THE IMPACT OF WATER AND NUTRIENT STRESS ON FOUR POTATO VARIETIES GROWN IN THE CENTRAL AREA OF ROMANIA

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Abstract

The experiment in this article is an approximate replica of the experiment in the article "The Growth And Development Of The Potato According To Their Variety In The Central Area Of Romania" published in the "Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture", but in a different location in central Romania and with a slight resizing of the experimental plots. This research exposes the adaptability to water and nutrient stress conditions of three potato varieties (`Alouette`, `Salad Blue`, and `Paradiso`) compared to the control variety, `Productiv`, which is a native variety maintained in conservation by research stations. The three potato varieties (`Alouette`, `Salad Blue`, and `Paradiso`) were cultivated under the same conditions as the control. The experimental field was established in central Romania, in Brașov County, Mandra village. During the vegetation period, the following criteria were monitored: height of the main stem, number of main stems, number of leaves on the main stem, length of the median leaf on the main stem, and chlorophyll content of the leaves. Precipitation and daily temperatures were also recorded during the vegetation period. After data centralization and statistical analysis, it was concluded that the variety `Alouette` had the best development.

Key words: Solanum tuberosum L., variety, adaptability, water stress, SPAD.

INTRODUCTION

The potato is a plant introduced into cultivation around 8-10 thousand years ago, adapted to the cultivation environment from its wild forms, originating from the Andes region [23]. As for growing conditions, it was initially adapted to be cultivated at altitudes of over 3,000 meters above sea level, on saline soil, with high solar radiation [16]. Currently, potato varieties are acclimatized in areas with maximum altitudes of 1,000-1,500 meters above sea level, as opposed to sea level [4]. In Romania, it was introduced at the end of the 18th century, being cultivated for the first time by pharmacists in the botanical gardens of Transylvania [20]. In terms of caloric contribution, the potato tuber provides the highest energy content (5,600 kcal/m^3) and protein content (150 g/m^3) per unit of water compared to other cultivated plants [12]. Currently, according to the Food and Agriculture Statistics website, globally, potatoes rank sixth, following sugar cane, which holds the first position, followed by corn, wheat, rice, and oil palm fruits [1]. In Romania, potatoes rank fifth, after wheat, which holds the first position, followed by corn, sunflower, and barley – la fel si aici [1]. The potato is a cultivated plant that prefers moist and cool soils [14]. In Romania, the total quantity harvested annually of potato tubers experienced a sharp downward curve during the period 2019-2022. Specifically, the harvested quantity decreased from 2,626,790 tons in 2019 to 1,345,780 tons in 2022, indicating a decrease of 1,281,010 tons, nearly half, between 2019 and 2022 [13]. According to the Official Catalog of Cultivated Plants in Romania for the year 2023, there are 28 varieties cultivated, including the variety `Productiv` (which is chosen as the control variety in this experiment) [24]. Unofficially, in Romania, several potato seed varieties are

sold according to specialized websites that commercialize seed material. Currently, one of the problems encountered in practice is the nitrogen fertilization of potato crops. Excessive fertilization can lead to excessive vegetative growth, poor tuber quality due to delayed maturity, low dry matter content in small quantities, and probably the biggest issue in this case, water pollution, and inefficient use of nitrogen-based fertilizers [11]. To observe the effectiveness of certain varieties in utilizing the nitrogen present in the soil reserve, without initial fertilization or during vegetation, the morphological characteristics of the plant were monitored

from the soil surface and correlated with the results provided by the SPAD 502 [2]. Through the SPAD (Soil Plant Analysis Development) technology, it is possible to monitor the state of the vegetation of the crop through non-invasiv techniques [22]. The use of SPAD technology offers a practical and convenient method for its use in the field with which the amount of nitrogen in the plant can be observed [22]. In this paper, four varieties of potato were studied, more precisely: `Productiv`, `Alouette`, `Paradiso` and `Slad Blue`. They were cultivated in the Mandra village, in Brașov county (GPS position 45°81`59.92``N; 25°04`52.04``E).

Fig. 1. The location of the experimental site situated between Fagaras city and Brașov city
Source: QGIS - qgis.org.[29]

