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SUMMARY OF Ph.D. THESIS

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RESEARCH ON THE INFLUENCE OF SOME TECHNOLOGICAL CHAIN ON CERTAIN YIELDS PARAMETERS IN MILLETS (*PANICUM MILIACEUM* L.)

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INTRODUCTION

Millet is a member of the *Poaceae* family, *Panicoideae* subfamily, *Paniceae* tribe.

The millenary culture of millet, as well as its wide spread since the Old World in Asian, African and European countries, generate in the scientific world different conceptions and opinions regarding the nativity of millet, this issue being controversial and topical.

Throughout history, the introduction of corn crop has dethroned "the staple grain of our peasantry, who ate nutritious but difficult to digest millet porridge." (Săulescu N., 1947).

Millet is one of the plants whose genetics are poorly known, but which has potential for next-generation cereal breeding programs (Bandyopadhyay T., 2017).

In Romania, through the processes of hybridization and individual selection carried out in hybrid populations, the first Romanian millet variety was born in 1987 - Minerva (Gumaniuc Ludmila, 1988), followed by Mărgărit, Marte, Matador, Mirel and Marius, all creations of N.A.R.D.I Fundulea from 1987 to 2001, alongside these, at Podul Iloaiei, Pricop N. and Crețu L. created the Moldrom variety.

In Serbia, at the 2020 International Conference, "Healthy Food", aspects were pointed out regarding the importance of millet culture, which has a high biomass yield, which is why it is of great importance in bioenergy production. The priority is to procure raw materials and develop the biofuel production process in an economical way (Popovic Vera, 2020). Millet has the lowest water requirement compared to other cereals and is a significant crop in sustainable systems.

The short duration of vegetation (some varieties reaching maturity 60 days after sowing) and the wide adaptability to different environmental conditions, having a much more efficient productivity per unit of soil moisture than other cereals (Graybosch R.A., 2009), making the millet one of the most suitable crops for sustainable agriculture, guaranteeing future food security. It can provide significantly higher yields on marginal lands with low fertility and agricultural systems with low inputs, compared to many other crops, having special agrotechnical advantages: resistance to drought and pest attack, minimal requirements in terms of fertilization (Amadoubr I., 2013; Changmei S., 2014).

Currently, cereal consumption supports approximately 50% of the world’s total calorie intake and is largely provided by wheat, rice and maize (Awika J.M., 2011; Das S., 2019; Palchetti E., 2019). At the same time, climate change is accelerating land degradation and desertification, and extreme weather events are reducing yields

(Habiyeramye C., 2017; Kumar A., 2017; Ullah A., 2017). Cultivation and consumption of millets would not only reduce protein micronutrient malnutrition, but also contribute to crop and diet diversification.

In addition, recent increases in gluten-free product trends and escalating health awareness among people have created a renewed interest in the ancient grain. The food market for millet has found its way into various breakfast cereal mixes, bakery products, fermented products as well as in the manufacture of alcoholic drinks. The added value that millet flour brings to consumers is also reflected in its abundance in vitamins vitaminele B1, B2, B5, B6, E (Hulse J.H., 1980; Ragee S., 2006).

Thus, in food, millet grains still represent an important source of energy and protein for millions of people living in arid and semi-arid areas in emerging countries, while millet biomass represents an interesting feed source in some Asian countries, such as India (Blümme L. M., 2003; Brunette T., 2016).

Millet grains contain a large amount of lecithin which plays an important role in the neural health system, and the fiber and antioxidant content is also valuable in cancer prevention (Das S., 2019).

About 2/5 of the world's grain yield is used in animal nutrition, sometimes supplementing traditional feed, the associations between various animal species and specific grains being well known, namely: horses and oats, birds and millet; thus, the major market share for this species comes from the bird seed industries.

No matter how many health benefits it has, including gluten-free, low glycemic index, high protein and fiber content, millet is still struggling to enter the food industry.

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I also extend my deep thanks to my husband, my little girl, and my entire family for their understanding and constant help throughout this endeavor, as well as to all those who have been by my side and supported me throughout this period.

ABSTRACT

Keywords: *Panicum miliaceum* L., genotype adaptability, foliar fertilization, rate seed, rows distance, herbicides

The experiences carried out within the doctoral thesis entitled "**Research on the influence of technological chain on certain production parameters in millet (*Panicum miliaceum* L.)**" were carried out between 2022 and 2024, and were located in the experimental field of the A.R.D.S Secuieni Agricultural Research, Neamț.

The analyses regarding the quality of millet grains were carried out at the A.R.D.S Turda, Cluj. Three determinations were performed for each determined compound, the final results representing their average.

The primary purpose of this doctoral thesis is to develop and promote technological sequences specific to millet crop in order to increase productivity both quantitatively and qualitatively.

Achieving the goal requires completing the following objectives: studying some millet genotypes and establishing those with high adaptability to the pedoclimatic conditions specific to the Center of Moldova, establishing the effect of foliar fertilization on the yield level and quality, establishing the influence of row spacing on the yield level and quality, establishing the influence of ecological factors of the years of experimentation on yield grain, testing the effects of herbicides approved for various cereals, legumes, cruciferous or oilseeds on millet crop and introducing them into the crop technology, expanding it into zonal agriculture by disseminating the results obtained.

The fulfillment of the objectives proposed within the doctoral thesis was achieved by establishing 3 experiences of the type 2x3x5, 5x3 and 10x2.

The 2 x 3 x 5 experiment aims to identify the genotype that presents the most pronounced adaptability to the pedoclimatic characteristics of the A.R.D.S Secuieni influence area, as well as to establish the optimal seed rate and research the influence of foliar fertilization on the millet grains yields and quality. Factor A represents the genotype, namely: a_1 = Marius variety, a_2 = local population Secuieni, B factor represents rate seed, namely: b_1 = 10 kg/ha, b_2 = 14 kg/ha, b_3 = 18 kg/ha, and C factor represents foliar fertilizer, namely: c_1 = unfertilized, c_2 = TerraSorb (2,0 l/ha), c_3 = Asfac (1,0 l/ha), c_4 = Albit (0,04 l/ha) and c_5 = Albit (0,06 l/ha).

The 5 x 3 experiment aimed to identify millet genotypes that show pronounced adaptability to the ecological characteristics of the area, as well as to establish the optimal distance between plant rows. Factor A represented the genotype, namely: a_1 = Marius variety, a_2 = local population Secuieni, a_3 = BG 1 genotype, a_4 = BG 2

genotype, a_5 = BG 3 genotype, and factor B represents distance between plant rows, namely: b_1 = 12,5 cm, b_2 = 25 cm and b_3 = 50 cm.

The 10 x 2 experiment aimed to identify herbicides and optimal doses to which millet is not sensitive, without affecting its good growth. Factor A represents the commercial product, namely: a_1 – Stomp, a_2 = Gallup Super, a_3 = Aloha, a_4 = Gardoprim, a_5 = Adengo, a_6 = Basagran, a_7 = Dicopur, a_8 = Ceredin Super, a_9 = Agil, a_{10} = Corum, factor B represents dose, namely: b_1 = minimum recommended dose and b_2 = maximum recommended dose.

Structurally, the doctoral thesis comprises two parts, accumulating a total of 10 chapters and a number of 189 pages, 67 figures and 62 tables.

The first part, entitled "**The current state of national and international research on millet crop**", comprises 3 chapters, totaling 33 pages (16,84%).

The first chapter reports the origin and history of the name of millet, its distribution, importance, systematics, biology and morphology, genetics, breeding and biotechnology of millet.

The second chapter includes the requirements of millet for temperature, humidity, light and soil, and **the third chapter** summarizes aspects regarding the technology of millet crop.

The second part is called "**Results obtained - presentation and interpretation. Conclusions and recommendations**", presents 7 chapters, having 162 pages (83,16%). This part includes information on the natural setting in which the research was carried out, the purpose and objectives of the doctoral thesis, the material and research method used, as well as the own results of the experimental research carried out.

In chapter four, the description of the natural environment in which the experiments were set up was carried out, referring to:

• the geographical location of the experimental field;

• the thermal, pluviometric and other climatic factors;

• soil types and agro-productive characteristics.

In chapter five are presented the purpose and objectives of this doctoral thesis, the biological material used, the way the experiments were set up and the methodology used.

The material used was represented by the 5 millet genotypes, which included a Romanian variety (Marius), a local population (Secuieni) and 3 genotypes from the Suceava Gene Bank (BG 1, BG 2 and BG 3).

The methods carried out in the field and laboratory were:

- methodology of phenological investigations and biometric measurements;

- methodology of physiological and biochemical investigations carried out in the laboratory;
- methodology of statistical and economic analysis.

The sixth chapter presents the climatic conditions recorded during the research period, with a focus on the thermal regime and the rainfall regime in the 2021 – 2024 agricultural period. **The seventh chapter** highlights the results on the influence of the researched factors on millet grain yields (*Panicum miliaceum* L.). The research results are presented in detail on:

- the influence of temperature on grain germination;
- biometric observations and measurements;
- the influence of genotype on grain yield;
- the influence of foliar fertilization on grain yield;
- the influence of seed rate on grain yield;
- the interaction of genotype x foliar fertilization on grain yield;
- the interaction of foliar fertilization x seed rate on yield;
- the interaction of genotype x foliar fertilization x seed rate;
- the interaction of genotype x row spacing on grain yield;
- testing some herbicides and their influence on grain yield.

These parameters were monitored throughout the vegetation period in the years of experimentation, presenting the results obtained for each experimental year separately, as well as the average of the years.

The average of the three years indicates that the genotype represented by the Secuieni local population presents the greatest adaptability to the conditions of the area, having the highest value of the average grain production (2410 kg/ha).

Following the use of foliar fertilization, the variants fertilized foliarly with the commercial products Asfac (dose 1,0 l/ha) and TerraSorb (dose 2,0 l/ha) are noted, whose productions had the highest values, namely 2786 kg/ha and 2767 kg/ha.

The results obtained after experimenting with the 3 seed norms, on average for the 3 years, the seed norm considered ideal, is 18 kg/ha.

The interaction between genotype x foliar fertilization, on average, for the three years of experimentation (2022 – 2024), shows us that the highest production, 2845 kg/ha, was in the variant sown with the Marius variety and foliar fertilized with the commercial product Asfac at a 1,0 l/ha dose.

The interaction between seed rate and foliar fertilizer, on average, had the maximum production (3235 kg/ha), reached by the interaction 18 kg/ha x Asfac 1,0 l/ha.

In conclusion, the obtained results showed us that for the zonal conditions specific to the A.R.D.S Secuieni, the best variant for millet crop is represented by the interaction Local population Secuieni x 18 kg/ha x Asfac at 1,0 l/ha dose, which achieved a production of 3180 kg/ha.

On average for the experimental period, in terms of the interaction between genotype and seed rate, was obtained an average yield grain (1895 kg/ha), the maximum value was obtained at the interaction genotype BG 3 x 12,5 cm between rows (2874 kg/ha).

