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Fodder Quality of Peanut and Borage Improved by Exogenous Application of Fertilizers in the Intercropping System

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ABSTRACT

This study aimed to investigate the effects of organic and chemical fertilizers on the forage quality and quantity of borage (*Borago officinalis* L.) and peanut (*Arachis hypogaea* L.) in an intercropping system. This experiment was conducted in a factorial arrangement based on a randomized complete block design with three replications in the research farm of the Kurdistan University during 2021 and 2022. The treatments included fertilizer (control, organic, and chemical) and cropping patterns (sole cropping of borage, sole cropping of peanut, 50%, and 100% additive intercropping). The results indicated that intercropping enhanced the quality traits of borage forage. The fertilization treatments improved the yield and qualitative traits of peanut fodder. Organic fertilizer increased crude protein in borage and peanut fodder by 29% and 20.4%, respectively, compared to the control. Intercropping increased the protein yield of borage by 16.6% compared to sole cropping. The NDF, ADF, dry matter digestibility, and ash content in borage fodder in the 100% intercropping with organic fertilizer increased by 46%, 46%, 30%, and 58.4%, respectively, compared to sole cropping without fertilizer. Overall, this study suggests that with appropriate agricultural management in the additive intercropping systems, there is potential to enhance the quality of borage and peanut fodder for livestock feeding.

Keywords: Ash, Cell wall, Fodder digestibility, Metabolizable energy, Sustainable agriculture.

INTRODUCTION

In the livestock industry, nutrition is crucial to animal husbandry, making up 70% of the costs of raising animals. To ensure proper nutrition for ruminants, it is essential to accurately determine the nutritional value of each feed ingredient using standardized methods. Conversely, the cost of providing feed for livestock has increased globally in recent years, directly impacting livestock producers' profitability. One strategy to address this issue and

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alleviate fodder shortages is using unconventional feeds, such as agricultural waste. Utilizing these by-products in animal nutrition reduces feed costs and mitigates environmental pollution (Babu et al., 2022). Intercropping systems and fertilizers application generally improve the dry weight of fodder, dry matter digestibility, crude protein, neutral detergent-soluble fiber, and water-soluble carbohydrates (Ullah et al., 2018). Therefore, replacing a portion of livestock forage with agricultural by-products, especially legume residues, will enhance the nutritional value and digestibility.

Legumes have a vital role in intercropping due to their ability in biological nitrogen fixation (Caporali, 2011). The presence of Fabaceae plants in the intercropping increases soil fertility and reduces environmental pollution by decreasing chemical inputs (Fotohi Chiyaneh et al., 2024). The role of Fabaceae plants in enhancing the production and quality characteristics of various crops in many intercropping systems has been reported (El-Mehy et al., 2022).

Peanut (*Arachis hypogaea* L.) is one of the most important plants in the Fabaceae family, with all its parts being useful for humans and livestock (Yol et al., 2018). Peanut straw is rich in crude protein and highly digestible for livestock feed. Replacing wheat straw with peanut straw increases dry matter intake, nutrient consumption, digestibility, and nitrogen retention in livestock (Khan et al., 2013). Borage (*Borago officinalis* L.) is also a valuable herbaceous plant from the Boraginaceae family, suitable for cultivation in many countries, including European countries, the Mediterranean region, North Africa, and many regions of Asia (Zahed Chakovari et al., 2016). In ancient sources, borage is recognized as a medicinal, industrial, and forage plant (McLaughlin, 2023).

Previous studies reported the positive effects of intercropping and organic fertilizers on the yield and quality of forage from various plants. In the intercropping of ajowan (*Carom capticum* L.) +fenugreek (*Trigonella foenum-graecum* L.) +pea (*Pisum sativum* L.), the quality of forage improved compared to sole cropping (Fotohi Chiyaneh et al., 2024). Other researchers have indicated that intercropping systems can more effectively balance the concentrations of fiber and crude protein in forage according to the nutritional needs of ruminants compared to sole cropping. These researchers also reported a significant reduction in the percentages of NDF and ADF in cereal within the intercropping systems (Liu et al., 2023). Additionally, researchers noted an increase in the forage quality of red clover treated with organic fertilizers compared to chemical fertilizers (Purwin et al., 2024). No study has evaluated the effect of organic and chemical fertilizers on the fodder quality of borage and peanut in the intercropping system. Furthermore, there is a consensus that specific interactions between fertilizers and borage intercropped with peanut must be considered, limiting the ability to make generalizations.

With this in mind, and considering the significant production of peanut straw as well as the considerable biological yield of borage compared to its economic performance, and to optimize use and reduce feeding costs to make livestock feed production more economical, this study focused on the residues from the harvest of borage and peanut for livestock feeding. The quality of fodder from these products was evaluated using standard methods across various sole and additive intercropping patterns influenced by different fertilizer sources. According to the scientific hypothesis, additive intercropping of borage and peanut treated with organic fertilizers can improve the fodder quality, suggesting an eco-friendly approach for sustainable production in soils where limited organic matter is the primary factor restricting crop growth, particularly in arid and semi-arid areas.

