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Effectiveness of pumpkin cultivation in crop rotation on forest brown soil

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ABSTRACT

Background: The rapid growth of the global population, coupled with the challenges posed by a changing climate, is creating significant obstacles in food production worldwide. As agricultural practices intensify to meet rising demand, the strain on land resources has increased in recent years, accelerating land degradation processes. Land degradation represents a significant challenge to ensuring global food security. One of the key strategies for promoting sustainable agriculture is crop rotation and the preservation of biodiversity. Properly implemented crop rotation enhances soil fertility, reduces pest populations, and improves nutrient availability. It also enhances food's functional value, supporting environmental and nutritional sustainability.

Objective: The research was conducted in two communities of Syunik Marz, RA, to study the efficiency of pumpkin cultivation in forest brown soils under crop rotation conditions.

Methods: The research was conducted from 2017 to 2024, during which a crop rotation scheme was implemented on 100 hectares of land. Pumpkin yield indicators and functional value were studied under monoculture and crop rotation conditions.

Results: Monoculture pumpkin farming, however, encountered severe issues such as fungal diseases (shriveling and false shriveling) and tick infestations, problems absent under crop rotation conditions. Additionally, the nutritional and functional values of the pumpkin were enhanced. The study revealed that under crop rotation conditions, the content of soluble solids in pumpkin fruits was 1.46%, dry matter 1.63%, reducing sugars 1.63%, and total sugars 1.63% higher than in pumpkins grown under monoculture conditions. In contrast, monoculture pumpkin farming faced significant issues with fungal diseases like shriveling and false shriveling and tick infestations, which were not present when pumpkins were grown using crop rotation.

Conclusion: Under crop rotation conditions in forest brown soils, humus, and water-stable aggregates' content is higher than in monoculture cultivation. The pumpkin yield under crop rotation conditions increased by 5 tons per hectare compared to monoculture cultivation. The functional element levels for the mentioned crop sequence were higher than pumpkins grown in monoculture.

Keywords: Crop rotation, pumpkin, functional food, bioactive compound, intensification.

Graphical Abstract: Effectiveness of pumpkin cultivation in crop rotation on forest brown soil

INTRODUCTION

Global climate change, the ongoing growth of the Earth's population, land degradation, and other factors pose significant challenges to achieving food security [1, 2, 3]. In this context, sustainable intensification of agriculture is essential. It offers a pathway to increasing land productivity and improving resource use efficiency while minimizing negative environmental impacts as much as possible [4-7]. Crop rotation is one of the most effective strategies for promoting sustainable agriculture [8-13]. Monoculture farming, practiced for many years, depletes soil nutrients and facilitates the spread of pests and diseases [14, 15]. However, implementing a well-planned crop sequence can mitigate these issues, reducing the need for pesticides. Also, proper crop rotation improves soil fertility and reduces reliance on chemical fertilizers. Therefore, crop rotation enhances soil resource efficiency and supports the development of sustainable agricultural production [16-24]

The functional and species diversity within crop rotation significantly influences soil organic matter. Studies have demonstrated that crop yields increase when plants are sequenced correctly, linked to adding organic matter, total nitrogen, and macroaggregates in the soil, in contrast to monoculture farming [25].

One of the primary challenges in developing sustainable agriculture is increasing crop yields and enhancing the soil's qualitative characteristics. Proper nutrition is vital in maintaining health by supplying the body with essential nutrients. Consuming foods rich in bioactive substances is crucial to ensure a healthy lifestyle. The role of functional components in disease prevention is critically important [26-30]. Currently, producers are focusing on implementing systems that increase the presence of functional elements in crops, thereby enhancing the functional value of food [31-38].

Pumpkin (Cucurbita maxima), part of the Cucurbitaceae family, is extensively utilized in phytotherapy. It is a rich source of functional compounds, including antioxidant components that positively impact the body by neutralizing free radicals. These antioxidants help reduce the risks of malignant diseases and cardiovascular and neurodegenerative conditions [39]. The pumpkin's skin, pulp, and seeds are notably high in carotenoids, flavonoids, total phenols, and essential microelements. In addition, pumpkin is a valuable source of nutritional elements such as fats, proteins, and carbohydrates. Studies have shown that pumpkins can be incorporated into the human diet to help manage conditions like diabetes and hypercholesterolemia [40].

Pumpkin is a rich source of fiber, vitamin C, vitamin E, vitamin B6, magnesium, potassium, and other essential nutrients [41].

This study seeks to develop a crop rotation system optimized for soil consolidation and evaluate pumpkin cultivation's effectiveness within this framework. Increasing pumpkin yields and enhancing the crop's quality characteristics and functional value is crucial.

