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Comparative study of qualitative traits of lentil accessions grown in outdoor hydroponic and soil conditions in Armenia

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ABSTRACT

Introduction: One major global challenge of this century is achieving a Second Green Revolution, focusing on enhancing food security through legumes such as lentils. Legumes are vital for low- and middle-income countries due to their nitrogen-fixing properties and contribution to sustainable agriculture. However, legumes are underutilized in the human diet despite their health benefits. To address this, alternative farming technologies such as hydroponics are necessary to boost yields. Climate change, technological advancements, and the need for self-sufficiency highlight the importance of introducing lentils in Armenian farming practices. These products can serve as a valuable and nutritious crop.

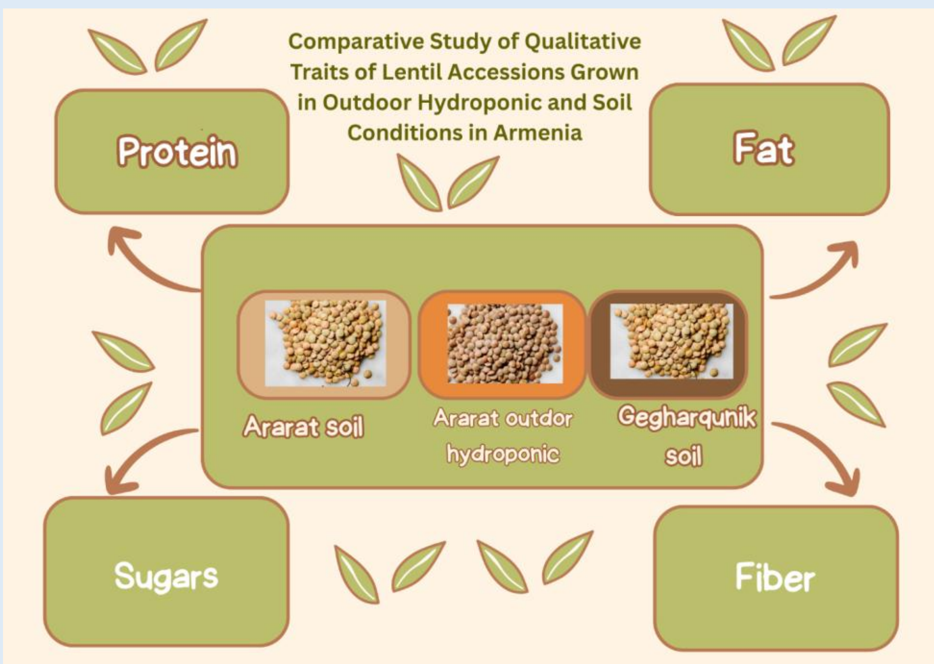
Objective: This study uses traditional farming methods and a controlled hydroponic system to evaluate the feasibility and efficiency of cultivating lentils in the Ararat Valley, including the mountainous foothill zone. It also aims to evaluate the nutritional value of lentil seeds. These products' biochemical and bioactive components, such as proteins, fats, carbohydrates, and dietary fiber, were assessed.

Methods: Experiments were conducted in 2022-2023 in outdoor hydroponics, using current soil conditions in the Ararat and Gegharkunik regions of Armenia. Several genetic resources of lentils from ICARDA, including Flip 2007-12, Flip 2006-4L, Flip 2007- 3L, Flip 2007- 30L, Ep-54, SellFrom 1767LL, and local varieties Talini 6 and Haykakan 88 (controls) were used. The protein content was determined using the Micro-Kjeldahl method. Total sugars were determined using the Bertrand method. Fats were determined by the Soxhlet extraction method. Dietary fiber was analyzed according to the American and International Standards.

Results: The results show that the protein, total sugar, crude fat, and total fiber contents of lentils grown under the soil conditions of the Ararat region ranged from 20.1 to 26.5%, 6.0 to 6.7%, 1.1 to 1.5%, and 9.0 to 13%, respectively. Outdoor hydroponics in the same region yielded lentils with 20,1-26,1% protein, 6.0-6.8% total sugar, 1.2-1.9% crude fats, and 9.5-11% total fiber. The lentils raised in the Gegharkunik region contain 20,1-26,5% protein, 6.2-6.8% total sugars, 1.2-1.5% fats, and 10.5-12.5% dietary fiber. Under hydroponic conditions in Ararat Valley, lentil yield increased, with seed weight per plant ranging from 14.9-21.0 g, compared to 4.3-7.7 g in soil conditions in Ararat and Gegharkunik.

