

RESPONSES OF POTATO VARIETIES TO CLIMATIC FLUCTUATIONS: VARIABILITY IN PRODUCTIVITY AND PHYSICAL QUALITY TRAITS

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Abstract. Increasing climatic variability, characterized by frequent extreme events, strongly influences potato yield formation, tuber size distribution and key quality attributes. This study assessed the response of five potato varieties (Castrum, Cezarina, Darilena, Sevastia, Ervant) under contrasting weather conditions over three growing seasons (2023-2025) in the Brașov area. The analysis focused on total yield (t/ha), number of tubers per m², distribution across size classes, specific gravity, dry matter content and starch content. In addition, physical quality indicators were evaluated, including the proportion of shrivelled, mechanically damaged and peeled tubers, as well as defects such as deformation, cracking, sprouting and greening. Results revealed pronounced interannual and genotypic variability. During the analysed period 2023-2025, in the potato growing season (April–September), a trend of increasing temperatures (especially in 2024 and 2025) and an increase in rainfall variability is observed. Yield and tuber number fluctuated significantly depending on climatic conditions, with more pronounced differences observed in years with higher thermal and hydric stress. Quality parameters, including dry matter, starch content and specific gravity, were also influenced by seasonal variability. The incidence of physical defects increased under stress conditions, highlighting their sensitivity to environmental factors. Under the analyzed experimental conditions, the influence of interannual climatic variability on the analyzed parameters was stronger than genetic differences, with moderate differential responses to temperature and precipitation variations being observed for the varieties studied.

Keywords: climatic variability, potato yield, tuber quality

INTRODUCTION

Climate change introduced new challenges for sustainable crop production (KUMAR and KUMAR, 2020). Drought represents a significant constraint on potato production globally (GERVAIS et al., 2021). Potato (*Solanum tuberosum* L.) is a cold-climate species, and the growth and formation of tubers are strongly influenced by temperature and water availability. Increasing temperatures above optimal thresholds lead to yield decline and reduced tuber formation efficiency (GOUEROU et al., 2025). Optimal temperatures for tuberization are generally 15–20°C, and deviations lead to significant decreases in production and quality. Climate change (increasing temperature and variability of precipitation) causes yield reduction and changes in tuber quality (HANDAYANI et al, 2019; HUMANS, 2003). Increased temperature accelerates canopy senescence and reduces the duration of tuber bulking, negatively affecting yield stability and tuber size distribution (HAVERKORT and VERHAGEN, 2008). The growth and development of potato plants under drought and high-temperature stress conditions are inhibited, leading to a significant reduction in potato tuber yields and degradation of tubers quality (FANG et al., 2024)

High temperatures and water deficit reduce photosynthesis and disrupt the transport of assimilates to tubers, which directly affects their formation and growth (LAL et al., 2022). Heat stress causes a decrease in the harvest and tuber mass, reducing the total yield (DAHAL et al., 2019). It has been shown that heat and water stress affect varieties differently, depending on

the genotype and stage of development, some being more tolerant than others (NASIR and TOTH, 2022).

Climatic stress (especially high temperatures) affects the tuberization and filling phase of tubers, which leads to: a reduction in the number of commercial tubers, an increase in the proportion of small tubers, uneven size distribution (EWING and STRUIK, 2010). Disruption of the transport of assimilates to the tubers causes a reduction in growth and, implicitly, in the tubers size class (DEL SOCORRO et al., 2024).

The internal quality of tubers is closely linked to the accumulation of starch and dry matter. Thermal and water stress reduce the accumulation of carbohydrates in tubers by affecting photosynthesis and sugar translocation (DAHAL et al., 2019). Also, the variability of growing conditions (including precipitation and soil fertility) significantly influences the dry matter content and chemical composition of tubers (KEITHELLAKPAM et al., 2026).

Climatic stress frequently causes the appearance of physiological defects: cracking, deformation, secondary growths (DAHAL et al., 2019; LEVY and VEILLEUX, 2007); shriveling occurs under conditions of water deficit or water loss during development and storage. Temperature stress affects the quality resulting in physiological disorders, influences dormancy and triggers early germination (MUHIE, 2022).

The tolerance of varieties to climatic stress is genetically determined and influenced by the phenological stage and stress duration. (NASIR and TOTH, 2022). Drought stress significantly alters tuber size distribution, increasing the proportion of small tubers and reducing marketable yield. Genotypic variation plays an important role in determining resilience to water stress and yield stability (ALICHE et al., 2019).