MATERIALS AND METHODS

Specifications of the Research Location

This experiment was conducted at the research farm of the Kurdistan University, located 45 kilometers east of Sanandaj city, at a longitude of 47° 18´ E, a latitude of 35° 19´ N, and an elevation of 1866 meters above sea level. The experiment started on 15 May 2021 and lasted for two growing seasons until 15 October 2022. The meteorological data for this location are presented in Fig. 1.

Experimental Design, Soil, and Fertilizer Characteristics

The experiment used a factorial arrangement within a randomized complete block design with three replications. The experimental factors included fertilizers at three levels (control, organic, and chemical fertilizer) and cropping patterns in four variations (borage sole cropping, peanut sole cropping, and intercropping with 50% and 100% peanuts intercropped with borage). The fertilizers used included organic fertilizer (24 t. ha^{-1}) and chemical fertilizers, including urea (140 kg. ha^{-1}) and triple superphosphate (100 kg. ha^{-1}). The organic fertilizer consisted of digested organic matter prepared through anaerobic fermentation by combining cow manure, kitchen waste, and water in ratios of 1, 0.6, and 1.6, respectively (Yunita, 2019). It took 30 days from mixing these materials until the organic fertilizer was ready. Before sowing, soil samples from 0 to 30 depth were taken at the experimental site to analyze physicochemical properties. pH and electrical conductivity (EC) were measured using a pH-meter and a conductometer, respectively. Organic carbon (OC) by dry combustion (Nelson and

Sommers, 1996), nitrogen (N) by the Kjeldahl method (Bremner and Mulvaney, 1982), phosphorus (P) by a spectrophotometer (Murphy and Riley, 1962), and potassium (K) were measured by a flame photometer (Rowell, 1994). The other nutrients, including Mg, Fe, Zn, Cu, and Mn were measured according to Lindsay and Norvell, 1978. The results of the soil and organic fertilizer analysis are presented in Table 1. The planting of two plants was carried out manually and simultaneously on 15 May 2021 and 2022. Each plot contained 6 rows in the sole cropping, while in the intercropping, each plot had 11 rows. The row spacing was 50 cm in sole cropping and 25 cm in intercropping. The planting lines were 3 m long, with 1 meter between plots and 2 meters between blocks. The spacing between borage seeds was 15 cm. For peanuts, the spacing was 20 cm in sole cropping and 100% intercropping and 40 cm in 50% intercropping. The field was irrigated instantly after seed sowing, and a drip irrigation system was used once a week. Weeding was carried out manually and as necessary throughout the growing season. In both years, all borage plants per plot were harvested on 15 September, and all peanut plants per plot were harvested on 15 October, excluding the marginal effects. After harvesting the plants, the economic parts were separated, and then their residues were tested as forage.

Evaluation of the Characteristics of Borage and Peanut Fodder

The ash was determined using the method of Van Soest et al. (1991). The crude protein content was measured using the Kjeldahl titration method (Nelson and Sommers, 1973). The NDF and ADF were measured using the method developed by Van Soest et al. (1991). The percentage of dry matter digestibility was obtained using the formula proposed by Oddy et al. (1983) (Equation 1).

$$\%DMD = 83.58 - 0.824 \times \%ADF + 2.262 \times \%N \qquad (1)$$

Metabolizable energy was calculated using the formula provided by the Australian Agricultural Council (1990) (Equation 2).

$$ME\ (Mj/kg) = 0.17\ DMD\% - 2 \qquad (2)$$

Data Analysis

After assessing the homogeneity of variances based on Levene's test, a compound analysis of variance was conducted using SAS Version 9.4. The LSD test was employed for mean comparisons. The data were analyzed using Proc mixed model analysis of variance (Littell et al., 2006), and mean comparisons were performed using the lsmeans test. To categorize the means by distinct letters, %PDMIX800 macro was used (Saxton, 1989). The significance of the variances was assessed based on the expected value of the mean squares.

RESULTS

Ash

The effects of fertilizer, cropping pattern, the interaction effects of fertilizer × cropping pattern, and year × fertilizer on the ash of borage fodder were significant (Table 2). Also, the effects of main treatments and year × fertilizer on the mentioned trait of borage fodder were significant (Table 5). The 100% intercropping pattern with organic fertilizer application increased the ash of borage forage by 58.43% compared to the borage sole cropping without fertilizer (Table 3). In the first year of the experiment, chemical fertilizer had a greater effect on the forage ash of borage (Table 4) and peanuts (Fig. 3), while in the second year, organic fertilizer had a more significant impact. The effect of the cropping pattern on the ash percentage of peanut forage is also illustrated in Fig. 2. The organic fertilizer application increased the ash percentage of peanut forage by 16.91% compared to the control treatment (Fig. 5).