The results from testing some herbicides on millet showed a large variation in millet grain yield, which had values ranging between 930 kg/ha (Gallup Super, 5,0 l/ha) and 2550 kg/ha (Gardoprim, 3,5 l/ha). Millet was intolerant to propaquizafop, the active ingredient in the herbicide with the trade name Agil, which applied post-emergence completely destroyed the crop.

In **chapter eight**, the results regarding the influence of the studied factors on the chemical composition of millet grains are presented.

For the experimental period, on average, the interaction genotype x seed rate x foliar fertilizer brings to the fore the following variants:

- Marius variety x 14 kg/ha x Asfac – 1,0 l/ha, highest starch content (54,60%);
- Marius variety x 10 kg/ha x Albit – 0,04 l/ha, highest protein content (12,53 %);
- Local population Secuieni x 10 kg/ha x Asfac – 1,0 l/ha, highest fiber content (6,46%);
- Local population Secuieni x 10 kg/ha x Albit – 0,06 l/ha, highest ash content (2,0%);
- Local population Secuieni x 14 kg/ha x Albit – 0,04 l/ha, highest ash content (2,0%);
- Local population Secuieni x 18 kg/ha x Albit – 0,06 l/ha, the highest ash content (2,0%).

Chapter nine presents the economic efficiency of the crop, so that on average, in the 3 years of experimentation, the lowest value of the yield cost was obtained at the interaction Local population Secuieni x 18 kg/ha x Asfac 1,0l/ha (0,723 lei/kg), and the most expensive was the interaction Local population Secuieni x 10 kg/ha x Unfertilized (1,044 lei/kg). And **chapter ten** consists of conclusions and recommendations.

The bibliography includes 186 titles from the specialized literature, national and international

FIRST PART

CURRENT STATUS OF NATIONAL AND INTERNATIONAL RESEARCH ON MILLET CROP

CHAPTER I
CURRENT STATUS OF RESEARCH ON THE SPECIES PANICUM MILIACEUM L. (MILLET)

Cereals have been used by people since ancient times, their name coming from the Roman goddess. *Ceres* (Mogârzan Aglaia., 2012).

1.1. The origin and history of the name millet

The term "millet" covers a number of plants with small seeds (Lorenz K., 1980).

According to archaeological evidence, millet was first used in agriculture 10,000 years ago BC, in northern China (Lu H., 2009).

The exact location of a center of millet domestication in China is the subject of ongoing debate. Reports of both proso millet and foxtail millet from Cishan and Peiligang led to the emphasis on the Central Yellow River Valley as ground zero of agricultural origins in northern China. However, the presence of other early millet sites some distance from the Yellow River valley—Dadiwan in the Loess Plateau, Xinle and Xinglonggou in the northeast—has led to suggestions that the concentration of millet domestication may have occurred elsewhere, or that there may have been multiple centers in China (Crawford G.W., 2006; Hu X., 2009).

1.2. The spread

The geographical distribution of early archaeobotanical finds is intriguing because of the disjunction between groups of sites separated by several thousand km and raises questions about the relationship between cultivated populations in both European countries and Asian countries such as China. It has been postulated that these may represent distinct episodes of domestication at each end of the Eurasian steppe region, or that the formation of millet in a single center was followed by its spread across this wide region 7,000 years ago (Jones M.K., 2004). Moreover, evidence for such a spread would constitute substantially the earliest indication of contact between societies in eastern and western Eurasia. No other domesticated cereal was spread over such a vast geographical area at such a distant time (~5000 BC), and the exchange of material goods is not attested until 4000 BC (Sherratt A., 2006).

1.3. The importance

Agronomic importance

Short duration (some varieties producing grain only 60 days after sowing) and high adaptability to different environmental conditions, much more efficient productivity per unit of soil moisture compared to other cereals (Graybosch R.A., 2009), make millet one of the most suitable crops for sustainable agriculture, also guaranteeing future food security (Calamai A., 2020). Millet can provide significantly higher yields on marginal lands with low fertility and low-input farming systems, compared to many other crops.

Dietary and nutritional importance

Cultivation and consumption of millets would not only reduce protein micronutrient malnutrition but would also contribute to crop and diet diversification.

Following studies carried out by Leder (2004) it turns out that 100 g of millet has 10 g of protein, 4.0 g of lipids, 70 g of carbohydrates, 8 mg of Ca, 2.9 mg of Fe.

Panicum miliaceum L. is receiving increasing attention due to its nutraceutical properties: the grains have a high protein content (12.5%) and are generally rich in essential amino acids (e.g. methionine and cysteine), with the exception of lysine and threonine (Sage R.F., 2011; Amadoubr I., 2013).

The recent rise in gluten-free trends and the escalating health awareness among people have created a renewed interest in ancient grains. The food market for millet has found its way into various breakfast cereal mixes, baked goods, fermented products, as well as in the manufacture of alcoholic beverages.

Importance in animal nutrition

Approximately 2/5 of the world's cereal production is used in animal nutrition, sometimes supplementing traditional fodder, and the associations between various animal species and specific cereals are well known, namely: horses and oats, poultry and millet.

Industrial animal husbandry is one of the major cereal consuming sectors, an important part of animal nutrition. Straw is also transformed into brooms (Kaume R.N., 2006); but the millet crop can be used for emergency fodder (Tran G., 2017).

Major market share for millet comes from bird seed industries. Regardless of how many health benefits it has, including gluten-free, low glycemic index, high protein and fiber content, millet is still struggling to enter the human food markets.

1.4. The systematic

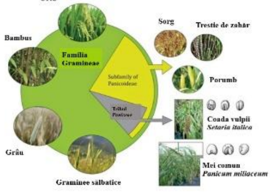


Fig. 1.2. – Botanical relatives of millet (Panicum miliaceum L.) (Martin L., Baudais D., 1993)

Centers of formation for cultivated plants are often inferred from the distribution of their wild progenitors. The wild ancestor of millet is not known with certainty. A weedy form, *Panicum miliaceum* subsp. *ruderale*, was first described from Manchuria (Kitagawa M., 1937) and has a wide distribution in a region stretching from the Aral-Caspian basin to China (Zohary D., 2000; http://www.agroatlas.ru). These types are found in Central Europe (Scholz H., 1991) and in North America, where they represent a serious weed in corn crops. (Bough M., 1986; Colosi J.C., 1997, Colosi J.C., 2017). These types differ from cultivated millet by their characteristic, spreading panicles (Scholz H., 1991) and could represent either wild ancestors or derived wild forms. Accurately identifying the nature of the evolutionary relationship between domestic plants and related weed forms is not trivial (Ellstrand N.C., 2010); at present, there are too few genetic data for Panicum miliaceum L. to allow this problem to be resolved.

1.5. The biology and morphology

Among the C4 panicoids (subfamily: *Panicoideae*), millet (*Panicum miliaceum* L.) possesses morpho-physiological traits that confer tolerance to abiotic stress and exhibit greater adaptability than major cereal crops under different environmental conditions (Bandyopadhyay T., 2017; Vetriventhan M., 2018). Based on panicle morphology and shape, millet can be divided into five races: *miliaceum*, *patentissimum*, *contractum*, *compactum* și *ovatum* (Saruhan V., 2005; Flajšman M., 2019).

1.6 Millet genetics, breeding and biotechnology

Millet is a potential candidate for next-generation cereal breeding programs (Bandyopadhyay T., 2017).

Panicum miliaceum L. is related to *Panicum miliare* Lam., a species widespread in Southeast Asia, India, Transcaucasia, both species having the same number of chromosomes.

CHAPTER II – THE REQUIREMENTS OF THE MILLET REGARDING CLIMATE FACTORS

2.1. Millet temperature requirements

Temperature requirements are high. Thus, the minimum seed germination temperature is 10 – 12ºC, and the total amount of temperatures above 10ºC required during vegetation is approximately 800-850ºC (Roman V., 2015).

2.2. Millet moisture requirements

It does not have high humidity requirements, the transpiration coefficient being 180 – 250 (Roman V., 2015).

2.3. Millet light requirements

The duration of sunshine in our country is between 1,600 hours and 2,300 hours. (vremea.ro).

2.4. Millet soil requirements

The most suitable soils are those with medium texture, well supplied with fertilizing elements, with a neutral reaction (table 2.1) because the root system is shallow (90–120 cm) and has a short growth period (60–90 days) (Theisen A.A., 1978; Matz S.A, 1986; Gupta A., 2006).

CHAPTER III – MILLET CROP TECHNOLOGY

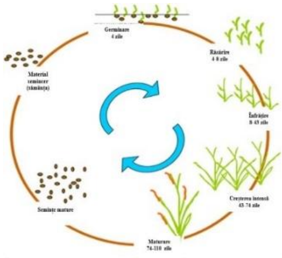


Fig. 3.1 – Life cycle of millet plan (Quetzalcóatl O.R., 2003)

3.1. Crop rotation

In Romania, more recent studies support that in the main crop, millet should follow autumn/spring grassy cereals, annual forage plants or weeders (sunflower, corn, beet, potato) (Muntean L.S., 2003; Roman V., 2015).

3.2. Crop fertilization

The specific consumption to obtain 100 kg of grains and the related secondary production (straw) is 3.0 kg of nitrogen, 1.4 kg of phosphoric acid, 3.5 kg of potassium oxide (Bîlteanu Gh, 1989; Roman V., 2011) and 1.0 kg of calcium oxide (Gumovschi A., 2024).

3.3. Soil tillages

Soil tilleges do not deviate from the basic principles of other cereal crops; it is worth mentioning that weed eradication, soil fragmentation and water accumulation in the soil must be pursued. (Roman V., 2015).

3.4. The seed and the sowing

Millet sowing begins when the soil, at a depth of 10 cm, has a temperature of at least 10 – 12°C (Bîlteanu Gh., 1989). Calendar-wise, the optimal period falls between April 15 – 25 (plain) and April 25 – May 5, in hilly areas (Muntean L.S., 2003; Roman V., 2015). The recommended distance between rows is 12.5 cm, the seed quantity is 15 – 18 kg/ha (Bîlteanu Gh., 1989), and the sowing depth is 3 cm.

3.5. Care tillages

Soil tilleges for millet as the main crop is similar to that for corn (Starodub V., 2008). The main care work is weed control using methods specific to cereal crops. Among millet diseases, the most important is blackleg, which is combated by seed treatments with carboxin-based preparations. (Roman V., 2011).

3.6. The harvesting

Grain ripening is staggered, from the upper part of the panicle to the lower part. Millet is harvested in splits, when 80-85% of the grains are at the full ripening stage or 3-4 days before the full ripening of the entire panicle. The ratio between the grain and straw harvest is 1:1.3-1.5 (Roman V., 2011, 2015).

3.7. Yields

Under the conditions of our country, productions of 1000 – 1500 kg of grains/ha can be obtained under non-irrigated conditions and respectively 1500 – 3000 kg of grains/ha. (Roman V., 2015).

