The influence of hydrothermal conditions in the Middle Amur Region on main characteristics of pea varieties of various uses

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Abstract. The paper considers the influence of meteorological factors on the productivity indicators of different pea varieties in the Middle Amur Region. The studies were conducted in 2017–2019 for three groups of pea varieties identified by their use. A difference was found in the reaction of each group of varieties to unfavourable hydrothermal growing conditions. The average values of productivity indicators for pea classes in favourable and unfavourable years are calculated. It was found that the most significant indicators characterizing the different classes of pea are the number of internodes to the first pod, the length of the stem, and the 1000-seed weight. The relationship between the number of internodes to the first pod and the climatic characteristics of the growing season for both grain and forage varieties were revealed. As independent variables, the model includes the growing duration and the average temperature of the flowering-maturation period ($R^2$ is 0.85 for forage and $R^2$ is 0.56 for grain).

1. Introduction

Peas are one of the main leguminous crops in Russia. The vast area occupied by this crop testifies to its tolerance of soil and climatic conditions in comparison with other more heat-loving crops [1]. A high amount of protein in seeds (from 18 to 35%) and green mass (from 14 to 24%) allows the use of peas for food and forage purposes. The presence of provitamin A, vitamins of groups B and C, as well as choline in green peas contributes to their widespread use in diets [2]. The agro-technical significance of peas as green manure is great, and, with the current increase in sown areas of soybean, it has become very important. At the same time, the main requirement for all pea varieties is their adaptability to soil and climatic conditions of cultivation, that is, the potential of the plant genotype should correspond to factors of the hydrothermal regime and soil nutrition [3].

The Russian Far East is a large economic region with huge potential. Further socio-economic development of the region poses great challenges for agriculture to provide the region with food and forage [4]. Certain difficulties in growing crops are associated with special climatic characteristics of the Middle Amur Region [5]. High humidity and temperature contribute to the rapid spread of diseases and pests, and monsoon rains complicate plant care and harvesting. Providing agricultural enterprises with seeds of pea varieties that are best suited to local conditions is a priority to implement territorial development.

The study of cultural genetic resources is the basis for the creation of new highly productive pea varieties that meet the requirements of modern agricultural production and adapted to local conditions [6]. Great importance in the breeding of new varieties of crops using the ecological and geographical factor has the scientifically sound selection of the source material, its diversity and degree of knowledge. Therefore, in the new environmental conditions, plants change the rhythm, speed and
morphology of growth and development as well as yield and product quality. Adaptation to new conditions can occur through both the restructuring of plant traits and/or the formation of new reaction standards in the process of natural or artificial selection [8].

The main purpose of our research was a comparative assessment of the influence of hydrothermal conditions in the Middle Amur Region on the manifestation of the genetic characteristics of pea varieties grouped by their use.

2. Materials and methods
The studies were conducted in 2017–2019 on the vegetable fields of the Far East Scientific Research Institute of Agricultural Sciences. The collection was studied following the Russian Institute of Plant Industry's methodological instructions [7].

The studied varieties were bred: in Russia (30%), Belarus (22%), USA (7%), Ukraine (6%), the Netherlands (6%), Germany (6%), etc. (figure 1). It should be noted that the collection of grain and forage peas was mainly made up of varieties of the Russian Federation and Belarus, and the collection of garden varieties was bred in the USA and Russia.

Figure 1. Varieties origin.

There were 39 pea varieties divided to three groups according to their use: grain (having high protein content and nutritional value, used in dried forms to prepare pea porridge and other dishes)—23 varieties, forage (used for livestock feed) –11 varieties and garden (used by gardeners, unripe seeds (green peas) are eaten) – 5 varieties. All pea characteristics were calculated for each group separately.

The soil of the experimental plot is meadow-brown podzolized, and due to the heavy mechanical composition and low permeability during heavy precipitation, it is quickly wetted. The humus content in the arable layer is 3.6–3.8%, the pH of the salt extract is 4.9–5.6 and the hydrolytic acidity is 1.1–2.4 me per 100 g of soil. The P₂O₅ content was 9.9–15.5 mg/100g (for absolutely dry soil), and the K₂O content was 12.4–30.4 mg/100g of absolutely dry soil. The precursor in 2017 and 2018 was spring wheat, and in 2019, it was barley.

