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Influence of weather condtion on the field peas (*Pisumsativum*L.ssp. sativum) vegetation period and yield

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Abstract. Field pea (*Pisumsativum* L. *ssp. sativum*) is a universal pulse crop. One of the actual problems in its production is the influence of weather condition on the variability of pea economic characters and its properties. The purpose of the research (2009–2018) was to compare the vegetation period and interstage periods of the Hangildin and Chishminskiy 229 pea varieties with weather condition and seed yield. According to the results of the conducted research, it can be seen that the duration of the vegetation period and the yield of field pea grain was influenced by weather condition. The average daily air temperature affected the duration of the sowing-sprouting period in pea varieties Hangildin and Chishminskiy 229. The duration of the two periods (sprouting-flowering and flowering-ripeness) was influenced by features of the used varieties and the temperature condition ($r = -0.472$, the link is significant and $r = -0.788$). The duration of the sprouting-ripeness period depended on the average daily temperatures ($r = -0.481$), the amount of precipitation ($r = 0.937$), and the HTC (hydrothermal coefficient) ($r = 0.927$). Precipitation increased the duration of the full vegetation period ($r = 0.892$). On average, over 10 years of research on field pea it should be noted that there wasa close relationship between the duration of its vegetation period ($r = 0.844$), the duration of the flowering-ripeness period ($r = 0.679$) and the yield of seeds. The relationship between the seed yield and the sowing - sprouting period ($r = 0.451$) and between the seed yield and the sprouting - flowering period ($r = 0.446$) was revealed. The connection was found positive. The connection with the average daily air temperature of this period was negative ($r = -0.213$). The results of the research can be successfully used during cultivation of domestic and foreign varieties of field pea. In international practice, the results of this experiment can be successfully applied in selective improvement of field pea and the development of new, high-tech varieties.

Key words: field pea, variety, weather condition, vegetation period, yield.

INTRODUCTION

Grain legumes have important food and fodder value (Dahl et al., 2012). In many countries around the world, an increase in production of grain legumes, including peas is observed. The production is increased in order to solve the problem of food and fodder protein (Rungruangmaitree & Jiraungkoorskul, 2017). This is due to the fact that the proteins of grain legumes are dissolved in water, weak solutions of alkalis and neutral salts. As a result they are well absorbed by the bodies of both humans and animals (Kuznetsov et al., 2018). American scientists point out that research on incorporating more effective and sustainable production strategies into existing agricultural and food systems is necessary for growing agricultural crops in order to reduce the negative impact on the environment. The inclusion into the daily diet of organic, alternative main food crops such as nutritious field pea can ease the problem of micro-element deficiencies and enable more sustainable farming methods worldwide (Powers & Thavarajah, 2019).

Pea is one of the most popular leguminous plants in Western Europe. In Poland, it is particularly important due to its short vegetation period. It is cultivated throughout the entire country. Due to its high demand, the number of publications related to modeling the yield of this crop has lately increased (Grabowska & Kuchar, 2008). According to French scientists, increasing the yield stability of peas is the main selection goal. Therefore, it is very important that breeders understand the basis of the phenomenon of yield instability in order to create stable and high-yielding varieties (Kosev & Vasileva, 2019).

Field pea is a universal leguminous crop that is successfully cultivated in various soil and climatic zones of the Russian Federation. Field pea is widely spread in the middle Volga region as well as, in the Central black earth and North-Western regions. It occupies large areas in the Ural, lower Volga, Volga-Viatka and North Caucasus regions of the Russian Federation. Pea culture has a high ecological plasticity, when judging it by its distribution areas and cultivation zones. As a result, the study of bio-climatic parameters of field pea is important (Badretdinov et al., 2019).

One of the important issues in pea cultivation technology is the optimal temperature for its growth and development. According to scientists (Davletov et al., 2016; Ayupov et al., 2019), -25 °C are considered to be the optimal temperature. When cool weather conditions occur, there is an increase in the duration of the vegetative period of field pea and its reduction under hot weather conditions. The sum of active temperatures for field pea, depending on the vegetation period is 1,360–2,790 °C (Aiupov et al., 2019).