3.8. A.R.D.S Secuieni crop technology

According to the millet crop technology, at A.R.D.S Secuieni, during the development of the experimentation of millet crop, in order to achieve the proposed research objectives, a work program was generated, thus, the culture technology applied is as follows:

- the stubble removal of the preceding crop and the basic plowing were carried out in the fall, the field must retain as much water as possible, the lack of precipitation since summer being an increasingly present problem in our area;
- the next spring, the plowing was carried out to destroy the still existing clods;
- no fertilizers were applied, except for the experience in which foliar fertilizers were tested;
- on the day before sowing, a pass with the combine was carried out to prepare the land for sowing, because millet needs a smooth, level and well-prepared germination bed;

- the sowing of the experiments took place in the first decade of May and was carried out with the Haldrup experimental seeder, specific for the experimental plots (fig. 3.2);
- the experiments were sown in the field according to the subdivided plot method, in 3 repetitions each;
- the moment of harvesting the field experiments was when the millet crop reached technological maturity, namely, when 2/3 of the grains in the panicle reached maturity;
- the harvesting was carried out with a combine for experimental plots, Wintersteiger.

Fig. 3.2 – Haldrup seeder for experimental field (original)

Fig. 3.3 – Millet experimental field (original)

Fig. 3.4 – Wintersteiger combines for experimental field harvesting (original)

SECOND PART
RESULTS OBTAINED - PRESENTATION AND INTERPRETATION

CHAPTER IV – NATURAL ENVIRONMENT AND ECOLOGICAL CONDITIONS OF EXPERIMENTATION

4.1. Geographical location and characteristics of the area

The Secuieni Agricultural Research and Development Station is located in the southeastern part of Neamț County, 26051'00' east longitude and 46051'15' north latitude, belonging to the Central Moldavian Plateau (Trotuș Elena, 2017).

4.2. The thermic regime

The meteorological station of the Secuieni Agricultural Research and Development Station was established in 1962, in the vicinity of the experimental field, from where climatic data were used to characterize the climatic conditions of the station. In 2006 and 2016, it was replaced by a new and automated station.

The average annual temperature recorded in the period 2000 – 2024 is 9,0°C.

4.3. The pluviometric regime

For the period 2000 – 2024, the average amount of precipitation was 531.9 mm, unevenly distributed throughout the plant growing season.

4.4. Other climatic factors

In the area, hail falls at least once every two years and also, between 50-80 days/year, dew is present, and the fog has a maximum density during the night and much less during the day. Thus, fog is recorded in ~ 40 days/year, the maximum frequency being in November (17 days). 36 days of frost have also been recorded (autumn and spring). The first frost falls in mid-September, and the last in April (Trotuș Elena, 2022).

Winds from the N, N – W directions have high speeds (over 4 m/s), and from the other directions, they have intermediate speeds (2 – 3 m/s) (Pochișcanu Simona, 2015). During the year, wind speed has higher values in winter and spring.

4.5. Soil type and agro-productive properties

The experimental research fields are located on the 2nd terrace of the Siret River and in the Siret Meadow, where the predominant soil types are typical cambic phaeozeum and brown eumesobasic mollic (BM-mo). The degree of saturation in bases is between 84-91%, and other characteristics vary as follows: apparent density 1.26-1.33 t/mc, total porosity 50-52%, wilting coefficient 11.5-12.1%, field water capacity 25.5-26% and hydraulic conductivity 50-20 mm/h (Lupu Cornelia, 2002, 2007, 2012).

CHAPTER V – MATERIAL AND RESEARCH METHODS

Fig. 5.1 – Field aspects (original)

5.1. The purpose and objectives

The primary goal of this Ph.D. thesis is to develop and promote technological sequences specific to millet cultivation with the aim of increasing productivity both quantitatively and qualitatively.

Achieving the goal requires the following objectives:

- studying some millet genotypes and establishing those with high adaptability to the pedoclimatic conditions specific to the Center of Moldova;
- establishing the effect of foliar fertilization on the level and quality of yield;
- establishing the influence of row spacing on the level and quality of yield;
- establishing the influence of ecological factors of the years of experimentation on grain yield;

➢ testing the effects of herbicides approved for various grasses, legumes, oilseeds and tubers, on millet crop and their introduction into the crop technology;
➢ expanding into zonal agriculture by disseminating the results obtained.

5.2. The experimental factors

- The technological parameters taken in the study of this Ph.D. thesis are made up of the seed rate (10 kg/ha, 14 kg/ha and 18 kg/ha), foliar fertilization (TerraSorb (2.0 l/ha), Asfac (1.0 l/ha), Albit (0.04 l/ha) and Albit (0.06 l/ha), the distance between plant rows (12,5 cm, 25 cm and 50 cm) and the tolerance of millet to some herbicides (Stomp, Gallup super, Aloha, Gardoprim, Adengo, Basagran, Dicopur, Ceredin super, Agil and Corum.

The knowledge of genotypes with high adaptability to the pedoclimatic conditions specific to the area and those parameters of the crop technology that ensure the increase in the harvest level are of paramount importance. Thus, in order to achieve this goal, three experiences were established in the experimental field of A.R.D.S. Secuieni, in Neamț County, such as:

🕮 2 x 3 x 5; 🕮 5 x 3; 🕮 10 x 2.

5.3. The biological material

Currently, the only representative of millet in the Official Catalogue of Varieties in Romania is the Marius variety, so for the proper development of the topic of this Ph.D. thesis, we also used the Local population Secuieni, as well as 3 genotypes from the Suceava Gene Bank (Bg 1, Bg 2 and Bg 3).

The foliar fertilizers used in the experiment are represented by the commercial products TerraSorb (2.0 l/ha), Asfac (1.0 l/ha), Albit (0.04 l/ha) and Albit (0.06 l/ha).

Regarding the tolerance of millet to various active substances in herbicides, we tested the following commercial products:

- with pre-emergence application: Stomp (pendimetil 455 g/l), Gallup super (glifosat), Aloha (S-metolaclor 960 g/l), Gardoprim (S-metolaclor 312,5 g/l + trebutilazin 187,5 g/l), Adengo (isoxaflutol 225 g/l + tiencarbazon-metil 90 g/l + ciprosulfamide 150 g/l);
- with post-emergence application: Basagran (bentazol 480 g/l), Dicopur (acid 2 – metil-4 -clorfenoxiacetic (MCPA) 750 g/l), Ceredin super (acid 2,4 D 300 g/l + dicamba 100 g/l), Agil (propaquizafop) și Corum (imazamox 22,4 g/l + bentazol 480 g/l).

5.4. Field work, methodology of phenological investigations and biometric measurements

5.4.1. Field work

In order to achieve the proposed research objectives, a work program was generated to cover all the stages that take place both in the field and in the laboratory.

The specialized foreign literature is very extensive in terms of the systematics, culture technology and chemical composition of this species, but in Romania the research on millet is more limited.

5.4.2. Methodology of phenological observations and physiological characteristics

5.4.2.1. Phenological observations and biometric determinations made in vegetation: date of emergence, earing, technical maturity.

Morpho-physiological characters: height, density, drought resistance, resistance to falling, harvest date.

5.4.2.2. Observations on the behavior of the species towards environmental factors: resistance to falling, resistance to diseases and pests.

5.4.2.3. Production data processing: harvesting

5.5. Methodology of physiological and biochemical investigations carried out in the laboratory

In the laboratory, determinations of the physiological properties of the biochemical composition of millet grains were carried out and germination tests were carried out, which consisted of determining the percentage of pure seeds, capable of producing normal germs and which, when placed in favorable cultivation conditions, produced normally developed plants.

5.6. The methodology of statistical and economic analysis

The processing and valorization of the results within the experiments were carried out according to the variance analysis method (Onisie T., 1992; Jităreanu G., 1994; Jităreanu G., 2020).

To establish the economic efficiency of the species *Panicum miliaceum* L. (millet), the estimated cost of expenses incurred for a framework technology with the achievement of phytotechnical parameters will be calculated. The production cost and gross profit will be calculated.

CHAPTER VI – CLIMATIC CONDITIONS

On average, for the 3 years of experimentation, the aridification trend and the dry character of the A.R.D.S Secuieni area of influence are also observed from fig. 6.1 and 6.2, which show the thermal and pluviometric regime. We thus observe that for the millet vegetation period, the average temperatures have values above the multiannual average, the warmest month being July, with an average for the 3 years of experimentation of 22.4°C.

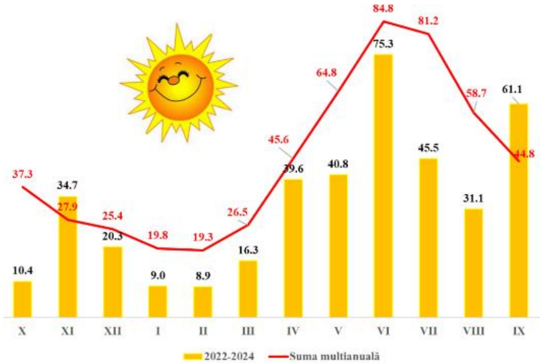


Fig. 6.1 – Average temperatures during the period 2022 – 2024

Regarding the average precipitation recorded during the period October 2021 - September 2024, we observe in fig. 6.2 that only in two autumn months (September and November) did the amount of precipitation have values higher than the multiannual amount, with a rainfall deficit being recorded in the other months.

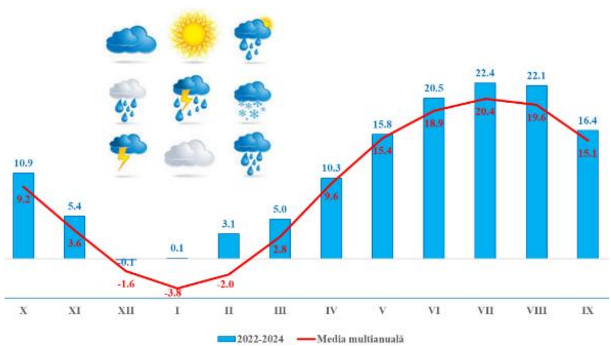


Fig.6.2 – Average precipitation during the period 2022 – 2024

CHAPTER VII – RESULTS OBTAINED

Fig. 7.1 – Experimental millet field (original)

7.1. The influence of temperature on the grain germination of Panicum miliaceum L

Analyzing the results obtained over 7 days, we observe that a temperature of 10°C ensures the germination of 50.25% of millet grains, while a temperature of 20°C has a significantly greater impact, determining an impressive germination rate of 97.75%. 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 (fig. 7.6).

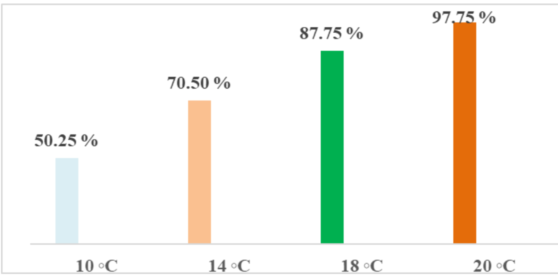


Fig. 7.6. – Effect of temperature on the percentage of germinated grains

7.2. Biometric observations and measurements

During the research (2022 – 2024), at S.C.D.A Secuieni, we faced a period of drought, which was quite prominent during the millet sowing period; thus, from sowing to emergence, millet required 12 days – 14 days to complete its initial developmental cycle.