CP and Protein Yield

The main effects of treatments and the interaction of year × fertilizer on the crude protein and protein yield of both plants were significant (Tables 2 and 5). Moreover, the interaction effect of year × fertilizer × cropping pattern on the crude protein and fertilizer × cropping pattern on the protein yield of peanut fodder were significant (Table 5). Intercropping enhanced crude protein (Fig. 4) and protein yield in borage (Fig. 5) by 14.67% and 16.59%, respectively, compared to sole cropping. The percentage of crude protein and protein yield in both plants were more affected by chemical fertilizer in the first year of the experiment, while in the second year, they were more affected by organic fertilizer (Table 4 and Fig. 6). Overall, the quality of borage fodder in terms of protein content (at its best, 14.52%) was higher than that of peanut fodder (at its best, 12.63%).

NDF and ADF

The effects of fertilizer, cropping pattern, fertilizer × cropping pattern, and year × fertilizer on the NDF and ADF in borage (Table 2) and peanut fodder (Table 5) were significant. The 100% intercropping pattern treated with organic fertilizer improved the quality of borage fodder in terms of NDF and ADF by 46% compared to the sole cropping of borage without fertilizer (Table 3). Fertilizer application increased borage fodder quality regarding NDF and

ADF in both years (Table 4). Sole cropping of peanut treated with organic and chemical fertilizers produced the best quality regarding NDF and ADF percentages (Table 6).

Fodder Yield

Fodder yield of both plants was significantly affected by fertilizer, cropping pattern, and their interaction impacts (Tables 2 and 5). Chemical fertilizer application significantly affected the fodder yield of both plants. The highest and lowest borage fodder yield belonged to 100% intercropping treated with chemical fertilizer and sole cropping without fertilizer, respectively (Table 3). Meanwhile, peanut sole cropping with chemical fertilizer had the highest fodder yield (Table 6).

DMD

The effects of fertilizer, cropping pattern, and the interactions of fertilizer × cropping pattern on the DMD of both fodder plants were significant (Tables 2 and 5). Also, the interactions effect of year × fertilizer on the DMD of borage fodder was significant (Table 2). The DMD of borage fodder in the 100% intercropping with organic fertilizer increased by 30% compared to the borage sole cropping without fertilizer (Table 3). Organic fertilizer had a greater effect on the mentioned trait in the second year (Table 4). The highest digestibility of peanut fodder was obtained from sole cropping patterns were treated with chemical and organic fertilizers (Table 6). The lowest value of this trait belonged to 100% intercropping without fertilizer (Table 6).

ME

The main effects and the interaction effects of them on the metabolic energy of both plants were significant (Tables 2 and 5). Also, the metabolic energy of borage fodder was significantly affected by the interaction impact of year × fertilizer (Table 2). The highest ME of borage fodder was obtained from 100% intercropping patterns treated with organic and chemical fertilizers (Table 3). ME of borage fodder was more influenced by organic fertilizer in the second year of the experiment (Table 4). Sole cropping of peanut patterns treated with fertilizers enhanced this trait by 21.72% compared to 100% intercropping without fertilizer (Table 6).

DISCUSSION

Soil nutrient management is major in fodder quality and livestock feeding (McLaughlin, 2023). Organic fertilizers application is a key approach for high-quality forage production in sustainable agricultural systems like intercropping. These fertilizers increase soil organic matter, improve water retention capacity and provide suitable growth conditions, especially in arid and semi-arid areas (Ghalkhani et al., 2023). In this experiment, organic fertilizer enhanced the ash percentage of borage forage. The ash content of borage fodder in intercropping with peanuts increased due to better nutrient absorption than sole cropping. Crude protein is also one of the most important indicators for assessing fodder quality. The increament in crude protein percentage of borage fodder in the intercropping patterns appears to be related to the peanut's ability to fix nitrogen. Borage and peanuts complement each other in nitrogen consumption; borage absorbs the nitrogen it needs from the soil, while peanuts obtain most of their nitrogen through biological fixation. This difference reduces competition for nitrogen absorption between both plants. Furthermore, the form of nutrients available in organic fertilizer allows for greater and easier absorption of these materials by plants (Lee et al., 2023). Thus, organic fertilizers supplying nutrients, particularly nitrogen, develop leaf area, enhance leaf-to-stem ratio, increase protein values, and reduce woody and lignin portions in forage (Ghalkhani et al., 2023). In agreement with these results, the ash percentage and crude protein of sorghum (*Sorghum bicolor* L.) forage enhanced in the intercropping system with soybean (*Glycine max* L.) affected by organic fertilizer application (Sadafzadeh et al., 2023).

Organic fertilizer had a more positive effect on the qualitative traits, including both plants' ash and protein yield of both plants in the second year of the experiment vs. chemical fertilizer. Organic fertilizer could improve the nutrient cycle, soil aeration, microorganism activity, and soil-plant relations. Consequently, soil's physical, chemical and biological properties can be improved (Xu et al., 2016). Excessive application of chemical fertilizers contributes to air and water pollution by releasing toxic chemicals and gases, degrading soil quality by causing nutrient imbalances due to over-reliance on specific chemical components. Therefore, utilizing organic fertilizers offers a sustainable alternative, providing a diverse range of nutrients through organic matter decomposition and promoting environmental health in the long term (Lee et al., 2023). Thus, it can be said that the influence of organic fertilizer added up to positively affect fodder quality in the second year, when soil conditions and nutrient availability were better.