Soil preparation was carried out according to the generally accepted technique. The experiments were designed with plot areas of 0.4–1.2 m² and 2 repetitions. Sowing, harvesting and processing of sheaves were carried out manually. In the process of pea vegetation, phenological observations were carried out; the type of leaf and the colour of the corolla were noted. Harvesting was carried out by maturation. In laboratory conditions, the following indicators were determined: stem length, number
of internodes to the first pod, number of nodes with pods and number of pods per plant, number of seeds per pod, the mass of seeds per plant and 1000 seed-weight. The studied indicators characterizing the varieties of peas are presented in table 1.

**Table 1. Main indicators for comparing pea varieties.**

| Indicator                        | Variable | Indicator                           | Variable |
|----------------------------------|----------|-------------------------------------|----------|
| Stem length, cm                  | x₁       | Duration of the emergence-flowering period, days | y₂       |
| Internodes to first pod node     | x₂       | Duration of the flowering-maturation period, days | y₃       |
| Number of nodes with pods        | x³       | Growing season average temperature, °C | y₄       |
| Number of pods per plant         | x₄       | Emergence-flowering period average temperature, °C | y₅       |
| Number of seeds per pod          | x₅       | Flowering-maturation period average temperature, °C | y₆       |
| Mass of seeds per plant, g.      | x₆       | Growing season precipitation, mm. | y₇       |
| 1000-seed weight, g.             | x₇       | Emergence-flowering period precipitation, mm. | y₈       |
| Growing duration, days           | y₁       | Flowering-maturation period precipitation, mm. | y₉       |

The agrometeorological conditions of the growing season had significant differences in the heat and moisture supply. In 2017 and 2018, spring was early, and in 2019 spring came at the usual time for the climate zone. Sowing was carried out at the optimum time, depending on moisture supply; the germination period lasted 14–17 days. The most favourable year was 2017, and 2019 was the coldest and wettest (table 1). In 2018, a long period of waterlogging of the soil coincided with the period of flowering and filling of pods (R2–R4 stages). Under those conditions, especially sensitive varieties could not form a harvest. In 2019, a period of severe waterlogging of the soil was noted before mass flowering. Despite its short duration, the prevailing hydrothermal conditions also adversely affected plant productivity.

**Table 2. Hydrothermal indicators in pea growing season 2017–2019.**

| Indicator                          | Year | Emergence-flowering | Flowering-maturation | Growing season |
|------------------------------------|------|----------------------|-----------------------|----------------|
| Average air temperature, °C        | 2017 | 15.8                 | 22.1                  | 18.6           |
| Precipitation, mm                  | 2018 | 16.7                 | 21.7                  | 18.7           |
|                                   | 2019 | 15.9                 | 21.6                  | 18.4           |
|                                   | 2017 | 89.9                 | 137.7                 | 227.5          |
|                                   | 2018 | 152.1                | 100.7                 | 257.7          |
|                                   | 2019 | 188.2                | 208.1                 | 396.1          |

Because 2018 and 2019 were less favourable for the development of peas, we further studied the comparative characteristics of varieties separately in 2017 and as average values for 2018–2019. A comparison of the average values of the indicators of the three classes of peas was carried out using one-way analysis of variance [9]. Pairwise comparison of indicators characterizing soybean productivity was carried out using the Scheffé test [10].

### 3. Results and discussion

The study of the growing season characteristics is one of the most important problems in agronomic science and agricultural production [11]. A high yield of peas is possible at the end of the growing
season before monsoon rains. Such early ripening varieties can be the result of breeding only when studying the individual variability of the growing season [12]. The growing duration is determined by genetic factors, plant growth conditions (temperature, humidity) and specific conditions for particular varieties that can accelerate or slow down the onset of the flowering phase; genetic factors determine the ordinal node of the first inflorescence [7]. As can be seen from table 3, in each group of varieties there were both medium-early and medium-late samples. Adverse factors that developed in 2018 during the period of mass flowering significantly reduced the flowering-maturation interphase in all groups of varieties. This entailed a significant decrease in productivity indicators. This fact suggests that the period from flowering to maturation is critical, as confirmed by European researchers [13]. In 2019, the negative effects of hydrothermal conditions on the growing duration are not so notable. The dependence of the emergence-flowering period duration on the average daily temperature \( (r = 0.69 \pm 0.02) \) and on the amount of precipitation \( (r = 0.84 \pm 0.01) \) and the flowering-maturation period on the precipitation \( (r = 0.63 \pm 0.02) \) were revealed.