Pea is the main leguminous crop in the Republic of Bashkortostan. Its share in the structure of sown areas in individual agricultural facilities reaches 9% (Davletov & Gainullina, 2013). The yield of field pea in recent years has not been high enough (Davletov et al., 2016).

Review of the research on the influence of weather condition on the duration of the vegetative period and the yield of pea grain shows the need to conduct research on specific varieties of field pea, which are adapted to specific growing conditions. The purpose of our research was to compare the vegetation and interstage periods of Hangildin and Chishminskiy 229 pea varieties with weather condition and seed yield.

MATERIALS AND METHODS

Field experiments were conducted in 2009–2018 on experimental fields of an educational and scientific center of BSAU (Bashkir State Agrarian University). As part of the research, the reaction of 15 most promising varieties of seed peas for the conditions of the Ural region and the Republic of Bashkortostan was studied. The article presents the results of research on the most productive varieties of field pea (Hangildin and Chishminskiy 229). All studies were performed in 4 repetitions. The soil type on the experimental site is leached black soil with a heavy loamy mechanical composition (humus -10.5%, total phosphorus -0.19%, total nitrogen -0.5% and potassium-1.2%, pH with a salt extract of 6.0–6.2).

It was found that weather conditions influence the duration of vegetation, interstage periods and grain yield. In accordance with this, there were many problems being solved in the research, such as; determination of the sowing-sprouting period duration for Hangildin and Chishminskiy 229 pea varieties; the relationship of seed yield of pea with the length of the full vegetation period and amount of precipitation; determination of the dependence of the sowing-sprouting period duration on the average daily air temperature, HTC (hydrothermal coefficient) and the amount of precipitation. Selyaninov hydrothermal moisture coefficient (HTC) − characteristic of the level of water availability of the territory. The ratio of precipitation during the active vegetation period to the sum of average daily temperatures over the same time. Calculated by the formula: $K = R \times 10/\Sigma t$; where R is the sum of precipitation in millimeters over a period with temperatures above +10 °C, Σt is the sum of temperatures in degrees Celsius (°C) over the same time; the relationship of seed yield of pea with the length of the full vegetation period and the sowing - sprouting period; the relationship of seed yield of pea with the length of the full vegetation period and the average daily air temperature.

A unique aspect in the Republic of Bashkortostan is its climate. It is moderately warm in summer and cold in winter. The frost-free period is 93–123 days. According to the average annual data, frosts are observed in the summer period (beginning of June). Autumn frosts are observed in the last 10 days of August. The sum of active temperatures (above +10 °C) is equal to 1,810–2,210 °C (over the vegetation period). Annual precipitation is 410–505 mm (132–185 mm during the vegetation period) (Ayupov et al., 2019). The weather conditions during the of experimental period was unfavourable, i.e. 2010, 2012, and 2013 were characterized by very dry conditions 2009, 2015, 2016 and 2018 were dry, but 2011, 2014 and 2017 were characterized by wet conditions.

Agricultural technique used in the experiments was generally accepted for the zone. Predecessor was winter rye. Primary tillage was carried out, followed by moldboard plowing to a depth of 30 cm. Pre-sowing treatment of soil included carrying out early spring harrowing with heavy harrows followed by cultivation in the aggregate with medium harrows. The accepted parameters of mineral fertilizers application in the experiments were taken on the basis of general recommendations for their use around the zone (Gabitov et al., 2014) and made up $N_{30}P_{60}$ K_{40}. The experimental plots were sown in optimal time, with 130 seeds per m^2 and row spacing (15 cm) using the RS-1 selective seeder. The area of each option was 10 m^2, the repeatability was four times. Crop tending is generally accepted for the zone. Experimental work with field pea was conducted in accordance with the guidelines of the All-Russian Institute of Genetic Plant Resources named after N.I. Vavilov. On the territory of Russia, all research with promising varieties is controlled by the state Commission of the Russian Federation for testing and protection of breeding achievements. Published 5 issues of guidelines for all crops. In our research, we were guided by the requirements of the first and second issues (Fedin, 1985; Methods of statevariety testing of agriculturalcrops (issue two), 1989). Mathematical processing of research results was carried out using B.A. Dospekhov's method (Dospekhov, 1985). Snedecor application program was used.

