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Assessing the Impact of Intercropping on Smooth Vetch (*Vicia dasycarpa*) and Coriander (*Coriandrum sativum*) with Diverse Biological and Zeoponic Nutrition

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Abstract. This study presents a comprehensive examination of the application of intercropping as a pivotal strategy for enhancing agricultural diversity, with a focus on evaluating diverse biological and Zeoponic nutrition systems in the intercropping of smooth vetch (*Vicia dasycarpa*) and coriander (*Coriandrum sativum*). The experimental design employed was a randomized complete block format with three replications, conducted at the Kermanshah University Research Farm during the cropping year of 2021-2022. The primary plot configuration included four different fertilizer types: a control without any fertilizer (C), with biofertilizer (B), with Zeoponic fertilizer (Z), and a compound strategy with biofertilizer combined with 50% Zeoponic fertilizer (BZ50). Subplots were dedicated to additive intercropping systems, namely: 100% vetch (V100), 100% vetch intercropped with 50% coriander (V100C50), and 100% vetch intercropped with 100% coriander (V100C100). The findings of this experiment revealed that the highest fresh forage yield (12,227 kg/ha) was achieved through the sole cropping of vetch with biofertilizer and a 50% application of Zeoponic fertilizer. Both species exhibited enhancement of different attributes when intercropped under various fertilization regimes. Particularly, the crude protein content (24.5%) and total ash content (10.25%) of vetch were highest in sole cultivation. Furthermore, in the intercropping system with the application of biofertilizers, the highest levels of indigestible fiber (39.6%) and neutral extract fiber (NDF) (34.44%) were recorded. Consequently, the additive intercropping of vetch and coriander is proposed as a recommendable strategy for a medicinal forage combination within the geographic scope of this study.

Keywords. Biological fertilizer, Intercropping, Medicinal forage, Organic fertilizer, Weeds biomass.

1. Introduction

Agricultural diversity is significantly enriched through the practice of intercropping, which involves cultivating multiple crops simultaneously and fostering interrelationships between different crop species [1]. The benefits of intercropping are numerous, including increased yield per unit area, efficient resource utilization, pest and disease reduction, crop stability, and enhanced nutrition for both humans and animals [2]. This sustainable agricultural practice aims to achieve ecological balance, optimize resource use efficiency, increase crop yield and quality, and mitigate damage from pests, diseases, and weeds. In the realm of sustainable agriculture, intercropping serves to diminish reliance on pesticides while sustaining product quality and meeting market demand [3].

Studies on intercropping dynamics, such as the Berseem clover (*Trifolium alexandrinum*) and basil (*Ocimum basilicum*) combination, have demonstrated the superiority of the Berseem clover-basil (75%) system. Combined fertilization, specifically the use of organic fertilizer in conjunction with 50% chemical nitrogen fertilizer, emerges as a favorable alternative to sole reliance on chemical nitrogen fertilizer alone [4]. Optimal methods for intercropping sweet basil (*Ocimum basilicum L.*) with maize (*Zea mays L.*) have been identified, with the most effective approach being the intercropping of 75% basil with maize [5].

Studies involving the intercropping of vetch (*Vicia dasycarpa Ten*) with barley (*Hordeum vulgare*) and triticale have shown higher fresh forage yields, dry matter, and crude protein compared to vetch-triticale intercropping [6]. Similarly, the impact of vetch on forage maize yield was apparent when intercropped with varying nitrogen levels [7]. Intercropping vetch with oats (*Avena sativa*) resulted in higher yields compared to sole cropping, emphasizing resource utilization advantages [8]. Additionally, the intercropping of peppermint (*Mentha × piperita*) with soybean (*Glycine max*) demonstrated an increase in peppermint yield [9]. Furthermore, the intercropping of sudangrass (*Sorghum sudanense*) with cowpea (*Vigna unguiculata*) has been shown to enhance forage yield and quality [10]. However, the introduction of fertilizer in such systems increased biomass yield by 15%, albeit with a simultaneous 24% reduction in vetch biomass dry matter [11].