Conclusion: Several genetic resources of lentils from ICARDA (Flip 2007-12, Flip 2006-4L, Flip 2007-30L, Flip2007-3L, Ep-54, Sell from1767L) and local varieties (Talini 6, Haykakan 88) exhibited high levels of biochemical properties (protein, total sugars, fats, dietary fiber) when grown in the outdoor hydroponics of the Ararat region. This method contributed to increased yields; the seed weight per plant in open hydroponics reached 14.9-21.0 grams, and in soil conditions (4.3-6.2 grams, compared to 5.4-7.7 grams in soil conditions of the Gegharkunik region of Armenia).

Keywords: lentil, outdoor hydroponic, protein, monosaccharides, fats, dietary fiber.



INTRODUCTION

Lentils (*Lens culinaris*; Family: *Fabaceae*) are native plants grown annually in Western Asia and other regions, including North America. They have spread from the Hindu Kush region to Afghanistan, and from Ethiopia to the Mediterranean countries [1]. Lentils are known for their lens-shaped edible seeds, rich in essential macro- and micronutrients [2]. Their color varies from yellow, orange, red, green, brown, and black based on genetic variability, the specific cultivar, and the composition of the seed coat [3-4].

Lentils are rich in protein, essential amino acids, minerals, and fiber, making them a valuable nutritional source. Due to bioactive compounds, lentils may reduce chronic disease risk. Key polyphenols such as phenolic acids, flavonoids, and anthocyanins offer antioxidant protection against degenerative diseases [5-7].

Defined as specific protein fragments, bioactive proteins positively influence bodily functions and overall health. Their presence in the diet contributes significantly to human nutrition through their impact on key systems in the body, such as the cardiovascular, digestive, immune, and nervous systems [8-9].

There is a pressing need to investigate climate-resilient agricultural systems that prioritize resilience, resource efficiency, and disease management. Hydroponics, a method of soilless cultivation, is gaining traction for its ability to lessen dependence on agricultural land and pesticides, offering a suitable alternative for regions with poor soil quality or extreme weather events [10-12].

This study examines the qualitative traits of lentil accessions grown under two different conditions: outdoor hydroponics in Ararat Valley and traditional soil cultivation in the Ararat and Gegharkunik regions of Armenia. The study aimed to determine how differing growing environments influence lentil characteristics such as growth rate, yield, pod quality, seed quality, and nutrient content [13].

MATERIAL AND METHODS

Experiments conducted in 2022-2023 at the Institute of Hydroponics Problems experimental stations in Yerevan, Darakert, and Martuni focused on evaluating the feasibility and efficiency of growing lentil cultivars in outdoor hydroponics. Meanwhile, the soil conditions in Armenia’s Ararat and Gegharkunik regions were assessed. The study included several genetic resources of lentils from ICARDA, such as Flip2007-12L, Flip2006-4L, Flip2007-3L, Flip2007-30L, Ep-54, Sell from 1767L, and local varieties Talini 6 and Haykakan 88 (controls). Yerevan and Darakert are in the Ararat Valley, and Martuni is located in the Gegharkunik region of Armenia. The height of the Ararat Valley is 800-1000 m above sea level; the climate is sharply continental, and the average summer temperatures range from 25 to 26 °C. In Darakert, summer temperatures typically range from a low of around 15 °C (59 °F) at night to a maximum of about 38-40 °C (100–104 °F) during the day. In winter, temperatures usually fall to a low of about -6 °C (21 °F) at night and rise to a maximum of around 2 °C (36 °F) during the day. In the Martuni community of the Gegharkunik region, at Grigori Khlyghatyan's farm, crops were cultivated in irrigated gray meadow soils. The experimental plot was situated at an altitude ranging from 1800 to 2000 m above sea level, where summer temperatures typically range from a low of around 11 °C (52 °F) at night to a maximum of about 25 °C (77 °F) during the day. In winter, temperatures usually drop to a low of approximately –13 °C (9 °F) at night and rise to a maximum of about –4 °C (25 °F) during the day [14].

