drying capacities may exceed 0.4-0.5 million tonnes. Lack of modern cereals and legumes production capacities, as well as other cereals processing products; the region's climatic conditions do not allow for mass production of quality class I and II wheat, limit the development of maize and chickpea production.

The production of grain and leguminous crops plays a leading role in the development of the region's agro-industrial complex. Grain and leguminous crops accounted for 50.6% in the structure of crop production sold by agricultural organisations in 2018-2020.

The main area of specialisation of the region's grain farming is the production of winter and spring wheat; its share in the structure of grain sold by agricultural organisations in the region exceeded 75% in 2017-2020 (Table 2).

Table 2. Structure of grain sales by agricultural organisations in Penza region, %.

| Period   | wheat | rye | millet | buckwheat | rgrain | barley | oats | grain- leguminous |
|----------|-------|-----|--------|------------|--------|--------|------|------------------|
| 2005-2009| 64.5  | 7.5 | 0.4    | 0.5        | 0.1    | 19.6   | 3.8  | 3.6              |
| 2016-2020| 75.0  | 0.3 | 0.2    | 0.4        | 6.1    | 14.2   | 0.4  | 3.4              |

The increase in the share of wheat in the structure of grain sales is due to the increase in its production. In 2016-2020, the average gross yield of this crop reached 1,086,000 tonnes, which is almost
three times higher than in 2006-2009. The key factors ensuring the development of wheat production are the intensification of its production that leads to an increase in average winter wheat yield from 2 tons per ha on average in 2005-2009 to 3.4 tons per ha on average in 2016-2020, or by 70%; spring wheat area increase by 36% (Table 4), and average yield from 1.53 tons per ha in 2005-2009 to 2.8 tons per ha in 2016-2020. This situation is typical for all 4 natural-economic zones of the region [11].

At the same time the specific weight of winter rye decreased to 0.3 %, which was caused by the reduction of cultivated areas by almost 10 times in comparison with the level of 2005-2009. This is caused by the fall in demand for winter rye by food industry enterprises of the region, its displacement from crop rotation by more productive and demanded winter wheat (Table 3). The conditions of Penza region are optimal for the cultivation of this crop, which is less demanding to soil and climatic conditions than wheat. In this regard, winter rye has the largest share in the structure of the grain wedge - 13.2% in the Nikolsk-Gorodisheche zone (Table 4). Over the past ten years, the dynamics of buckwheat and millet sown areas has been characterised by sharp fluctuations (Table 3) due to market conditions. One of the important factors negatively affecting the sustainability of production of these crops in Penza region is the lack of a cereal plant that provides a relatively stable demand for these types of crops. The main production of buckwheat is concentrated in Vadinsk-Mokshan and Belinsk-Serdobsk areas. The sown areas of millet are distributed relatively evenly across the soil-economic zones of the region, due to the high adaptive properties of this crop (Table 4).

Dynamics of the sown areas and volumes of barley and oats production is caused by demand on the given crops from enterprises of the compound feed industry, and also concerning brewing barley from breweries. The development of their processing into cereals and other types of products demanded in the food market can become an additional factor in the growth of production of these crops [10].

Table 3. Dynamics of sown area and gross harvest of cereals, leguminous crops and soybeans in Penza region.