In the pursuit of sustainable agriculture, this study recommends intercropping organic medicinal forages, such as vetch and coriander (*Coriandrum sativum*), to enhance forage yield and quality. The investigation delves into their intercropping dynamics under different nutritional systems to elucidate the potential for achieving superior medicinal forage effects.

2. Materials and Methods

2.1. Study Location

The research was carried out at Jihad Daneshgahi Kermanshah University Research Farm, situated at Latitude 34°19'N, Longitude 47°4'E, and an Altitude of 1520 m. The study was conducted during the cropping year of 2021-2022.

2.2. Soil Analysis

Soil samples were systematically collected from a depth of 0-30 cm at the study location. These samples were then dispatched to the Soil and Water Research Center in Kermanshah for comprehensive analysis. The physical and chemical properties of the soil, crucial for understanding the growing conditions, were meticulously measured. The detailed results of the soil analysis are presented in Table 1.

Table 1. Physical and chemical properties of the soil of the test site.

Zn ppm	Fe ppm	Mn ppm	Cu ppm	K ppm	P ppm	Organic carbon (%)	Saturated acidity	Soluble solutes ($EC\times10^6$)	Neutralizing materials (%)	Soil texture	Soil depth(cm)
0.90	11.94	22.94	1.78	448	6.43	0.99	7.43	1.92	25	Silty-clay	0-30

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2.3. Experimental Design

The experiment employed a completely randomized block design with three replications. The main plot treatments consisted of four fertilizer types: control (C), biofertilizer (B), Zeoponic fertilizer (Z), and a combination of biofertilizer and 50% Zeoponic fertilizer (BZ50). Sub-plots were designated for sole and additive cropping systems, including sole vetch (V100), intercropping of 100% vetch + 50% coriander (V100C50), and intercropping of 100% vetch + 100% coriander (V100C100). Each replication comprised 12 plots, and the experimental area was divided into three blocks with a 2 m spacing between each block.

2.4. Sowing and Fertilization

On December 20, 2021, soil preparation commenced, with six rows in each plot featuring a plant-to-plant spacing of 25 cm and a length of 4 m. Buffer lines were maintained between subplots. Vetch seeds were planted at a density of 100 kg ha-1, and coriander seeds were intercropped at densities of 50% and 100%. Biofertilizers were applied through seed inoculation. The corresponding fertilizer treatment plots were enriched with Zeoponic fertilizer (200 kg ha-1) and complete bio-NPK fertilizer. Planting took place on December 23, 2021.

2.5. Irrigation and Weed Management

Drip tape irrigation was immediately implemented after sowing. Manual weed removal, targeting species such as *Trogopogon graminifolius*, *Agropyron repens*, *Convolvulus dorycnium*, *Salvia officinalis*, and *Carthamus oxyacantha,* was conducted on February 5, 2022.

2.6. Sampling and Harvesting

The first sampling occurred on March 15, 2022, in the northern half of each plot, utilizing 1 m2 quadrats for the determination of moisture content and dry weight. A second sampling took place on May 8, 2022, in the southern half of the plot, focusing on assessing seed yield. Harvesting of intercrops and sole crops was performed separately.

2.7. Forage Quality Analysis

Forage samples underwent a series of processes, including drying, grinding, and analysis via near-infrared spectroscopy (NIR) to determine quality traits such as ADF, ASH, CF, CP, and NDF. The normality of the data was assessed using Minitab software. Statistical analyses, including analysis of variance, mean comparison, and relevant tests, were conducted using MSTAT-C and SAS software. Figures and tables were generated using Excel. Subsequent to analysis of variance, the Duncan multiple-range test was applied for mean comparison at significance levels of 5% and 1%.

3. Results and Discussions

3.1. Quantitative Traits of Forage

The results of the analysis of variance indicated that the simple effect of intercropping and the interaction between fertilizer levels and intercropping significantly influenced the fresh forage yield. However, the effects of fertilizer types, intercropping, and their interaction did not exhibit a significant impact on the dry forage yield. These findings are comprehensively presented in Table 2. Notably, the highest forage yield (12,270 kg/ha) was observed in the intercropping system of 100% vetch and 100% coriander (referred to as V100C100), particularly when supplemented with biological fertilizer and 50% zeoponic fertilizer (Figure1).