The seeds were dried at room temperature, after which an average sample was chosen for biochemical analysis. Throughout the study, biometric measurements, morphological evaluations, and biochemical tests were conducted to assess the obtained yield qualitatively.

Protein content was determined using the Kjeldahl method, while crude fiber content was determined following the Official Methods of Analysis by AOAC International [15]. Fat content was analyzed using the Soxhlet method [16], and total sugars were assessed via the Bertrand method. Protein estimation involved measuring the nitrogen content in soybean seeds and multiplying it by a nitrogen-to-protein conversion factor of 6.25.

The objective of the work is to study the biochemical key indicators (protein, total sugar, fiber, and fat) of the varieties we have examined: Flip 2007-12L, Flip 2006- 4L, Ep-54, Sellfrom1767LL, Flip 2007- 30L, and Flip 2007- 3L.

RESULTS AND DISCUSSION

Biochemical indicators in agricultural crop fruits are influenced by genotype, climate, and fertilizers [17-24. Other factors such as precipitation, light intensity, day length, temperature, planting density, weeds, and soil type may also affect the biochemical properties [25-26]. Studies have shown that variations in plant growth, environmental conditions, and fertilization can enhance fruits' bioactive and antioxidant properties. Significant differences in biologically active compounds were observed in the cultivars studied under varying ecological conditions [27].

Table 1 presents data on the yield per plant under conditions of the Ararat region. The results show that the control variety Haykakan 88 produced significantly lower yields than the small-seeded varieties: Flip 2007-3L yielded 1.3 times more, and Flip 2007-30L yielded 1.2 times more. Talin 6 (the other control) had lower yields than the large-seeded varieties: Sellfrom 1767L, Flip 2007- 12L, and Ep-54 yielded 1.2 times more, while Flip 2006- 4L yielded approximately the same as the control. In the Gegharkunik region, the yield of small-seeded Flip 2007- 3L and Flip 2007- 30L outperformed the control Haykakan 88 by 10.4%. Among large-seeded varieties, Sellfrom 1767L, Flip 2007-12L, Flip 2006-4L, and Ep-54 exceeded the control Talin-6 by 5.5%, 20.3%, 40.7%, and 42.6%, respectively.

Under hydroponic conditions, Flip 2007- 3L yield exceeded Haykakan 88 by 42.9%, while Sellfrom 1767L yielded 3.3% less than the control. Compared to Talin-6, Flip 2007-12L, Flip 2006-4L, and Ep-54 showed higher yields by 18.8%, 36.3%, 22.0%, and 12.0%, respectively.

Under Ararat region conditions, Flip 2007- 3L and Flip 2007- 30L had 29.3% and 9.7% more protein than Haykakan 88. Among large-seeded varieties, Sellfrom 1767L was 6.9% lower, while Flip 2007- 12L, Flip 2006- 4L, and Ep-54 were 14.4%, 6.9%, and 5.6% higher than Talin-6, respectively.

Under the soil conditions of the Gegharkunik region, Flip 2007- 3L and Flip 2007- 30L demonstrated a protein content increase of 29.3% and 9.8%, respectively, compared to Haykakan 88. Among the large-grain varieties, Flip 2007- 12L, Flip 2006- 4L, and Ep-54 exhibited protein content enhancements of 26.4%, 20.9%, and 4.5%, respectively, surpassing the performance of Talin-6.

Under hydroponic conditions, Flip 2007- 3L and Flip 2007- 30L had 29.8% and 7.3% more protein than Haykakan 88, respectively. Among large-seeded varieties, Flip 2007-12L, Flip 2006-4L, and Ep-54 exceeded Talin-6 by 20%, 24.4%, and 7.3%.

Lentil yield data revealed that hydroponically grown lentils in the Ararat region had higher seed weight per plant (14.9 to 22.0 g) than those grown in soil (4.3-6.5 g). In the soil conditions of the Gegharkunik region, seed weight ranged from 5.4 to 7.7 g.

Biochemical analysis showed that lentil seeds in the soil conditions of the Ararat region contained 20.1-24.6% protein, 6.0-6.7% total sugar, 1.1-1.7% fats, and 9.0-13% fiber. The soil conditions of the Gegharkunik region yielded lentil seeds with 20.1-26.6**%** protein, 6.5–6.8% total sugars, 1.2-1.6% fat**s**, and 10.5-11.2% fiber.