The purpose of this study was to evaluate the response of five potato varieties to interannual climatic variability over the 2023–2025 growing seasons in the Braşov area, with emphasis on yield performance, tuber size distribution, physicochemical quality traits, and the incidence of physical defects under contrasting temperature and precipitation conditions.

MATERIAL AND METHODS

The study was conducted over three growing seasons (2023, 2024, 2025) in non-irrigated field conditions in Braşov area. For five potato varieties: Castrum, Cezarina, Darilena, Sevastia, Ervant, in addition to total yield (t/ha), number of tubers per m² were graded by tuber diameter into four size classes: small (<35 mm), medium (35-55 mm), large (55-75 mm), and very large (>75 mm). Tuber dry matter, starch content and specific gravity were determined, and physical quality characteristics were assessed.

For the evaluation of external physical characteristics, each tuber from samples of 50 tubers per variety was analysed by an experienced evaluator who established whether the potato tubers were affected by external defects. The evaluation of physical quality indicators determined the proportion of shrivelled, mechanically damaged and peeled tubers, as well as defects such as deformation, cracking, sprouting and greening.

This study used climate data on average monthly temperatures and the sum of monthly precipitation for the months of April–September, corresponding to the period 2023–2025, compared to the multiannual average 1993–2022. The climate data were processed to highlight deviations from the reference climatological values. The thermal and rainfall parameters were organized in the form of monthly time series, allowing the analysis of interannual and seasonal variations. This information was used to correlate climatic conditions with stress manifestations on the potato, especially with regard to the combined effects of high temperatures and precipitation regime on production quality. The data were interpreted in an

agroclimatic context, aiming to identify risk situations determined by the alternation of dry periods with episodes of heavy precipitation.

Data analysis was performed using principal component analysis (PCA), correlation analysis, Microsoft Excel, Past 5 statistical software for the Pearson correlation coefficient matrix analysis and descriptive analysis.

RESULTS AND DISCUSSIONS

The analysis of climatic data for the April–September period in 2023–2025, compared with the multiannual average (1993–2022) (Figure 1), highlights significant deviations in both thermal and rainfall regimes, with direct implications for vegetation conditions. From a thermal perspective, 2023 began with slightly below-average temperatures in spring, followed by a warmer-than-normal summer and early autumn, particularly in August and September. The year 2024 was characterized by consistently above-average temperatures throughout the analysed period, with deviations exceeding 2–3°C during the summer months, indicating an excessively warm regime. In 2025, a cooler spring was followed by elevated temperatures from July to September, outlining a pronounced seasonal contrast. Regarding precipitation, 2023 recorded an initially surplus regime, with above-average rainfall in April–June, but ended with a marked deficit in September. In 2024, a generalized precipitation deficit was observed, especially in May, June, and August, suggesting a dry year. The year 2025 was marked by extreme variability, with alternations between very dry periods (April, June, August) and episodes of abundant rainfall (May, July). This uneven distribution, often associated with high temperatures, generated pronounced climatic stress conditions, favouring the occurrence of phenomena such as deformation, greening, sprouting, and cracking of tubers, particularly in the context of the succession between rainfall deficit and subsequent rainfall events.

