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YIELD AND PROTEIN CONTENT OF WINTER PEA (*Pisum sativum*) VARIETIES IN AN ORGANIC FARMING SYSTEM

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Abstract

Pea (Pisum sativum) is one of the most important crops in the Fabaceae family, second only to soybean in significance. Its protein content, which ranges from 13% to 38%, is influenced by both environmental and genetic factors, making it a promising source of high-quality protein. A field experiment was conducted during the 2022–2024 years in an organic farming system in Satu Mare County, Romania, to evaluate the yield and protein content of winter pea. The study focused on three winter pea varieties: Andrada, Olguța, and Ghittia. The results indicated that the environmental conditions in the region were favourable for the growth, development, and yield formation of pea plants. The yield of the studied varieties exceeded 2500 kg ha⁻¹, with protein content surpassing 23%. These findings demonstrate that winter pea is a promising crop for Satu Mare County, offering a valuable source of protein. Additionally, the results provide practical insights for agricultural producers, enabling them to select pea varieties based on quality characteristics such as protein content.

***Key words**: winter pea, protein content, yield, organic farming.*

INTRODUCTION

Pea, alongside common bean and soybean, is one of the most important cultivated species in the *Fabaceae* family (Jezierny et al., 2010; Shanthakumar et al., 2022). Its mature dry seeds have diverse applications (Wrigley et al., 2004), primarily as food and animal feed (Singh et al., 2013).

Pea seeds contain approximately 60-65% carbohydrates, with starch comprising 35-40%, 23–30% protein, 1–2% lipids, and smaller amounts of minerals and vitamins, depending on the cultivar, cultivation conditions, and the maturity stage of the seeds at harvest (Lam et al., 2018; Bogahawaththa et al., 2019; Lu et al., 2019; Saurel, 2020). The protein content, in particular, ranges from 23.3% to 31.7% across different genotypes and pedoclimatic conditions (Barac et al., 2010; Bogahawaththa et al., 2019).

Although pea protein has been studied since the 1980s (Johnson and Brekke, 1983; Koyoro and Powers, 1987; Sumner, Nielsen, and Youngs, 1981), interest in this crop has significantly increased in recent years. This increased attention is attributed both to its relevance in the food industry and to the increasing consumer awareness of the health benefits associated with products derived from pea seeds (Lam et al., 2018).

The rising global demand for plant-based proteins, linked to reduced risks of obesity, hypertension, and diabetes, has further reinforced its relevance. Pea protein is rich in lysine, an amino acid that supports a healthy immune system (Huntrakul et al., 2020). Overall, pea proteins exhibit antioxidant, antihypertensive, and anti-inflammatory properties (Liao et al., 2019). Furthermore, research has shown that regular consumption of pea protein-rich foods has been associated with reduced risk of cardiovascular disease and diabetes and may provide protective effects against several types of cancer, including breast, renal, and colon cancers (Ge et al., 2020). Additionally, the consumption of whole peas contributes to lowering blood glucose levels, improving gastrointestinal health, and increasing satiety (Tulbek et al., 2017). In food production, pea protein is used in a variety of products, including bread (Sahagun and Gomez, 2018), pasta (Tulbek et al., 2017), in meat analogues, dairy alternatives, dairy

substitutes, and fortified beverages such as protein shakes and sports drinks (Philipp et al., 2017; 2018). Tulbek et al. (2017) provided solutions for replacing eggs in pasta, cakes, and bakery products with pea-based ingredients.
From an agronomic point of view, one of the most significant advantages of cultivating pea is its ability to enrich the soil with nitrogen through biological nitrogen fixation, which can subsequently benefit succeeding crops (Wysokinski et al., 2021; Ntatsi et al., 2019). Pea is a particularly valuable crop from an agronomic perspective (Roman et al., 2015). It vacates the field early and leaves behind significant quantities of organic matter and nitrogen in the soil. Furthermore, it leaves the land relatively free of weeds and without crop residues. Due to these characteristics, pea is an excellent precursor for many crops, especially winter wheat (Muntean et al., 2014).
According to available data (https://statistics.fibl.org/world/selected-crops-world.html), in 2023, the total area cultivated organically with peas in the European Union reached 70,528.77 hectares. The largest organically cultivated areas were recorded in Germany, with 14,000 hectares (representing 19.85% of the total EU area), Spain with 7,393.43 hectares (10.48% of the total), and France with 6,750 hectares (approximately 9.57%). Romania ranked fifth at the European level, with a total of 4,337 hectares of organically cultivated peas in 2023, accounting for 6.15% of the total EU area, highlighting the growing interest in organic practices and legume integration in sustainable cropping systems. Expanding the cultivation of pea in organic farming systems offers significant agronomic, economic, and environmental benefits, including reduced reliance on synthetic nitrogen fertilizers and improved nitrogen cycling through biological fixation (Faligowska et al., 2022). In this context, the aim of the present study is to evaluate the yield performance and protein content of three winter pea varieties cultivated under organic farming in the specific soil and climatic conditions of Satu Mare County, Romania. The specific objectives of the study were to: (1) assess the yield and yield components of three winter pea varieties; (2) determine the protein content of the pea genotypes studied.