In outdoor hydroponics of the Ararat region, lentils contained 20.1-25.5% protein, 6.4-6.7% total sugars, 1.2-1.9% fats, and 9.5-11.5% fiber. This cultivation method resulted in a seed weight per plant of 14.9-22.0 g. The seed weight per plant in the Ararat region was 4.3-6.5 g and 5.4–7.7 g in the soil conditions of the Gegharkunik region.

Table 1. Yield and Protein Content of Lentil Samples under Different Ecological and Cultivation Conditions.

Varieties	Ararat region			Gegarqunik region			Ararat region, hydroponic		
	Yield of one plant, g	Protein %	Protein output g/plant	Yield of one plant, g	Protein, %	Protein output g/plant	Yield of one plant, g	Protein %	Protein output g/plant
Haykakan 88	4,7±0,25	20,5±0,6	1,0±0,1	6,7±0,1	20,5±0,6	1,4±0,1	15,4±0,5	20,5±0,4	3,2±0,2
Flip 2007-3L	6,5±0,05	26,5±0,6	1,7±0,1	7,4±0,3	26,5±0,6	2,0±0,1	22±0,1	26,6±0,8	5,8±0,1
Flip 2007-30L	6,4±0,14	22,5±1,5	1,4±0,1	7,4±0,3	22,5±1,5	1,6±0,1	14,9±0,7	22,0±1,4	3,2±0,1
Talini-6	4,3±0,2	21,5±0,8	1,0±0,1	5,4±0,3	21,5±0,8	1,1±0,1	15,0±0,1	20,5±0,4	3,0±0,1
Sellfrom 1767L	5,4±0,2	20,1±0,8	1,0±0,2	5,7±0,1	20,1±0,8	1,1±0,2	18,3±0,3	20,1±0,6	3,7±0,1
Flip 2007-12L	5,2±0,2	24,6±1,4	1,2±0,1	6,5±0,3	26,6±0,5	1,7±0,2	21,0±0,8	24,6±1,5	5,1±0,1
Flip 2006-4L	4,7±0,1	23±0,4	1,0±0,1	7,6±0,1	26,0±0,6	1,9±0,1	18,8±0,6	25,5±0,8	4,7±0,1
Ep-54	5,2±0,2	22,7±0,5	1,1±0,1	7,7±0,1	22,0±0,4	1,7±0,1	16,8±0,6	22,0±0,6	3,6±0,1

Values are mean values ± SD

In Ararat region conditions, small-seeded varieties Flip 2007- 3L and Flip 2007- 30L produced 0.7 g and 0.4 g more protein per plant than the control Haykakan 88, respectively. Among the large-seeded varieties, Flip 2007- 12L and Ep-54 produced 0.2 g and 0.1 g more protein per plant than the control Talini-6. In Gegharkunik, the small-seeded variety Flip 2007- 3L had the highest protein output, exceeding the control by 42.8%. Flip 2007- 12L exceeded the control by 72.7% among the large-seeded varieties.

Under open hydroponic conditions, Flip 2007- 3L exhibited 81.2% higher protein output compared to Haykakan 88. Among large-seeded varieties, Flip 2007- 12L demonstrated a 70% increase, Flip 2006- 4L showed a 56.6% increase, Sellfrom 1767L presented a 23.3% increase, and Ep-54 exhibited a 20% increase in protein output compared to the Talini-6 control.