The sowing of this crop was carried out in the first decade of May.

Analyzing from a climatic perspective, the growing season of millet in the three years of research, we observed that it was characterized as warm and extremely dry, the general trend for this area being one of aridification.

The panicle appeared in the first decade of June, thus marking the beginning of the process of grain formation, and the entire vegetation period of millet totaled 95-98 days.

It is important to note that despite the presence of potential stressors for the millet crop, it did not suffer significant damage (table 7.2). However, continuous monitoring of diseases and pests in the millet crop is necessary to assess and manage possible risks in the future, but overall, this species proves to be robust in the face of potentially dangerous biotic factors. This relative resistance to pathogens and pests may contribute to bringing millet to the attention of farmers as an attractive option, given its ability to adapt to various environmental conditions and to react effectively to potential threats.

Table 7.2

Resistance to pathogens, pests, falling and shaking

Genotip	Distanța între rânduri	Rezistența la atacul dăunătorilor		Rezist. la boli		Rezist. la cădere		Rezist. la scuturare
		Oscinella frit	*Ostrinia nubilalis*	*Sorosporium panici-miliacei*	*Helminthosporium sp*	În vegetație	Înainte de recoltare	La recoltare
Soi Marius	12,5 cm	1	1	1	2	1	1	2
	25 cm	1	1	1	2	1	1	2
	50 cm	1	1	1	2	1	1	2
Populația locală Secuieni	12,5 cm	1	1	1	2	1	1	2
	25 cm	1	1	1	2	1	1	2
	50 cm	1	1	1	2	1	1	2
BG 1	12,5 cm	1	1	1	2	1	1	2
	25 cm	1	1	1	2	1	1	2
	50 cm	1	1	1	2	1	1	2
BG 2	12,5 cm	1	1	1	2	1	1	2
	25 cm	1	1	1	2	1	1	2
	50 cm	1	1	1	2	1	1	2
BG 3	12,5 cm	1	1	1	2	1	1	2
	25 cm	1	1	1	2	1	1	2
	50 cm	1	1	1	2	1	1	2

Following the research carried out, it was observed that the experimental technological sequences also had influences on the phenological characters of the plants (table 7.3). With the increase in the seed rate, an increase in the number of main plants/ha was observed, but depending on the foliar fertilizer used, there were both increases and decreases in the number of siblings/ha (table 7.3).

Table 7.3

Interaction of the studied factors on the ratio between the number of main plants/ha and the number of tillers/ha in Panicum miliaceum L., average 2022-2024

Genotip	Normă sămânță	Fertilizant foliar	Nr total plante (mii)	Plante principale		Frați	
				mii	%	mii	%
Soiul Marius	10 kg/ha	Nefertilizat	1421	1137	80	284	20
		TerraSorb 2.0 l/ha	972	648	67	324	33
		Asfac 1.0 l/ha	1346	1010	75	337	25
		Albit 0.04 l/ha	1630	1222	75	407	25
		Albit 0.06 l/ha	816	408	50	408	50
	14 kg/ha	Nefertilizat	2671	2137	80	534	20
		TerraSorb 2.0 l/ha	2295	1836	80	459	20
		Asfac 1.0 l/ha	1757	1318	75	439	25
		Albit 0.04 l/ha	1646	1234	75	411	25
		Albit 0.06 l/ha	2914	2497	86	416	14
	18 kg/ha	Nefertilizat	2767	2296	83	471	17
		TerraSorb 2.0 l/ha	2116	1411	67	705	33
		Asfac 1.0 l/ha	1824	1216	67	608	33
		Albit 0.04 l/ha	3875	3229	83	646	17
		Albit 0.06 l/ha	3323	2769	83	554	17
Populatia locală Secuieni	10 kg/ha	Nefertilizat	1484	1187	80	297	20
		TerraSorb 2.0 l/ha	1194	796	67	398	33
		Asfac 1.0 l/ha	1054	703	67	351	33
		Albit 0.04 l/ha	1974	1645	83	329	17
		Albit 0.06 l/ha	2015	1679	83	336	17
	14 kg/ha	Nefertilizat	2040	1632	80	408	20
		TerraSorb 2.0 l/ha	1771	1328	75	443	25
		Asfac 1.0 l/ha	918	459	50	459	50
		Albit 0.04 l/ha	1732	1299	75	433	25
		Albit 0.06 l/ha	1301	868	67	434	33
	18 kg/ha	Nefertilizat	3341	2784	83	557	17
		TerraSorb 2.0 l/ha	2026	1351	67	675	33
		Asfac 1.0 l/ha	1759	1173	67	586	33
		Albit 0.04 l/ha	2390	1792	75	597	25
		Albit 0.06 l/ha	2443	1833	75	611	25

7.3. The influence of the researched factors on grain yields in Panicum miliaceum L.

7.3.1. The influence of genotype on grain yield in millet

On average, during the three years of experimentation, in comparison with the control of the experience, the variant sown with the Marius variety, whose production had the value of 2389 kg/ha, statistically unassured production differences were obtained (table 7.7).

Table 7.7

Genotype influence on grain yield, average 2022 – 2024

Genotip	Producția (kg/ha)	Dif. față de martor (%)	Dif. față de martor (kg/ha)	Semnificație
Soiul Marius	**2389**	**Mt**		
Populația locală Secuieni	2410	101	21	
BG 1	2138	89	-251	
BG 2	2088	87	-301	
BG 3	2165	91	-224	
Media	2200	92	-189	
DL5%		459		
DL 1%		644		
DL 0,1%		912		

Regarding millet grain yield, it is observed that, on average, for the period between 2022 and 2024, it reached the value of 2200 kg/ha (table 7.7), varying between 2410 kg/ha (Secuieni local population) and 2088 kg/ha (BG 2 genotype).

By highlighting these data, researchers and agricultural specialists can analyze in more detail the evolution of yield and identify the possible influences of specific factors on this aspect, thus orienting future agricultural strategies and research in the field.

Also, this information can be useful to farmers and researchers in their efforts to optimize millet yield, contributing to increase sustainability and efficiency in the agricultural sector.

7.3.2. The influence of foliar fertilization on grain yield in millet

The foliar fertilizers used in this experiment are represented by the commercial products TerraSorb – dose 2.0 l/ha, Asfac – dose 1.0 l/ha, Albit – in doses of 0.04 l/ha, respectively 0.06 l/ha. These products are not approved for millet, and the doses used in the experiment are based on the recommended dose for straw grains.

The analysis of the variation in millet grain production, carried out during the three years of experimentation, highlights that, in relation to foliar fertilization, the productions recorded for the tested variants oscillated on average between 2382 kg/ha and 2786 kg/ha (table 7.11 and fig 7.18).

Compared to the unfertilized variant, the control of the experiment, all variants to which foliar fertilizers were applied recorded increases:

Following this experiment, the variants fertilized foliarly with the commercial products Asfac (dose 1.0 l/ha) and TerraSorb (dose 2.0 l/ha) stand out, whose productions had the highest values.

Table 7.11

Fertilizer influence on grain yield, average2022 – 2024

Compus	Prod. (kg/ha)	Dif. față de martor (%)	Dif. față de martor (kg/ha)	Semnificație
Nefertilizat	**2382**	**100**	**Mt**	
TerraSorb 2.0 l/ha	2767	116	385	***
Asfac 1.0 l/ha	2786	117	404	***
Albit 0.04 l/ha	2647	111	265	**
Albit 0.06 l/ha	2682	113	300	***
Media	2720	114	339	***
DL5%			150	
DL 1%			209	
DL 0,1%			293	

7.3.3. The influence of seed rate on grain yield in millet

As part of the experiment, we investigated how the rate seed used for sowing influences the yield of the millet crop, starting from the hypothesis also mentioned in the specialized literature, namely that the minimum seed rate is 10 kg/ha (Roman Gh V., 2011).

The results obtained highlighted a significant correlation between the seed rate applied and grain yield. In particular, we found that the use of a higher seed rate led to increased grain yield. This observation can be explained by the fact that a higher seed density at sowing can favor competition between plants, stimulating their growth and development. Also, a higher seed rate can contribute to more efficient land coverage, optimizing the use of available resources and creating more favorable conditions for plant development.

Results obtained over the three years of the study (2022 – 2024) suggest that the seed rate of 18 kg/ha provided an optimal balance between plant density and available resources, leading to maximum grain yield in millet.

Our statement has important practical implications for farmers, suggesting that the use of a seed rate of 18 kg/ha could represent an effective strategy for maximizing millet yield under the specific conditions of Secuieni.

Compared to the control of the experiment, the seed rate of 10 kg/ha, the experimental variants obtained yield increases with values ranging from 158 – 346 kg/ha, the latter being statistically assured and interpreted as distinctly significant (table 7.15).

Table 7.15

Seed rate influence on grain yield in millet, average2022 – 2024

Compus	Producția (kg/ha)	Dif. față de martor (%)	Dif. față de martor (kg/ha)	Semnificație
10 kg/ha	**2462**	**100**		
14 kg/ha	2620	106	158	
18 kg/ha	2808	114	346	**
Media	2714	110	252	*
DL5%			208	
DL 1%			296	
DL 0,1%			429	

7.3.4. The influence of genotype x foliar fertilization interaction on grain yield in millet

For the three years of experimentation (2022 – 2024), on average, compared to the control of the experience (the interaction Marius variety x unfertilized), statistically assured yield increases were obtained between 285 kg/ha (Secuieni local population x Albit 0.06 l/ha) and 491 kg/ha (Marius variety x Asfac 1.0l/ha).

The yield increase of 55 kg/ha (Secuieni local population x Unfertilized) had no statistical assurance (table 7.19).

On average, for the three years of experimentation (2022 – 2024), yield recorded value of 2686 kg/ha (table 7.19), oscillating between 2354 kg/ha (Marius x unfertilized variety) and 2845 kg/ha (Marius x Asfac variety – 1.0 l/ha).

Table 7.19

Influence of genotype x foliar fertilization interaction on grain yield in millet, average2022 – 2024

Genotip	Fertilizant	Prod. kg/ha)	Dif. față de martor (%)	Dif. față de martor (kg/ha)	Semn.
Soiul Marius	**Nefertilizat**	**2354**	**Mt**	**Mt**	
	TerraSorb 2.0 l/ha	2817	120	463	***
	Asfac 1.0 l/ha	2845	121	491	***
	Albit 0.04 l/ha	2651	113	297	**
	Albit 0.06 l/ha	2724	116	370	***
Populația locală Secuieni	Nefertilizat	2409	102	55	
	TerraSorb 2.0 l/ha	2716	115	362	***
	Asfac 1.0 l/ha	2728	116	374	***
	Albit 0.04 l/ha	2643	112	289	**
	Albit 0.06 l/ha	2639	112	285	**
Media		2686	114	332	***
DL A*C 5%				146	
DL A*C 1%				206	
DL A*C 0.1%				319	

7.3.5. The influence of the interaction foliar fertilization x seed rate on grain yield in millet

Compared to the experimental control (interaction between the norm of 10 kg/ha x unfertilized) on average over the three years of study, yield increases ranging from 230 kg/ha to 999 kg/ha were obtained.