| Indicators                              | 1986-1990 | 2005-2009 | 2016 | 2017 | 2018 | 2019 | 2020 | 2016-2020 |
|-----------------------------------------|-----------|-----------|------|------|------|------|------|-----------|
| Sown area of cereals and leguminous crops, thousand ha                               |
| Total winter crops:                    | 500.9     | 362.5     | 300.9| 308.8| 323.8| 331.5| 378.2| 328.6     |
| winter wheat                           | 176.0     | 287.6     | 287.6| 299.2| 316.7| 325.8| 369.8| 319.8     |
| winter rye                             | 325.0     | 73.5      | 11.5 | 8.5  | 6.4  | 5.2  | 7.9  | 7.9       |
| Total spring crops:                    | 727.6     | 359.3     | 383.5| 367.9| 340.2| 430.1| 437.7| 391.9     |
| spring wheat                           | 154.8     | 131.8     | 165.9| 144.5| 144.8| 213.3| 226.0| 178.9     |
| barley                                 | 198.4     | 130.7     | 146.9| 94.9 | 116.5| 132.2| 120.6| 122.2     |
| oats                                   | 255.5     | 70.7      | 34.4 | 31.0 | 31.8 | 34.1 | 28.2 | 31.9      |
| buckwheat                              | 26.2      | 11.1      | 25.3 | 31.6 | 6.1  | 3.9  | 4.3  | 14.2      |
| millet                                  | 92.7      | 14.2      | 4.2  | 3.9  | 5.5  | 6.0  | 10.3 | 6.0       |
| grain maize                             |           |           | 0.8  | 38.7 | 50.5 | 26.5 | 31.5 | 37.7      |
| leguminous crops including:            |           |           |      |      |      |      |      |           |
| peas                                    | 151.4     | 9.5       | 17.4 | 25.5 | 29.2 | 27.5 | 25.6 | 25.1      |
| lentil                                  | 1.1       | 0.3       | 3.1  | 9.1  | 16.1 | 6.1  | 3.5  | 7.6       |
| lupine for grain                       | 0.1       | 0.04      | 2.8  | 2.3  | 2.3  | 3.2  | 2.6  | 2.7       |
| other leguminous crops                 | 23.05     | 20.2      | 5.3  | 7.2  | 5.8  | 2.1  | 2.9  | 4.6       |
| Gross harvest of cereals and leguminous crops, thousand tonnes                |
| 1848.7                                 | 1183.0    | 1943.9    | 2370.4| 1744.6| 1856.8| 3221.7| 2227.5 |          |

The growing interest in production of maize for grain among agricultural producers in the region has led to an increase in the share of this crop in the structure of grain sales from 0.1 % in 2007-2009
to 6.1% in 2018-2020. Maize production is developing dynamically in the Russian Federation. Thus, from 2010 to 2020 the sown area increased from 1,410 thousand ha to 2,855 thousand ha respectively or 2 times [11].

The development of maize production in Penza region in industrial volumes started in 2008, when its areas sown reached 1.6 thousand hectares. In earlier period maize was practically not grown in the region; from 2000 till 2007 its areas sown varied from 5 to 180 ha. The development of maize production in Penza region was promoted by: introduction of early-ripening maize hybrids, the amount of positive temperatures during the growing season is enough to form a grain crop in the conditions of the most part of the region; growth of demand for this crop from the feed industry due to the significant increase in livestock and poultry, in the framework of large investment projects in meat poultry and pork production; availability of demand for maize from the distilleries [1].

The dynamics of sown areas of maize in Penza region was characterised by significant fluctuations (Table 3). In 2019-2020 there was a recovery of sown areas of this crop and in 2020 they amounted to 37.7 thousand hectares or 75% to the level of 2017, the positive trend continues according to operational data in 2021. With the selection of varieties and hybrids of maize, adapted to the conditions of a particular soil and economic zone and correct agrotechnics in 2019-2020 in Penza region there was an increase in the average yield of maize in farms of all categories to 5.55 tons per 1 ha, in agricultural organizations the average yield was 6 tons per 1 ha. Agricultural commodity producers of Spassk, Bekovo and Belinsk regions achieved the average yield of 9.2, 7.5 and 6.8 tons per 1 ha accordingly. The growth of maize yield and its selling prices in 2020 made it possible to achieve the profitability of the crop sales - 30%, the amount of profit per 1 ha was 15.5 thousand rubles. [8]

Table 4. Location of cereal and legume crop production in the region (data are average for 2016-2020).