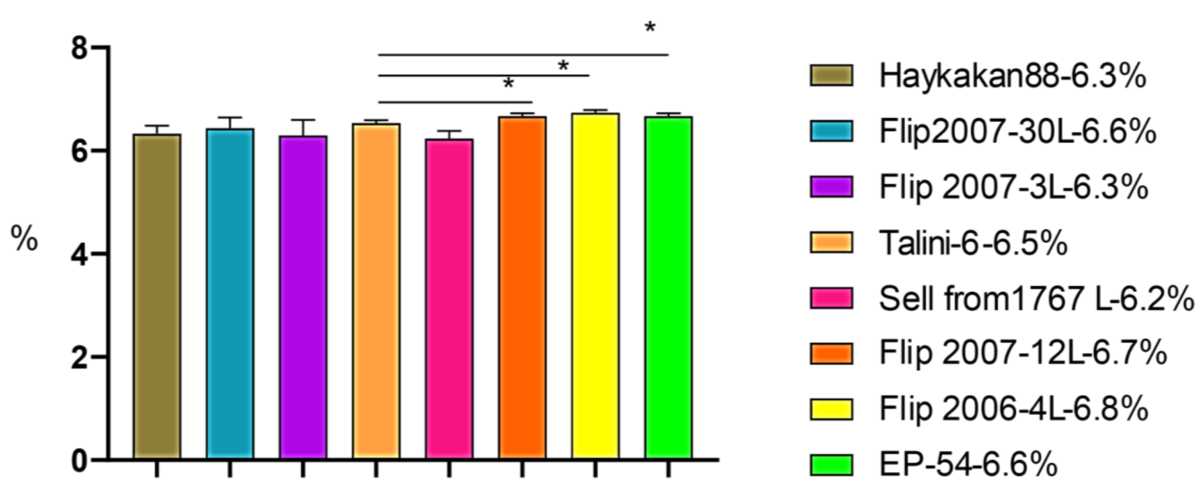


Figure 1. Content of total sugars in the studied varieties of lentils grown in the Gegharkunik region. Different letters indicate significant differences (* P<0.01).

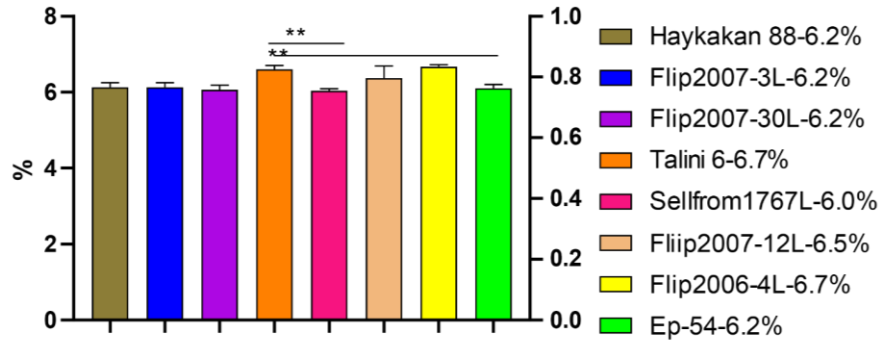


Figure 2. Content of total sugars in the studied varieties of lentils grown in Ararat Valley. Different letters indicate significant differences (**-p<0.001).

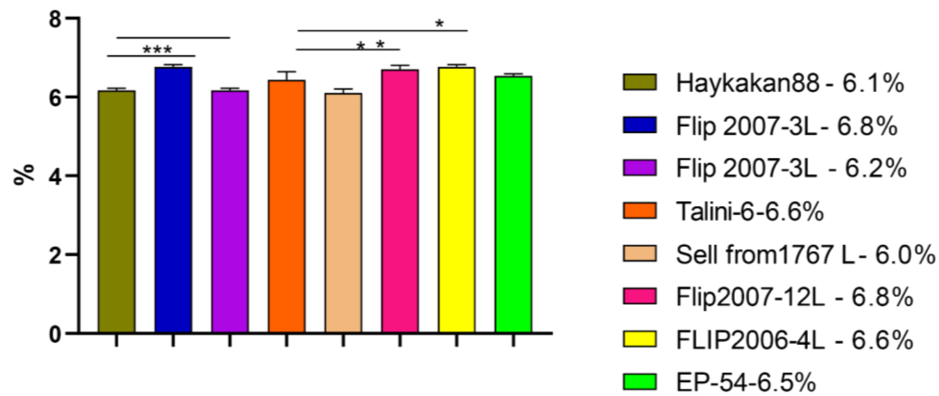


Figure 3. Content of total sugars in the studied varieties of lentils in hydroponic systems. Different letters indicate significant differences (*** P<0.001).

In comparison of total soluble sugars across the varieties in Figs. 1 and 2, no significant differences were found among most cultivars. However, in the Gegharkunik region, large grain cultivars Flip 2007- 12L, Flip 2006- 4L, and Ep-54 showed significant differences compared to the control. The control Talin 6 outperformed all studied cultivars in total sugar content in the Ararat region, except for Flip 2006- 4L. Additionally, Fig.3 indicates that in open hydroponics, the small grain control Haykakan 88 was surpassed by Flip 2007-3L, while Flip 2007-12L and Flip 2006-4L outperformed the extensive grain control Talin 6.

