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THE EFECT OF TEMPERATURE IN THE MILLET SEED GERMINATION AND THE INFLUENCE OF ROW SPACING ON THE PERFORMANCE OF SEVERAL *Panicum miliaceum* L. GENOTYPES UNDER THE PEDOCLIMATIC CONDITIONS OF A.R.D.S. SECUIENI

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Abstract

Millet is a secondary crop in Romania but at the global scale it occupies substantial cultivated areas in arid regions (Asia and Africa), where its grains constitute a staple food for populations. In the context of recent climatic changes, the diversification of cultivated species has become a well-established objective. Consequently, in 2022, Panicum miliaceum L. was incorporated into the research portfolio of the A.R.D.S. Secuieni. The investigation focuses on two main objectives: the effect of temperature on millet seed germination and the interaction between genotype and row spacing on millet grain yield. Laboratory experiments demonstrated a directly proportional relationship between temperature and germination percentage, with 50.25% germination recorded at 10°C and 97.75% at 20°C. Field trial results revealed that millet demonstrates pronounced adaptability to the pedoclimatic conditions of the Secuieni area in 2022. Under these conditions, the evaluated genotypes produced average yields ranging from 1984 kg/ha (cultivar Marius - 12.5 cm row spacing) to 1664 kg/ha (BG 1 - 50 cm row spacing), highlighting an inverse relationship between grain yield and row spacing.

Key words*: germination percentage, millet, row spacing, yields.*

INTRODUCTION

Currently, grain consumption supports about 50% of the world's total calorie intake and is largely provided by wheat, rice, and maize (Awika, 2011; Das, 2019; Palchetti, 2019).

At the same time, climate change accelerates land degradation and desertification, and extreme weather events decrease yields (Habiyaremye, 2017; Kumar, 2017; Ullah, 2017).

Growing and eating millet would not only reduce protein micronutrient malnutrition, but also help diversify crops and diets.

Millet, botanically, is a member of the *Poaceae* family, sub-family *Panicoideae*, tribe *Paniceae*, representing the *milium* of the Romans and the *dokhan* of the Jews.

Panicum miliaceum L. is one of the world's first domesticated crops and was cultivated before the spread of rice, maize and wheat (Crawford, 2006; Sage, 2011). Throughout history, the introduction of corn into cultivation dethroned "the chief cereal of our peasantry, which ate millet polenta (mălai) nutritious but difficult to consume" (Săulescu, 1947).

Ten thousand years ago, it appeared as a staple food in the semi-arid regions of East Asia and later spread throughout the Eurasian region (Lindquist, 2005; Cavers, 2016), millet grains are still an important source of energy and protein for millions of people living in arid and semi-arid areas in emerging countries, while millet biomass is an important source of food in some Asian countries, such as India (Blümme et al., 2003; Brunette et al., 2016).

About 2/5 of the world's cereal production is used in animal nutrition, sometimes complementing traditional fodder and associations between various animal species and specific grains are well known, for example: horses and oats, poultry and millet so the major

share for millet goes to the poultry feed industry. No matter how many health benefits it has, including gluten-free, low glycemic index, high protein and fiber content, millet is still struggling to break into the food industry.

Among the C_4 panicoids, millet (*P. miliaceum* L.) is known to possess morpho-physiological traits that confer tolerance to abiotic stress and show greater adaptability than other cereal crops in different environmental conditions (Bandyopadhyay, 2017; Vetriventhan, 2018), having a fasciculated, very well developed and branched root system

The most popular name of *P. miliacum* L. is "proso millet" comes from the general Pan-Slavic name for millet (Croatian: proso, Serbian: просо) (Enea, 2023).

Millet is considered a low-input ingredient because it requires low production costs (it can be grown on marginal lands) having special agrotechnical advantages: resistance to drought and pest attack, minimum requirements in regarding fertilization (Amadoubr, 2013; Changmei, 2014). Adding to these the short vegetation period, between 60-100 days (Baltensperger, 2002).

Given the current and future scenarios, scientists suggest that an effective strategy could be to replace cereal crops that have high water requirements with others adapted to drought conditions (Ndiku, 2014).

MATERIALS AND METHODS

This paper focuses on the results obtained from 2 distinct research studies, one conducted in a controlled environment, in the laboratory, and one conducted in the experimental field.

