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***Research article***

# The Impact of Climatic Changes on Forage Pea (*Pisum sativum var. arvense*) Production

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## Abstract

The yield of agricultural crops is significantly influenced by climatic factors. This impact has been intensified as a result of rapid changes in agroclimatic indicators. These factors are constantly changing. Climate indicators such as temperature, precipitation amount and distribution, snowfall amount and duration, have shown significant changes over the past decades. The sustainability of agricultural farms can only be positive by treating them as sustainable agroecosystems. Technologies and agricultural practices need to be harmonized with ongoing climate changes. The study is based on a multi-year analysis of climatic indicators in the Korça region, examining the impact of these changes on morphological, physiological, and production of the forage pea "Voskopoja." Climatic changes was reflected in significant changes in green mass yield, seed numbers per pod and seed weight per pod (g) and seed yield. Climatic changes was not reflected in significant changes in the number of pods per plant and the weight of 1,000 seeds. Climate change showed significant effects on seed protein content and protein yield. Prcentage of protein content in seeds was higher in the year with the lowest amount of rainfall and the highest temperature of the April-June period. Protein yield (kg/ha) was the highest in the year with the greatest amount of rainfall and the lowest temperature of the April-June period. The experimental conclusions are based on the statistical analysis of variance between different climatic indicators and productivity.

**Keywords:** climate changes; forage pea; precipitation; seed yield; temperature

## 1. Introduction

In the natural vegetation of the Voskopoja region in the Korça district (Albania), around the 1980s, a plant similar to common forage pea but with some biomorphological characteristics distinguishing it from regular forage peas was collected. The forage pea "Voskopoja" is a "gift" of centuries-old natural selection, especially valuable for forage in the Mediterranean mountainous climate zone. The "Voskopoja" forage pea tolerates climate changes better than other forage pea cultivars.

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Forage peas (*Pisum sativum var. arvense*) are valued as a protein source in animal diets, and are suitable for a wide variety of ruminant diets (Soto-Navarro et al., 2012). According to Dabral et al. (2021), pea pods had positive effects on growth, nutrient utilization and hemato-biochemical components of calves. Biological nitrogen fixation improves soil fertility, plant productivity, especially for cereals, and reduces the need for chemical fertilizers (Dhillon et al., 2022; Gungaabayar et al., 2022). Forage pea "Voskopoja" exhibits high resistance to cold and drought. It withstands low temperatures down to -16°C and under snow cover down to -25°C. Resistance to low temperatures is associated with rhizome nodulation. The more nodulated the rhizome, the more resistant to cold the plants are. High temperatures above 30°C during the flowering phase cause flower sterility and reduce seed yield.

Climatic factors have a significant impact on forage pea growth and agronomic parameters. The main climatic factors are rainfall and temperatures, which are especially critical during the spring months when plants actively grow (Ceyhan & Karadaş, 2023). Growth phases (germination-flowering and flowering-maturity) were influenced by average daily temperatures. Precipitation increased the duration of the entire growing season (Bénézit et al., 2017; Kuznetsov et al., 2020).

Forage peas are highly sensitive to water stress. Plants increase dry weight in vegetative organs, number of pods per plant, the number of seeds per pod, seed weight per pod and weight of 1000 seeds under normal water conditions. According to Grabowska & Banaszkiewicz (2009), water stress is the main cause of pea yield reduction.

Studies carried out on climate indicators in the Korce region over the last 30 years have shown significant changes in air temperature, amount of precipitation, and precipitation distribution during the year (Maho et al., 2023). The analysis of climate data has shown an increase in the average temperature, and an increase in the number of days with high temperatures in the flowering period of fodder pea (Tmax > 25°C in the month of June). The number of frosty days during winter has become lower. The number of rainy days has decreased, but the amount of daily rainfall has increased.

Fodder pea is sensitive to climate stress. Biological nitrogen fixation is sensitive to water stress. Physiological processes that determine plant productivity are sensitive to water stress, and to high maximum temperatures. Climatic changes have caused a low productivity of spring fodder pea cultivars. The fodder pea cultivar "Voskopoja" is a winter cultivar that reduces the effects of climate stress on yield. Increase in the number of days with high temperature during the flowering period of the fodder pea and the change in the distribution of rainfall have brought problems in its cultivation. The aim of this research was to evaluate the effects of climate changes on the yield of forage pea "Voskopoja" in the Korça region, Albania.