Table 2. Analysis of variance the effect of fertilizer treatment and intercropping on quantitative traits.

Source of variation	df	Fresh forage yield	Dry forage yield	Weed biomass	Seed yield
Replication	2	930833	30277	267.7	4969
Fertilizer (A)	3	1932129 $^{n.s}$	9351 $^{n.s}$	1478 *	192481 ^{ns}
Ea	6	1673796	34907	233.9	54384

Source of variation	df	Fresh forage yield	Dry forage yield	Weed biomass	Seed yield
Intercropping (B)	2	6790000**	50902n.s	3043**	2119 n.s
A*B	6	7312962**	63032	4093**	47.356 n.s
Eb	16	718055	53541	281.9	33084
CV (%)	-	8.54	17.10	16.52	16.88

** and * have significant differences (Duncan 1 and 5%) and n.s no significant difference, respectively.

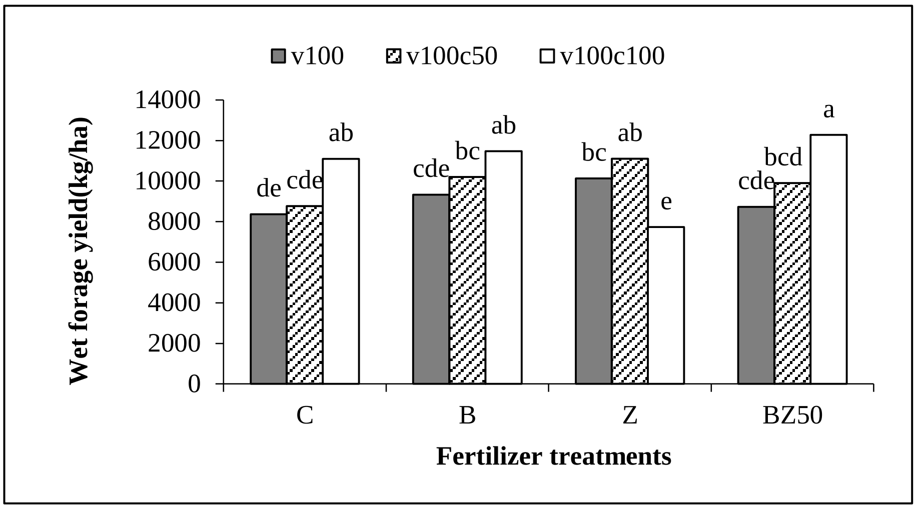

Figure 1. Effect of fertilizer kinds and intercropping on fresh forage yield.

Similar letters indicate no significant differences between means (Duncan 5 and 1%). V100: sole cultivation of 100% vetch, V100C50: intercropping of 100% vetch + 50% coriander, V100C100: intercropping of 100% vetch + 100% coriander. C: Control, B: biological fertilizer, Z: Zeoponics fertilizer, BZ50: biological fertilizer + 50% zeoponics fertilizer.

This outcome underscores the effectiveness of intercropping, specifically the combination of vetch and coriander, in enhancing fresh forage yield. The synergy between biological fertilizer and zeoponic fertilizer further contributed to the optimization of forage production.

The lack of significant impact on dry forage yield may suggest that intercropping and fertilizer types primarily influence the water content and succulence of the forage rather than its overall dry matter. Further investigation into the specific biochemical and physiological aspects contributing to the observed fresh forage yield is warranted.

The interaction between different fertilizer levels and intercropping systems demonstrates the complexity of factors influencing forage productivity. The superior performance of the V100C100 system indicates the potential for optimizing crop combinations to achieve maximum forage yield in sustainable agricultural practices.

In summary, the intercropping of 100% vetch and 100% coriander, along with the application of biological fertilizer and 50% zeoponic fertilizer, emerges as a promising strategy for maximizing fresh forage yield. These findings contribute valuable insights into the optimization of forage production through synergistic crop combinations and judicious fertilizer applications.