MATERIALS AND METHODS

Description of the experimental site
The present study was developed on Mandra, a village near Fagaras city, Brașov County (Fig.1).
Climatic conditions
Climatic conditions during the vegetation period, specifically maximum and minimum temperatures of the days, along with

precipitation, are presented in the graph in Fig. 2. Temperatures and precipitation are recorded starting from the day the tubers were planted (22nd April) until the day of harvest (8th September). The sum of the degrees was 2,536 ^{0} [17], and the total precipitation was observed with the help of a rain gauge installed near the plots, amounting to 381 mm during the entire vegetation period.
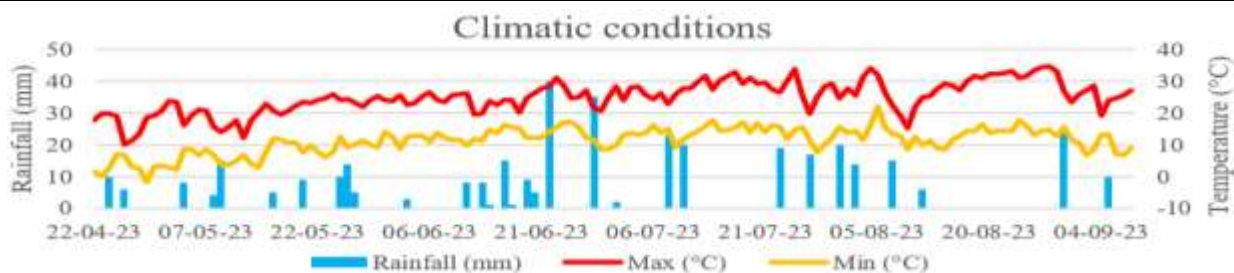
Fig. 2. The climatic conditions during the experimental period in Mandra, Brașov County
Source: meteoblue.com [17].

Description of varieties
The varieties used in this research are the same as in the experiment in Rusciori village, Sibiu county [8]. All of them are certified plant material obtained from Potato Research – Development Stations from Targu Secuiesc (SCDCTS), Romania and Potato Research - Development Stations from Miercurea Ciuc (SCDCMC), Romania and they are:
-`Alouette`, native from the Netherlands;
-`Paradiso`, native from the Netherlands; -`Productiv`, an autochthonous variety, developed at SCDCTS, currently maintained in the conservation stage according to the Official Catalog Of varieties, from Romania;
-`Slad Blue`, native from Scotland.
All four varieties are described on the Table 1, in order to their provider, type of variety, shape of tuber, epidermis and flesh color [8].

Experiment design
The experiment was designed on a plot with dimensions of 11 x 10 m (Lxl), which means 110 m^2, where the four varieties were planted. Each variety was planted on a subplot with a size of 2.50 x 11 m (Lxl), with a total area for each variety 27.5 m^2. The distance between the

subplots was 0.5 m with a 0.8 m protection strip for each outer side of the plot. The tubers were planted at a distance of 0.5 m between rows and 0.25 m between tubers per row, as in the case of the experiment in Rusciori village, Sibiu county [8], resulting in 33 plants per row.

The experimental procedure
The land preparation was carried out through autumn plowing, and the seedbed preparation was done by soil tillage using a motorized cultivator. No fertilizers or amendments were applied to the plots, and no irrigation was applied. Planting was done manually at the beginning of April 2023. Hilling of the rows was performed at the beginning and end of May 2023, and the plots were weeded after plant emergence. During the vegetation period, four treatments were applied against manna (*Phytophthora infestans*) with phytosanitary products containing dimethomorph, propamocarb, zoxamid, cimoxanil and metiram, and phytosanitary products were used for harmful pests (*Leptinotarsa decemlineata* L.) based on cyhalothrin and metaflumizone (Table 2). Tubers were harvested on September 8th, 2023.

Table 1. Summary characterization of *Solanum tuberosum* L. varieties studied

Variety	Provider	Variety	Shape of Tuber	Epidermis Color	Flesh Color
`Alouette`	SCDCMC	Early	Oval-long	Red	Yellow
`Paradiso`	SCDCMC	Early	Oval-long	Yellow	Yellow
`Productiv`	SCDCTS	Early	Round-oval	Yellow	Yellow
`Salad Blue`	SCDCTS	Early	Oval	Blue	Purple to blue

Note: SCDCTS – Potato Research - Development Stations from Targu Secuiesc; SCDCMC – Potato Research – Developmen Stations from Miercurea Ciuc

Source: Original.

Table 2. Phytosanitary treatments performed on the experimental site

Crt. No.	Date of treatment	Vegetation phenophase	Active substance	Pest/disease
1	01.05.2023	Leaf development	Metribuzin	Weeds
2	04.06.2023	Formation of side shoots	Metiram	*Phytophthora infestans*
			Cyhalothrin	*Leptinotarsa decemlineata* L.
3	15.06.2023	Flowering	Metaflumizon	*Leptinotarsa decemlineata* L.
4	30.06.2023	Development of fruits	Metaflumizon	*Leptinotarsa decemlineata* L.
			Zoxamid + cimoxanil	*Phytophthora infestans*
5	10.07.2023	Development of fruits	dimetomorf +propamocarb	*Phytophthora infestans*

Source: Original by own determination.