## 2. Materials and Methods

### 2.1 Experimental design and conditions

The study on the impact of climatic conditions on the yield of forage pea "Voskopoja" was conducted in Albania from 2020 to 2023, specifically in the Southeastern region (Trestenik, Devoll, Korçë) at coordinates 40°34'55'' N, 21°01'36'' E, at an altitude of 955 m. The experimental soil type was middle clay loam with recognized fertility. Forage peas were cultivated in rotation with wheat. The forage pea "Voskopoja" (a landrace with the widest distribution in the Korça district, Albania) was studied by applying three planting densities (60, 80, and 100 seeds per 1 $m^2$) and three row spacings (20, 30, and 40 cm) in randomized blocks, with four repetitions in plots of 24 $m^2$ (2.4 m x 10 m). Planting was done during the experimental years from September 20 to September 30.

## 2.2 Climate data

To assess the impact of climatic factors, especially temperature and precipitation, data covering the years 2020 to 2023 were collected from monthly climate bulletins, and publications of the Institute of Geosciences. The observed data for the relevant periods related to the biological cycle of the plant (October - June) were processed. Key climate factors included:

- Average, maximum and minimum monthly and annual temperatures.
- Amount of monthly and annual rainfall.
- Maximum and absolute minimum daily and monthly temperatures.

These processed data were used to examine the correlation with biological and productive indicators.

## 2.3 Experimental field observations

To assess the influence of climatic factors on plant development and their yield, field observations were conducted, documenting phenological phases and biometric measurements of the plants. The following parameters were recorded: number of pods per plant, number of seeds per pod, seed weight per pod (g), 1,000 seed weight (g), seed yield (calculated at 14% moisture content), protein content in seeds (%), and protein (kg/ha).

Biometric measurements were taken before harvest in fully ripe plants. The Kjeldahl method was used to analyze the protein content in the seeds. It was carried out through a digestion, distillation and titration scheme. Protein content was calculated: Protein (kg/ha) = Yield (kg/ha) x Protein content in seeds (%).

## 2.4 Statistical analysis methods

Data were collected from the experiment in randomized complete blocks with four repetitions. Correlation analysis was used for statistical assessment, and the significance of results was verified with the least significant difference test at the significance levels of α = 0.01 and 0.05. The correlation analysis between the April-June precipitation and yield is based on the correlation coefficient using the following formula (Xhuveli & Salillari, 1984):

$$r = \frac{\sum XiYi - nXavgYavg}{\sqrt{(\sum Xi^2 - nXavg^2)(\sum Yi^2 - nYavg^2)}}$$

where:

Xi = average numbers of days of the flowering period;
Yi = yield values kg/ha;
Xavg = average values of days in flowering;
Yavg = average yield values kg/ha;
n = number of groups in the study.

The analysis of the correlation between amount of rainfall in the April-June period and production was based on the coefficient of correlation according to the following formula (Xhuveli & Salillari, 1984):

$$r = \frac{\sum XiYi - nXmeanYmean}{\sqrt{(\sum Xi^2 - nXmean^2)(\sum Yi^2 - nYmean^2)}}$$

where:

Xi = average values of day per flowering;
Yi = yield values kg/ha;
Xavg = average values of days in flowering;
Yavg = average yield values kg/ha;
n = number of groups in the study.

## 3. Results and Discussion

### 3.1 Results

#### 3.1.1 Impact of climatic factors on forage pea seed yield

In the current study, after processing climate data, climatic indicators showed significant changes from year to year. There is a trend of increasing temperatures throughout the year, while it is difficult to conclude the same for precipitation quantity. From the collected data, it can be seen that the average temperature for these months increased from 0.3°C in June to 1.6°C in May. The average increase for the 3 years of the experiment in this period was 1.4°C. Also, for the same period, there were significant changes in the monthly amount of rainfall. The largest amount of precipitation occurred in 2023, while the smallest was in 2021 (Table 1).

From the experimental data, it was observed that the fodder pea seed yield was influenced by climatic factors. One of the reasons for the variability in fodder pea seed yield was the amount and distribution of rainfall during the years. The period with the most significant impact on fodder pea seed yield, according to our experimental data, was April to June. The climatic conditions during this period determined the duration of the flowering time, the formation of inflorescences, and the maturation of seeds. The highest amount of rainfall for this period occurred in 2023, while the lowest occurred in 2021. Notably, the fodder pea seed yield was highest in 2023 (1,156.4 kg/ha) and lowest in 2021 (918.7 kg/ha). The higher fodder pea seed yield in 2023 was also influenced by a lower average air temperature during the growing season. Processed data for some of the main indicators of forage peas depending on years are given in Table 2.