Only the variant sown with a norm of 10 kg/ha and foliar fertilized with the commercial product Albit (0.06 l/ha) achieved a statistically unassured yield increase (230 kg/ha), especially the variants sown with a norm of 18 kg/ha and foliar fertilized.

On average, for the three years of study (2022 – 2024) the average grain yield was 2754 kg/ha, with the maximum (3235 kg/ha) reached by the interaction 18 kg/ha x Asfac 1.0 l/ha.

As a result of this experiment were noticed, in the millet variants sown with 14 kg/ha and 18 kg/ha both of foliar fertilizers applied, Asfac (1.0 l/ha) and Albit (0.04 l/ha, respectively 0.06 l/ha) (table 7.23).

Table 7.23

Influence of foliar fertilization x seed rate interaction on grain yield in millet, average 2022 – 2024

Norma de sămânță	Fertilizant foliar	Prod. medie kg/ha	Dif. față de martor %	Dif. față de martor kg/ha	Semn.
10 kg/ha	Nefertilizat	2236	100	MT	
	TerraSorb 2.0 l/ha	2801	125	565	***
	Asfac 1.0 l/ha	2647	118	411	**
	Albit 0.04 l/ha	2504	112	268	*
	Albit 0.06 l/ha	2466	110	230	
14 kg/ ha	Nefertilizat	2562	115	326	**
	TerraSorb 2.0 l/ha	2634	118	398	**
	Asfac 1.0 l/ha	2718	122	482	***
	Albit 0.04 l/ha	2769	124	533	***
	Albit 0.06 l/ha	2892	129	656	***
18 kg/ha	Nefertilizat	2591	116	355	**
	TerraSorb 2.0 l/ha	3050	136	814	***
	Asfac 1.0 l/ha	3235	145	999	***
	Albit 0.04 l/ha	2841	127	605	***
	Albit 0.06 l/ha	2844	127	608	***
Media		2754	123	518	***
DL B*C 5%				233	
DL B*C 1%				320	
DL B*C 0.1 %				439	

7.3.6. The influence of genotype x foliar fertilization x seed rate interaction on grain yield in millet

Compared to the experimental control (Marius variety x 10 kg/ha x unfertilized), during the period 2022 – 2024, yield increases ranged between 148 – 1033 kg/ha, some being distinctly significant (table 7.27), the best option for millet crop being represented by the interaction Local population Secuieni x 18 kg/ha x Asfac at a dose of 1.0 l/ha, (3180 kg/ha).

Table 7.27

Influence of genotype x seed rate x foliar fertilization interaction on grain yield in millet, average 2022 – 2024

Genotip	Norma sământă	Fertilizant foliar	Prod kg/ha	Dif. martor %	Dif. martor kg/ha	Semn.
Soiul Marius	10 kg/ ha	**Nefertilizat**	**2147**	**100**	**Mt**	
		TerraSorb 2.0 l/ha	2898	135	751	***
		Asfac 1.0 l/ha	2795	130	648	**
		Albit 0.04 l/ha	2500	116	353	*
		Albit 0.06 l/ha	2554	119	407	*
	14 kg/ ha	Nefertilizat	2507	117	360	*
		TerraSorb 2.0 l/ha	2588	121	441	**
		Asfac 1.0 l/ha	2670	124	523	**
		Albit 0.04 l/ha	2730	127	583	**
		Albit 0.06 l/ha	2924	136	777	***
	18 kg/ha	Nefertilizat	2409	112	262	
		TerraSorb 2.0 l/ha	2965	138	818	***
		Asfac 1.0 l/ha	3070	143	923	***
		Albit 0.04 l/ha	2723	127	576	**
		Albit 0.06 l/ha	2694	125	547	**
Populatia locală Secuieni	10 kg/ ha	Nefertilizat	2084	97	-63	
		TerraSorb 2.0 l/ha	2592	121	445	**
		Asfac 1.0 l/ha	2386	111	239	
		Albit 0.04 l/ha	2368	110	221	
		Albit 0.06 l/ha	2295	107	148	
	14 kg/ ha	Nefertilizat	2461	115	314	
		TerraSorb 2.0 l/ha	2556	119	409	*
		Asfac 1.0 l/ha	2616	122	469	*
		Albit 0.04 l/ha	2651	123	504	**
		Albit 0.06 l/ha	2692	125	545	**
	18 kg/ha	Nefertilizat	2682	125	535	**
		TerraSorb 2.0 l/ha	3001	140	854	***
		Asfac 1.0 l/ha	3180	148	1033	***
		Albit 0.04 l/ha	2910	136	763	***
		Albit 0.06 l/ha	2930	136	783	***
Media			2670	124	523	**
Dl A*B*C 5%					285	
Dl A*B*C 1%					418	
Dl A*B*C 0.1%					703	

7.3.7. The influence of genotype x row spacing interaction on grain yield in millet

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

Scientific research from abroad has highlighted the fact that there is an inversely proportional relationship between yield and row spacing, thus increasing this distance can negatively influence the yield of millet crops (Agdag M., 2001).

When the row spacing is correctly optimized, millet plants benefit from the space necessary to develop their root system and access water resources and nutrients from the soil efficiently. This can lead to better absorption of sunlight, a uniform distribution of the plant in the field and, ultimately, to a higher grain production.

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

Romanian specialized literature recommends sowing in rows at a distance of 12.5 cm (Zamfirescu N, 1965), later, specialists suggested that the optimal distance between rows is 25 cm or 50 cm on weedy lands (Roman V, 2011, 2015).

Under the conditions at A.R.D.S. Secuieni, we verified this aspect by setting up an experiment consisting of 5 millet genotypes (the Marius variety, the Secuieni local population, the Suceava Gene Bank genotypes BG 1, BG 2 and BG 3) and three row distances (12.5 cm, 25 cm and 50 cm), using a seed rate of 10 kg/ha.

Within this experience, on average over the three years (2022 – 2024), compared to the experiment control (interaction variety Marius x 12.5 cm), statistically assured yields differences were obtained:

- negative significant – interactions: Local population Secuieni x 25 cm, BG 3 x 25 cm;

- negative distinctly significant – interactions: BG 3 x 12.5;

- negative very significant – interactions: variety Marius x 50 cm, Local population Secuieni x 50 cm, BG 1 x 25 cm, BG 1 x 50 cm, BG 2 x 12.5 cm, BG 2 x 25 cm, BG 2 x 50 cm and BG 3 x 50 cm (table 7.31).

Thus, on average for the three years (2022 – 2024) an average grain yield of 1895 kg/ha was obtained (table 7.31), the maximum value being obtained with the genotype BG 3 x 12.5 cm between rows interaction (2874 kg/ha).

Table 7.31

Influence of genotype x row spacing interaction on grain yield in millet, average 2022 – 2024

Genotip	Distanța între rânduri (cm)	Producția medie 2022-2024 (kg/ha)	Diferența față de martor (%)	Diferența față de martor (kg/ha)	Semnificația
Soiul Marius	**12,5**	**2388**	**Mt**	**Mt**	
	25	2116	89	-272	
	50	1622	68	-766	ooo
Populația locală Secuieni	12,5	2409	101	21	
	25	2007	84	-381	o
	50	1568	66	-820	ooo
BG 1	12,5	2287	96	-101	
	25	1771	74	-617	ooo
	50	1344	56	-1044	ooo
BG 2	12,5	1789	75	-599	ooo
	25	1518	64	-870	ooo
	50	1420	59	-968	ooo
BG 3	12,5	2874	120	486	oo
	25	1990	83	-398	o
	50	1808	76	-580	ooo
Media		1895	79	-494	oo
Dl A*B 5%				303	
Dl A*B 1%				407	
Dl A*B 0,1 %				542	

7.3.8. Results obtained regarding the testing of some herbicides and their influence on millet grain yield

Research from abroad claims that for good care of this crop, herbicides based on S-metolachlor are effective, so these substances were also used in this test (Giri S., 2024).

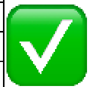
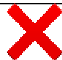
The experiment consists of testing herbicides approved for various grasses, legumes, oilseeds or tubers, herbicides that are very accessible to farmers, which are normally found on farms.

The results obtained from testing herbicides on millet showed a large variation in millet grain yield, which had values between 930 kg/ha (Gallup Super, 5 l/ha) and 2550 kg/ha (Gardoprim, 3.5 l/ha).

Millet was intolerant to propaquizafop, the active substance in the herbicide with the trade name Agil, which applied post-emergence completely destroyed the crop (table 7.32).

Table 7.32

Yield and tolerance of millet to herbicides, average 2022 – 2024

Denumire erbicid	Doza (l/ha)	Mod de aplicare	Producție (kg/ha)	Dif. față de martor (%)	Dif. față de martor (kg/ha)	Semn.	Toleranță
Stomp	2		1355	76	-419	ooo	
Stomp	2.9		1780	100	6		
Gallup Super	4		1780	100	6		
Gallup Super	5		930	52	-844	ooo	
Aloha	1		2275	128	501	***	
Aloha	1.2	preemergent	2355	133	581	***	
Gardoprim	3.5		2550	144	776	***	
Gardoprim	5		1965	111	191	***	
Adengo	0.3		1635	92	-139	ooo	
Adengo	0.4		2065	116	291	***	
Basagran	1.8		1860	105	86	*	
Basagran	2		1835	103	61		
Dicopur	0.8		2160	122	386	***	
Dicopur	1		2220	125	446	***	
Ceredin super	0.8	postemergent	2135	120	361	***	
Ceredin super	1		2070	117	296	***	
Agil	0.5		0	0	-1774	ooo	
Agil	1.2		0	0	-1774	ooo	
Corum	0.2		2325	131	551	***	
Corum	0.25		2186	123	412	***	
Media			1774	100	Mt		
Dl 5%					62		
Dl 1%					88		
Dl 0,1%					116		

CHAPTER VIII – GRAIN QUALITY

8.1. The influence of the studied factors on the chemical composition of millet grains

The chemical composition of millet grain contains 11.3% crude protein, 59% non-nitrogenous extractives, 3.8% fatty substances, 3.6% ash, 8.9% cellulose and 13.0% water (Ștefan M., 2004). Starch is the major component of millet grains, representing 58.1–77.9% of the total grain weight. (Yang et al., 2018).

In this experiment, comparing with the unfertilized variants, it was observed that the use of TerraSorb foliar fertilizer at a dose of 2.0 l/ha led to the accumulation of a higher percentage of lipids (4.41 – 4.58%) and starch (52.27 – 53.96%) in the case of variants sown with the Marius variety (table 8.1).

Foliar fertilization with the commercial product Asfac at a dose of 1.0 l/ha generated the accumulation of higher amounts of starch in millet grains, in the case of variants sown with the Marius variety, varying between (53.44 – 54.60%), compared to the same variants in an unfertilized system (table 8.1).