| Indicators               | Vadinsk-Mokshan area | Belinsk-Serdobsk area | Nikolsk-Gorodishche area | Kuznetsk-Lopatino area |
|--------------------------|-----------------------|-----------------------|--------------------------|------------------------|
|                          | Sown area, thou.s.    | Gross harvest, thou.s. | Sown area, thou.s.       | Gross harvest, thou.s.  |
| Cereals and legumes total:| 359.05                | 1084.4                | 289.84                   | 916.7                  |
| Winter grain crops including: |                     |                       |                          |                        |
| winter wheat             | 146.1                 | 509.0                 | 131.0                    | 476.8                  |
| winter rye               | 2.1                   | 6.2                   | 2.2                      | 5.3                    |
| Spring grain crops including: |                     |                       |                          |                        |
| spring wheat             | 193.1                 | 541.6                 | 144.1                    | 411.3                  |
| barley                   | 96.8                  | 275.9                 | 64.3                     | 186.3                  |
| oats                     | 60.6                  | 166.5                 | 51.6                     | 142.5                  |
| maize for grain          | 11.7                  | 21.8                  | 4.8                      | 7.0                    |
| buckwheat                | 15.0                  | 69.2                  | 15.3                     | 69.1                   |
| millet                   | 6.1                   | 5.68                  | 6.6                      | 4.25                   |
| Grain legumes including: | 17.63                 | 27.18                 | 12.39                    | 23.39                  |
| peas                     | 12.47                 | 20.93                 | 9.41                     | 20.34                  |
| lentil                   | 1.02                  | 0.97                  | 1.92                     | 2.00                   |
| lupine for grain         | 2.08                  | 2.40                  | 0.36                     | 0.45                   |
| other legumes            | 2.06                  | 2.88                  | 0.69                     | 0.62                   |

Maize sown areas are mainly concentrated in Belinsk-Serdobsk and Vadinsk-Mokshan areas, 41.4% and 40.5%, respectively, where there is the most favorable combination of natural and climatic...
conditions for this crop (soil fertility, sum of positive temperatures and relatively uniform precipitation). About 17.5% of the area of this crop is located in the Kuznetsk-Lopatino area. In favorable weather conditions in 2020, the average corn yield in the first two areas was 7.5 to 3.65 tons per hectare and 7.4 to 4.87 tons per hectare, respectively; in Kuznetsk-Lopatino area - from 5.67 to 2.73 tons per 1 ha. Penza region is the 5th by sown area of maize for grain and the 3rd by gross harvest - 207.8 thousand tons [11].

The analysis of the development dynamics of maize production in Penza region and the structure of sown areas of agricultural crops showed that there are 2 possible ways to increase its production. First, the intensification of its production on the basis of technologies adapted to the conditions of natural-economic zones of the region with the increase in the average corn yield to 7.5 tons per 1 ha. Secondly, it is possible to increase seeding areas without including maize in one crop rotation with sunflower in conditions of the region by 30 thousand hectares, with bringing of total seeding area up to 72 thousand hectares. The development of corn production in two above-mentioned directions will increase the gross output up to 540 thousand tons, that is 2.6 times more than in 2020. Due to this, grain and leguminous crops production volume in the region as a whole may increase by 2020 by 10%, and to an average level for the years 2016 to 2020 - 17%.

Lentil is a traditional legume crop for Penza region. On the basis of Penza Research Institute of Agriculture (currently a separate subdivision of Penza Research Institute of Agriculture of FSBSI "Federal Scientific Center of Bast Crops" (Tver), and its structural subdivision "Petrovskaya" selection and experimental station, a successful work on breeding and seed-growing of this crop, as well as the development of its production technology, adapted to the conditions of the region, was carried out. The following high-yielding (up to 2-3 tons per 1 hectare) lentil varieties were bred and introduced into the production: Petrovskaya 4/105, Penzenskaya 14, Petrovskaya zelenozernaya, Petrovskaya jubilee, Petrovskaya 6, Vehovskaya.

This was facilitated by the relative decline in wheat grain prices in 2016-2018, as a result of which many agricultural producers began actively introducing into crop rotations new grain and legume crops with market demand. From 2017-2018, lentil cultivation reached the highest levels in Penza region in the last 35 years. The most important factor influencing the fluctuations in lentil sown areas (Table 3) is the lack of experience in its production by many agricultural producers, which, in case of violation of cultivation technology and adverse weather conditions in some periods of the growing season, resulted in low yields. As a result, the average yield of this crop in 2018 was quite low - 0.78 tons per ha. At the same time: in 2018 in the farms of Neverkino district the yield of lentils reached 1.46 tons per 1 ha, in Vadinsk district - 1.77 tons per 1 ha, which indicates the possibility of obtaining high yields of this crop with proper farming techniques [4,6].