Based on the statistical analysis of variance, the influence of climatic conditions (factor Y) on the number of pods per plant and 1,000 seed weight was not proven. Based on the statistical analysis of variance, the significant influence of climatic conditions (factor Y) on the number of seeds per pod and the weight of seeds per pod (g) was proven (Table 2). Important changes in the yield of pea seeds also appeared due to climatic factors. The change from year to year in temperature and precipitation showed significant changes in the yield of pea seeds. Significant differences were observed in the yield of pea seeds in terms of the interaction of the factors (R × D), distance between rows (R) and planting density (D). The collected data were systematized for the purpose of statistical analysis. General data are presented in Table 3. Statistical analysis of interval plot of yield (kg/ha) is presented in Figure 1 and differences of means for yield (kg/ha) is presented in Figure 2. Climatic factors significantly affected the length of the plant growth cycle and the duration of various growth phases. Based on field observations, the following 3-year experimental averages were obtained. Data are presented in Table 4.

**Table 1.** Weather conditions at the experiment site

| Months | 2020 | 2021 | 2022 | 2023 | 1991-2020 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|
| *Total precipitation (mm)* | | | | | | *Deviations from the mean of total monthly precipitation of 1991-2020 (%)* | | | |
| April | 54 | 53 | 78 | 66 | 75 | -28 | -29.3 | 4 | −12 |
| May | 41 | 18 | 16 | 110 | 67 | -38.8 | -73.1 | −76.1 | 64.2 |
| June | 41 | 85 | 80 | 142 | 34 | 20.6 | 150 | 135.3 | 317.6 |
| April-June | 136 | 156 | 174 | 318 | 176 | -22.7 | -11.4 | −1.1 | 80.7 |
| Average precipitation (mm) | | | 2020-2023 | 196 | 176 | 11.4 | | | |
| *Average air temperature (°C)* | | | | | | *Deviations from the average monthly air temperature of 1991-2020 (°C)* | | | |
| April | 9.8 | 9.4 | 10 | 9.2 | 8.8 | 1 | 0.6 | 1.2 | 0.4 |
| May | 15 | 15.8 | 16.7 | 13.6 | 13.4 | 1.6 | 2.4 | 3.3 | 0.2 |
| June | 18.3 | 19.4 | 20.9 | 18.8 | 18 | 0.3 | 1.4 | 2.9 | 0.8 |
| April-June | 14.4 | 14.9 | 15.9 | 13.9 | 13.4 | 1 | 1.5 | 2.5 | 0.5 |
| Average | | | 2020-2023 | 14.8 | 13.4 | 1.4 | | | |

**Table 2.** Pea yield components depending on years

| Factor | No. of Pods per Plant | No. of Seeds per Pod | Seed Weight per Pod (g) | 1,000 Seed Weight (g) |
|---|---|---|---|---|
| 2021 | 2.4 | 3.35 | 0.491 | 146.6 |
| 2022 | 2.38 | 3.42 | 0.513 | 150 |
| 2023 | 2.79 | 3.38 | 0.518 | 153.4 |
| Mean | 2.54 | 3.383 | 0.509 | 150 |
| Y | ns | ** | ** | ns |

** $p < 0.01$; ns = not significant

**Table 3.** The influence of three factors: climate (Y), row spacing factor (R), planting density factor (D) on pea seed yield (kg/ha)

| Factor Years (Y) | Factor Row Spacing (R) | Factor Planting Density (D) | | | Factor | Years(Y) |
|---|---|---|---|---|---|---|
| | | 60 seeds | 80 seeds | 100 seeds | Amount | Mean |
| 2021 | 20 cm | 782 | 854 | 862 | | |
| | 30 cm | 944 | 1087 | 1045 | 8268 | 918.7 |
| | 40 cm | 823 | 957 | 914 | | |
| 2022 | 20 cm | 821 | 865 | 884 | | |
| | 30 cm | 996 | 1146 | 1124 | 8786 | 976.2 |
| | 40 cm | 860 | 1058 | 1032 | | |
| 2023 | 20 cm | 896 | 906 | 954 | | |
| | 30 cm | 1186 | 1430 | 1380 | 10408 | 1156.4 |
| | 40 cm | 1167 | 1285 | 1204 | | |
| Amount | | 8475 | 9588 | 9399 | 27462 | 3051.3 |
| Mean | | 941.7 | 1065.3 | 1044.3 | 3051.3 | 1017.1 |