Furthermore, applying organic fertilizers is both cost-effective and economically advantageous, especially over the long term. Indeed, organic fertilizers enable the production of high-quality crops without chemical residues. By adopting this approach, farmers can optimize their agricultural yields while conserving valuable resources for future generations. Reducing reliance on chemical fertilizers helps preserve vital resources such as soil, water, biodiversity, and human health. Thus, organic fertilizers can improve soil health, productivity and farm profitability (Culas et al., 2025).

Crude protein and protein yield of peanut fodder were higher in the solecropping patterns. In additive intercropping, the increased density of plants leads to softer and thinner stems, resulting in a reduction of fodder's fibrous, cellulosic, and lignin materials. These findings are in line with Zeiditoolabi et al. (2023), who reported that the protein yield of vetch (*Vicia sativa* L.) was lower when intercropped with barley (*Hordeum vulgare* L.).

High ADF and NDF values reduce the palatability of fodder due to its indigestibility. In other words, ADF and NDF are negatively correlated with digestibility, affecting the amount of energy available to ruminants. The mentioned treatments decreased in borage fodder intercropping patterns treated with fertilizers. Similarly, other researchers indicated that the use of organic fertilizers leads to a reduction in ADF and NDF and consequently, an enhancement in the nutritional value of the forage of ajowan and fenugreek (Fotohi Chiyaneh et al., 2024) and corn (Lee et al., 2023) in sustainable agricultural systems. The reduction of ADF and NDF in peanut fodder in a sole cropping pattern can be attributed to eliminating interspecific competition for resources (primarily light) and, as a result, a decrease in the stem-to-leaf ratio. Other researchers, by examining the intercropping of barley and annual legumes, found that the lowest values of ADF and NDF were associated with the sole cropping of chickpea, which aligns with the findings of the present study (Yolcu et al., 2009).

The highest fodder yield of borage and peanut belonged to intercropping and solecropping patterns, respectively. It seems that the biological nitrogen fixation of peanut supplied more nitrogen absorbtion of borage according to the facilitate principle. Consequently, vegetative growth and borage fodder yield were enhanced. Similarly, Other researchers found that Kochia (*Kochia scoparia*) fodder yields were higher when intercropped with Sesbania (*Sesbania aculeate*), and Guar (*Cyamopsiste tragonoliba*) (Ghaffarian et al., 2021). Density is considered the first and most important component of yield, and the higher fodder yield of peanuts in sole cropping compared to intercropping patterns was primarily due to a greater number of plants per unit area. These results align with researchers who reported that legume yield such as soybean (Liu et al., 2017) and fenugreek (Zandi et al., 2023) was greater in sole cropping patterns in the intercropping systems.

Environmental and nutritional factors affect the digestibility of forage, and with an increase in soil nitrogen, soluble proteins within the cells increase, leading to a rise in the percentage of DMD (Aquino et al., 2020). In the present study, organic fertilizer appears to enhances the digestibility of dry matter by creating suitable conditions for improving the activity of beneficial soil microorganisms and facilitating the absorption of macro and micronutrients. Likely, that the higher digestibility of borage fodder in the intercropping patterns compared to the sole cropping pattern of this plant is due to the increased leaf-to-stem ratio in the intercropping systems and the herbaceous nature of the leaves resulting from a lower ADF content. If the DMD of forage is above 50 percent, it can be benefit livestock (Aquino et al., 2020); in the current study, the digestibility of peanut fodder was above 60.94 percent. Due to the negative correlation between ADF and DMD, the digestibility of fodder increased as the concentration of ADF decreased, the digestibility of fodder increased. Furthermore, metabolic energy decreased by increasing the percentage of ADF and NDF in the fodder. In agreement with these findings, the metabolic energy of *Dactylis glomerata* and *Medicago sativa* L. fodder was enhanced by nitrogenous fertilizers application (Xue et al., 2020).

CONCLUSIONS

These findings indicated intercropping of borage and peanut and organic fertilizer application enhanced qualitative characteristics of fodder, including ash percentage, crude protein, protein yield, neutral detergent fiber, acid detergent fiber, dry matter digestibility, and metabolizable energy. These results offer farmers can leverage these techniques to achieve sustainable increases in healthy forage production. Indeed, the harmonious integration of two agroecological methods (intercropping and organic fertilization) demonstrates a sustainable approach that enhances fodder productivity and quality and minimizes environmental impacts, reflecting a commitment to cleaner production and responsible environmental stewardship.

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Table 1. Characteristics of soil and organic fertilizer in this experiment.

	pH	EC (dS/m)	OC (%)	N (%)	P (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)
Soil	7.83	0.583	0.84	0.08	14	251	17.9	8.5	0.2	0.1	0.3
Organic fertilizer	5.98	8.34	1.28	0.509	4.5%	1.36%	227	28.5	2	0.5	2.5

Table 2. A combined analysis of variance of fodder characteristics of borage affected by fertilizer and cropping system in 2021 and 2022.