The use of the foliar fertilizer Albit at a dose of 0.04 l/ha, compared to the unfertilized variants, determined the accumulation of a higher amount of lipids (4.34 – 4.52%) and starch (53.14 – 53.40%), in the case of variants sown with the Marius variety (table 8.1).

Variants sown with the Marius variety, foliar fertilized with the Albit product (0.06 l/ha) achieved a higher lipid content (4.47 – 4.80%) (table 8.1).

Table 8.1

Genotype x seed rate x foliar fertilizer interaction on millet grain quality, average 2022 – 2024

Genotip	Norma de sămânță (kg/ha)	Fertilizant foliar	Lipide (%)	Fibre (%)	Proteine (%)	Amidon (%)	Cenușă (%)
Marius	10 kg/ha	Nefertilizat	4.41	5.68	12.20	51.82	1.96
		TerraSorb - 2.0 l/ha	4.42	5.61	12.14	52.27	1.96
		Asfac - 1.0 l/ha	4.60	5.27	11.96	53.44	1.93
		Albit - 0.04 l/ha	4.49	5.49	12.53	53.14	1.94
		Albit - 0.06 l/ha	4.71	5.61	12.09	52.18	1.92
	14 kg/ha	Nefertilizat	4.31	5.45	12.15	53.18	1.90
		TerraSorb - 2.0 l/ha	4.41	5.42	12.24	53.37	1.95
		Asfac - 1.0 l/ha	4.57	5.37	11.90	54.60	1.92
		Albit - 0.04 l/ha	4.34	5.52	12.05	53.40	1.94
		Albit - 0.06 l/ha	4.47	5.59	11.97	52.39	1.88
	18 kg/ha	Nefertilizat	4.35	5.29	12.16	53.46	1.96
		TerraSorb - 2.0 l/ha	4.58	5.37	12.10	53.96	1.94
		Asfac - 1.0 l/ha	4.58	5.28	12.27	54.48	1.96
		Albit - 0.04 l/ha	4.52	5.70	12.02	53.14	1.94
		Albit - 0.06 l/ha	4.80	5.32	12.06	53.88	1.97
Populația locală Secuieni	10 kg/ha	Nefertilizat	4.63	6.12	11.70	50.08	1.94
		TerraSorb - 2.0 l/ha	4.75	6.19	11.44	50.86	1.99
		Asfac - 1.0 l/ha	4.82	6.46	11.60	50.10	1.98
		Albit - 0.04 l/ha	4.82	6.36	11.77	50.14	1.96
		Albit - 0.06 l/ha	4.87	6.17	11.51	51.25	2.00
	14 kg/ha	Nefertilizat	4.71	6.07	11.85	51.52	1.98
		TerraSorb - 2.0 l/ha	4.85	6.10	11.77	51.55	1.99
		Asfac - 1.0 l/ha	4.73	6.16	11.61	51.21	1.92
		Albit - 0.04 l/ha	4.58	6.29	11.46	51.26	2.00
		Albit - 0.06 l/ha	4.61	6.07	11.45	52.56	1.94
	18 kg/ha	Nefertilizat	4.67	5.88	11.48	53.94	1.99
		TerraSorb - 2.0 l/ha	4.42	5.52	11.88	52.33	1.91
		Asfac - 1.0 l/ha	4.63	5.84	11.67	52.34	1.93
		Albit - 0.04 l/ha	4.81	6.31	11.30	51.29	1.92
		Albit - 0.06 l/ha	4.73	6.42	11.16	51.14	2.00

On average, for the experimental period (2022 – 2024) in the interactions in which the Local Secuieni Population was used, the norm of 18 kg/ha by using foliar fertilizers, compared to the unfertilized variant, were noted:
- TerraSorb – 2.0 l/ha – led to a higher accumulation of proteins (11.88%);
- Asfac – 1.0 l/ha – helped to store a high percentage of proteins in the grains (11.67%);
- Albit – 0.04 l/ha – its application led to a higher content of lipids (4.81%) and fibers (6.31%);
- Albit – 0.06 l/ha – led to the accumulation of a greater amount of lipids (4.73%) and ash (2.00%) in the grains (table 8.1).

The interaction between genotype and row spacing shows that as the seed rate increased, the percentage of starch in the grains also increased (table 8.2).

Table 8.2

Genotype x seed norm interaction on millet grain quality, average 2022 – 2024

Genotip	Norma de sământă	Lipide (%)	Fibre (%)	Proteine (%)	Amidon (%)	Cenușă (%)
Marius	10 kg/ha	4.53	5.53	12.18	52.57	1.94
	14 kg/ha	4.41	5.46	12.06	53.45	1.92
	18 kg/ha	4.57	5.39	12.12	53.78	1.96
Populația locală Secuieni	10 kg/ha	4.75	6.28	11.63	50.30	1.97
	14 kg/ha	4.69	6.14	11.63	51.62	1.97
	18 kg/ha	4.67	6.06	11.45	52.16	1.96

CHAPTER IX – ECONOMIC EFFICIENCY OF CROP

9.1. General considerations

From an economic point of view, millet is a productive plant, unpretentious to soil fertility and drought, involving minimal costs for cultivation. This species does not produce losses, the plant residues being recoverable, for example, millet biomass represents a source of feed in some Asian countries such as India (Blümme L. M., 2003; Brunette T., 2016).

9.2. Analysis of the economic efficiency

On average, in the 3 years of experimentation, the lowest value of the yield cost was obtained in the interaction Local Secuieni population x 18 kg/ha x Asfac 1.0l/ha (0.723 lei/kg), and the most expensive, Local Secuieni population x 10 kg/ha x Unfertilized (1.044 lei/kg). Following these experiments, we conclude that, in order to achieve high values of gross profit, we recommend using a higher seed rate, in our case, for the interactions where the seed rate of 18 kg/ha was used, on average the production cost value was the lowest (0.723 – 0.827 lei/kg) (table 9.4).

Table 9.4

Economic efficiency of millet crop, average 2022 – 2024

Genotip	Normă sămânță	Fertilizant foliar	Producția medie (kg/ha)	Valoarea producției (lei/kg)	Cheltuieli totale (lei/ha)	Cost de producție (lei/kg)	Profit brut (lei/ha)
Soiul Marius	10 kg/ ha	Nefertilizat	2416	25759	2471	1.023	23288
		TerraSorb 2.0 l/ha	3240	34542	2611	0.806	31931
		Asfac 1.0 l/ha	3142	33492	2493	0.793	30999
		Albit 0.04 l/ha	2768	29510	2515	0.909	26995
		Albit 0.06 l/ha	2846	30338	2537	0.891	27801
	14 kg/ ha	Nefertilizat	2878	30682	2471	0.859	28211
		TerraSorb 2.0 l/ha	2939	31327	2611	0.888	28716
		Asfac 1.0 l/ha	3019	32181	2493	0.826	29688
		Albit 0.04 l/ha	3066	32679	2515	0.820	30164
		Albit 0.06 l/ha	3183	33926	2537	0.797	31389
	18 kg/ha	Nefertilizat	2745	29257	2471	0.900	26786
		TerraSorb 2.0 l/ha	3245	34587	2611	0.805	31976
		Asfac 1.0 l/ha	3398	36221	2493	0.734	33728
		Albit 0.04 l/ha	3040	32409	2515	0.827	29894
		Albit 0.06 l/ha	3054	32559	2537	0.831	30022
Populatia locală Secuieni	10 kg/ ha	Nefertilizat	2367	25232	2471	1.044	22761
		TerraSorb 2.0 l/ha	2920	31127	2611	0.894	28516
		Asfac 1.0 l/ha	2743	29239	2493	0.909	26746
		Albit 0.04 l/ha	2724	29042	2515	0.923	26527
		Albit 0.06 l/ha	2644	28182	2537	0.960	25645
	14 kg/ ha	Nefertilizat	2783	29663	2471	0.888	27192
		TerraSorb 2.0 l/ha	2885	30754	2611	0.905	28143
		Asfac 1.0 l/ha	2954	31494	2493	0.844	29001
		Albit 0.04 l/ha	2972	31680	2515	0.846	29165
		Albit 0.06 l/ha	3002	32004	2537	0.845	29467
	18 kg/ha	Nefertilizat	3013	32120	2471	0.820	29649
		TerraSorb 2.0 l/ha	3249	34631	2611	0.804	32020
		Asfac 1.0 l/ha	3446	36736	2493	0.723	34243
		Albit 0.04 l/ha	3150	33582	2515	0.798	31067
		Albit 0.06 l/ha	3171	33799	2537	0.800	31262
Preț de vânzare: 2,62 lei/kg							

CHAPTER X
CONCLUSIONS

10.1. Conclsions

Millet is an autogamous, C4 type species. whose ancestor is still unknown.

It first appeared in Manchuria (China), but the ways in which this species migrated are unknown, and today it is found on all continents.

Panicum miliaceum L. is one of the first domesticated crops in the world and was cultivated before the spread of rice, maize and wheat (Crawford G.W., 2006; Sage R.F., 2011). Ten thousand years ago. it appeared as a staple food in the semi-arid regions of East Asia (China, Korea, Japan, Russia and India) and later spread throughout the Eurasian region (Lindquist J.L., 2005; Cavers P.B., 2016).

Today, millet grains are still an important food source for energy and protein for millions of people living in arid and semi-arid areas of emerging countries, while millet biomass is an important source of feed in some Asian countries, such as India (Blümme L. M., 2003; Brunette T., 2016). In the Western world, Panicum miliaceum L. is considered a minor cereal due to its low economic importance and is therefore usually used as food or animal feed (Crawford G.W., 2006; Lindquist J.L., 2005).

10.1.1 Conclusions regarding the natural environment

The environment of the Secuieni Agricultural Research and Development Station is conducive to field crops, where in normal years from a climatic point of view, high yields are obtained for all crops established within the unit, with millet also being promising.

The multiannual average temperature according to data recorded by the meteorological station at ARDS Secuieni is 8,40 C, and the amount of precipitation is 531,9 mm.

10.1.2 Conclusions regarding the influence of temperature on the grain germination of *Panicum miliaceum* L

This experiment found that there is a positive correlation between high temperatures and germination percentage, we observed that a temperature of 10°C ensures the germination of 50,25% of the millet grains, while a temperature of 20°C has a significantly greater impact, resulting in an impressive germination rate of 97,75%.

10.1.3 Conclusions on observations and biometric determinations carried out during the growing season of grain millet

On average, from sowing to emergence, millet needed 13 days.

The sowing of this crop was carried out in the first decade of May.

The increased sensitivity of the millet crop to weeds, in the first phases of vegetation, required the performance of a herbicide with the commercial product Dicopur, at a dose of 1,0 l/ha, in the phenological phase represented by the end of the millet twinning.

The development stage of millet characterized by the formation and development of inflorescences, appeared in the first decade of June (marks the beginning of grain formation).