Data collection and analyzing

On June 16th, June 30th, and July 16th, biometric observations were collected on 10 plants from each variety. The plants were randomly selected from within the experimental plots to determine the influence of each variety on the height of the main stem, the number of main stems, the number of leaves on the main stem, and the length of the median leaf. The height of the main stems was measured by assessing each stem from the soil level to the top (Photo 1).

Subsequently, the number of main stems, the number of leaves on the main stem, and the length of the median leaf were determined using a similar determination method as used by Tessema et al [25; 26]. All determinations were made on 10 different plants from the same variety. Additionally, the average of twenty determinations was determined for the chlorophyll content of the leaves for each plant. The determination of chlorophyll content was performed using the SPAD-502PLUS device created by Konica Minolta, Japan. The device measures the wavelengths of light in the red light spectrum (650 nm) and near-infrared (960 nm) (Photo 2).The SPAD-502PLUS device is capable of measuring the chlorophyll content of the plant by applying the measuring sensor to the plant's leaves [27] All collected data were processed using the IBM SPSS software, applying the Duncan test, using a one-way analysis of variance with four variables. Each variable represents one of the studied varieties.

Photo 1. Determination of the height of the main stem in the experimental field. Each segment of the ruler is 10 cm
Source: Original by own determination.

Photo 2. Measuring the chlorophyll content with the SPAD-502PLUS device, on a potato leaf from the experimental field in Rusciori
Source: Original by own determination

RESULTS AND DISCUSSIONS

During the vegetation period, to protect the plants from pathogens and pests, 6 treatments were applied exactly as presented in the materials and methods section. The pathogens targeted by the treatments are the main agents of potato infestation globally, including *Phytophthora infestans* [15] and *Alternaria solani* [19] . Generally, potato diseases can be prevented through three general methods of control, namely: inducing greater plant resistance to a specific pathogen through selection and improvement, creating resistant varieties in this manner [21], selecting seed material that shows no signs of infection with pathogens and ultimately applying phytosanitary treatments to plants in the vegetative stage [9]. For the height of the main stem, significant differences were observed only between the `Salad Blue` variety, having the shortest height (35.90 cm), and the other three varieties, with the `Alouette` variety having the tallest main stem (64.60 cm). The results of the test regarding the number of main stems were the same for the control `Productiv` variety and the `Alouette` variety (4.33), with the lowest result recorded by `Salad Blue`. `Alouette` had the highest average (12.90) for the number of leaves per main stem, compared to the lowest average recorded by the control variety `Productiv` (11.33). The highest average length of the median leaf was recorded by the `Alouette` variety (22.06 cm), while the lowest average was recorded by the `Salad Blue` variety (16.60 cm). In conclusion, the most relevant indicator for this study was the chlorophyll content that the plants had at the time of observations. `Alouette` was classified as the best following the Duncan test on field-collected data (37.90 SPAD units), followed by `Productiv` (36.31 SPAD units), `Paradiso` (33.65 SPAD units), and lastly `Salad Blue` (32.78 SPAD units) (Table 3). The value Several expressed in the SPAD index is closely related to the nutrients contained in the potato plant on which the measurement is applied [7].

Table 3. Biometric observations on the experimental site regarding the growth of plants

Variety	Height of the main stem (cm)	No. of principal stems	Leaves no. on the main stem	Length of leaf (cm)	The clorophyll content of leaves (SPAD units)
`Alouette`	64.60[a]	4.33[a]	12.90[a]	22.06[a]	37.90[a]
`Paradiso`	60.66[a]	3.70[ab]	12.13[a]	18.26[b]	33.65[bc]
`Productiv`	60.40[a]	4.33[a]	11.33[a]	20.66[a]	36.31[ab]
`Salad Blue`	35.90[b]	3.16[b]	12.90[a]	16.60[b]	32.78[c]

Note: The means in the column inside the table followed by different letters are significant according to Duncan`s MR test (p<0.05).
Source: Original by own calculation.

Researchers have demonstrated that if the SPAD index is between 49 and 56, the plants are very well supplied with nitrogen and can achieve maximum yield if other environmental conditions are optimal [3; 6; 10; 18].

A similar research took place in Brașov County, in the years 2013 and 2014, on two local potato varieties, but unlike the experiment in this article, the plots were fertilized. Similar to the present experiment, Barascu and colleagues performed biometric measurements for: main stem height, average leaf length, number of main stems, and chlorophyll content in leaves using the SPAD [2]. The data obtained by the authors from June 19th, July 1st, and July 16th, 2013, and June 10th, June 23rd, July 7th, and July 21st, 2014, were compared, these days coinciding with the vegetation periods in the present article for which the same data were collected. Following centralization, the Duncan test was applied, using the IBM SPSS program (Table 4), to identify if there are similarities, especially for chlorophyll content. The results of the Duncan test indicate significant differences for main stem height, average leaf length, and number of main stems, which can be explained by the fact that the two varieties in Barascu`s experiment had a greater development of the upper part due to optimal nitrogen fertilization, nitrogen being the nutrient element with the highest contribution to plant biomass accumulation [5]. Studies show that nitrogen, as a factor that can influence the yield of potato plants, has a percentage contribution of 40 to 50% [28]. Another study carried out on potato crops that