		Mean Squares							
SOV	df	Ash	CP	NDF	ADF	Fodder yield	Protein yield	DMD	EM
Year	1	0.228^{ns}	0.115^{ns}	1.49^{ns}	0.79^{ns}	53263^{ns}	3038.01^{ns}	0.759^{ns}	0.023^{ns}
Replication (year)	4	1.187	1.069	5.31	2.814	8979	9608.1	2.492	0.073
Fertilizer	2	531.82^{**}	105.59^{**}	1465^{**}	774.98^{**}	1624093^{**}	1140590^{**}	742.82^{**}	21.458^{**}
Cropping pattern	2	194.25^{**}	19.55^{**}	765.52^{**}	404.85^{**}	224900^{**}	209144^{**}	339.64^{**}	9.811^{**}
Fertilizer × Cropping pattern	4	10.75^{**}	0.147^{ns}	5.647^{**}	2.955^{**}	12490^{**}	1635.5^{ns}	1.422^{**}	0.041^{**}
Year ×Fertilizer	2	88.52^{**}	29.75^{**}	6.552^{**}	3.459^{**}	1.054^{ns}	250488^{**}	14.621^{**}	0.042^{**}
Year × Cropping pattern	2	0.0009^{ns}	0.0002^{ns}	0.0093^{ns}	0.005^{ns}	0.754^{ns}	12.546^{ns}	0.003^{ns}	0.00004^{ns}
Year× Fertilizer × Cropping pattern	4	0.64^{ns}	0.333^{ns}	0.352^{ns}	0.183^{ns}	0.152^{ns}	3138.3^{ns}	0.013^{ns}	0.0003^{ns}
Error	32	0.246	0.482	0.495	0.261	732.544	3968.07	0.174	0.005
C.V (%)		4.654	7.294	3.476	3.474	2.301	7.311	2.689	2.864

ns, *, and ** $p > 0.05$, $p \le 0.05$, and $p \le 0.01$, respectively.

Table 3. Fodder characteristics of borage affected by cropping pattern and fertilizer in 2021 and 2022.

Fertilizer	Cropping pattern	Ash (%)	NDF (%)	ADF (%)	Fodder yield (kg/ha)	DMD (%)	EM (Mj/kg)
	Sole cropping	$9.82{\pm}0.76^{f}$	$65.1{\pm}1.20^{a}$	$47.35{\pm}0.87^{a}$	$8553{\pm}51.27^{f}$	$48.56{\pm}0.67^{f}$	$6.26{\pm}0.12^{f}$
Control	Intercropping 50%	$11.95{\pm}0.66^{e}$	$58.08{\pm}1.36^{b}$	$42.25{\pm}0.99^{b}$	$8692{\pm}34.65^{e}$	$53.01{\pm}0.76^{e}$	$7.01{\pm}0.13^{e}$
	Intercropping 100%	$15.47{\pm}0.63^{d}$	$51.03{\pm}0.68^{c}$	$37.11{\pm}0.50^{c}$	$8786{\pm}43.13^{d}$	$57.78{\pm}0.62^{d}$	$7.82{\pm}0.11^{d}$
	Sole cropping	$20.29{\pm}3.21^{c}$	$47.83{\pm}1.39^{d}$	$34.79{\pm}1.01^{d}$	$8991{\pm}48.88^{c}$	$60.55{\pm}1.32^{c}$	$8.29{\pm}0.22^{c}$
Organic Fertilizer	Intercropping 50%	$21.6{\pm}2.65^{b}$	$44.02{\pm}1.33^{e}$	$32.01{\pm}0.96^{e}$	$9007{\pm}38.02^{c}$	$63.32{\pm}1.28^{b}$	$8.76{\pm}0.22^{b}$
	Intercropping 100%	$23.62{\pm}1.78^{a}$	$35.49{\pm}0.65^{f}$	$25.81{\pm}0.47^{f}$	$9213{\pm}44.27^{b}$	$68.86{\pm}1.09^{a}$	$9.71{\pm}0.18^{a}$
	Sole cropping	$20.27{\pm}3.06^{c}$	$47.83{\pm}1.11^{d}$	$34.78{\pm}0.80^{d}$	$9163{\pm}35.49^{b}$	$60.55{\pm}1.09^{c}$	$8.29{\pm}0.19^{c}$
Chemical Fertilizer	Intercropping 50%	$21.58{\pm}2.49^{b}$	$44.02{\pm}1.16^{e}$	$32.01{\pm}0.84^{e}$	$9297{\pm}38.12^{a}$	$63.31{\pm}1.08^{b}$	$8.76{\pm}0.19^{b}$
	Intercropping 100%	$23.61{\pm}1.60^{a}$	$35.49{\pm}0.43^{f}$	$25.81{\pm}0.32^{f}$	$9341{\pm}42.08^{a}$	$68.86{\pm}0.88^{a}$	$9.71{\pm}0.15^{a}$

In each column, the averages with at least one common letter do not have a significant difference at the five percent probability level based on the LSD test. Values are Mean ± Standard deviation, SD.

Table 4. The fodder qualitative characteristics of borage affected by year and fertilizer in 2021 and 2022.