In the laboratory, the influence of temperature on the percentage of germinated grains was investigated.

As a working methodology, germination samples were carried out which consisted of determining the percentage of pure seeds, capable of producing normal germs and which, put in favorable cultivation conditions, produce normally developed plants.

From the pure, well-homogenized seed, four samples of 100 seeds were randomly counted, which were placed on the vegetation layer, in Petri dishes.

For a better investigation of the thermophilic character of this species and to highlight its plasticity and adaptability the millet samples were placed in the germination chamber at for different temperatures:

- 10ºC;
- 14ºC;
- 18ºC;
- 20ºC.

The result of the germination test was calculated as an average of the four samples of 100 seeds and was expressed in numerical percentages of normal germs.

In the experimental fields of A.R.D.S. Secuieni, in 2022, the millet experiences placed that the aim to:

- establishing the adaptability of some millet genotypes to the pedoclimatic conditions in Central Moldova;
- establishing the optimal row spacing.

The bifactorial experiment, of the 5x3 type, was located according to the method of subdivided plots, consisting in:

- Factor A – genotypes;
- Factor B – row spacing.

In the experiment the rate seed of sowing was 10 kg/ha.

P. miliaceum L., today in the Official List of Cultivated Varieties in Romania, has as its representative only the variety Marius.

The genotypes used in the field experiment consisted of:

- Marius variety (from N.A.R.D.I. Fundulea);
- local population Secuieni (here referred as "Secuieni");
- BG 1 genotype from Mihai Cristea Plant Genetic Resources Bank Suceava;
- BG 2 genotype Mihai Cristea Plant Genetic Resources Bank Suceava;
- BG 3 genotype Mihai Cristea Plant Genetic Resources Bank Suceava.

The row spacing used for these five varieties was:

- 12.5 cm;
- 25 cm;
- 50 cm.

The millet experimental crop was sown in the optimal epoch for this geographic area (Central Moldavian Plateau), the beginning of May (first 1decade), in a dry land as a result of rainfall deficit recorded in 2022, it was harvested in

mid-August, the vegetation period for millet under the conditions of A.R.D.S. Secuieni was 95 days and the obtained data were processed and statistically interpreted according to the variation analysis method (Jităreanu, 1994).
During the experiment, the harvested area was 10 sqm, the rows of plants had a length of 10 m, and their width was 1 m for the distance between rows of 12.5 cm and 25 cm and 2 m, respectively, when the distance between the rows of plants was 50 cm. Also, the number of rows/experimental plot was 8 (distance of 12.5 cm between rows) and 4 (distances of 25 cm and 50 cm between rows).
The experimental field of A.R.D.S. Secuieni where the bifactorial experience was located has the following characteristics:

- phaeozem (chernozem) typical cambic with a medium texture;
- slightly acidic, having a pH $_{H2O}$ = 5.98;
- poor-medium fertile, with active humus (1.88%);
- low-medium nitrogen supply (16.2 ppm N-NO_3);
- poorly supplied with potassium (124.6 ppm K_2O);
- Well stocked with:
  - phosphorus (77.6 ppm PAL);
  - calcium (13.6 meq/100 g sol);
  - magnesium (1.8 meq/100 g soil) (Enea, 2025).

RESULTS AND DISCUSSIONS

Proso millet, a well known C_4 species, shows a notable preference for higher thermal conditions, which decisively influences its germination process.
It is well known that in order for millet grains to start the germination process in an efficient way, it is essential to have higher ambient temperatures. This aspect was studied under laboratory conditions, analyzing four thermal variables to determine the percentage of millet grain germination over 7 days (Table 1).
The results of this research revealed that high temperatures are a significant factor in stimulating the germination of millet grains.
Studies have shown that temperatures maintained within a specific range generated a higher germination percentage compared to lower temperatures. This information is particularly useful in helping to understand the specific needs of millet and to develop optimal agricultural practices to ensure healthy germination and robust growth of this plant.
Analyzing the data presented in Table 1, it can be seen that there is a positive correlation between high temperatures and germination percentage.
When temperatures are higher, there is a significant increase in the rate of seed germination.