RESULTS AND DISCUSSION

The duration of the vegetation period plays a crucial role in the cultivation of any crop in one or another region. The duration of each stage such as sowing-shoots (initial), shoots-flowering (average) and flowering-maturation (final) is of interest for selection and production. This largely depends on specific soil and climate conditions.

According to the existing data in our study, the duration of interstage periods in the years of research in varieties Hangildin and Chishminskiy 229 was within the limits of as follows: sowing-sprouting - 10–12 days (same for both varieties); sprouting-flowering - 27–38 days (Hangildin variety) and 28–44 days (Chishminskiy 229), flowering-ripeness - 23–38 days (same for both varieties); sprouting-ripeness - 53–75 days and 56–78 days; sowing-ripeness - 63–86 days (Hangildin variety) and 66–90 days (Chishminskiy 229). Duration of the periods between stages was different for each variety. Thus, the vegetation period of pea varieties depended on the characteristics of the variety and environmental conditions. In some years (2010, 2012), the Hangildin early ripening variety matured in 54–55 days, while the mid ripening Chishminskiy 229 variety matured in 57 days. Serious attention to the formation of pea yields from the vegetation period is paid by Turkish scientists. The yield of dry matter is influenced not only by the number of days of the vegetation period (from 78 to 91 days), but also by the height of plants (68–102 cm), the degree of lodging and other factors. The collection of dry matter in the cultivation of field pea, depending on these factors, can range from 4,861 to 6,853 kg ha^{-1} (Tan et al., 2013). This is in many ways combined with our research results. The characteristics of the varieties affected the passage of interstage periods.

According to the results of our experiments, the duration of the vegetation and interphase periods is largely determined by the combination of heat and moisture, as well as the reaction of the genotype of varieties to these conditions. This is in agreement with the results of Kosev's research (2015) during the formation of the model of high-productive varieties in forage pea. Kristal variety had high ecological plasticity and could be considered as close to an ideal type as possible. It can be grown in a wide range of environments. This is also confirmed by research of Chinese scientists. It has a stronger influence on the daily variability of the water potential of spring wheat leaves and field pea (Zhang et al., 2008).

Sowing-sprouting period

According to Davletov et al. (2016), pea seeds begin to germinate at a temperature of 1–4 °C (if they are provided with enough moisture). With an increase in temperature from 11 to 19.5 °C the sowing – sprouting period is noticeably reduced. The sowing-sprouting period for field pea during our experiments was 10–12 days with an average of 10.9 ± 0.29 days (variation coefficient V = 8.6%). During this period, the average daily air temperature was 11.6–18.6 °C with an average of 14.0 ± 0.91 °C (variation coefficient V = 20.7%). The amount of precipitation for the period was 0.8–35.1 mm (on average 14.8 ± 3.89 mm). HTC (Hydrothermic coefficient) - 0.04–2.71 (average 1.06 ± 0.29).

The shortest duration of the sowing-sprouting period was observed in 2010, from 2013 to 2014 and in 2018. At that time the average daily temperature of air was above 14 °C. So, based on the results of ten years of research, we can note a significant connection between the duration of the sowing-sprouting period and the average daily air temperature. In our studies the sowing - sprouting period and the temperature conditions had a negative relationship (r = -0.506). Correlation analysis of the duration of the sowing - sprouting period with the amount of precipitation for the sowing - sprouting period had a very low correlation (r = 0.019). This is due to the sufficient amount of moisture reserves in the arable layer (45–55 mm in years), which was enough for seeds swelling.

Sprouting-flowering period

During this period, compared to the previous period, the need for heat is increased. Period 6°C is the lowest period, the optimal periods were periods 16–18 °C. During this period, the need for moisture in pea increases (Davletov & Gainullina, 2013).

