

Effect of Vetch and Grass Pea Intercropping with Barley on Yield, Seed Multiplication Ratio, Broad-Leaved Weed Suppression

¹Hoda Abou Younes, ²Abdul Aziz Niane, ³Khaled Al Shamaa and ⁴Muhammad Imtiaz

¹International Center for Agricultural Research for Dry Areas, Zahle 1801, Bekaa, Lebanon

²International Center for Agricultural Research for Dry Areas, Ministry of Climate Change and Environment, Sheikh Zaid Road, United Arab Emirates

³International Center for Agricultural Research for Dry Areas, 2 Port Said, Victoria Sq, Ismail El-Shaer Building, Maadi, Egypt

⁴International Center for Agricultural Research for Dry Areas, National Agriculture Research Center, Park Road, Pakistan

Corresponding Author: Hoda Abou Younes (h.abou-younes@cgiar.org)

ABSTRACT

Background and Objective: Intercropping cereals with legumes can improve crop productivity, suppress weeds, and enhance the efficient use of soil resources. This study aimed to evaluate the effects of different mixture rates of vetch and grass pea with barley on grain yield, biomass yield, seed multiplication ratio, and broadleaf weed suppression. **Materials and Methods:** Four mixture ratios of legume and barley were evaluated: 100:0, 75:25, 50:50, and 25:75. The effects of increasing seeding rates and different crop mixtures on grain and biomass yields, seed multiplication ratio, and broadleaf weed biomass and stem density were assessed. The trial followed a randomized complete block design with two treatment factors: Biomass yield potential (2 levels: High biomass and low biomass) and [barley:legume] mixture ratio (4 levels: 100:0, 75:25, 50:50, and 25:75), replicated 3 times in 2019 and 4 times in 2020 and 2021. The effects of increasing seeding rates and different crop mixtures was evaluated against 5 parameters: Grain yield, biomass yield, seed multiplication ratio, broadleaf weed biomass yield and broadleaf weed stem density. **Results:** Increasing the seeding rate significantly increased the relative grain and biomass yields of the three crops. Mixed cropping produced significantly higher total forage yields than the respective pure stands. The seed multiplication ratio was highest under the 25:75 mixture ratio. Intercropping also significantly reduced broadleaf weed biomass and the number of weed stems. However, no significant differences in weed suppression were observed among the different mixture ratios. **Conclusion:** The findings demonstrate beneficial interactions between barley and legume crops in mixed cropping systems. Barley may contribute to weed suppression and provide physical support to the legume crops, while vetch and grass pea may improve soil fertility through biological nitrogen fixation. Appropriate barley-legume mixtures may therefore provide a promising strategy for improving forage productivity and weed management.

KEYWORDS

Barley, vetch, grass pea, mixed cropping

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INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereals crops in the world for being grown in a large diversified geographic area¹. It is a fast growing and highly adaptable crop^{2,3} that is well adapted to Mediterranean low rainfall environments as well as highlands and mountains and is grown in marginal low-input production systems^{1,4,5}. It is considered a weed suppressant due to its well-holding root system and its allelopathy with weeds through its ability to a quick establishment during the early stages of growth and shading out the weeds⁶.

Legumes, on the other hand, are characterized by having a symbiotic reaction with bacteria called Rhizobia, which allows the legumes to fix the atmospheric nitrogen (known as "Biological Nitrogen Fixation"), making it available to the plant⁷⁻⁹. In addition, legumes play an important role in crop rotation systems, especially in cereal-based systems, by breaking the cycle of weeds, pests, and diseases¹⁰.

Mixed cropping of cereal crops with legumes is an agricultural practice where the two crops (one cereal crop and one legume crop) are grown in the same space at the same time, and without a specific crop arrangement, favoring biological interactions¹¹⁻¹⁴. Mixed cropping practices play a role in increasing resource utilization, improving soil physical and microbial properties, and increasing weed suppression, all leading to higher yields^{6,12,15}.

While legumes increase the soil's nitrogen content through biological N fixation, cereal crops absorb the available nitrogen and play the role of nutrient recycler in soils with high nitrogen levels; in this context, a mixture of cereals and legumes intercropped creates a balance in the soil's nitrogen content⁶. It has been also proved that intercropping enhances the number of microbial communities in the soil, which improves the soil nutrient status, leading the higher yields^{12,16}.

Additionally, in mixed cropping with legumes, barley plays the role of a "nurse crop" and provides physical support to legume crops like vetch and grass pea, which enhances its stand, increases its light exposure, and facilitates its mechanical harvestability⁶.

Finally, intercropping two crops that share the field only part of the season, like the association of forages with oats, barley, or wheat, is an effective weed suppression strategy that optimizes the resources usage of sunlight and nutrients during the early stages of the forage development¹³.