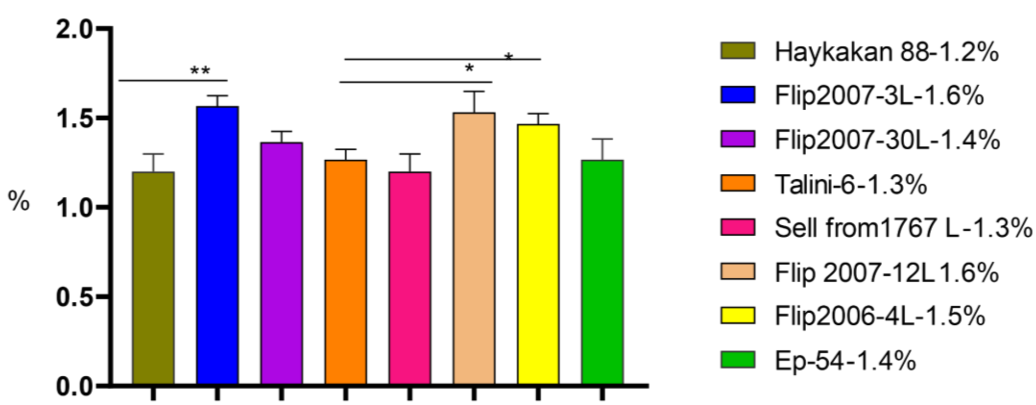


Figure 4. Content of crude fat in studied varieties of lentils grown in Gegharkunik regions. Different letters indicate significant differences (** P<0.01, *P<0.1).

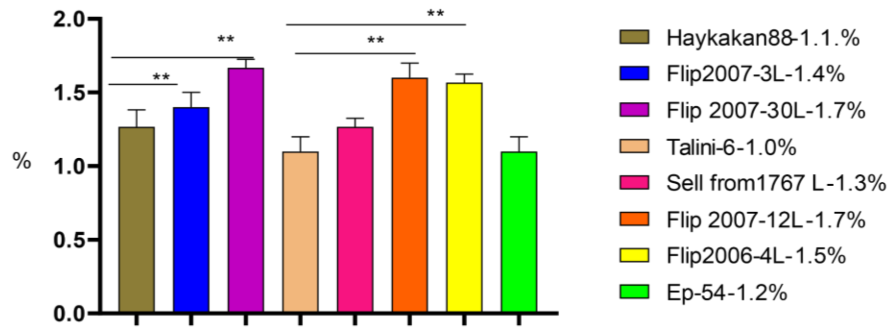


Figure 5. Crude fat content in the studied varieties of lentils grown in Ararat Valley. Different letters indicate significant differences (** P<0.001).

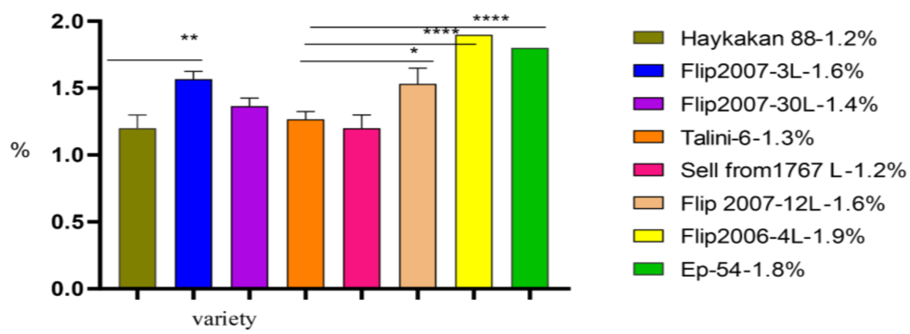


Figure 6. Content of crude fat in studied varieties of lentils grown in hydroponic systems. Different letters indicate significant differences (* P<0.01,**P<0.001, P<0.0001).