The average daily temperature of air during the years of the experiments varied from 14.4 °C (2017) to 20.7 °C (2015). At the same time, the change in the amount of precipitation varied from 12.2 mm (2009) to 131.1 mm (2017). The duration of the sprouting-flowering period in Hangildin pea variety was closer related to the amount of precipitation (r = 0.583, the link is significant). The relationship between the duration of the sprouting-flowering period and the temperature level (r =-0.472, the link is significant) was mid negative. The sprouting-flowering period was within 26–44 days in our experiments. The amount of precipitation for the period was 12.3–131.5 mm (on average 45.0 ± 11.65 mm). HTC (Hydrothermic coefficient) - 0.21–2.32 (average 0.72 ± 0.20). The variability of the sprouting-flowering period in Hangildinvariety was V = 11.7% and Chishminskiy 229 pea variety by year was V = 11.3% (Table 1).

In our experiments the correlation coefficient for the duration of the sprouting-flowering period with precipitation was r = 0.583, with HTC- r = 0.575. The experiments showed an increase in the duration of interstage periods with an increase in precipitation and a decrease in the average daily air temperature. In 2017, the sprouting-flowering period of the Hangildin variety lasted 38 days (the amount of precipitation was 131.0 mm, the temperature was 14.5 °C). The sprouting-flowering period of the Chishminskiy 229 variety lasted 44 days (the amount of precipitation was 131.5 mm, the temperature was 14.6 °C). The shortest duration of the sprouting-flowering period was observed in 2015, when the average daily air temperature was 20.8 °C. It lasted 27 days for Hangildin variety and 229–28 days for Chishminskiy 229 variety.

Table 1. Correlation coefficient of the duration of the vegetation and interphase periods of peas with weather conditions (2009–2018)

Interstage periods	Correlation coefficient *		
	Precipitation	Daily air temperature	HTC
Sowing-sprouting	0.019	-0.506	0.052
Sprouting-flowering	0.583	-0.472	0.575
Flowering-ripeness	0.408	-0.788	0.241
Sprouting-ripeness	0.937	-0.481	0.927
Sowing-ripeness	0.892	-0.166	0.877

* Note: – the correlation coefficient is significant at 5% of the significance level (0.22).

Thus, the analysis of data collected over many years showed that the duration of the sprouting-flowering period is closely related to weather conditions. It is significantly influenced by varietal characteristics and the genotype.

In the course of research, it was found that pea plants of different varieties differ in the growth rate in the initial phase of vegetation. Depending on the conditions of the year in the branching phase, their height reached 5.1–12 cm. On average, in 2009–2018, the growth reached its maximum value in the flowering phase (from 4.1 to 5.3 cm per day). In our experiments, the increase in height was greater in wet years. Under the influence of drought and elevated temperatures, growth processes were suppressed (Fig. 1).

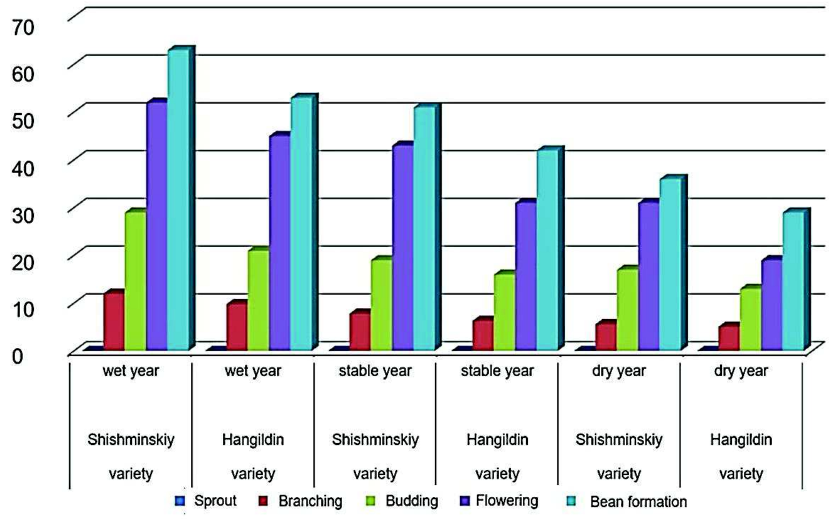

Figure 1. Influence of humidification conditions on the growth of pea plants of the Chishminsky 229 and Hangildin varieties for 2009–2018, cm.