MATERIALS AND METHODS

Study site

The research was carried out on a certified organic private farm located in Chereușa, Satu Mare County, Romania, over two consecutive agricultural years (2022-2023 and 2023-2024). In the research area, soil analyses indicate a slightly alkaline reaction, a very good supply of phosphorus (P), and a medium supply of nitrogen (N) and potassium (K). These analyses were delivered by the Laboratory for soil and plant analysis, Faculty of Agriculture, University for Agricultural Sciences and Veterinary Medicine Cluj-Napoca.
During the vegetation period (November to June), monthly average temperatures showed interannual variability.
The mean temperature recorded throughout the growth cycle was 7.475°C in the first season and 12.375°C in the second season, which significantly influenced the growth and development of the pea plants (Figure 1).

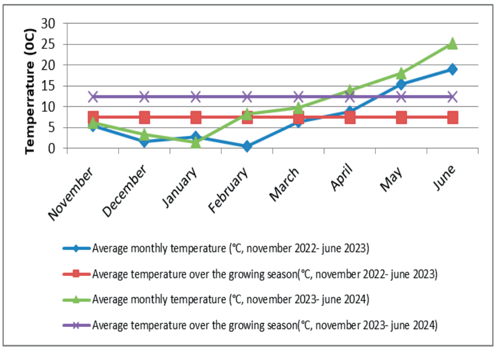

Figure 1. Average temperature over the growing season

The total precipitation recorded during the November 2022 - June 2023 period was 355.4 mm, while for the November 2023 - June 2024 period, it amounted to 471.2 mm (Figure 2). Climatic data were used to interpret growth dynamics and production levels of the studied genotypes.

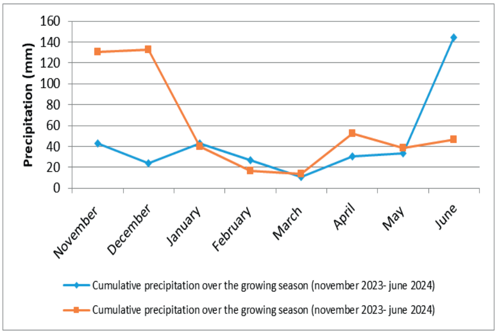

Figure 2. Cumulative precipitation over the growing season

Experimental design

The biological material consisted in three afila-type pea (*Pisum sativum* L.) cultivars - Olguța, Ghiția, and Andrada, under certified organic farming conditions. These cultivars, developed at the National Agricultural Research and Development Institute (NARDI) Fundulea, represent notable advancements in the genetic improvement of autumn-sown pea, offering high-performance alternatives to spring cultivars, particularly relevant in the context of climate change. The cultivars combine favourable agronomic traits such as adaptability, high productivity, superior seed quality, and resistance to biotic stress, thus representing promising options for growers across various agroecological zones of Romania.

The experiment was conducted within a crop rotation system, with winter wheat serving as the preceding crop. Sowing took place during the first ten days of November, in accordance with the technical requirements of organic production systems. No synthetic chemical inputs were applied throughout the growing season. Peas were harvested in the second decade of June, each experimental year. The moisture content of the seeds was 18%.

Phytosanitary observations

Throughout the growing seasons, the phytosanitary status of the crop was closely monitored. No pest or disease infestations above economic thresholds were recorded. Limited occurrences of powdery mildew (*Erysiphe polygoni*), anthracnose (*Ascochyta pisi*), and grey mold (*Botrytis cinerea*) were observed, but the severity of these attacks remained low and did not impact the overall plant health or yield.

Yield components and seed yield

Prior to harvest, the following yield components were determined: total number of pods per plant and seeds per pod and thousand seed weight (TSW). The TSW was determined in accordance with STAS standard methodology (SR 6123/99). Eight replicates of 100 seeds each were manually counted and individually weighed. The average of the eight values was multiplied by 10 to obtain the final TSW.