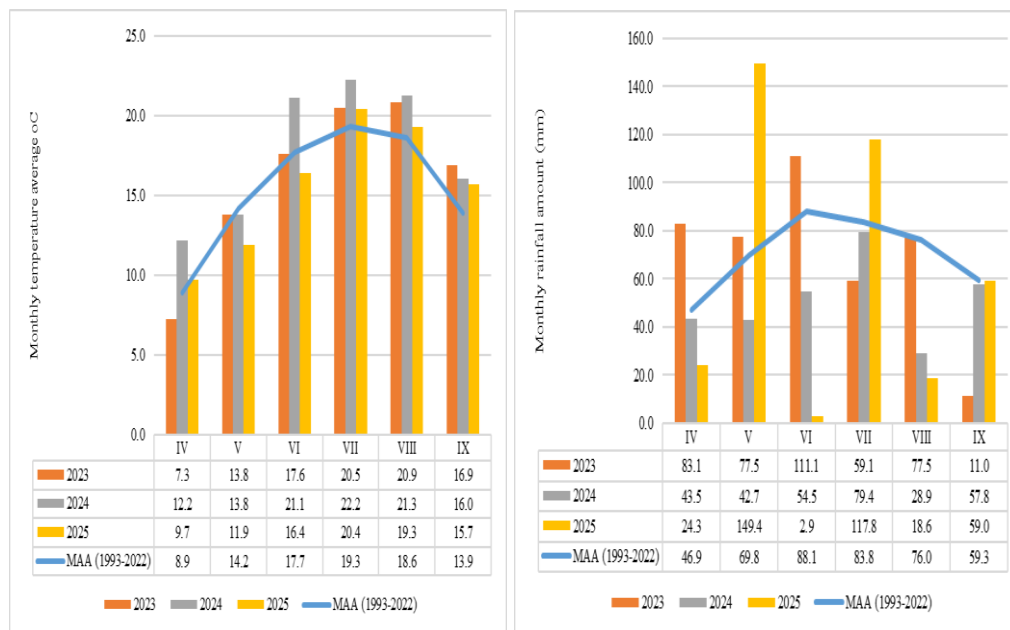


Figure 1. Monthly temperatures average and rainfall amount during the potato growing season in 2023-2025 (April-September) and multiannual average MAA (1993-2022), Braşov

Principal component analysis (PCA) for potato production of the five varieties, by size, depending on the climatic conditions of the three years, revealed a well-defined structure of data variability, with the first two components explaining 84.90% of the total variation (PC1 = 50.79%, PC2 = 34.11%). The distribution of observations in the PCA space indicates a clear separation of the study years, which suggests a pronounced interannual climatic effect on potato production (Figure 2). From the point of view of climatic conditions, the years 2023 and 2024 proved to be more favourable, while the year 2025 is positioned opposite them, standing out as the most unfavourable. This differentiation is associated with an unbalanced rainfall regime, characterized by an excess of precipitation in May, followed by deficient periods, aspects that contributed to the separation of observations in the PCA space.

The high temperatures in June, July and August favoured the formation of a higher proportion of tubers from very small fractions, while the precipitation recorded during the summer period contributed to obtaining high yields of tubers from large (55–75 mm) and very large (>75 mm) fractions.

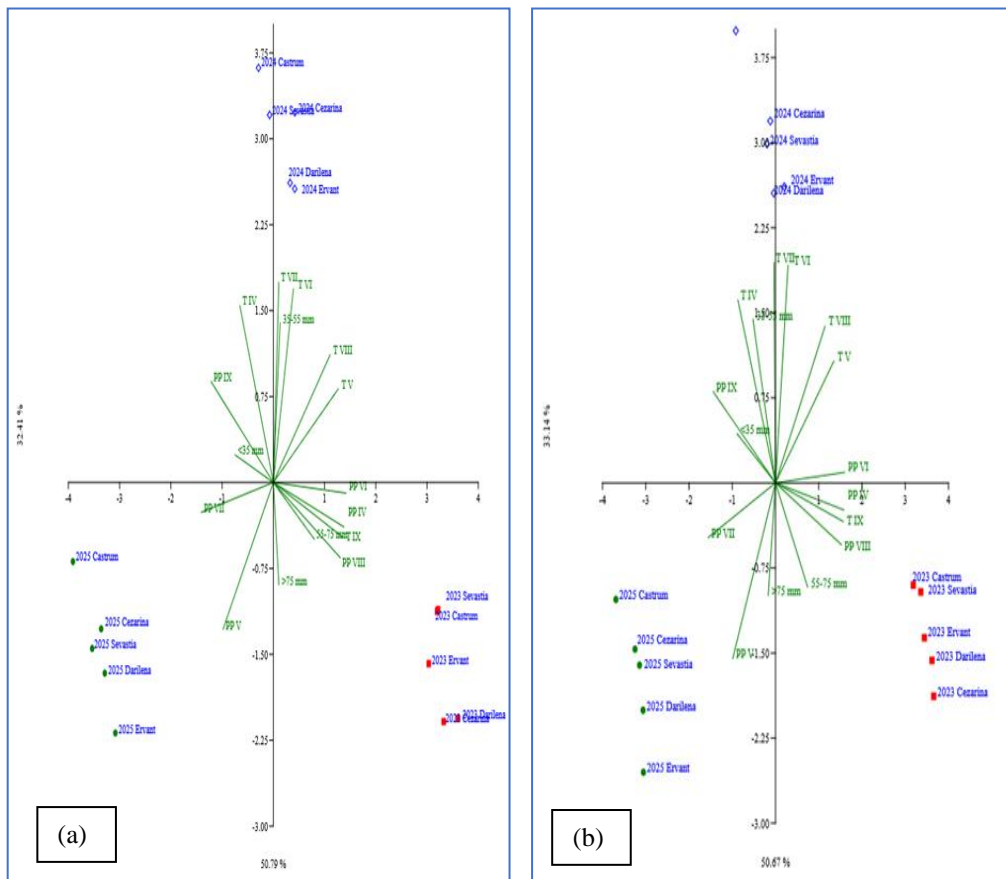


Figure 2. The relationship between climatic conditions and potato production (a), respectively between climatic conditions and the number of tubers (b) by size classes highlighted by principal component analysis

The situation is similar for the number of tubers per fraction depending on the temperature and precipitation conditions in the three experimental years, the variance being explained in this case in a proportion of 83.82%. In 2023, the largest number of tubers was classified in the large fraction (55-75 mm), while in 2025 there were most very small tubers (<35 mm).