Flowering-ripeness period

According to French scientists Roche et al. (1999), the time of flowering in pea is mainly related to the photoperiod (P) and mean temperature (T(m)) during the vegetation period. In field conditions, both variables depend mainly on the latitude (LAT) and the date of sowing (RDS). The lowest limits of temperature for pea should not be lower than 10 °C (Davletov et al., 2016). The optimum temperature is 18–20 °C.

The variability of the flowering-ripeness period in Hangildin and Chishminskiy 229 pea varieties by year was V = 17.3–17.6%. The coefficient of variation of the flowering-ripeness period with HTC and precipitation for 2009–2018 was 47.7–47.8% and 50.0–50.1%, respectively.

The duration of the flowering-ripeness period, according to our research, had a close relationship with precipitation and temperature conditions. This is confirmed by the results of the research done by French scientists. Their research shows high yield variability, which depends on provision of soil with water during the flowering period (Biarnès-Dumoulin et al., 1996).

In 2010, 2012, 2013, 2016, 2018 the flowering-ripeness period for Hangildin and Chishminskiy 229 variety lasted 23–27 days (the average daily air temperature was 21.4–23.2 °C). In 2014 with a temperature of 17.1 °C it was only 38 days. The amount of precipitation for the period was 5.0–70.1 mm (on average 40.3 ± 6.30 mm). HTC

(Hydrothermic coefficient) - 0.09–1.10 (average 0.65 ± 0.03). The correlation coefficient between the number of days during the flowering-ripeness period and the average daily air temperature was r = -0.788. The duration of the flowering-ripeness period was influenced by the amount of precipitation (r = 408).

According to Molchanov (2003) in the period of budding-full ripeness, the relationship between the yield of peas of the Malyshok variety and hydrothermal factors was as follows: between the yield and the duration of the growing season, the dependence was highly positive r = 0.92, between the amount of rainfall and yield positive r = 0.67, between the yield and average daily air temperature - negative (r = - 0.32). The results of the experiments have a similar trend with our research, the influence of varieties and cultivation conditions (Kuban) is manifested.

As can be seen in our research, the most difficult period for the development of pea plants is the flowering-ripeness period. This is confirmed by the results obtained by Hungarian researchers. Most favourable part of the vegetation period is in spring, when precipitation and evapotranspiration increase month after month. The least favorable period for soil moisture conditions lasts from July to September, when evapotranspiration significantly exceeds the amount of precipitation (Varga-Haszonits et al., 2008). In our experiments, a weak connection between the duration of the flowering-ripeness period and HTC was found r = 0.241 (Table 1).

Sprouting-ripeness period

The duration of the sprouting-ripeness period in Hangildin variety was closely related to the amount of precipitation (r = 0.937). The duration of the sprouting-ripeness period had an average negative connection with the temperature level (r = -0.481). The sprouting-flowering period in our experiments was within 53–78 days. The variability of the sprouting-ripeness period in pea varieties Hangildin and Chishminskiy 229 by year was V = 9.5–10.1%.

The experiments showed an increase in the duration of interstage periods with an increase in precipitation and a decrease in the average daily air temperature. The high dependence between pea seed yield and the period of sowing-ripeness was shown in the studies of Indian scientists Nagarajan et al. (2002).With delay in sowing, there was an increase in flowering days(7–26 days). In their experiments, they came to the conclusion that the change in thermal units during the growing season of pea had a high correlation with seed yield per ha (r = 0.937, P = 0.0015). Therefore this coincides with the results of our research. In 2014 and 2017, the sprouting - ripeness period of the Hangildinpeavariety lasted 69–75 days (with a temperature of 17.1 to 17.5 °C). The sprouting-ripeness period of the Chishminskiy 229 variety lasted 71–78 days (with a temperature of 17.2 to 17.5 °C). The coefficient of variation for the sprouting-ripeness period and the average daily air temperature was 6.2–6.4%. With an increase in the average daily air temperature, there was a reduction in the period from sprouting to ripeness. In the experiments, the shortest duration of the sprouting-maturation period was observed in the Hangildin pea variety and was 53 days. The shortest period of sprouting-maturation for Chishminskiy 229 pea variety was 56 days in 2010. The average daily air temperature during this period was 20.8°C the amount of precipitation - 27.2 mm. The duration of the period from sprouting to ripeness in Hangildin pea variety is closely, in a good way, correlated with the amount of precipitation (r = 0.937) and the HTC (r = 0.927). In all legumes crops waterlogging at flowering led to damage, which could not be recovered during seed filling (Pampana et al., 2016).The connection between the duration of the period from sprouting to ripeness and the average daily air temperature was negative (r = -0.481).