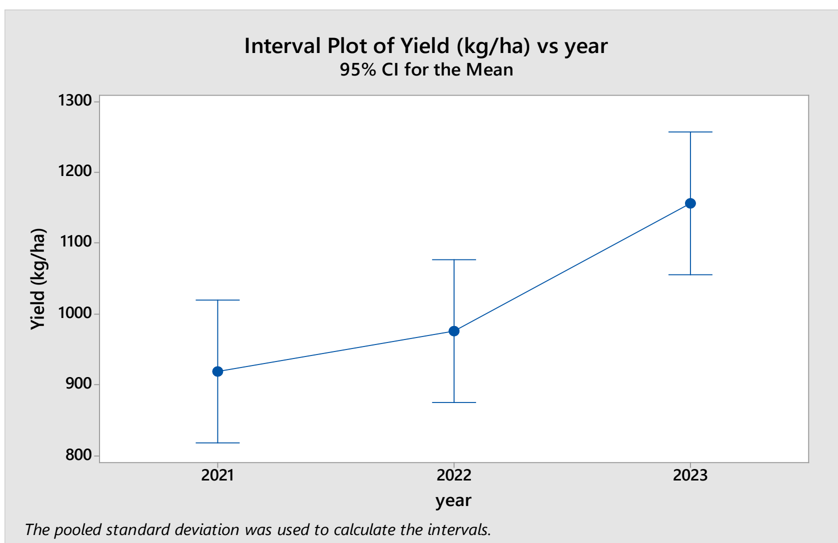


**Figure 1.** Interval plot of yield (kg/ha) vs year 95% CI for the mean

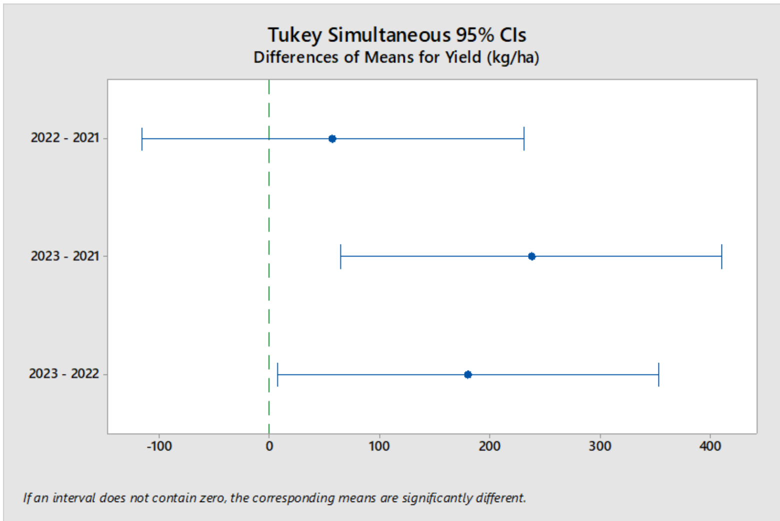


**Figure2.** Differences of means for yield (kg/ha)

**Table 4.** Impact of climatic factors on the length of the flowering phase and seed yield

| Study Years | 2021 | 2022 | 2023 |
|---|---|---|---|
| Length of flowering phase (in days) | 45 | 52 | 58 |
| Yield (kg/ha) | 918.7 | 976.2 | 1,156.40 |

To assess the relationship between the average daily flowering values and the yield values of forage seeds, we calculated the correlation coefficient. For this purpose, we constructed the following Table. Data are presented in Table 5.

**Table 5.** Calculation of the correlation coefficient

| Genotype | Day to flowering $X_i$ | Yield (kg/ha) $Y_i$ | $X_i^2$ | $Y_i^2$ | $X_iY_i$ |
|---|---|---|---|---|---|
| Forage peas “Voskopoja | 45 | 918.7 | 2,025 | 844,009 | 41,341.50 |
| | 52 | 976.2 | 2,704 | 952,966 | 50;762.4 |
| | 58 | 1,156.40 | 3,364 | 1,337,260 | 67,071.20 |
| Amount | 155 | 3,051.30 | 8,093 | 3,134,237 | 159,175.1 |
| Averages | 51.67 | 1,017.10 | 2,697.70 | 1,044,745 | 53,058.4 |

The correlation coefficient was calculated using the formula:

$$\frac{\sum XiYi - nXmesYmes}{\sqrt{(\sum Xi^2 - nXmes^2)(\sum Yi^2 - nYmes^2)}}$$

where: r = 0.95

Based on the value of the correlation coefficient, the relationship between the average daily values of flowering and the yield values of forage seeds was strong.

The linear productivity function as a consequence of the influence of climatic factors was determined based on the correlation analysis.