MATERIALS AND METHODS

The object of this study is the brown forest soils of the Syunik region in Armenia. The research involved an investigation of their chemical composition and analyzing crop rotation schemes under both monoculture and crop rotation conditions. Based on the findings, a crop rotation scheme was designed. Additionally, the effectiveness of pumpkin cultivation was examined under both monoculture and crop rotation conditions.

The crop rotation design scheme was developed based on factors such as relief, soil conditions, area, field sizes, contours of fields and plots, distance from economic centers, the composition of crops, and other relevant considerations.

A 5-field crop rotation was implemented in the Norashenik community. In the area designated for the project, 100 hectares of arable land were allocated for crop rotation, with the average size of each field being 20 hectares. The crop rotation scheme is presented in Table 1.

Table 1. The crop rotation scheme

The name of the crops	The number of fields	The average field area, hectare	The actual field area, hectare	The deviation, hectare
Winter wheat + Alfalfa	1	20	21,8	+1.8
Alfalfa	1	20	20,1	+0,1
Pumpkin	1	20	18,7	-1,3
Potato	1	20	19,2	-0,8
Cereal crops	1	20	20,2	+0,2
Total	5	100	100	-

Over the four years of implementing crop rotation, the Bambino variety of pumpkin was cultivated, with alfalfa as the preceding crop. Organic fertilizer (manure) was applied to the pumpkin. Imidacloprid was used as an insecticide, while Triadimefon was employed as a fungicide.

Manure was applied to the soil in the autumn at a rate of 30 tons per hectare. Sowing was performed at a depth of 10 cm, with 150 cm between rows and 75 cm between plants. The irrigation volume was 3000 m^3 per hectare.

The yield was calculated, and the qualitative characteristics of the crop were thoroughly examined. Vitamin C levels were determined using Tillman's method. In contrast, the content of total carotenoids, total and reducing sugars (via the Lane-Eynon method), and soluble solids (measured in degrees Brix using a refractometer, ATAGO-POCTEL) were also analyzed. Additionally, the dry matter content was assessed.

Statistical assessment of the experimental results: Statistical analysis was conducted using the two-sample t-test (an independent t-test). It is appropriate when comparing the means of two independent groups (crop rotation and monoculture cultivation) to determine whether a statistically significant difference exists between them. The results of this study demonstrate that crop rotation significantly improves several functional elements in pumpkin cultivation compared to monoculture cultivation. These functional elements include carotenoids, vitamin C, starch, soluble solids, dry matter, reducing sugar, and total sugar. For each parameter, the p-value was less than 0.05, indicating that crop rotation leads to statistically significant increases in pumpkins' nutritional and quality components. Therefore, based on the statistical analyses, crop rotation is the preferred method for cultivating pumpkins, as it improves yield and enhances the produce's nutritional value and quality. This makes crop rotation a more sustainable and efficient approach for pumpkin farming, especially regarding long-term soil health and product quality.

RESULTS AND DISCUSSION

The crop rotation design was carried out in planning and implementation. The community of Norashenik, with a total of 472.0 hectares of agricultural land, has 143.0 hectares of arable land designated for crop rotation.

These lands are situated at an altitude of 1,060 meters above sea level, on slopes ranging from 30° to 70°, 70° to 90°, and 70° to 110°. The crop rotation sequence is shown in Figure 1.

Year	I Field	II Field	III Field	IV Field	V Field
1	Winter wheat + Alfalfa				
2	Alfalfa 1-year	Winter wheat + Alfalfa			
3	Alfalfa 2-year	Alfalfa 1-year	Winter wheat + Alfalfa		
4	Cucurbits	Alfalfa 2-year	Alfalfa 1-year	Winter wheat + Alfalfa	
5	Potato	Cucurbites	Alfalfa 2-year	Alfalfa 1-year	Winter wheat + Alfalfa
6	Winter wheat + Alfalfa	Potato	Cucurbits	Alfalfa 2-year	Alfalfa 1-year

Figure 1. The crop sequence in the rotation.

The chemical composition of the forest's brown soils was analyzed. The results indicated that the humus content is lower under pumpkin monoculture cultivation (0.65–2.70%) than crop rotation conditions (1.06–3.78%). The carbonate content decreases with depth (Table 2). The cation exchange capacity ranges from 17.90 to 33.0 meq, with calcium being the predominant cation. The soil solution has a mildly alkaline reaction.