Year	Fertilizer	Ash (%)	CP (%)	NDF (%)	ADF (%)	Protein yield (kg/ha)	DMD (%)	EM (Mj/kg)
	Control	$12.37{\pm}2.55^{c}$	$10.28{\pm}0.88^{c}$	$58.27{\pm}6.21^{a}$	$42.38{\pm}4.51^{a}$	$890{\pm}85.59^{c}$	$52.98{\pm}4.06^{c}$	$7.0{\pm}0.69^{c}$
2021	Organic Fertilizer	$19.54{\pm}2.09^{b}$	$13.18{\pm}0.87^{b}$	$43.2{\pm}5.75^{b}$	$31.42{\pm}4.18^{b}$	$1192{\pm}90.41^{b}$	$63.23{\pm}3.75^{b}$	$8.75{\pm}0.64^{b}$
	Chemical Fertilizer	$23.96{\pm}0.91^{a}$	$15.74{\pm}1.49^{a}$	$41.99{\pm}5.34^{bc}$	$30.54{\pm}3.89^{bc}$	$1455{\pm}146.9^{a}$	$65.03{\pm}3.67^{a}$	$9.05{\pm}0.63^{a}$
	Control	$12.46{\pm}2.57^{c}$	$10.35{\pm}0.89^{c}$	$57.87{\pm}6.16^{a}$	$42.09{\pm}4.48^{a}$	$902{\pm}86.77^{c}$	$53.25{\pm}4.03^{c}$	$7.05{\pm}0.69^{c}$
2022	Organic Fertilizer	$24.13{\pm}0.91^{a}$	$15.85{\pm}1.5^{a}$	$41.7{\pm}5.31^{c}$	$30.33{\pm}3.86^{c}$	$1444{\pm}150.01^{a}$	$65.25{\pm}3.66^{a}$	$9.09{\pm}0.62^{a}$
	Chemical Fertilizer	$19.68{\pm}2.11^{b}$	$13.27{\pm}0.88^{b}$	$42.9{\pm}5.71^{bc}$	$31.20{\pm}4.15^{bc}$	$1235{\pm}90.75^{b}$	$63.45{\pm}3.73^{b}$	$8.79{\pm}0.63^{b}$

In each column, the averages with at least one common letter do not have a significant difference at the five percent probability level based on the LSD test. Values are Mean ± Standard deviation, SD.

Table 5. A combined analysis of variance of fodder characteristics of peanut affected by fertilizer and cropping system in 2021 and 2022.

S.O.V	df	Mean Squares							
		Ash	CP	NDF	ADF	Fodder yield	Protein yield	DMD	EM
Year	1	0.092^{ns}	0.079^{ns}	0.658^{ns}	0.347^{ns}	1756.5^{ns}	81.254^{ns}	0.365^{ns}	0.01^{ns}
Replication (year)	4	0.257	0.271	0.158	0.178	54539	878.94	0.046	0.0014
Fertilizer	2	27.059**	26.146**	182.4**	97.835**	2861756**	67360**	236.12**	6.63**
Cropping pattern	2	232.33**	61.724**	509.24**	283.28**	50181419**	790786**	284.29**	8.218**
Fertilizer × Cropping pattern	4	1.218^{ns}	0.13^{ns}	9.765**	4.436**	152168**	3609**	12.612**	0.365**
Year × Fertilizer	2	14.861**	9.31**	0.491^{ns}	0.048^{ns}	38.5^{ns}	51.87^{ns}	0.848^{ns}	0.024^{ns}
Year × Cropping pattern	2	0.003^{ns}	0.001^{ns}	0.0061^{ns}	0.0034^{ns}	129.8^{ns}	30.68^{ns}	0.0013^{ns}	0.00008^{ns}
Year × Fertilizer × Cropping pattern	4	0.783^{ns}	0.476**	0.099^{ns}	0.007^{ns}	24.3^{ns}	7.59^{ns}	0.124^{ns}	0.0036^{ns}
Error	32	1.514	0.068	1.052	0.607	8256.4	103.672	0.487	0.014
C.V (%)		12.37	4.731	5.244	5.384	7.796	7.865	3.016	3.228

ns, *, and ** $p > 0.05$, $p \leq 0.05$, and $p \leq 0.01$, respectively.

Table 6. Fodder characteristics of peanut affected by cropping pattern and fertilizer in 2021 and 2022.