This noteworthy outcome highlights the synergistic impact of specific plant components and fertilization regimens, resulting in optimal dry forage yields. The enhanced performance observed in intercropping compared to sole cropping can be attributed to its efficient utilization of environmental resources, including light, water availability, and soil nutrient content.

In the context of experimental studies investigating the effects of vermicompost applications and intercropping strategies involving vetch and coriander, significant findings have emerged. Particularly, the utilization of 50% vermicompost in conjunction with 50% and 75% coriander in intercropping systems resulted in superior cumulative forage yields. This finding, as reported by Ebn Nasir et al. [12], underscores the intricate interactions between various factors influencing forage yield dynamics.

In a related study, Asghari Midani et al. [13] conducted a comprehensive investigation spanning three cropping years to identify the most suitable intercropping approach for vetch and barley. The study revealed significant treatment effects on fresh forage and dry forage yield during the flowering and post-flowering stages of vetch. Additionally, treatment effects were observed on the yield of straw, whole plant, and seed at maturity. These results further emphasize the multifaceted impact of different intercropping strategies on various components of forage production.

Taken together, these findings contribute valuable insights into the nuanced dynamics of forage yield optimization through intercropping and strategic fertilization. The observed superior performance of specific intercropping combinations highlights the potential for tailored agricultural practices to enhance overall forage production efficiency.

3.2. Weeds Biomass

The analysis revealed that the effects of fertilizer types, intercropping, and their interactions were significant on dry weed biomass, as summarized in Table 2. This observation underscores the influence of fertilizer treatments and intercropping strategies on the biomass production of unwanted vegetation.

Understanding the impact of these factors on weeds biomass is crucial in evaluating the overall effectiveness of intercropping systems and fertilizer applications in weed management. The significance of these findings highlights the need for careful consideration of fertilizer types and intercropping configurations to minimize weed biomass, ultimately contributing to a healthier and more productive agricultural environment. Further investigation into the specific mechanisms by which fertilizer types and intercropping influence weed biomass is warranted to develop targeted weed control strategies in sustainable agricultural practices.

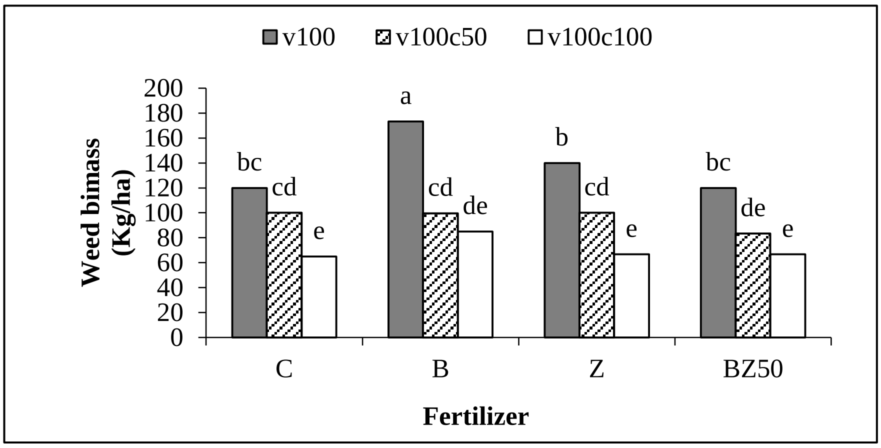

Figure 2. Effect of fertilizer kinds and intercropping on weed biomass.

Where similar letters indicate no significant differences between means (Duncan 5 and 1%). V100: sole cropping of 100% vetch, V100C50: intercropping of 100% vetch + 50% coriander, V100C100: intercropping of 100% vetch + 100% coriander. C: Control, B: biological fertilizer, Z: Zeoponics fertilizer, BZ50: biological fertilizer + 50% zeoponics fertilizer.