| Table 3. Growing and interphase durations averaged for 2017-2019. |
|---------------------------------------------------------------|
| **Group** | **Year** | **Emergence-flowering duration, days** | **Flowering-maturation, days** | **Growing duration, days** |
|           |         | **Min-max** | **Average** | **Min-max** | **Average** | **Min-max** | **Average** |
| Grain     | 2017    | 36–49       | 41          | 24–46       | 31          | 71–84       | 77          |
|          | 2018    | 32–48       | 38          | 21–37       | 25          | 61–79       | 70          |
|          | 2019    | 31–48       | 42          | 27–44       | 32          | 70–87       | 79          |
|          | 2017    | 40–51       | 40          | 19–45       | 33          | 69–87       | 78          |
| Forage    | 2018    | 34–48       | 43          | 22–36       | 24          | 61–82       | 72          |
|          | 2019    | 35–48       | 46          | 28–42       | 33          | 72–86       | 82          |
|          | 2017    | 35–43       | 37          | 30–43       | 36          | 69–82       | 72          |
| Garden    | 2018    | 32–45       | 41          | 19–36       | 24          | 61–78       | 68          |
|          | 2019    | 35–47       | 42          | 37–43       | 40          | 70–84       | 83          |

Table 4 presents the statistical processing of the main characteristics for each group of pea varieties in 2017, and table 5 shows the characteristics for each group of varieties in 2018–2019. As can be seen from the tables, in 2017-2019, the least variable indicators were growing duration and emergence-flowering duration. One-way analysis of variance did not reveal significant differences in average values in individual groups of varieties. It was established that in 2017 significant differences were between the average values in different groups of pea varieties in terms of \( x_1, x_3, x_5 \) and \( x_6 \). An additional pairwise assessment using the Scheffe criterion showed that the average values of \( x_4 \) significantly differed for the grain and forage varieties.

| Table 4. Main characteristics of pea varieties in 2017. |
|------------------------------------------------------|
| \( x_1 \) | \( x_2 \) | \( x_3 \) | \( x_4 \) | \( x_5 \) | \( x_6 \) | \( x_7 \) | \( y_1 \) | \( y_2 \) |
| Grain (n = 21) |
| \( \bar{x} \) | 88.8 | 15.9 | 9.0 | 14.2 | 4.1 | 12.8 | 223.8 | 76.2 | 43.3 |
| \( \sigma \) | 20.2 | 2.1 | 2.1 | 3.0 | 0.8 | 2.8 | 43.1 | 3.7 | 7.9 |
| \( V, \% \) | 22.7 | 13.4 | 22.8 | 20.9 | 18.3 | 21.6 | 19.2 | 4.9 | 18.2 |
| \( \Delta \bar{x} \) | 9.2 | 1.0 | 0.9 | 1.3 | 0.3 | 1.3 | 19.6 | 1.7 | 3.7 |
For garden varieties, the reaction is expressed in a sharp decrease in the indicators $x_1$, $x_4$, and $x_6$ sharply decreased, and the variation in terms of $x_5$ and $y_2$ slightly decreased. Under unfavourable conditions for forage varieties, $x_1$, $x_4$ decreased, and $x_5$ changed in different directions. For garden varieties, the reaction is expressed in a sharp decrease in the indicators $x_1$, $x_3$ and $x_7$.

### Table 5. Main characteristics of pea varieties in 2018-2019.

|       | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ | $y_1$ | $y_2$ |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Grain (n = 21) |       |       |       |       |       |       |       |       |       |
| $\bar{x}$ | 58.9  | 14.6  | 4.0   | 5.8   | 3.8   | 4.8   | 201.0 | 76.1  | 46.1  |
| $\sigma$ | 13.6  | 1.9   | 1.2   | 1.6   | 0.6   | 1.5   | 41.7  | 2.9   | 7.0   |
| $V, \%$ | 23.0  | 12.6  | 30.4  | 26.9  | 15.2  | 32.1  | 20.8  | 3.8   | 15.1  |
| $\Delta \bar{x}$ | 6.2   | 0.9   | 0.6   | 0.7   | 0.3   | 0.7   | 19.0  | 1.3   | 3.3   |
| Forage (n = 13) |       |       |       |       |       |       |       |       |       |
| $\bar{x}$ | 70.5  | 15.4  | 4.0   | 5.5   | 3.8   | 4.4   | 226.0 | 76.0  | 44.3  |
| $\sigma$ | 22.7  | 2.7   | 1.2   | 1.3   | 1.3   | 1.3   | 60.0  | 2.6   | 3.1   |
| $V, \%$ | 32.2  | 17.5  | 29.2  | 22.7  | 34.5  | 29.2  | 26.5  | 3.4   | 7.0   |
| $\Delta \bar{x}$ | 13.7  | 1.6   | 0.7   | 0.8   | 0.8   | 0.8   | 36.2  | 1.6   | 1.9   |
| Garden (n = 5) |       |       |       |       |       |       |       |       |       |
| $\bar{x}$ | 59.3  | 12.3  | 5.2   | 5.6   | 4.3   | 3.7   | 162.7 | 74.9  | 42.6  |
| $\sigma$ | 17.2  | 1.5   | 2.4   | 2.3   | 0.6   | 1.3   | 16.0  | 2.6   | 2.3   |
| $V, \%$ | 29.0  | 12.0  | 46.3  | 41.6  | 13.0  | 35.8  | 9.8   | 3.4   | 5.5   |
| $\Delta \bar{x}$ | 21.4  | 1.8   | 3.0   | 2.9   | 0.7   | 1.6   | 19.9  | 3.2   | 2.9   |