Table 1. Influence of temperature on the germination of millet grains

Temperature (°C)	Germinated grains (%)
10	50.25
14	70.50
18	87.75
20	97.75

This result suggests that the dynamics of the germination process are favorably influenced by optimal thermal conditions, which can be crucial in optimizing millet cultivation and production.
This finding provides valuable insight for farmers and researchers, pointing to the importance of appropriate temperatures in the millet cultivation process to ensure efficient germination and optimal production.
Analyzing the results obtained over 7 days, we see that the temperature of 10°C ensures the germination of 50.25% of millet grains, while the temperature of 20°C has a significantly greater impact, causing an impressive germination rate of 97.75% (Figure 1).

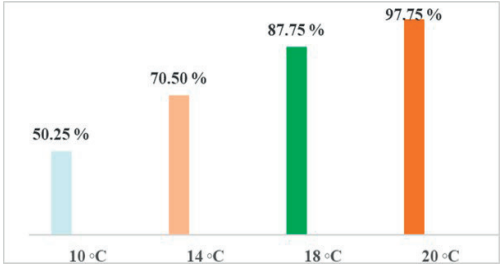

Figure 1. Effect of temperature on the percentage of germinated grains

Data on germination at different temperatures emphasize the importance of thermal influence in the process of millet seed development.
The higher temperature seems to create favorable conditions for rapid and efficient germination, as illustrated in the significant

percentage of 97.75% (Figure 1). This information is very useful in the context of optimizing cultivation conditions, providing farmers and researchers with practical guidelines for improving yield and efficiency in millet production.

The agricultural year 2021/2022 was characterized as:

- hot: +1.6oC compared to the multiannual average;
- very dry: deficit: -264.0 mm.

Throughout its period being characterized by an uneven distribution of rainfall and a trend of aridization.

The millet vegetation period (May – August) in 2022 was characterized as:

- hot: deviation of +1.9oC;
- very dry: deficit -163.4 mm (Enea Andreea, 2022) (Figures 2 and 3).

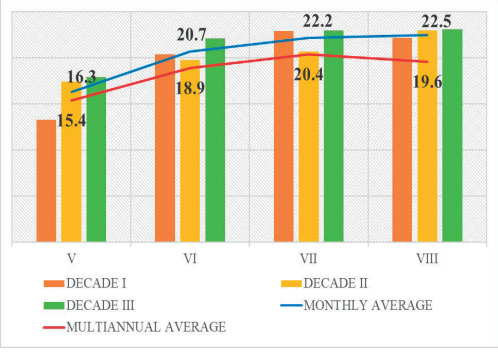

Figure 2. Temperatures (ºC) during the millet vegetation period, A.R.D.S. Secuieni, 2022

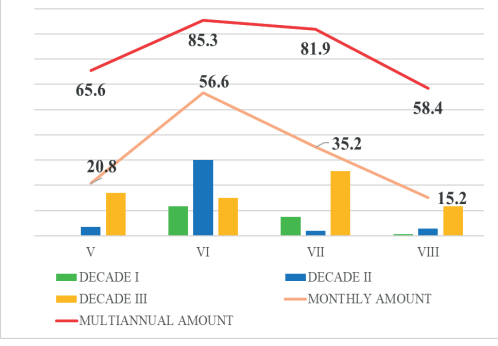

Figure 3. Precipitation (mm) during the millet vegetation period, A.R.D.S Secuieni, 2022

In May, when the millet crop was sown, the temperatures had a deviation of +0.9ºC, and the rainfall deficit was -44.8 mm.

The hottest period was represented by the summer months, the deviation being +1.8 ºC (June and July) and 3.1ºC (August), aimed rainfall deficits -28.7 mm (June), -46.7 mm (July) and -43.2 mm (August), during this period the growth, filling and maturation of millet grains are achieved, but this species has a pronounced ecological plasticity, proving in these conditions the high resistance it has in drought conditions.

The yield stability in field crops is given by the varieties with a high yield potential, with a superior yield quality and a better adaptability to the biotic and abiotic environmental conditions.

Recommending the optimal distance between the rows of plants in the cultivation of millet is an essential aspect in obtaining optimal yields in this crop.

Scientific research abroad has shown that there is an inversely proportional relationship between production and row spacing, which means that increasing this distance can negatively influence millet crop production (Agdag, 2001).

When the row spacing is properly optimized, millet plants benefit from the necessary space to develop their root system and access water and nutrient resources in the soil efficiently.