In the experimental treatments, it was evident that the utilization of biofertilizers in conjunction with the intercropping method of 100% vetch and 50% coriander led to a notable reduction in weed biomass, quantified at 30.2 kg/ha. Conversely, the highest weed biomass was recorded in sole vetch cultivation without fertilization (65 kg/ha) and when Zeoponic fertilizer was applied in conjunction with intercropping of 100% vetch and 50% coriander (67.7 kg/ha).

The observed decrease in weed biomass attributed to intercropping can be explained by the weakened competitive interactions between the main crop and weeds for essential resources such as water, nutrients, and light. This phenomenon aligns with the findings of Hamzaei et al. [14], who reported a reduction in weed dry matter weight when chickpeas were intercropped compared to chickpeas grown in isolation.

These results emphasize the potential of specific intercropping configurations, particularly when coupled with biofertilizers, in effectively managing weed biomass. Understanding the intricate dynamics between intercropping, fertilization, and weed suppression provides valuable insights for the development of sustainable agricultural practices that enhance crop yield and reduce the impact of unwanted vegetation. Further research into the underlying mechanisms of these interactions will contribute to the refinement of weed management strategies in agroecosystems.

3.3. Seed Yield

The data analysis revealed that seed yield is not significantly affected by fertilizer types, intercropping, or their interactions, as summarized in Table 2. This suggests that variations in fertilizer treatments or intercropping methods did not exert a statistically significant influence on the production of seeds.

The lack of significance in seed yield may indicate that the examined fertilizer types and intercropping systems primarily impact other aspects of forage production, such as fresh forage yield and weed biomass, while not significantly altering the seed yield. This result underscores the importance of considering multiple factors in optimizing different components of agricultural production.

Further exploration into the specific physiological and biochemical factors influencing seed development, in the context of varying fertilizer types and intercropping strategies, may provide additional insights into the observed results. The non-significant impact on seed yield suggests that other aspects of the plant's reproductive process may play a more dominant role in seed production.

3.4. Qualitative Traits of Forage

The analysis of variance results has highlighted the independent effects of intercropping, fertilizer types, and their interactions on certain qualitative forage traits, as presented in Table 3. This underscores the diverse impacts of intercropping and fertilization treatments on the qualitative characteristics of the forage.

Understanding the influence of these factors on qualitative traits is essential for assessing the nutritional composition and overall quality of the forage. The findings presented in Table 3 will provide valuable insights into how specific intercropping configurations and fertilizer applications contribute to the enhancement or modification of qualitative attributes such as nutritional content, digestibility, and other relevant traits.

Further exploration and interpretation of the specific effects on qualitative forage traits will contribute to a more comprehensive understanding of the interplay between cultivation practices and forage quality. These insights are crucial for making informed decisions in sustainable agriculture, ensuring optimal forage quality for both livestock and other end-users.

Table 3. Analysis of variance the effect of fertilizer treatment and intercropping on qualitative forage traits.

Source of variation	**df**	**Crude fiber**	**Total ash**	**Insoluble fibers in acid detergents**	**Crude protein**	**Insoluble fibers in neutral detergents**
Replication	2	11.33	0.745	2.150	2.74	2.23
Fertilizer(a)	3	8.59 n.s	1.672n.s	37.66**	20.27 ns	30.30**
Ea	6	4.29	0.684	3.311 n.s	7.80	3.02
Intercropping (b)	2	5.22 n.s	1.57*	9.064 n.s	13.99**	7.81**
A*B	6	0.991 n.s	0.415 n.s	9.799 n.s	8.16 n.s	4.52 n.s
Eb	16	3.097	0.340	281.9	3.96	1.91
CV (%)	-	6.36	5.91	6.297	8.50	3.25

3.5. Crude Protein Content (CP)

The effect of intercropping on crude protein content was significant (Table 3) and the highest

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crude protein content was obtained from sole cultivation of 100% vetch (V100) (24.5%) and intercropping of 100% vetch + 100% coriander (V100C100) (23.4%) , respectively (Figure 3).