Fertilizer	Cropping pattern	NDF (%)	ADF (%)	Fodder yield (kg/ha)	Protein yield (kg/ha)	DMD (%)	EM (Mj/kg)
Control	Sole cropping	30.24±0.54^{c}	21.95±0.42^{c}	2601±146^{c}	263.1±14.2^{c}	69.74±0.32^{b}	9.86±0.06^{b}
	Intercropping 50%	32.95±0.26^{b}	23.97±0.10^{b}	348±15.3^{e}	24.7±1.9^{f}	66.81±0.16^{d}	9.36±0.02^{d}
	Intercropping 100%	42.68±2.23^{a}	31.22±1.74^{a}	560±24.6^{e}	41±0.7^{f}	60.94±1.51^{e}	8.36±0.26^{e}
Organic Fertilizer	Sole cropping	23.92±0.35^{d}	17.29±0.25^{d}	3259±141^{b}	407.1±18.9^{b}	74.58±0.26^{a}	10.68±0.04^{a}
	Intercropping 50%	31.82±0.55^{bc}	23.23±0.35^{bc}	539±23.6^{e}	48.8±5.7^{ef}	68.24±0.53^{c}	9.60±0.09^{c}
	Intercropping 100%	33.59±0.83^{b}	24.50±0.63^{b}	902±39.5^{d}	83.5±6.4^{d}	67.28±0.65^{cd}	9.44±0.11^{cd}
Chemical Fertilizer	Sole cropping	23.92±0.33^{d}	17.29±0.18^{d}	4605±227^{a}	575.3±27.6^{a}	74.58±0.15^{a}	10.68±0.02^{a}
	Intercropping 50%	31.82±0.38^{bc}	23.23±0.23^{bc}	495±21.7^{e}	44.8±4.7^{f}	68.24±0.36^{c}	9.60±0.06^{c}
	Intercropping 100%	33.59±0.77^{b}	24.50±0.59^{b}	802±35.2^{d}	74.2±5.4^{de}	67.28±0.59^{cd}	9.44±0.10^{cd}

In each column, the averages with at least one common letter do not have a significant difference at the five percent probability level based on the LSD test. Values are Mean ± Standard deviation, SD.

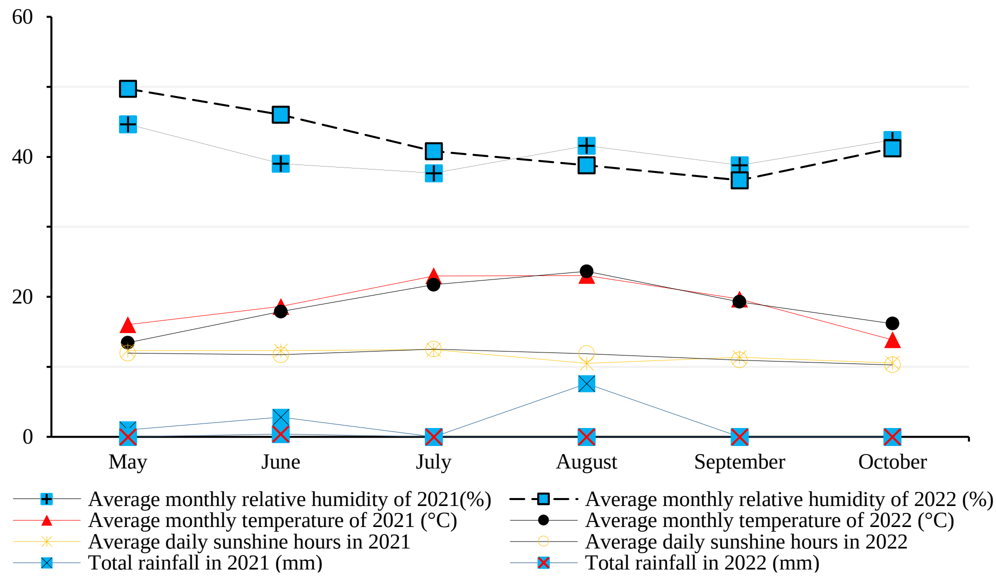

Figure 1. Meteorological statistics in 2021 and 2022 growing seasons in the experimental area.

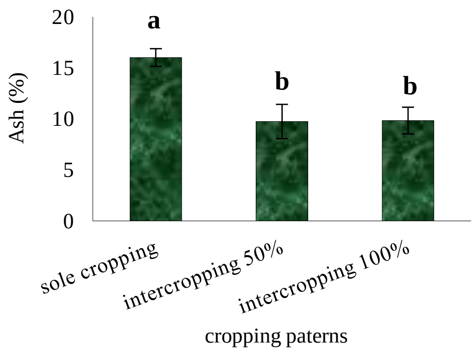

Figure 2. The ash of peanut fodder affected by cropping pattern in 2021 and 2022. (Data dispersion is based on standard deviation).

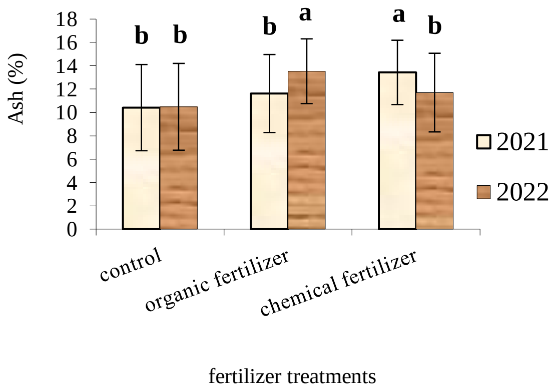

Figure 3. The Ash of peanut fodder affected by year×fertilizer in 2021 and 2022. (Data dispersion is based on standard deviation).