Regarding the genotypes (Castrum, Cezarina, Darilena, Sevastia and Ervant), no clear separation is observed in the principal components plan, indicating that the influence of interannual climatic variability is stronger than genetic differences in the analysed experimental conditions. However, certain clustering trends can be observed, suggesting moderate differential responses of the varieties to temperature and precipitation variations.

Regarding tuber quality, strong positive correlations were identified between the three quality indices analysed (starch, dry matter and specific gravity), while precipitation in July and high temperatures during the summer period seem to be negatively, but weakly correlated with tuber quality. Regarding tubers defects, drought in July contributes to tuber deformation and greening, while reduced precipitation in the same period correlated with high temperatures during the summer months leads to an increase in the percentage of sprouted and cracked tubers (Figure 3).

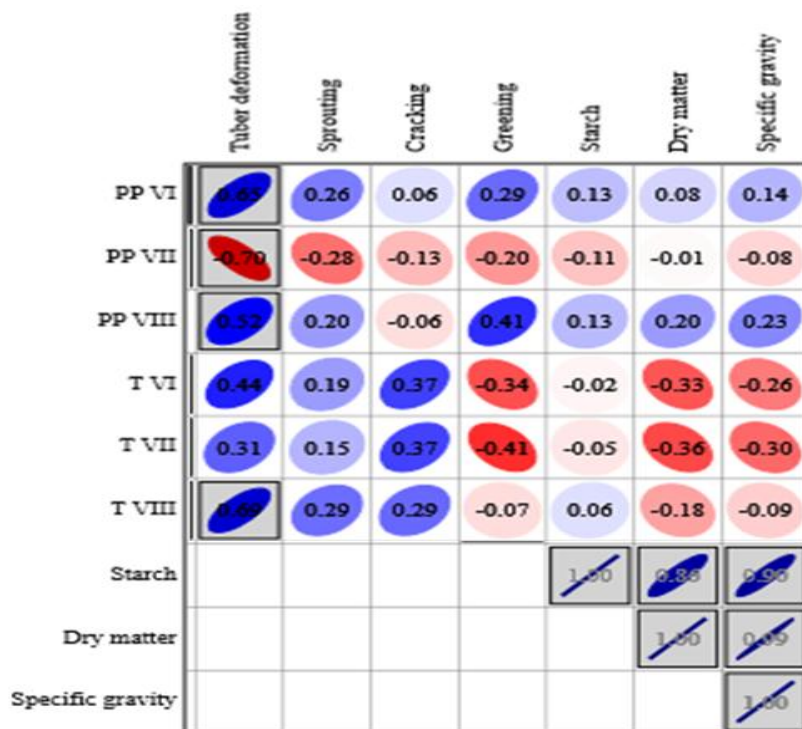


Figure 3. Correlation matrix of summer climatic conditions (T - temperature, PP - precipitation) and potato tuber quality traits

Descriptive statistics of tuber production by fractions highlight a differentiated distribution of values between genotypes and a significant variability depending on the size of the tubers (Figure 4). The >75 mm fraction presents a low mean (2.9) and the highest relative variability (CV = 78.26%), the presence of very large tubers being strongly influenced by the genotype × environment interaction. This fraction appears with minimum values of zero in some genotypes (Sevastia) and moderate maximums in Ervant (5.36 t/ha).

The 55–75 mm fraction, corresponding to the main commercial size, records the highest mean value (10.9 t/ha) and a moderate variability (CV = 33.80%), indicating a relatively good stability of this production interval in the five potato varieties analysed. This fraction can be considered the most important from an agronomic point of view, reflecting a constant productive potential, with maximum values in the Darilena genotype (14.1 t/ha).

The 35–55 mm fraction also presents high average values (12.0 t/ha) and moderate variability (CV = 34.95%), suggesting that a significant part of the production remains in the intermediate size range, without reaching commercial sizes. The maximum in this category was recorded in the Castrum potato variety (18.9 t/ha).

The <35 mm fraction presents the lowest average (2.3 t/ha), but a relatively high variability (CV = 69.82%), being dependent on environmental conditions and genetic peculiarities of the varieties. The maximum values were observed, on average, in the three years in the Castrum variety (5.1 t/ha).