aimed to identify the most important factors that can influence the quality of tubers was carried out in the Loess Plateau of China, and the result was that nitrogen was the most important, before phosphorus, potassium and pH in ground [30]. Likewise, the nitrogen content of the plant had an important influence on the total content of soluble sugar, vitamin C, the intensity of browning and the activity of polyphenol oxidase [30]. But for chlorophyll content, the comparison between the `Alouette`, `Productiv`, and `Christian`, `Raclos` varieties shows a slight similarity in results, which may mean that the two `Alouette` and `Productiv` varieties may have genetic potential for adaptability to nutritional stress conditions. For an overview of this research, for which two experimental fields were created, in two different localities, a Duncan test was applied to the obtained results (Table 5).

Table 4. Differences between the results of this experiment and those of Brascu (source: original by own calculation)

Variety	Height of the main stem (cm)	Length of leaf (cm)	No. of principal stems	SPAD index
`Alouette`	64.60[b]	22.06[c]	4.33[b]	37.90[ab]
`Paradiso`	60.66[b]	18.26[de]	3.70[b]	33.65[bc]
`Productiv`	60.40[b]	20.66[cd]	4.43[b]	36.31[abc]
`Salad Blue`	35.90[c]	16.6[e]	3.16[b]	32.78[c]
`Christian`	82.28[a]	29.15[b]	6.08[a]	41.27[a]
`Raclos`	84.57[a]	33.42[a]	6.32[a]	39.57[a]

Note: The means in the column inside the table followed by different letters are significant according to Duncan`s MR test ($p < 0.05$).
Source: Original by own calculation.

Table 5. The results obtained on the experimental fields in Mandra and Rusciori

Variety	Height of the main stem (cm)		No. of principal stems		Leaves no. on the main stem		Length of leaf (cm)		SPAD index	
	Rusciori	Mandra	Rusciori	Mandra	Rusciori	Mandra	Rusciori	Mandra	Rusciori	Mandra
`Alouette`	43.54[b]	64.60[a]	6.24[a]	4.33[bc]	11.40[bc]	12.90[a]	13.90[c]	22.06[a]	38.24[ab]	37.90[ab]
`Paradiso`	30.24[c]	60.66[a]	4.02[c]	3.70[cd]	9.38[d]	12.56[a]	13.90[b]	18.26[b]	36.24[b]	33.65[c]
`Productiv`	38.22[c]	60.40[a]	5.36[b]	4.43[bc]	10.00[cd]	11.03[bc]	17.88[b]	20.66[a]	36.31[b]	36.31[b]
`Salad Blue`	28.64[d]	35.90[c]	5.64[a]	3.16[d]	9.48[d]	12.56[a]	14.24[c]	16.6[b]	31.63[c]	32.78[c]

Note: The means in the column inside the table followed by different letters are significant according to Duncan`s MR test ($p < 0.05$).
Source: Original by own calculation.

CONCLUSIONS

Considering the results obtained in this experiment, the variety `Alouette` presented the best development among the four varieties of the experiment, with acceptable assimilation of nitrogen from the soil even in the conditions of an unfertilized plot, which can lead, according to the specialized literature and at a high yield of tubers, provided that the other pedoclimatic factors meet the standard vegetation conditions for potato plants. Another argument to determine that the `Alouette` variety has a good ability to adapt to less favorable conditions and to argue that from a physiological point of view it is the variety

with the best results from this experiment, is the statistical comparison with the results of the research done by Barascu and the collaborators, also in Brașov county, with the two local varieties, but who had a part in the application of fertilizers on the experimental plot. The reduced precipitation during the vegetation period did not have such a significant negative influence as on the other varieties in the experiment. Similar to the experiment in the village of Rusciori, Sibiu county, we can consider that the `Alouette` variety could be one of the options for potato growers in the area of Brașov county, showing good adaptability to the pedoclimatic conditions of the region. On the other hand, the variety `Salad Blue`, based on the unsatisfactory results, cannot be considered a good option for cultivation in this area, offering a low yield in terms of nitrogen assimilation from the soil, which leads to a low yield of tubers. Making an overall analysis of the two experiments, the statistical results, according to Table 5, indicate that the best results for chlorophyll content were obtained for the varieties: `Productiv` and `Alouette` in Rusciori locality and `Alouette` in Mandra locality. These claims are supported by the above statistical results of the biometric measurements and readings taken with the SPAD-502PLUS device. We plan to continue the research with the determination of the yield for the two experimental fields and the biochemical analysis of the tubers.

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