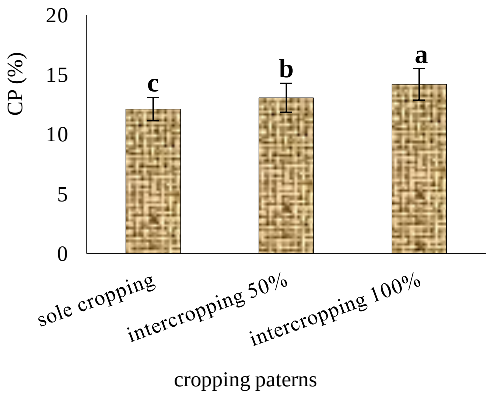

Figure 4. The crude protein of borage fodder affected by cropping pattern in 2021 and 2022. (Data dispersion is based on standard deviation).

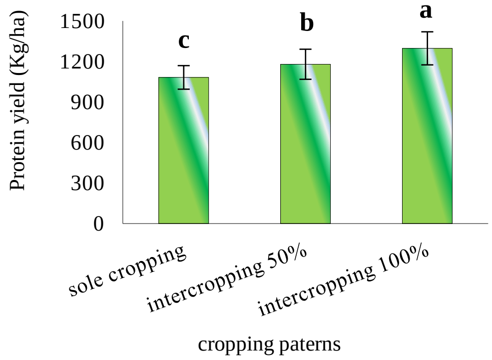

Figure 5. The yield protein of borage fodder affected by cropping pattern in 2021 and 2022. (Data dispersion is based on standard deviation).

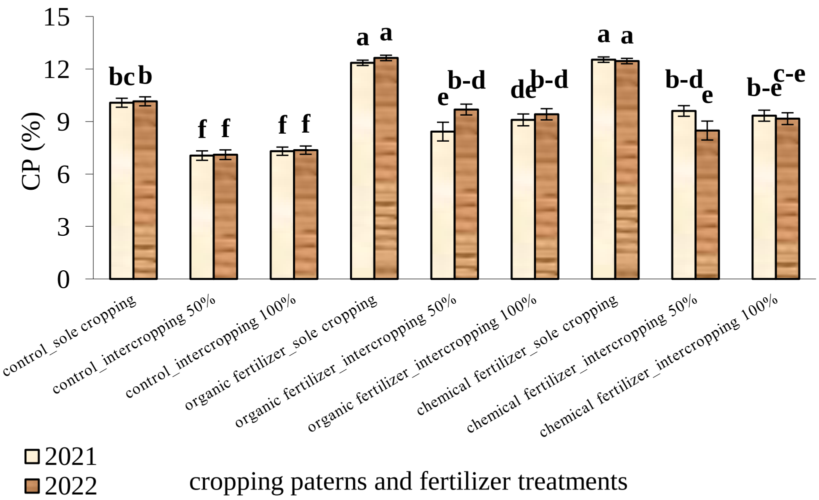

Figure 6. The crude protein of peanut fodder affected by year×fertilizer×cropping pattern in 2021 and 2022. (Data dispersion is based on standard deviation).

بهبود کیفیت علوفه بادام زمینی و گاوزبان اروپایی با کاربرد کودها در سیستم کشت مخلوط

فریده سالاری، شیوا خالص‌رو، غلامرضا حیدری، و سمیرا زارعی

چکیده

هدف این پژوهش ارزیابی کیفی و کمی علوفه گاوزبان و بادام زمینی در سیتم کشت مخلوط تحت تاثیر کود بود. آزمایش مزرعه‌ای دوساله به‌صورت فاکتوریل در قالب طرح بلوک‌های کامل تصادفی با 3 تکرار در مزرعه تحقیقاتی دانشگاه کردستان در 1400 و 1401 اجرا شد. تیمارهای آزمایش امل کود (شاهد، ارگانیک و شیمیایی) و الگوهای کشت (کشت خالص گاوزبان، کشت خالص بادام زمینی، کشت مخلوط افزایشی 50% و 100%) بود. نتایج نشان داد کیفیت علوفه گاوزبان در کشت مخلوط نسبت به کشت خالص برتری داشت و تیمارهای کودی نسبت به تیمار شاهد عملکرد و صفات کیفی علوفه بادام زمینی را بهبود بخشیدند. کود ارگانیک، پروتئین خام علوفه گاوزبان و بادام زمینی را به ترتیب 29 و 20/4 درصد نسبت به تیمار شاهد افزایش دهد. کشت مخلوط موجب افزایش 16/6 درصدی عملکرد پروتئین گاوزبان نسبت به کشت خالص شد. NDF، ADF، قابلیت هضم ماده خشک و میزان خاکستر علوفه گاوزبان در کشت مخلوط 100% + کاربرد کود ارگانیک به ترتیب 46، 46، 30 و 58/4 درصد نسبت به کشت خالص بدون مصرف کود افزایش پیدا کرد. به‌طور کلی، می‌توان اذعان نمود که با مدیریت زراعی مناسب در سیستم‌های کشت مخلوط افزایشی، امکان افزایش کیفیت علوفه گاوزبان و بادام زمینی در تغذیه دام وجود دارد.