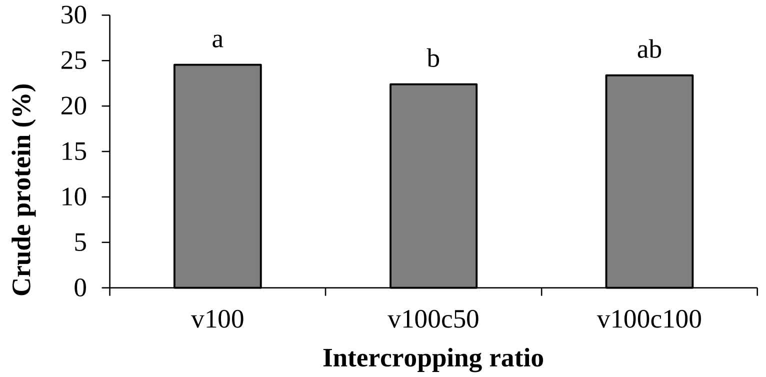

Figure 3. The effects of intercropping on crude protein content.

Similar letters indicate no significant differences between means (Duncan 5 and 1%). V100: sole cropping of 100% vetch, V100C50: intercropping of 100% vetch + 50% coriander, V100C100: intercropping of 100% vetch + 100% coriander

3.6. Acid Detergent Fiber Content (ADF)

The acid detergent fiber (ADF) content is significantly affected by fertilizer types, as indicated in Table 3.

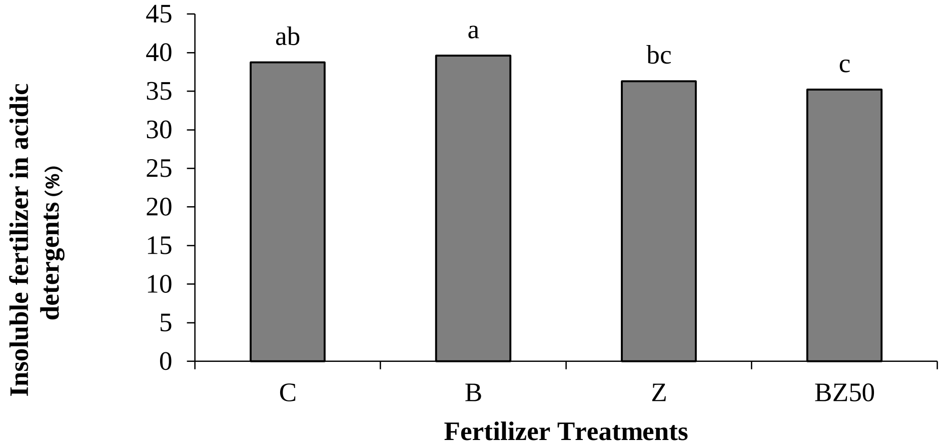

Figure 4. Effect of fertilizer treatments in vetch and coriander intercropping on forage insoluble fibers in neutral detergent.

Where similar letters indicate no significant differences between means (Duncan 5 and 1%). C: Control, B: biological fertilizer, Z: Zeoponics fertilizer, BZ50: biological fertilizer + 50% zeoponics fertilizer.

The biofertilizer group exhibited the highest ADF content (39.6%), while the control group and the biofertilizer + 50% zeolite fertilizer group had the lowest ADF content (35.2%) (Figure 4).

The percentage of ADF represents the share of the cell wall in forage yield, including cellulose and lignin, with increased digestibility as this factor decreases [15]. The application of biofertilizer + 50% zeolite fertilizer (BZ50) resulted in a decrease in ADF percentage, indicating potential improvements in forage digestibility. This aligns with the findings of Naghizadeh and Golui [16], who reported lower

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digestibility of dry matter, crude protein, and acid detergent fiber in mixed corn and barley cultivation compared to sole cultivation. However, the combined use of biological and chemical phosphate fertilizers has been shown to improve forage quality. Other studies have also reported reduced acid detergent fiber, increased protein percentage, and improved forage quality with the use of biofertilizers containing phosphorus-solubilizing bacteria in corn grains and forages [17].

3.7. Forage Total Ash (ASH) Content

The effect of intercropping on forage total ash content was found to be significant, as indicated in Table 3.