The content of crude fat in different bioecological conditions and cultivation methods is introduced in Fig. 4-6. As indicated in Fig. 4, the highest level of crude fat in small seed variants is in Flip 2007- 3L, which exceeds control Haykakan 88 by 5%. In Flip 2007- 3L and Flip 2007-30 variants from the Gegharkunik region, crude fat content increased by 26.6% and 22%, respectively, compared to the control variant (Haykakan 88). Flip 2007- 12L outperforms all tested cultivars in crude fat content regardless of climate or cultivation methods. The data in Fig. 4-6 on crude fat content show that the Haykakan 88 control had higher performance compared to other cultivars in the Gegharkunik region (Fig. 5), the Ararat region (Fig. 4), and open hydroponics (Fig. 6). Additionally, varieties Flip 2007- 12L, Flip 2006- 4L, and Ep 54 outperformed the large grain control Talin 6.

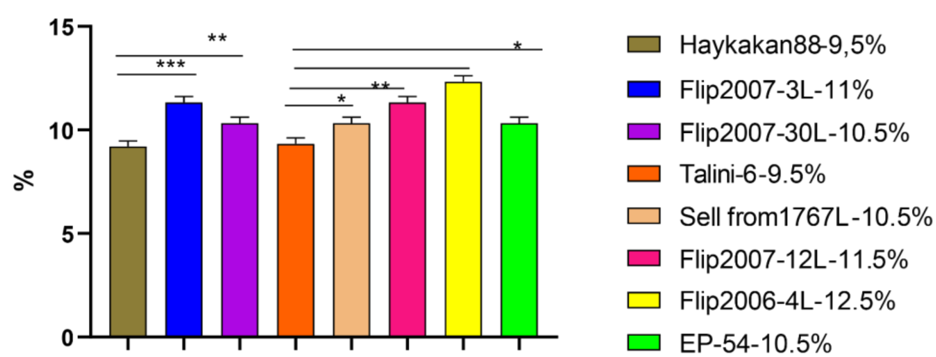


Figure 7. Content of total fiber in studied varieties of lentils grown in the Gegharkunik region. Different letters indicate significant differences *P<0.01,**P<0.001,***P<0.0001).

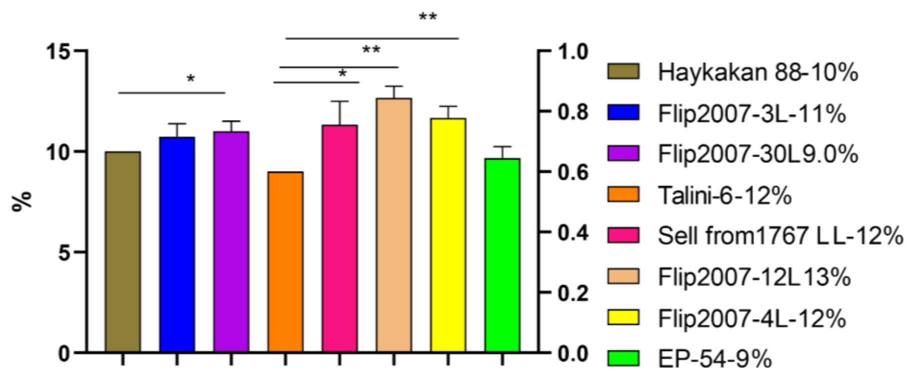


Figure 8. The total fiber content in the studied lentil varieties grows in the Ararat Valley. Different letters indicate significant differences (*P< 0.1, ** P <0.01).

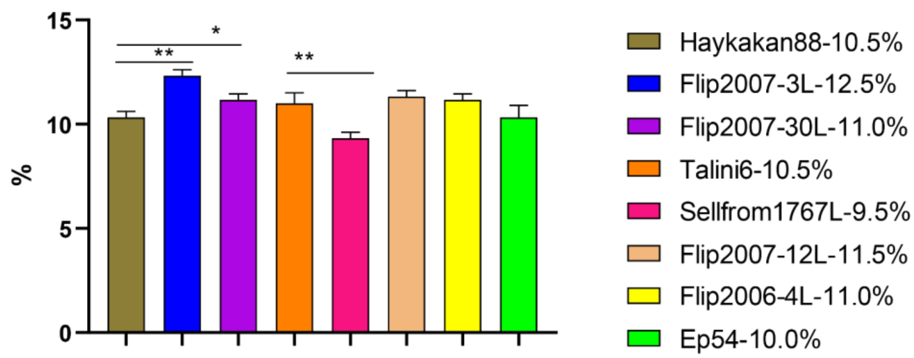


Figure 9. Content or total fiber in studied varieties of lentils grown in hydroponic systems. Different letters indicate significant differences (*P<0.1,*P<0.001).