Seed yield (Q, kg/ha) was estimated based on the following formula (Muntean et al., 2018):

$$Q\ (\text{kg/ha})\ \frac{Npl x Npp x Nbp x TSW}{100}$$

where:

Npl = average number of plants per m²;
Npp = average number of pods per plant;
Nbp = average number of seed per pod;
TSW = thousand seed weight (g).

Protein content

The protein content of the seeds was determined using the Kjeldahl method (Kjeldahl, 1983). This method involves digesting the samples in concentrated sulphuric acid in the presence of catalysts to convert organic nitrogen into ammonium, which is further distillate and titrated. The resulting total nitrogen content was further multiplied by a nitrogen-to-protein conversion factor of 6.25 to estimate the crude protein content.

Data analysis

All collected data were compiled and statistically analyzed using analysis of variance (ANOVA), followed by Duncan's multiple range test, to evaluate the adaptability and performance of the tested cultivars under organic farming conditions within the specific pedoclimatic context of the study area.

RESULTS AND DISCUSSIONS

Yield components and seed yield

The climatic conditions during the vegetation period play an essential role in determining the agronomic success of winter pea crops, directly influencing germination, overwintering, vegetative regrowth, flowering, fecundation, and physiological seed maturation.

In both experimental years (2022-2023 and 2023-2024), the temperatures recorded in November, immediately after sowing, were above the minimum germination temperature for pea seeds, estimated at 1-2°C (Muntean et al., 2014; Samuil, 2007). This situation, correlated with satisfactory rainfall amounts during the same period, favoured a uniform and vigorous seedling emergence.

It is also noteworthy that in both experimental years, the winters were mild, with positive average monthly temperatures recorded in December, January, and February, which enabled proper overwintering without significant plant losses.

In March and April, thermal values were favourable for the resumption of vegetation and the branching process. Temperatures of 6.3°C in March and 8.8°C in April were recorded in the first year, while 9.73°C and 13.95°C were observed in the second year. The optimal temperature range for vegetative development of pea is 14-15°C, according to Muntean et al. (2014), or 10-18°C, according to Devi et al. (2023). In this context, we can conclude that in the first experimental year thermal conditions approached the optimal range, supporting a balanced development of pea plants. In the second year, the higher temperatures accelerated the phenological processes, which led to a shortened accumulation phase and, consequently, had a negative impact on yield levels.

During the flowering period, the optimal temperature is between 15-18°C (Muntean et al., 2014; Roman et al., 2015), while during the ripening phase it ranges between 18-20°C (Muntean et al., 2014). In the 2023-2024 season, these values were exceeded in May and June, which resulted in floral abortion and a reduced number of fertilized pods, with a negative effect on the crop's productive potential.

From a pluviometric perspective, pea water requirements are comparable to those of beans, with a total demand of 350-500 mm (https://www.fao.org/land-water/databases-and-software/crop-information/pea/fr/). The total precipitation recorded between November and June amounted to 355.4 mm in the first year and 471.2 mm in the second year, falling within the optimal range. However, rainfall distribution was not uniform. In both years, February and March were characterized by rainfall deficits (27.1 mm and 10.8 mm in 2022-2023; and 16.6 mm and 14 mm in 2023-2024, respectively). Nevertheless, the consistent precipitation recorded in the preceding months (November and December) contributed to the replenishment of soil moisture reserves, ensuring acceptable conditions for subsequent plant development.

The number of pods is one of the most important yield determining components in several grain legume species (French, 1990). The duration of pod formation depends on the onset and end of flowering (French, 1990). The initiation of flowering is mainly influenced by the cultivar, but also by environmental factors, particularly temperature (Berry and Aitken, 1979). In the year 2023, the average number of pods per plant was 9.32 (Table 1). In 2024, higher temperatures during the flowering period resulted in a reduced number of pods per plant (8.31 in average). Across the two experimental years, the differences among cultivars were small and statistically insignificant, as confirmed by both analysis of variance and Duncan's multiple range test.