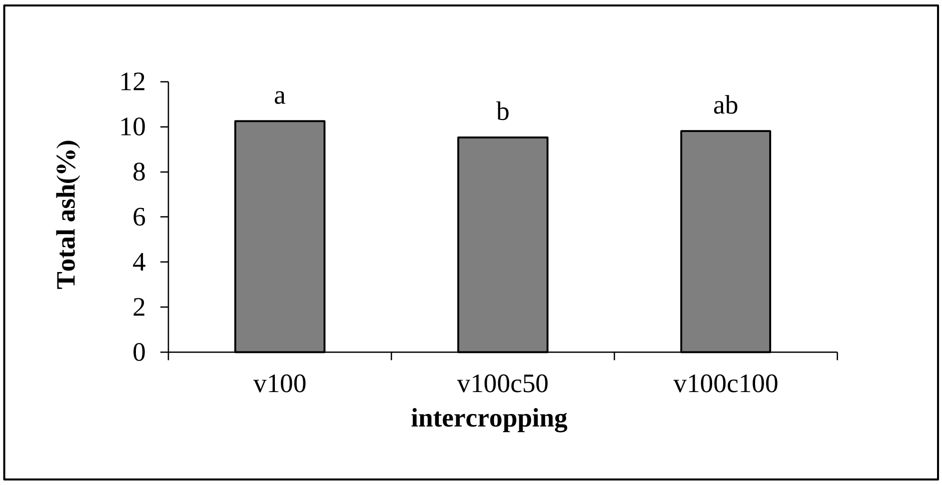

Figure 5. The effect of Fertilizer and coriander intercropping on total ash content.

Where similar letters indicate no significant differences between means (Duncan 5 and 1%). V100: Sole cropping of 100% Vetch, V100C50: intercropping of 100% Vetch + 50% Coriander, V100C100: intercropping of 100% Vetch + 100% Coriander.

The highest total ash content was observed in sole vetch plantings (10.25%) and intercropping of 100% vetch and 100% coriander (9.8%) (Figure 5).

Total ash content is a crucial parameter reflecting the mineral composition of forage. The observed variations in total ash content suggest potential differences in the mineral uptake and accumulation between sole vetch cultivation and intercropping configurations. These findings contribute to a deeper understanding of how intercropping practices impact the nutritional composition of forage, providing valuable insights for livestock nutrition and overall forage quality management.

3.8. Forage Neutral Detergent Fiber (NDF) Content

Both fertilizer types and intercropping significantly impacted forage-neutral detergent fiber (NDF) content, as outlined in Table 3. The highest NDF content (44.34%) was observed with biological fertilizer, followed by a decreasing trend in 100% vetch + 100% coriander (43.15%) and 100% vetch + 50% coriander (43.9%) (Figure 6).

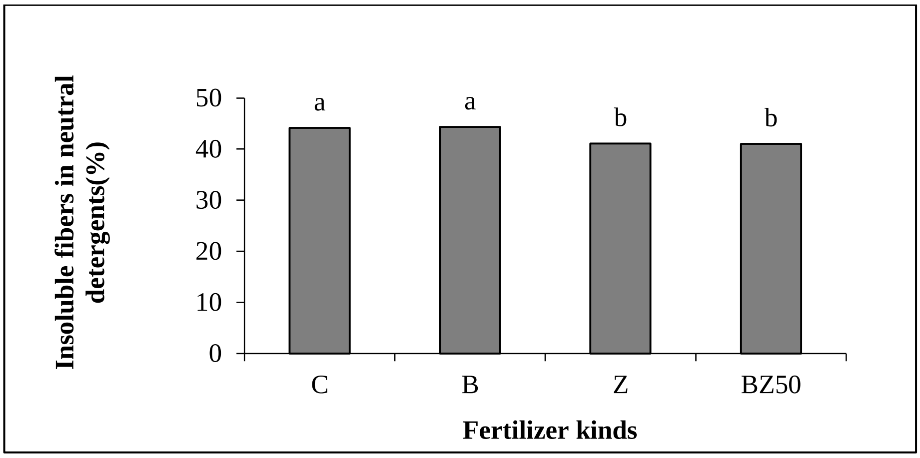

Figure 6. Effect of fertilizer kinds in intercropping of vetch and coriander on insoluble fibers in neutral detergents.