Data on the coefficients of variation (V, %) of the interstage periods of pea development and weather conditions. The conducted analysis shows that precipitation and HTC are more variable. Analysis of weather conditions for the entire vegetation period shows the negative impact of excess precipitation and low air temperature. This is more obvious during the flowering period of pea.

Grain yield

The creation of technologically advanced high yielding varieties is one of the main directions of selection. In ten years of research, the maximum grain yield was obtained in 2011. It was obtained during favorable for the growth and development of pea plants conditions. It was 2.69 t ha^{-1} for Hangildin pea variety and 229–2.70 t ha^{-1} for Chishminskiy 229 pea variety. The lowest grain yield was observed in a very dry year of 2010 and in a dry year of 2013 (Fig. 2).

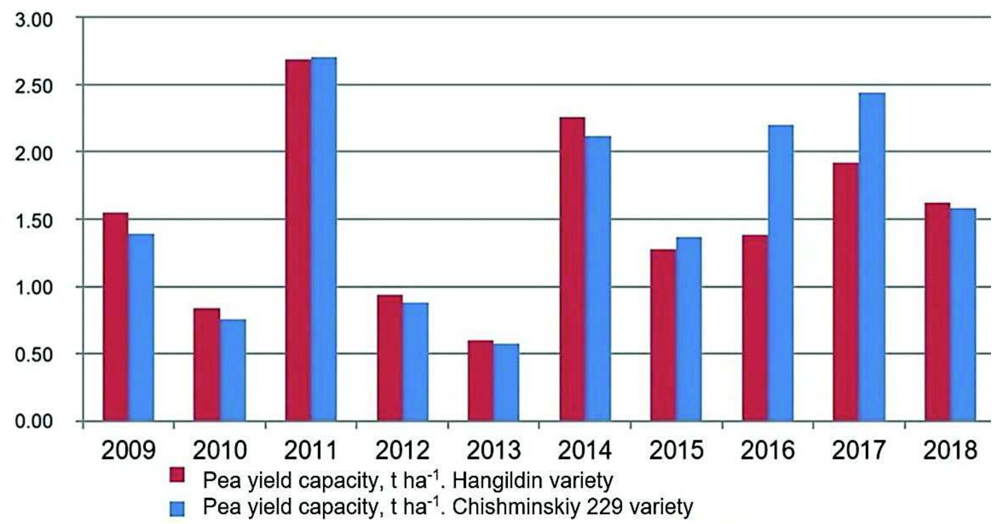

Figure 2. Pea grain yield for 2009-2018 (t ha^{-1}).

As can be seen in figure 1, during research years, the yield of pea grain in Hangildin pea variety and in Chishminskiy 229 variety ranged from 0.60 to 2.69 and from 0.58 to 2.70 t ha^{-1}, respectively (coefficients of variation – 40.96 and 42.84%). The average yield of Hangildin pea variety was 1.50 t ha^{-1} and 1.60 t ha^{-1} for the Chishminskiy 229 pea variety.

In the experiments of Shevtsova (2000) in the conditions of the Saratov Region (Russia), the influence of weather conditions on the yield of sowing peas is noted, which has a similar tendency with our research. On average for 1967–2000. Yields in wet years were 3.01 t ha^{-1}, in dry years - 1.51 t ha^{-1} and in extremely dry years - 0.61 t ha^{-1}. The coefficient of variation was 45.8%.