Lentil production is traditionally concentrated in farms in the Kuznetsk-Lopatino area (Table 4), where an average of 60% of the sown area and 56% of the gross yields of this crop were concentrated in 2016-2020. The commercial potential of this crop has not been fully exploited by regional agricultural producers. Gross lentil production in Russia in 2020 was 115.6 thousand tons, in 2019 - 116.6 thousand tons, indicating that there was demand for this crop. The leader in lentil production in the Volga Federal District is Saratov region, neighbouring Penza region, where the area sown in 2020 was 40,000 ha, with gross production of 40,100 tonnes or 35% of the national level. The second and third places in Russia by volume of lentil production are occupied by the Altai Krai (39.5 thousand tons in 2020), the third place is taken by Omsk region (12.0 thousand tons).

Thus, given the positive experience in lentil production development in these regions, with the recovery of cultivated areas of this crop in Penza region to 16 thousand ha and the average yield of 1.7 tons per hectare, its gross output can be 27.2 thousand tons, which ensured the growth of grain production by 1% by 2016-2020, and gross legume production by 37% by 2020.

Gross lupine production in Russia in 2020 was 103.7 thousand tons, in 2019 - 166.3 thousand tons. The main lupine production in Russia, taking into account soil and climatic conditions, is concentrated in the Central Federal District (91%). By the end of 2020, Penza region ranked first in the Central Federal District. Penza region is in first place by sown area and lupine production in the Volga Federal
District. The area under this crop in Penza region increased from 80 hectares in 2009 to 2,600 hectares in 2020. In Vadinsk-Mokshan and Belinsk-Serdobsk areas lupine is displaced from crop rotations by soybean, which influenced the reduction of sown areas of lupine in 2020 to the level of 2019 by 19%. The advantage of lupine is that high yields of this crop can be obtained on light sandy loam and light grey forest soils, where the cultivation of other legumes is practically impossible. In this regard, lupine is a priority commercial grain legume crop for Nikolsk-Gorodishche area.

3. Conclusions
The complex of measures aimed at the sustainable development of grain and legume crops production at the level of 3.0 million tons per year should include three blocks: scientific-production, organizational-economic and program-targeted [1].

1. Scientific-production block. Research and production block of activities should be based on the creation of a modern system of seed production, testing and implementation of adapted technologies for the production of different types of cereals and legumes, taking into account soil-climatic and economic conditions of the four zones of Penza region.

The coordinator of this work and the main regional research and production centre in Penza region can be Penza State Agrarian University. Regional scientific-production centre may have the following structure, which includes:
- a research laboratory specializing in primary seed production, reproduction, original seed material, cooperating with Russian research institutes specializing in breeding and seed production of these crops
- a laboratory conducting breeding work and organizing tests of promising numbers of cereals and leguminous crops before submitting them to state variety trials
- a centre for the development and implementation in production of varietal agro-technologies of released and perspective varieties and hybrids of cereal and leguminous crops that are adapted to the soil and climate conditions of the region.
- direct reproduction of seeds of high reproductions with their subsequent sale in the regional seed market and supply outside the region is advisable to organize on the basis of existing agricultural enterprises in Penza region with the status of seed farms.

2. Organizational-economic block. The basis of organizational-economic block of activities can become the creation of association of grain and legume crops producers, the main objectives of which should be: the study of demand in the market of legume crops and products of their processing of the Russian Federation, CIS and foreign countries; formation of export lots of legume crops and organization of their logistics to the final delivery points; participation in the development of breeding and seed production of grain and legume crops in Penza region; development of regional systems

3. Programme-targeted block. Should be implemented in close cooperation with the Government of Penza region in terms of developing programmes and attracting funds from the regional and federal budget on the basis of regional programmes: "Development of breeding and seed production in Penza region"; "Development of logistics system, storage, processing and sales of grain and leguminous crops".

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