Where similar letters indicate no significant differences between means (Duncan 5 and 1%). C: Control, B: biological fertilizer, Z: Zeoponics fertilizer, BZ50: biological fertilizer + 50% zeoponics fertilizer.

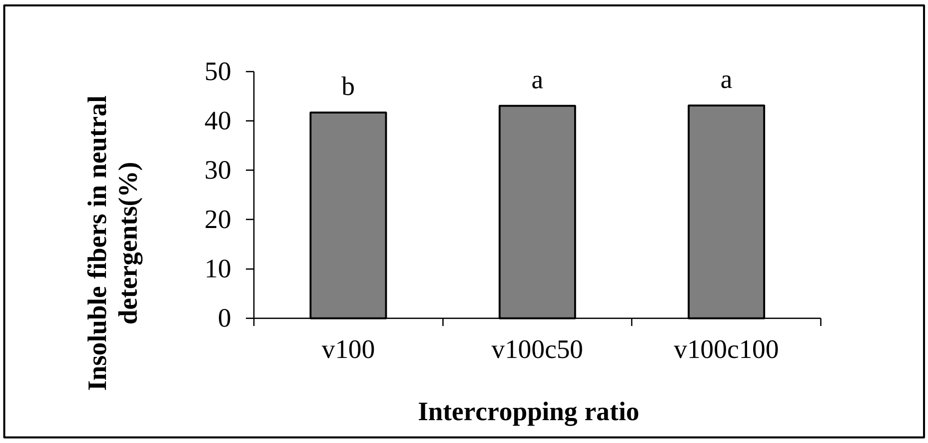

Figure 7. Effect of fertilizer kinds in vetch and coriander intercropping on forage insoluble fibers in neutral detergents.

Where similar letters indicate no significant differences between means (Duncan 5 and 1%). V100: Sole cultivation of 100% Vetch, V100C50: intercropping of 100% Vetch + 50% Coriander, V100C100: Mixed cultivation of 100% Vetch + 100% Coriander.

Increasing the level of coriander in additive intercropping of vetch resulted in an increase in the percentage of insoluble fiber in neutral detergents. Considering the low cellulose content of legumes, it is likely that the addition of coriander in intercropping resulted in an increased percentage of insoluble fiber compared to sole cropping of vetch. This claim is supported by [18], who reported that increasing the percentage of NDF mixed with sugar beet (*Beta vulgaris*) increased the percentage of insoluble fiber. On the other hand, the application of biofertilizer + 50% zeoponics fertilizer and zeoponics fertilizer resulted in a decrease in the percentage of insoluble fiber in neutral detergent.

[16] showed that the use of biophosphate fertilizer reduced the percentage of insoluble fiber in neutral detergents by approximately 5% and improved forage quality compared to the control treatment. The use of biofertilizers and mixed fertilizers reduces insoluble fiber and improves forage digestibility[19].

Conclusion

Ensuring an ample supply of high-quality forage is crucial in light of the growing global population and escalating demands for nutritional and protein resources. The findings of this experiment present

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compelling evidence that the synergistic cultivation of vetch and coriander, leveraging their medicinal forage properties, can significantly enhance both biomass yield and quality attributes. Moreover, the strategic use of biofertilizers, particularly in conjunction with Zeoponic, emerges as a promising approach with the potential to positively influence both the quantitative and qualitative aspects of medicinal forage production.
Significantly, intercropping strategies incorporating vetch and coriander, complemented by the incorporation of Zeoponic fertilizers, may serve as environmentally friendly solutions for effective weed management and biomass reduction.

Conflict of interest
The authors declare that there is no conflict of interest.

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Author contributions
G.S. and M.C. designed and directed the project; G.S., Y.K., K.S. and S.K. performed the experiments; G.S. and K.S. analyzed the results; G.S. and M. C. developed the theoretical framework; G.S., K.S and S.K. wrote the article.

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