In general, it can be noted that forage varieties are characterized by a longer stem length. They are also earlier than all garden varieties to enter fruiting and later than all grain varieties. Garden varieties proved to be the most demanding to the growing conditions; they form the largest number of productive nodes and numbers of seeds in a pod. In the garden group, there are varieties with the smallest seeds, and varieties with the largest seeds are forage.
One of the most important valuable indicators affecting early maturity is $x_2$ — the number of internodes to the first pod. The number of internodes to the first pod on the main stem is a stable varietal trait and is directly related to the length of the growing season [13]; early maturity and the number of nodes to the first pod have a close negative correlation [14]. In our experiments, this indicator is closely related to the amount of precipitation, average temperature and duration of the emergence-flowering period, as well as to the average temperature of the flowering-maturation period (table 6).

**Table 6. Correlation coefficients between $x^2$ and hydrothermal characteristics during pea growing.**

| Year          | 2017 | 2018–2019 |
|---------------|------|-----------|
|               | All  | Grain     | Forage | Garden | All  | Grain | Forage | Garden |
| Duration of emergence-flowering period, days | 0.61 | 0.73 | 0.44 | - | 0.57 | 0.52 | 0.64 | - |
| Emergence-flowering period average temperature, °C | 0.42 | - | 0.65 | - | 0.52 | 0.51 | 0.64 | - |
| Emergence-flowering period precipitation, mm. | 0.72 | 0.74 | 0.7 | - | 0.53 | 0.47 | 0.6 | - |
| Flowering-maturation period average temperature, °C | 0.6 | 0.65 | - | - | 0.48 | 0.31 | 0.64 | - |

As follows from table 6, the relationship between the number of internodes to the first pod and the climatic characteristics of vegetation periods was established both for grain and forage varieties. For garden varieties, such a relationship was not revealed, which may be due to the small number of garden varieties in the study.

We constructed regression equations for different groups to quantify some characteristics. Table 7 presents the coefficients of the regression equations according to the data of 2018–2019, as well as the corresponding value of $R^2$. The regression equation is written as follows:

$$x_2 = a_0 + a_1 \cdot y_3 + a_2 \cdot x_8$$

**Table 7. Regression and determination coefficients for pea groups in 2018–2019.**

| Group        | $a_0$  | $a_1$  | $a_2$  | $R^2$ |
|--------------|--------|--------|--------|-------|
| All varieties| -127.7 | 7.76   | 0.20   | 0.39  |
| Grain        | -56.8  | 2.42   | 0.25   | 0.56  |
| Forage       | -129.4 | 5.46   | 0.34   | 0.85  |

4. Conclusions
Different pea varieties were studied in 2017–2019. It was established that meteorological conditions have a strong influence on pea productivity indicators. The average values of indicators for the favourable (2017) and unfavourable (2018–2019) years were calculated.

Three classes of pea varieties were considered: grain, forage and garden. For each class, the average statistical values of productivity indicators were calculated, as well as the growing duration...
with phase separation. There were significant differences between classes under adverse conditions in terms of the number of internodes to the first pod (14.6 for grains, 15.4 for forage, 12.3 for a garden, respectively), stem length (58.9 for grain, 70.5 for forage), and 1000-seed weight.

A correlation was established between the number of internodes to the first pod and the hydrothermal characteristics during the growing season. In 2017, the most severe dependence was observed for grain peas between the number of internodes to the first pod and the amount of precipitation during the emergence-flowering period and in 2018–2019, for forage peas average temperature during the emergence-flowering period. The regression equations were obtained, where the growing duration and the average temperature of the flowering-maturation period ($R^2 = 0.85$ for forage and $R^2 = 0.56$ for the grain) are included as independent variables.

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