Table 1. Influence of cultivar × year interaction on the number of pods per plant

Year	Variety	Pods number	% to control	Difference/ Signifficance	Duncan Test
2023	Average	9.32	100	Mt.	-
	Ghittia	9.33	100	0.01⁻	a
	Andrada	9.13	98	-0.19⁻	a
	Olguța	9.50	102	0.18⁻	a
2024	Average	8.31	100	Mt.	-
	Ghittia	8.27	99	-0.04⁻	b
	Andrada	8.13	98	-0.18⁻	b
	Olguța	8.53	103	0.22⁻	b
LSD (p 5%)				0.43	0.43-0.46
LSD (p 1%)				0.62	
LSD (p 0.1%)				0.93	

The number of seeds per pod is a key genetic trait that reflects the productive potential of pea cultivars. According to specialized literature, this parameter generally ranges between 2 and 5 seeds per pod (Muntean et al., 2014, Roman et. al., 2015). In the present study conducted during the 2022-2024 period, the average values obtained for this trait exceeded 3 seeds per pod in both experimental years, indicating a high productive capacity of the analyzed cultivars.

The results presented in Table 2 highlight a significant influence of the cultivar × year interaction on this parameter. In 2023, the cultivar Olguța recorded an average of 3.39 seeds per pod, with a highly significant difference (***). In contrast, the cultivar Ghittia registered a value of 2.90 seeds per pod, which was significantly lower (000). The same trend was observed in 2024, when Olguța achieved 3.43 seeds per pod, while Ghittia recorded only 2.83 seeds per pod. These differences confirm the stability of the cultivars with respect to the number of seeds per pod.

Table 2. Influence of cultivar × year interaction on number of seeds per pod

Year	Variety	Seed number/ pods	% to control	Difference/ Signifficance	Duncan Test
2023	Average	3.19	100	Mt.	-
	Ghittia	2.90	91	-0.28^{000}	a
	Andrada	3.26	102	0.07*	c
	Olguța	3.39	107	0.21***	d
2024	Average	3.13	100	Mt.	-
	Ghittia	2.83	90	-0.30^{000}	a
	Andrada	3.13	100	0.00^{-}	b
	Olguța	3.43	110	0.30***	d
LSD (p 5%)				0.07	0.07-0.08
LSD (p 1%)				0.11	
LSD (p 0.1%)				0.16	

The thousand seed weight (TSW) is an important parameter reflecting the production potential of a cultivar. According to Muntean et al. (2015), TSW in pea can range between 50 and 450 grams. In this study, the TSW values fell within this range, varying between 156.00 g and 195.00 g depending on cultivar and year.

As shown in Table 3, the first year was more favourable for accumulation in seeds, with an average of 184.56 g, compared to 165.00 g in 2024. The highest TSW was consistently recorded by the Ghittia cultivar, with 195.00 g in 2023 and 177.00 g in 2024. In both years, the differences compared to the control were highly significant from a statistically point of view, indicating a superior ability to accumulate dry matter in seeds, which is often associated with larger seed size.

Conversely, Andrada and Olguța cultivars recorded lower TSW values, with significantly negative differences. Particularly in 2023, Andrada had a TSW of 175.67 g, and Olguța reached 183.00 g. In 2024, a general decline in TSW was observed, with the lowest value noted in Andrada (156.00 g), suggesting a higher sensitivity to less favourable climatic conditions.

Table 3. Influence of cultivar × year interaction on thousand seed weight (TSW)

Year	Variety	TSW (g)	% to control	Difference/ Signifficance	Duncan Test
2023	Average	184.56	100	Mt.	-
	Ghittia	195.00	106	10.44***	……….e
	Andrada	175.67	95	-8.89^{000}	c
	Olguța	183.00	99	-15.6^{-}	d
2024	Average	165.00	100	Mt.	-
	Ghittia	177.00	107	12.00***	c
	Andrada	156.00	95	-9.00^{000}	a
	Olguța	162.00	98	-3.00^{-}	b
LSD (p 5%)				3.95	3.94-4.29
LSD (p 1%)				5.75	
LSD (p 0.1%)				8.62	

Under the specific environmental conditions of the Satu Mare region, the most productive autumn pea cultivar was Olguța, with a yield of 3834.10 kg/ha in 2023 and 3086.08 kg/ha in 2024.

In 2023, a year with more favourable climatic conditions (as detailed previously), significantly negative differences in yield were observed for Ghittia and Andrada compared to the average, while Olguța showed highly significant positive differences (Table 4). In 2024, Ghittia displayed small and statistically non-significant differences, Andrada exhibited significantly lower yields, and Olguța again achieved highly significant positive differences. The Duncan test clearly highlighted significant differences in yield between Olguța and the other studied cultivars in both experimental years.