The entire vegetation period of millet totaled 95 – 98 days, reflecting the complex duration of the growth and maturation processes of the crop.

Panicum miliaceum L. is a species that knows a small number of pathogens and pests, in the studied area presenting interest for the pathogen *Helminthosporium* and for the pests *Oscinella frit* (Grain fly) and *Ostrinia nubilalis* (Corn borer), but which did not cause damage to this species.

The resistance of millet to falling, both during the vegetation period and at harvest was very good (note 1), and taking into account the specificity of the species, the resistance to shaking affected 20% of the millet plants.

The experimental technological sequences also had an influence on the phenological characters of the plants, so that with the increase in the seed rate, an increase in the number of main plants/ha was observed, and the application of the foliar fertilizers TerraSorb (2,0 l/ha), Asfac (1,0 l/ha) and Albit (0,06 l/ha) generated an increase in the number of tillers/ha.

10.1.4 Conclusions regarding the influence of genotype on millet grain yield

The average grain yield during the period 2022 – 2024 was 2200 kg/ha, the lowest average yield being in the BG 2 genotype (2088 kg/ha), and the highest yield value was recorded in the Secuieni Local Population (2410 kg/ha), while the yield value of the control variant (Marius variety) was 2389 kg/ha.

10.1.5 Conclusions on the influence of foliar fertilization on millet grain yield

On average, for the three years of experimentation, in the variants where the foliar fertilizer Asfac – 1,0 l/ha was used, the average yield achieved the highest value

(2786 kg/ha). Compared to the unfertilized variant (2382 kg/ha), the yield increase (+404 kg/ha) was very significant.

In the variants fertilized foliarly with the commercial product Terra Sorb (2,0 l/ha), the average yield was 2767 kg/ha, and in the case of the variants where the product Albit (0,04 l/ha) was used, the average yield was 2647 kg/ha, while at the dose of 0.06 l/ha Albit, the yield had a slightly higher average value, of 2682 kg/ha

10.1.6 Conclusions on the influence of seed rate on millet grain yield

Experimental results obtained with millet show that the seed rate influences the millet yield grain, thus, the higher the seed rate, the higher the grain yield.

In the years of experimentation, the ideal seed rate was 18 kg/ha, guaranteeing an average yield of 2808 kg/ha, ensuring an average yield increase of 346 kg/ha, compared to the control (rate of 10 kg/ha).

10.1.7 Conclusions on the influence of genotypes x foliar fertilization interaction on millet grain yield

During the experimental period, the most productive variant was achieved in the interaction Marius variety x Asfac 1,0 l/ha, whose average yield was 2845 kg/ha, with a yield increase of 491 kg/ha, compared to the control (Marius variety x unfertilized). Very good results were also obtained in the interaction Marius variety x Terra Sorb (2.0 l/ha), where the average yield was 2817 kg/ha, with a yieldincrease of 463 kg/ha, compared to the control.

In the case of the variants sown with the Secuieni local population, the highest average yield values were obtained in the case of using foliar fertilizers:

- Asfac, in a dose of 1.0 l/ha (2728 kg/ha), having a very significant production increase (374 kg/ha);
- Terra Sorb, at a dose of 2.0 l/ha (2716 kg/ha) with a very significant increase (362 kg/ha).

10.1.8 Conclusions on the influence of the interaction of foliar fertilization x seed rate on millet grain yield

On average, for the three years of study (2022 – 2024), following the interaction of seed rate x foliar fertilizer, the average yield was 2754 kg/ha, noting the interactions with the highest values of grain yield:

- 18 kg/ha x Asfac 1.0 l/ha with an average yield of 3235 kg/ha;
- 18 kg/ha x Terra Sorb 2.0 l/ha with an average yield of 3050 kg/ha;

10.1.9 Conclusions on the influence of the interaction of genotypes x foliar fertilization x seed rate on millet grain yield

Following the research carried out in the three experiments, in the millet crop there is a direct link between the interaction of the three factors, genotype, foliar fertilization and seed rate, an aspect highlighted on the grain yield obtained.

On average for the three years of experimentation (2022 – 2024), the interaction genotype x seed rate x foliar fertilization generated an average yield of 2670 kg/ha; the highest yield values were obtained in the interactions:

- Marius variety x 18 kg/ha x Asfac 1.0 l/ha – with an average yield of 3070 kg/ha; compared to the control (Marius variety x 10 kg/ha x unfertilized) having a very significant increase (932 kg/ha);
- Local population Secuieni x 18 kg/ha x Asfac 1.0 l/ha – with an average yield of 3180 kg/ha; compared to the control with a very significant increase (1033 kg/ha);
- Local population Secuieni x 18 kg/ha x TerraSorb 1.0 l/ha – with an average yield of 3001 kg/ha; compared to the control with a very significant increase (854 kg/ha).

10.1.10 Conclusions on the influence of genotype x row spacing interaction on millet grain yield

On average, for this experiment, the highest yields values were obtained in the variants where the row spacing was 12,5 cm.

The average yield value/experience was 1895 kg/ha, the maximum value being obtained in the interaction BG 3 x 12,5 cm (2874 kg/ha), followed by the Local population Secuieni x 12,5 cm (2409 kg/ha), variety Marius x 12,5 cm (2388 kg/ha).

For the row spacing of 25 cm, the highest value was obtained in the interaction Marius x 25 cm variety (2116 kg/ha), and for the row spacing of 50 cm, the highest yield value was 1808 kg/ha (BG 3).

10.1.11 Conclusions regarding the results obtained from testing some herbicides and their influence on millet grain yield

Following their testing, the grain yields of the herbicide variants achieved values ranging from 930 kg/ha (Gallup Super – 5.0 l/ha) – 2550 kg/ha (Gardoprim 3.5 l/ha).

Of the herbicides used in this experiment, millet is intolerant only to propaquizafop, the active substance in the herbicide with the trade name Agil, which completely destroyed the millet crop.

10.1.12 Conclusions regarding the influence of the studied factors on the chemical composition

Compared to the unfertilized variants, it was observed that the use of TerraSorb foliar fertilizer at a dose of 2,0 l/ha led to the accumulation of a higher percentage of lipids (4,41 – 4,58%) and starch (52,27 – 53,96%) for variants sown with the Marius variety.

Foliar fertilization with the commercial product Asfac at a dose of 1,0 l/ha generated the accumulation in millet grains of a higher amount of starch, in the case of variants sown with the Marius variety, this varying between (53,44 – 54,60%), compared to the same variants in an unfertilized system.

The use of the foliar fertilizer Albit at a dose of 0,04 l/ha, compared to the unfertilized variants, resulted in the accumulation of a higher amount of lipids (4,34 – 4,52%) and starch (53,14 – 53,40%), for variants sown with the Marius variety.

The variants sown with the Marius variety, foliar fertilized with the Albit product, at a dose of 0,06 l/ha, achieved a higher lipid content (4,47 – 4,80%). The interaction between genotype and row spacing shows that, with the increase in the seed rate, the percentage of starch in the grains also increased.

10.1.13 Conclusions regarding economic efficiency

On average, in the 3 years of experimentation, the lowest value of the production cost was obtained in the interaction Local population Secuieni x 18 kg/ha x Asfac 1,0l/ha (0,723 lei/kg), and the most expensive, Local population Secuieni x 10 kg/ha x Unfertilized (1,044 lei/kg). Following these experiments, we conclude that in order to achieve high net profit values, we recommend using a higher seed rate, in our case, for the interactions where the seed rate of 18 kg/ha was used, on average the production cost value was the lowest (0,723 – 0,827 lei/kg).

10.2 Recommendation

We propose to continue research on this species, but we also encourage farmers to introduce millet into their crop rotations, using both the Marius variety and the local population Secuieni; these two genotypes have very good adaptability to the pedo-climatic conditions specific to Central Moldova.

For a good grain harvest, we recommend sowing millet between May 5-15.

We also recommend a seed rate of 18 kg/ha, which ensures the highest grain yields, when the distance between the rows of plants is 12,5 cm.

To optimize production, we recommend the use of foliar fertilizers TerraSorb (2,0 l/ha) and Asfac (1,0 l/ha), applied during the twinning period, until the beginning of the flowering phase.

Weed control in millet crops is recommended to be achieved by using herbicides such as: Stomp, Gallup Super, Aloha, Gardoprim, Adengo, Basagran, Dicopur, Ceredin, Corum.

For the eradication of millet crops, the elimination of unwanted samulastra, we recommend the herbicide Agil, as millet is intolerant to the action of its active substances.

REFERENCES

1. Agdag M., Nelson L., Baltensperger D., Lyon D., Kachman S., 1998 – *Row spacing affects grain yield and other agronomic characters of proso millet,* Communications in Soil Science and Plant Analysis, vol 32 (13), 2001, p. 2021-2032, DOI:10.1081/CSS-120000266

2. Amadoubr I., Mahamadou E. Gounga, Guo-Wei Le, 2013 - *Millets: Nutritional composition. some health benefits and processing — A Review*, Emir. Journal Food Agriculture, nr 25, p. 501-508, doi: 10.9755/ejfa.v25i7.12045, http://www.ejfa.info/

3. Awika J.M., 2011 – *Major Cereal Grains Production and Use around the World. In Advances in Cereal Science: Implications to Food Processing and Health Promotion*; American Chemical Society, Washington, DC. USA, p. 1–13, **DOI:** 10.1021/bk-2011-1089.ch001

4. Bandyopadhyay T., Muthamilarasan M., Prasad M., 2017 – *Millets for Next Generation Climate-Smart Agriculture*, Frontier Plant Science, vol 8, p. 1266

5. Bîlteanu Gh., Birnaure V., 1989 – *Fitotehnie,* Ed. Ceres, București

6. Blümme L. M., Zerbini E., Reddy B.V.S., Hash C.T., Bidinger F., Ravi D. 2003 – *Improving the production and utilization of sorghum and pearl millet as livestock feed: Methodological problems and possible solutions*, Field Crop Research, vol 84, p. 123–142

7. Bough M., Colosi J.C., Cavers P.B., 1986 – *The major weed biotypes of proso millet (Panicum miliaceum L.) in Canada,* Canadian Journal of Botany, no. 64, p. 1188 – 1198

8. Brunette T., Baurhoo B., Mustafa A.F., 2016 – *Effects of replacing grass silage with forage pearl millet silage on milk yield, nutrient digestion, and ruminal fermentation of lactating dairy cows,* Journal Dairy Science, vol 99, p. 269 – 279

9. Calamai A., Masoni A., Marini L., Dell'acqua M., Ganugi Paola, Boukail Sameh, Benedettelli S., Palchetti E., 2020 – *Evaluation of the Agronomic Traits of 80 Accessions of Proso Millet (Panicum miliaceum L.) under Mediterranean Pedoclimatic Conditions,* Agriculture, vol 10(12), p. 578; https://doi.org/10.3390/agriculture10120578

10. Changmei S., Dorothy J., 2014 – *Millet-the frugal grain*, Interational Journal of Science Research, vol 3 (4), p. 75-90