It was found that, on average for 2009–2018, the yield of pea grain had a close correlation with the duration of the periods sowing-ripeness (r = 0.844) and flowering-ripeness (r = 0.679). A weaker positive correlation (r = 0.451 and r = 0.443, respectively) was observed between the duration of the sowing-germination and germination-flowering periods (Fig. 3).

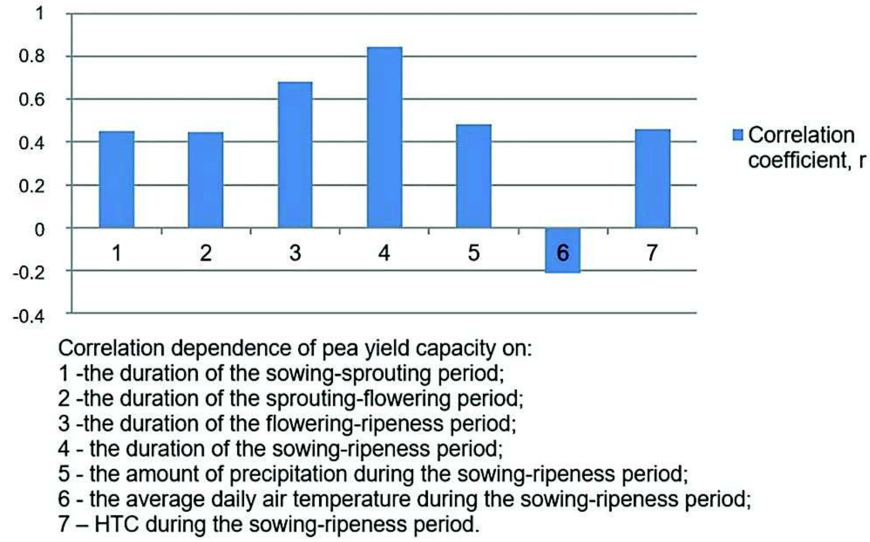

Figure 3. Correlation dependence of pea grain yield on the duration of the vegetation period, the duration of interstage periods and weather conditions (2009–2018).

** Note: – the correlation coefficient is significant at 5% of the significance level.*

For Hangildin pea variety during the sowing-ripeness period, there was a weak negative correlation between the yield of pea grain and the temperature regime (r = -0.213), and a positive correlation between the yield, the amount of precipitation and the HTC (r = 0.486 and r = 0.449, respectively). The Chishminsky 229 variety had a similar trend. During the sowing-maturation period, there was also a weak negative correlation between the yield of pea grain and the temperature regime of the variety (r = -0.217), positive correlation between the yield, the amount of precipitation and the HTC (r = 0.478 and r = 0.475 respectively). Analysis of research results, data from Figs 1 and 3, Table 1 shows a high dependence of pea yield on the amount of precipitation during the growing season.

At the same time, according to Masilionytė & Maikštėnienė (2011) when using organic fertilizers in the organic farming system, there was a strong connection between pea yield and the amount of precipitation. There was no such high dependence when $N_{30}P_{60}K_{60}$ mineral fertilizers were applied. A more significant relationship between the yield and the amount of precipitation is observed during the warm period. During this period, plants are able to use their moisture reserves more effectively.

CONCLUSIONS

The results of the research showed that weather conditions affect the duration of the growing season and the yield of field peas. The duration of the vegetation and interphase periods is determined largely by the combination of heat and moisture, as well as the reaction of the genotype of varieties to these conditions. In some years (2010, 2012), the early-matured variety of hangildin's Memory matured in 54–55 days, and the medium - matured Chishminsky 229 - in 57 days. The experiments showed an increase in the duration of interphase periods with an increase in precipitation and a decrease in the average daily temperature. This is most acute during the flowering period of peas. With an increase in the average daily air temperature, there was a reduction in the period from germination to maturation. The highest yield during 2009–2018 was formed by the medium-ripened variety of peas sown Chishminsky 229.

A comparative study of the vegetation period and interstage periods with weather condition and seed yield should help researchers to choose the starting material for the creation of new high-yielding, technological pea varieties for the conditions of the Republic of Bashkortostan.

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