Table 4. Influence of cultivar × year interaction on pea grain yield

Year	Variety	Yield (kg/ha)	% to control	Difference/ Signifficance	Duncan Test
2023	Average	3555.43	100	Mt.	-
	Ghittia	3433.38	97	-122.04^{0}	c
	Andrada	3398.80	96	-156.63^{0}	c
	Olguța	3834.10	108	278.67***	d
2024	Average	2788.29	100	Mt.	-
	Ghittia	2694.61	97	-93.68^{-}	a
	Andrada	2584.18	92.7	-204.11^{00}	a
	Olguța	3086.08	111	297.79***	b
LSD (p 5%)				120.84	120.59-131.32
LSD (p 1%)				175.77	
LSD (p 0.1%)				263.66	

Grain yield (kg/ha) is the most relevant parameter for evaluating economic efficiency, as it reflects the interaction between genetic traits and pedoclimatic conditions. The data presented in Table 4 show that the year 2023 was more favourable in terms of climate, with an average yield of 3555.43 kg/ha, compared to 2788.29 kg/ha in 2024.

The Olguța cultivar demonstrated outstanding productive capacity in both years, with 3834.10 kg/ha in 2023 (+278.67 kg/ha compared to the control) and 3086.08 kg/ha in 2024 (+297.79 kg/ha), both differences being highly significant. In contrast, Ghittia and Andrada produced yields below the average in most cases, with some significantly negative differences. Notably, in 2024, Andrada recorded a yield of 2584.18 kg/ha, with a significantly negative difference of -204.11 kg/ha compared to the control, indicating high sensitivity to the year's less favourable conditions.

Protein content

According to the data presented in Table 5, the average protein content of the studied varieties was 23.97% in 2023 and 24.24% in 2024, with relatively consistent values across the two years, despite significant differences in yield (3555.43 kg/ha in 2023 compared to 2788.29 kg/ha in 2024).

Table 5. The influence of the variety × year interaction on protein content

Year	Variety	Protein (%)	% to control	Difference/ Signifficance	Duncan Test
2023	Average	23.97	100	Mt.	-
	Ghittia	24.16	101	0.19^{-}	a
	Andrada	24.04	100	0.07^{-}	a
	Olguța	23.71	99	-0.26^{-}	a
2024	Average	24.24	100	Mt.	a
	Ghittia	24.34	100	0.11^{-}	a
	Andrada	24.27	100	0.03^{-}	a
	Olguța	24.10	99	-0.14^{-}	a
LSD (p 5%)				0.67	0.67-0.73
LSD (p 1%)				0.98	
LSD (p 0.1%)				1.47	

Regarding the varieties studied in this research, it was observed that although the Olguța variety recorded the highest yield values in both experimental years (3834.10 kg/ha in 2023 and 3086.08 kg/ha in 2024), it also exhibited the lowest protein content, namely 23.71% in 2023 and 24.10% in 2024.

In contrast, the Ghittia and Andrada varieties, which recorded yields below the annual average in both years, presented slightly higher protein content values. However, these differences were not statistically significant, neither in the analysis of variance nor according to Duncan's test. For example, in 2024, the Ghittia variety showed a protein content of 24.34%, and Andrada 24.27%, compared to the average of 24.24%. Although these values were higher than that of Olguța (24.10%), they were not statistically confirmed, indicating low variability and a relatively stable expression of this parameter. These results are consistent with those reported by Bărbieru (2022) for all the three varieties studied in this research.

CONCLUSIONS

The results obtained over the two experimental years (2022-2023 and 2023-2024) highlight the decisive influence of climatic conditions on the productive and qualitative performance of winter pea cultivars grown in the Satu Mare region. Positive average winter temperatures ensured proper overwintering without significant plant losses. Although the total precipitation amounts were within the optimal range for pea cultivation, their uneven distribution - especially in February and March - proved to be a limiting factor in both experimental years. Nevertheless, soil water reserves accumulated from precipitation in previous months contributed to maintaining an acceptable moisture regime.

Among the productivity traits analysed, the number of seeds per pod and the thousand seed weight (TSW) showed significant differences among cultivars, influenced by their interaction with the year of cultivation. The cultivar Olguța stood out with higher values for the number of seeds per pod, while Ghittia exhibited the highest TSW values.

Grain yield analysis confirmed the superiority of the Olguța cultivar in both experimental years, with very significant differences compared to the control. In contrast, the Ghittia and Andrada cultivars recorded yields below the control average, particularly in 2024, suggesting a higher sensitivity to unfavourable climatic conditions.

Concerning protein content, the values obtained were relatively stable across years and among varieties, with differences that were not statistically significant.

An inverse proportional trend was observed between yield and protein content, with the most productive variety (Olguța) exhibiting the lowest protein content values; however, these differences were not statistically confirmed.

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