Based on the analysis of the soil's mechanical composition and water-stable aggregates, it was found that the soils have a medium to heavy clay-loam texture. Under crop rotation conditions, the soil structure shows relatively high stability, with the content of water-stable aggregates in the upper soil layer ranging from 66.35% to 75.6% and fine particles ranging from 23% to 28% (Table 3). The structural characteristics of water-stable aggregates with 3-1 mm diameters are predominant. In contrast, the total amount of water-stable aggregates is lower under monoculture cultivation.

The study found that monoculture cultivation produced 20 tons per hectare yield. The plants were afflicted by powdery and false powdery mildew throughout the growing season. The cucumber aphid and spider mites were the most prevalent among the pests.

Under crop rotation conditions, the pumpkin yield was 25 tons per hectare. In contrast to monoculture cultivation, crop rotation conditions required no insecticides or fungicides during the growing season.

Table 2. The Chemical Composition of Forest Brown Steppe Soils

№	Horizons	Capacity, cm	Organic matter, %	Carbonates, %	PH	Exchangeable cations in 100 g soil		
						CEC, meq/100g	Ca	Mg
							%	
1	A1	0-25	3.78	1.77	7.40	33.40	92.80	7.20
	B	27-52	1.33	7.76	7.94	32.62	86.60	13.40
	B1	51-74	1.06	13.09	8.10	30.65	91.09	8.91
	A2	74-104	1.06	13.48	8.20	28.10	85.10	14.90
2	A1	0-25	2.70	1.79	7.60	33.00	85.0	15.0
	B	27-52	1.02	7.74	7.80	31.85	85.0	14.0
	B1	51-74	0.88	13.11	8.10	29.11	88.5	11.50
	A2	74-104	0.65	13.52	8.10	17.90	84.0	16.0

***Notation:** The chemical composition of Forest Brown Soils in crop rotation (1) and monoculture cultivation (2)

**Cation exchange capacity (CEC) is measured in milliequivalents per 100 grams of soil (meq/100g)

Table 3. Mechanical Composition and Water-Stable Aggregate Composition of Forest Brown Steppe Soils (%)

№	**Horizons**	**Capacity, cm**	**Mechanical composition**	**Aggregate composition, mm**				**The total amount of water-stable aggregates**
			Physical clay, < 0.01 mm	**10-3**	**3-1**	**1-0.5**	**0.5-0.25**	
1	**A1**	**0-25**	51.45	9.20	47.35	6.70	7.70	70.25
	B	**25-51**	43.12	2.70	42.54	7.0	11.70	63.94
	B1	**57-74**	48.65	-	-	-	-	-
	B2	**74-100**	51.02	-	-	-	-	-
2	**A1**	**0-25**	19.48	10.30	49.40	7.90	8.0	75.6
	B	**25-51**	1.93	3.0	43.55	7.80	12.0	66.35
	B1	**57-74**	22.07	-	-	-	-	-
	B2	**74-100**	17.71	-	-	-	-	-

The chemical composition of pumpkins grown under monoculture and crop rotation conditions has also been analyzed (Table 4). The results showed that under crop rotation conditions, the levels of carotenoids increased by 3.29 mg, vitamin C by 5.39 mg, and starch by 2 mg in the yield.

Table 4. Vitamin C, carotenoid, and starch content in pumpkin, mg/100g^{-1}

Variant	Carotenoids	Vitamin C	Starch
1. Pumpkin (monocultures)	7.14	21.45	4.11
2. Pumpkin (crop rotation)	10.43	26.84	6.11

The content of soluble solids, dry matter, reducing sugars, and total sugars in pumpkin fruits was also analyzed (Table 4). The study results revealed that under crop rotation conditions, the content of soluble solids in pumpkin fruits was 1.46%, dry matter 1.63%, reducing sugars 1.63%, and total sugars 1.63% higher than those grown under monoculture conditions.

Table 5. Content of soluble solids, dry matter, reducing and total sugars, %

Variant	Soluble solids	Dry matter	Reducing sugars	Total sugars
1. Pumpkin (monocultures)	5,12	6,45	1,11	2,69
2. Pumpkin (crop rotation)	6,58	8,08	2.74	4.32

CONCLUSION

Under crop rotation conditions in forest brown soils, humus, and water-stable aggregates' content is higher than in monoculture cultivation.

The pumpkin yield under crop rotation conditions increased by 5 tons per hectare compared to monoculture cultivation.

In the case of the mentioned crop sequence, the levels of carotenoids, vitamin C, starch, soluble solids, dry matter, reducing sugars, and total sugars in the pumpkin's chemical composition were higher than those found in pumpkins grown under monoculture conditions.

Abbreviations: RA: Republic of Armenia, CEC: Cations Exchange Capacity.

Competing Interests: The authors declare that there are no competing interests.

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