Overall, the analysis of the variation range indicates that the commercial fraction (55–75 mm) is the most stable and dominant component of production, while the extreme fractions (>75 mm and <35 mm) show high variability, reflecting an increased sensitivity to the interaction between genetic factors and environmental conditions.

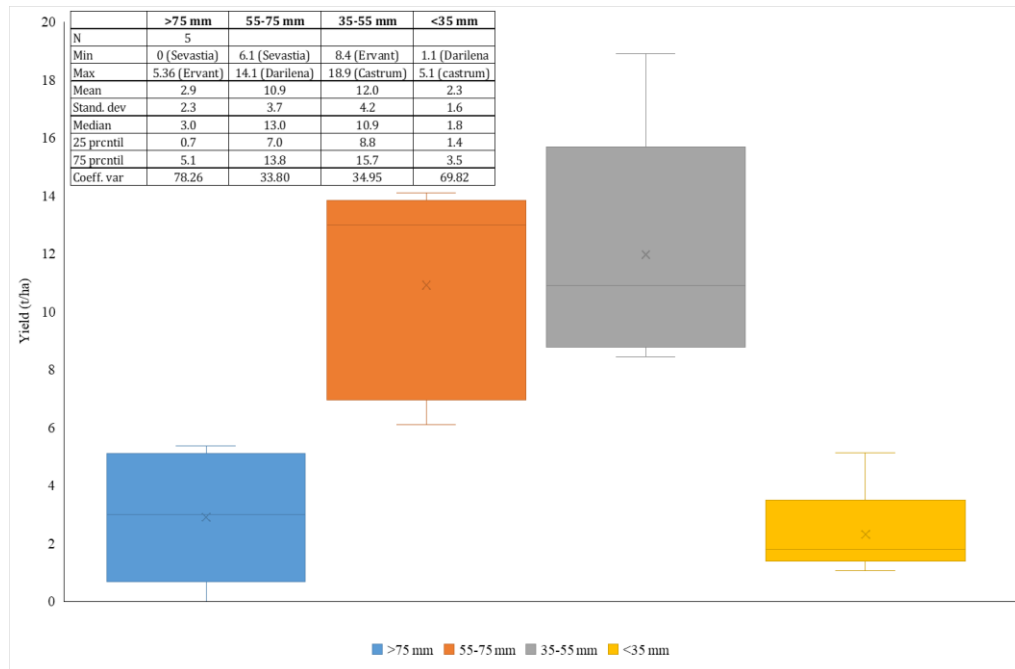


Figure 4. Descriptive statistics of potato yield in five varieties and 3 experimental years

The PCA analysis revealed a clear structure of the variability of potato production, with the first two components explaining 84.90% of the total variation, which confirms that the model effectively captures the main sources of variation in the data.

The distinct separation of years in the PCA space indicates a strong interannual climatic effect on production, with the years 2023 and 2024 being more favourable, while the year 2025 stood out as unfavourable, against the backdrop of an unbalanced rainfall regime and periods of water and thermal stress.

The analysis of the number of tubers by fractions confirmed the same pattern, with an explained variation of 83.82%, highlighting the predominance of commercial fractions in favourable years and the increase of small fractions under climatic stress conditions.

The genotypes analysed (Castrum, Cezarina, Darilena, Sevastia and Ervant) do not show a clear separation in the PCA space, which indicates a stronger influence of climatic factors compared to genetic differences, although there are trends of differential response to environmental conditions.

The analysis of the variation series revealed a differentiated distribution of production by fractions, with the greatest stability in the commercial fraction 55–75 mm (CV = 33.80%), considered the dominant agronomic component of production.

CONCLUSIONS

The climatic conditions during the vegetation period significantly influenced the calibration of tubers: precipitation favoured the formation of the large and very large fractions, while high temperatures determined the increase in the share of small fractions.

The extreme fractions (>75 mm and <35 mm) showed high variability, indicating an increased sensitivity to the genotype × environment interaction and to interannual climatic variations.

The correlations between quality indices (starch, dry matter and specific gravity) were strongly positive, confirming a close relationship between these parameters, while climatic factors showed weak and negative correlations with them.

Tubers defects were influenced by climatic stress: drought and high temperatures favoured deformation and greening, and the succession between rainfall deficit and subsequent precipitation, under high temperature conditions, determined the increase in the percentage of sprouted and cracked tubers.

The results highlight the fact that the performance and quality of potato production are determined predominantly by climatic conditions and by the relationship between the genetic factor and the temperature and precipitation conditions during the potato growing period.

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