11. Colosi J.C., Schaal B.A., 1997 – *Wild proso millet (Panicum miliaceum) is genetically variable and distinct from crop varieties of proso millet*, Weed Science, vol. 45, p. 509 – 518

12. Colosi J.C., Schaal Barbara A., 2017 – *Wild proso millet (Panicum miliaceum) is genetically variable and distinct from crop varieties of proso millet,* Published online by Cambridge University Press,12 June 2017
13. Crawford G.W., 2006 – *East Asian Plant Domestication. In Archaeology of Asia,* John Wiley & Sons, Ltd: Hoboken, NJ. USA, p. 77 – 95
14. Das S., Khound R.., Santra M., Santra D.K., 2019 – *Beyond Bird Feed: Proso Millet for Human Health and Environment*, Agriculture, vol. 9(3), p. 64; https://doi.org/10.3390/agriculture9030064
15. Ellstrand N.C., Heredia S.M., Leak-Garcia J.A., 2010 – *Crops gone wild: evolution of weeds and invasives from domesticated ancestors,* Evolutionary Applications, vol. 3, p. 494–504
16. Flajšman M., Štajner N., Kocjan Ačko D., 2019 - *Genetic diversity and agronomic performance of Slovenian landraces of proso millet (Panicum miliaceum L.),* Turkey Journal of Botany, vol.11, p. 185–195
17. Giri Santu, Das N.K., Kundu A.K., 2024 - *Weed Management in Millets*, Millets: The Miracle Grains of 21st Century, ISBN: 978-81-969534-8-5, https://www.kdpublications.in/
18. Graybosch R.A., Baltensperger D.D., 2009 – *Evaluation of the waxy endosperm trait in proso millet (Panicum miliaceum),* Plant Breeding, vol. 128, p. 70–73
19. Gumaniuc Ludmila, Varga P., 1988 – *Minerva, primul soi românesc de mei (Panicum miliaceum L.*), An. I.C.C.P.T. Fundulea, vol LVI, p. 166-119
20. Gumovschi A., 2024 - *Manualul fermierului pentru culturile de câmp: Ghid practic pentru producătorii agricoli, Partea a IIa*, Chişinău, Ed. Notograf Prim, ISBN 978-9975-87-842-5
21. Gupta A., 2006 – *Improvement of millets and pseudo-cereals for rainfed agriculture in hill region*. In: Gupta HS. Srivastva AK. Bhatt JC (Eds) Sustainable Production from Agricultural Watersheds in North West Himalaya, Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttaranchal, India, p 163 – 174
22. Habiyaremye C., Matanguihan J.B., D'Alpoim Guedes J., Ganjyal G., Whiteman M.R., Kidwell K.K., Murphy K.M., 2017 – *Proso Millet (Panicum miliaceum L.) and Its Potential for Cultivation in the Pacific Northwest. U.S.: A Review*, Frontiers in Plant Science, vol. 7, p. 1 – 17
23. Häfliger. E., Scholz. H., 1980 – *Grass weeds 1. Weeds of the subfamily*
24. Hu X., Wang J., Lu P., Zhang H., 2009 – *Assessment of genetic diversity in broomcorn millet (Panicum miliaceum L.) using SSR markers,* Journal of Genetics and Genomics, vol. 36, p. 491 – 500

25. Hulse J.H., Laing E.M., Pearson O.E., 1980 – *Sorghum and the Millets. Their Composition and Nutritional Value,* Academic Press, New York, p. 997
26. Jităreanu G., 1994 – *Tehnică experimentală,* Univ. Agronomică Iași
27. Jităreanu G. ș.a, 2020 – *Tratat de Agrotehnică,* Ed.Ion Ionescu de la Brad, Iași
28. Jones M.K., 2004 – *Between fertile crescents: minor grain crops and agricultural origins.* In: Traces of Ancestry: Studies in Honour of Colin Renfrew (ed. Jones MK), Oxbow Books, Cambridge, p. 127–135
29. Kaume R.N., 2006 – *Panicum miliaceum* L. in M. Brink and G. Belay eds., PROTA 1: Cereals and pulses/ Céréales et légumes secs. PROTA (Plant Resources of Tropical Africa), Wageningen, Netherlands, p. 122 – 126
30. Kitagawa M. 1937 – *A contribution to the Flora of Manchuria,* Botanical Magazine Tokyo, vol 51, p. 153–154
31. Kumar A., Tomer V., Kaur A., Kumar V., Gupta K., 2018 – *Millets: A solution to agrarian and nutritional challenges,* Agric. Food Security, vol. 7
32. Leder I., 2004 – *Sorghum and millets,* p 66-84 in G. Fuleky, ed Cultivated plants, primarily as food sources, Encyclopaedia of life support systems (EOLSS), Developed under the auspices of UNESCO, EOLSS Publishers Oxford, UK
33. Linduist
34. Lu H., Zhang J., Liu K., 2009 – *Earliest domestication of common millet (Panicum miliaceum) in East Asia extended to 10.000 years ago,* Proceedings of the National Academy of Sciences of the United States of America, vol. 106, p. 7367–7372
35. Lupu Cornelia, 2007 – *Condiții climatice. Volum omagial, 45 de ani de cercetare – dezvoltare agricolă la S.C.D.A Secuieni*
36. Lupu Cornelia, 2012 – *Condiții climatice. Volum omagial, 50 de ani de cercetare – dezvoltare agricolă la S.C.D.A Secuieni*
37. Lupu Cornelia, 2017 – *Caracterizarea climatică a zonei agricole din sfera de influență a S.C.D.A. Secuieni – Neamț (1962-2016),* Ed. Ion Ionescu de la Brad, Iaşi
38. Matz S.A., 1986 – Descriptors for *Panicum miliaceum* and *P. sumatrense*. International Board for Plant Genetic Resources: Rome
39. Mogârzan Aglaia, Morar G., Ştefan M., 2004 – *Fitotehnie,* Editura "Ion Ionescu de la Brad", Iaşi
40. Muntean L.S., Borcean I., Axinte M., Roman Gh.V., 2003 – *Fitotehnie.* Ediția a III-a, Ed."Ion Ionescu de la Brad", Iaşi
41. Onisie T., Jităreanu G., 1992 – *Lucrări practice de tehnică experimentală,* USAMV Iaşi
42. Palchetti E., Calamai A., Valenzi E., Rella G., Whittaker A., Masoni A., Bindi M., Moriondo M., Brilli L., 2019 – *Open field screening of the productive parameters.*

protein content, phenolic compounds, and antioxidant capacity of maize (Zea mays L.) in the marginal uplands of southern Madagascar, J. Agric. Rural Dev. Trop. Subtrop., vol 120, p. 45–54

43. Pochișcanu Simona – Florina, 2015 – *Teză de doctorat – Cercetări privind aplicarea unor secvențe tehnologice moderne la sorg (Sorghum bicolor L.) în condițiile pedolimatice din Centrul Moldovei*

44. Popović Vera, Ikanović Jela, Rajičić V., Mačkić Ksenija, Ljubičić Nataša, Kostić M., Radović M., Šarčević-Todosijević Lj., 2020 – *Millet – Panicum miliaceum L. production trend in the world. Importance of millet in nutrition and for bioenergy - Novi Sad: Ecological movement of Novi Sad*, XXIV International Eco-Conference XI Safe Food 23–25th September 2020, Novi Sad, Serbia

45. Quetzalcóatl O.R., 2003 – *Estudio demográfico de Panicum miliaceum L. en un cultivo de sorgo en Puruándiro Michoacán*, Universidad Autónoma Chapingo

46. Ragaee S., Abdel-Aal E.S.M., Noaman M., 2006 – *Antioxidant activity and nutrient composition of selected cereals for food use,* Food Chem, 2006, vol 98, p. 32–38

47. Roman Gh.V., Tabără V., Axinte M., Robu T., Ștefan M., Morar G., Pîrșan P., Cernea S., 2011 – *Fitotehnie vol I, Cereale și leguminoase pentru boabe* Ed. Universitară, 2011

48. Roman Gh.V., Pîrșan P., Ștefan M., Robu T., Duda M.M., Tabără V., 2015 – *Fitotehnie. Cereale și leguminoase pentru boabe. Ediția a II-a revizuită și adăugită*, vol I, Ed. Universitară

49. Sage R.F., Zhu X.G., 2011 – *Exploiting the engine of C4 photosynthesis,* J. Exp. Bot., vol 12, p. 2989–3000

50. Saruhan V., Ku A., 2005 – *The effect of different humic acid fertilization on yield and yield components performances of common millet (Panicum miliaceum L.),* Sci. Res. Essays, vol 7, p. 663–669

51. Săulescu N., 1947 – *Fitotehnica. vol I și II*, Tiparul ”Cartea Românească”, Bucuerști, p. 138, p. 141, 520

52. Scholz H., Mikoláš V., 1991 – *The weedy representatives of proso millet (Panicum miliaceum. Poaceae) in Central Europe*, Thaiszia, vol 1, p. 31–41

53. Sherratt A., 2006 – *The Trans-Eurasian exchange: the prehistory of Chinese relations with the West. In: Mair V, editor. Contact and Exchange in the Ancient World,* Honolulu, Hawaii: Hawaii University Press, pp. 1–9

54. Starodub Victor, 2008 – *Fitotehnie* – tehnologii în fitotehnie, Chișinău, p. 168-172

55. Ștefan M., 2004

56. Theisen A.A., Knox E.G., Mann F.L., 1978 – *Feasibility of introducing food crops better adapted to environmental stress,* Nati. Science Foundation, Individual crop reports, Arlington, VA, vol. II, p. 168–172
57. Tran G., 2017 – *Proso millet (Panicum miliaceum), forage*, Feedipedia, a programme by INRAE. CIRAD. AFZ and FAO. https://www.feedipedia.org/node/409 Last updated on September 1. 2017. 23:02
58. Trotuș Elena, 2017 – *55 de ani de Cercetare-dezvoltare. Volum omagial,* Ed. Ion Ionescu de la Brad, Iași
59. Trotuș Elena, 2022 – *60 de ani de Cercetare-dezvoltare. Volum omagial,* Ed. Ion Ionescu de la Brad, Iași
60. Ullah A., 2017 – *Recognizing production options for pearl millet in Pakistan under changing climate scenarios*, J. Integr. Agric., vol. 16, p. 762–773
61. Vetriventhan M., Upadhyaya H.D., 2018 – *Diversity and trait-specific sources for productivity and nutritional traits in the global proso millet (Panicum miliaceum L.) germplasm collection*, Crop J., vol. 6, p. 451–463
62. Yang 2018
63. Zamfirescu N., Velican V., Săulescu N., 1965 – *Fitotehnie*
64. Zohary D., Hopf M., 2000 – *Domestication of Plant in the Old World. The Origin and Spread of Cultivated Plants in West Asia*, *Europe and Nile Valley,* Oxford University Press, Oxford, p 316
65. ***http://www.agroatlas.ru
66. ***Conferința Internațională din anul 2020 ”Mâncare sănătoasă”
67. ***http://www.vremea.ro