Also, a properly optimized distance can lead to better absorption of sunlight, an even distribution of the plant in the field, and ultimately higher grain yield.

Since millet is a crop of secondary importance in our country, not being in the attention of farmers, data are limited in terms of its crop technology.

The Romanian literature recommends sowing in rows at a distance of 12.5 cm (Zamfirescu, 1965), subsequently, in more recent studies specialists suggested that the optimal distance should be 25 cm or 50 cm between rows on weeded land (Roman et al., 2011, 2015).

Adjusting the row spacing and proper variety selection can be key-strategies for optimizing proso millet yield crops.

Within this field experiment, compared to the control of the experience, the interaction of the Marius variety x 12.5 cm, which achieved 2984 kg/ha yield, statistically assured differences were obtained:

negatively significant – at the interactions: Marius variety x 25 cm (2423 kg/ha), Marius x

50 cm (2298 kg/ha) and BG 2 x 12.5 cm (2393 kg/ha) and BG 3 x 50 cm (2452 kg/ha);

- distinctly significant negatives - at interactions: BG 2 x 25 cm (2236 kg/ha) and BG 2 x 50 cm (2203 kg/ha);
- very significant negatives – at interactions: BG 1 x 12.5 cm (1878 kg/ha), BG 1 x 25 cm (1720 kg/ha) and BG 1 x 50 cm (1664 kg/ha) (Table 2).

The differences between the studied variants and the control have values ranging between -79 kg/ha (Local population Secuieni x 12.5 cm) and -1320 kg/ha (BG 1 x 50 cm).

These observations provide valuable information for farmers in terms of adapting crop practices to achieve superior yields.

Table 2. Table title example that should be replaced with your information

Genotype	Row distance (cm)	Average yield (kg/ha)	Control differance (%)	Control differance (kg/ha)	Semn
Marius variety	**12.5**	**2984**	**100**	**Mt**	
	25	2423	81	-561	o
	50	2298	77	-686	o
Local population Secuieni	12.5	2905	97	-79	
	25	2636	88	-348	
	50	2485	83	-499	
BG 1	12.5	1878	63	-1106	ooo
	25	1720	58	-1264	ooo
	50	1664	56	-1320	ooo
BG 2	12.5	2393	80	-591	o
	25	2236	75	-748	oo
	50	2203	74	-781	oo
BG 3	12.5	2738	92	-246	
	25	2623	88	-361	
	50	2452	82	-532	o
Average		2332	78	-652	o
Dl A*B 5%				511	
Dl A*B 1%				688	
Dl A*B 0,1 %				915	

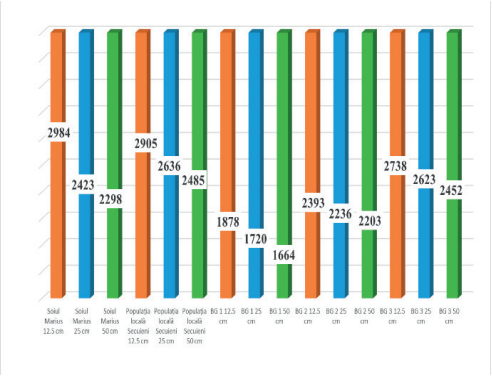

Figure 4. Influence of genotype x row spacing interaction (kg/ha), 2022

The average yields obtained (Figure 4) ranged from 1664 kg/ha (interaction BG 1 x 50 cm between rows) to 2984 kg/ha (interaction Marius variety x 12.5 cm between rows).

We also observe that in all genotypes studied, the yield level decreases with increasing distance between plant rows (Figure 4).

Similar research was carried out in Sidney, Nebraska (1998) which concluded that millet productivity, number of siblings and straw weight decreased as the distance between rows increased (Agdag, 2001).

CONCLUSIONS

Millet is a thermophilic species, which germinates at high temperatures (20ºC 98% of the grains germinated).

The agricultural year 2021/2022 was a hot and dry year.

Millet showed a very good adaptation to the pedo-climatic conditions specific to the Central Moldavian Plateau.

The 5 genotypes studied had yields between 2984 kg/ha (Marius variety x 12.5 cm) and 1664 kg/ha (BG 1 x 50 cm).

An inversely proportional relationship was observed between the distance between the rows of plants and the level of production.

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