Regarding total fiber content (Fig. 7-9), both small-grained and large-grained cultivars in the Gegharkunik region exceeded the local control. In hydroponic conditions, total fiber content was higher in small-grained cultivars. Only the Sellfrom 1767L cultivar's indicator is lower than the control among large-grained cultivars. In the Ararat region, Flip 2007- 3L outperforms the control from small grains, and all varieties from large grains except Ep-54. Bioactive proteins can affect major body systems, namely the cardiovascular, digestive, immune, and nervous systems. Human nutrition benefits from the presence of bioactive proteins in their respective diets. Bioactive proteins are defined as specific protein fragments that positively affect the function or condition of the body and can ultimately affect a person's overall health [28]. Functional foods are foods that provide health benefits beyond basic nutrition. These foods contain bioactive compounds that can improve health, prevent diseases, and enhance overall well-being. Functional foods are rooted in the idea that certain foods can positively impact specific bodily functions, such as digestion, immunity, and cognitive function. Functional foods represent a growing trend in the food industry, driven by increasing consumer health and wellness awareness. By incorporating functional foods into the diet, one may take proactive steps to improve one's health and prevent diseases. As research continues to evolve, the range of functional foods will likely expand, offering even more options for enhancing your diet and well-being. Lentils are rich in bioactive compounds and can be used as a functional food product. Research suggests that individuals with periodontitis who consume insufficient amounts of total dietary fiber, especially from vegetables, fruits, legumes, and cereals, may face an increased risk of heart attack [14, 29, 30].

As a result of this experiment, the yield of 8 varieties fluctuates between 860-1540 kg in soil variants and between 2384-3520 kg in hydroponics. According to research conducted in Australia, grain yields of 8 different lentil genotypes sown at different times averaged between 0.187 and 2.433 t/ha [25]. Research conducted in Ethiopia examined the performance of 64 lentil genotypes and found that seed yield ranged on average from 869.4 to 2401.5 kg/ha, which is consistent with the research data, and protein content ranged from 17.5 to 26.2%, which differs slightly from the data; in this case, it ranged from 20.1–26.6%. [26].

Another study conducted in India found that the average seed yield of 43 lentil genotypes ranged from 0.081 to 0.1907 kg/ m^2 [27].

A study of 20 lentil varieties in Uzbekistan found that the average lentil yield per hectare ranged from 10.5 to 23.5 centners. The same study also found that the protein content of these 20 lentil varieties ranged from 22.0 to 29.7% [28].

According to the United States Department of Agriculture (USDA, 2022), lentil seeds contain an average of 24.6% protein and 1.1% fat, which are within the range of the research data. [30].

The results of a study conducted in Spain show that the total protein content of 4 varieties of lentils (Beluga, Castellana, Stone, and Red), which are considered some of the most widely consumed in the world, ranged on average from 20.0% to 23.3 %. The fat content ranged from 0.52% to 1.2%. [31].

Scientific innovation and practical implications: For the first time, the efficiency of 8 lentil varieties was studied under hydroponic conditions in the Ararat Valley. The hydroponic method of growing plants allows for a more nutrient-rich yield that contains more biologically active compounds. This study can further serve as a basis for developing the hydroponic cultivation of lentils in the Republic of Armenia.

CONCLUSION

This study demonstrates that hydroponic cultivation of lentils in the Ararat Valley can significantly enhance yield and improve the nutritional quality of the seeds compared to traditional soil cultivation. The findings suggest that hydroponics may be a viable alternative farming technology that can contribute to food security and sustainable agriculture in regions with poor soil quality and extreme weather conditions.

The study highlights the need for further research to optimize hydroponic systems for lentil cultivation and explore the potential of other legume crops in similar conditions. By leveraging the benefits of hydroponics, farmers can achieve higher yields and better-quality produce, contributing to the overall goal of enhancing food security and promoting sustainable agricultural practices.

Author contributions: All authors contributed to this study.

List of Abbreviations: International Center for Agricultural Research in the Dry Areas – ICARDA; United States Department of Agriculture - USDA

Competing Interests: There are no conflicts of interest to declare.

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