The linear function of the productivity of the forage pea cultivar "Voskopoja" on the basis of the calculations comes out as follows:

$$y = 779.4 + 118.85\ x$$

The indicator 118.85 expresses that an average change of 118.85 kg/ha occurred as a result of the influence of climatic factors.

### 3.1.2 Protein content in seeds (kg/ha)

Experimental results regarding seed protein content and protein yield are given in Table 6. Climate change showed significant effects on seed yield, seed protein content and protein yield. Protein content in seeds was significantly affected by rainfall. The highest value was recorded in the hottest vegetation period with the lowest total rainfall.

**Table 6.** Impact of climatic factors on protein content in seeds

| Factor | Yield (kg/ha) | Protein Content in Seeds % | Protein Yield (kg/ha) |
|---|---|---|---|
| 2021 | 918.7 | 25.7 | 236.11 |
| 2022 | 976.2 | 26.3 | 256.74 |
| 2023 | 1,156.40 | 24.8 | 286.79 |
| Mean | 1,017.10 | 25.6 | 259.88 |
| Y | ** | * | ** |

** $p < 0.01$; * $p < 0.05$

## 3.2 Discussion

Climatic factors have the most significant impact on forage pea yield during the April-June period. The weather conditions during this period determine the duration of flowering, pod setting, and seed development. This climate change trend was also observed in the last decade 2013-2023 (Maho et al., 2023). While the temperature increase is confirmed by Kopali et al. (2012), the growth rates observed in this study are higher. Temperature is one of the most crucial ecological elements, determining the intensity of various plant functions such as germination, photosynthesis, respiration, and organic matter accumulation. Precipitation plays a crucial role in plant biology and various productivity indicators. Changes in precipitation quantity did not exhibit a clear trend. The changes, from a statistical perspective, were not significant.

Climatic changes showed significant changes in seed yield, protein seed content and protein yield. The yield of fodder peas was significantly affected by climatic factors. Climate change has a negative impact on the productivity of fodder pea (Bonciu et al., 2023; Sharma et al., 2023). The average number of seeds/pod, number of pods/plant, plant height and 1000-seed weight showed significant reductions under high temperature stress conditions (number of days with maximum temperature higher than 28°C) during the growth phase of flowering (Atung, 2018, Devi et al., 2025). Our study showed that the vegetative period with the greatest impact on grain yield was the flowering phase. The same conclusion was reached by Bueckert et al. (2015). Pea productivity is negatively affected by high temperatures above the critical temperature and low humidity (Gudko et al., 2024).

The longer these phases are, the higher the yield. Forage pea "Voskopoja" forms numerous flowers, but only 20-25% of them develop into mature pods; the rest, especially the young pods, fall off. The decline was significant in unfavorable conditions of drought, soil and air accompanied by high temperatures and hot winds. Optimum temperatures during the flowering phase and pod formation are between 18-22°C. This period is when fodder peas are very sensitive to this factor. The highest yield was recorded in 2023, which could be explained by the highest rainfall in May-June, the period when the establishment of flowers and fodder peas occurred. The lowest yield was recorded in 2021, correlating with lower rainfall in May-June. Favorable rainfall conditions affected seed yield, number of pods per plant, number of seeds per pod and 1000 seed weight. According to Ghodsi et al. (2022) and Prusiński and Borowska (2022), the most critical factor determining pea yield is the even distribution of rainfall during the growing season.

Protein content was affected by climate change. Higher temperatures and lower rainfall were associated with a higher protein content which was in agreement with the conclusions of Walter et al. (2022). Protein yield per ha was significantly affected by rainfall in the flowering period, and its highest value was recorded in 2023. Harsh et al. (2016) also reported that mild or moderate stress can reduce the content of sugar and protein.

## 4. Conclusions

Climatic factors affect the development of plants not separately, but in an integrated pattern. The yield of pea seeds is significantly influenced by cultivar characteristics, sowing time, and climatic factors that vary from region to region. The forage pea "Voskopoja" resilience to low temperatures allows for its cultivation in autumn, completing a long biological cycle. The critical period of flowering, pod setting, and seed growth extends into May-June when temperatures are moderate, and rainfall is abundant. Climatic changes reflected significant changes in green mass yield, number of seeds per pod and seed weight per pod and seed yield but it did not reflect significant changes in the number of pods per plant and 1,000 seed weight. Climate change showed significant effects on seed protein content and protein yield. Protein content in seeds (%) was higher in the year with the lowest amount of rainfall and the highest temperature of the April-June period. Protein yield (kg/ha) was the highest in the year with the greatest amount of rainfall and the lowest temperature of the April-June period.

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## 6. Conflicts of Interest

The authors declare no conflicts of interest.

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