This study was planned to evaluate the effect of different mixture rates of vetch and grass pea mixed cropped respectively with barley on grain yield components, biomass yield, seed multiplication ratio, and broad-leaved weed suppression.

MATERIALS AND METHODS

Study area and duration: This study was conducted in three different locations in the Bekaa area throughout three growing seasons (2018/2019, 2019/2020, and 2020/2021). In all three environments dominate a Mediterranean Climate.

Study design: A local variety of a 2-row Barley (*Hordeum vulgare, harmal*), 2 accessions of vetch (*Vicia* sp.) and grass pea (*Lathyrus* sp.) were studied (Table 1). In addition to the crop effect, the legume biomass yielding potential and the seeding rate ratio between the barley and the legumes were also studied.

The randomized complete block design was adopted, and the experimental plot consisted of 4 rows of 5 m length and 0.3 m spacing between the rows. Vetch and grass pea were planted as pure stands, and mixed cropped with barley at [25:75], [50:50], and [75:25] of [Legume:Barley] ratios. The seeding rates at

Table 1: List of planting materials

Crop	Biomass yielding potential	Designation
Vetch	High biomass	IG60209
	Low biomass	IG60433
Grass pea	High biomass	Bang-227
	Low biomass	Bang-226

Table 2: Experimental design, studied factors and treatments

Crop	Factor 1: Biomass yielding potential	Factor 2: Seeding mixture ratios
Vetch (<i>Vicia</i> sp.)	High biomass	100% Legumes
		75% Legumes+25% Barley
		50% Legumes+50% Barley
		25% Legumes+75% Barley
	Low biomass	100% Legumes
		75% Legumes+25% Barley
		50% Legumes+50% Barley
		25% Legumes+75% Barley
Grass pea (<i>Lathyrus</i> sp.)	High biomass	100% Legumes
		75% Legumes+25% Barley
		50% Legumes+50% Barley
		25% Legumes+75% Barley
	Low biomass	100% Legumes
		75% Legumes+25% Barley
		50% Legumes+50% Barley
		25% Legumes+75% Barley

pure stands were 100 seeds/m² for legumes and 300 seeds/m² for barley. The ratio used in the mixtures represents the percentage of the pure stand seeding rate for each crop. The different factors and treatment combinations are summarized in Table 2.

Statistical analysis: The statistical analysis was done using the WALD test through the REML analysis procedure with the modeling parameters consisting of the crop, biomass yielding potential, and the mixture ratios as fixed effects and the year and the replication as random effects. The table of means was associated with the SED divergence metrics. The calculated LSD (using the formula $LSD \approx 2 \times SED$), 5% probability was used to compare means between the different treatment factors.

Experiment: The agricultural practices were homogenized across the three seasons. A deep ploughing was performed during September, followed by an application of a top-dressing of 200 kg/ha of slow-release compound fertilizer (15N-15P-15K) during November. Soil cultivation using the rotary plough was performed for seedbed preparation. Seed sowing occurred in early December using a mechanical linear sowing machine. No pest control (herbicide, pesticide, and/or fungicide) was administered to the mixture of crops. Finally, one complementary irrigation of 40 mm aimed at enhancing heading for barley, and flowering and fruit set for the legume crops took place in April.

Data analysis: Data for different parameters were collected and analyzed as described below:

- **Grain yield (kg/ha):** The grain yield in kg/ha for clean seeds for each of the legumes and barley crops was calculated using the formula¹⁷:

$$\text{Grain yield (kg/ha)} = \frac{\text{Grain yield (g/plot)}}{\text{Plot size (m}^2\text{)}} \times 10$$

- **Total grain yield (kg/ha):** The total grain yield was calculated by adding both the legumes yield (kg/ha) and barley yield (kg/ha) together

- **Biomass yield (kg/ha):** To calculate the biomass yield, 0.5 linear meters were collected randomly by hand from the inner rows of the plot at the full maturity stage and weighed using the electronic balance. No biomass separation was made between the legumes and barley crops; the biomass yield of the mixed crops was studied. Considering that the plot length is 5 m, the number of rows in each plot is 4 and the total plot area is 6 m², the biomass yield per hectare (kg/ha) was calculated using this formula¹⁷:

$$\begin{aligned}\text{Biomass yield (kg/ha)} &= \frac{\text{Biomass yield (g/plot)}}{\text{Plot size (m}^2\text{)}} \times 10 \\ &= \frac{\text{Biomass yield in 0.5 m (g)} \times 2 \times 5 \text{ (m)} \times 4 \text{ (rows)}}{\text{Plot}} \times 10\end{aligned}$$

- The seed multiplication ratio (SMR), which represents the quantity of seeds produced (g) from a single seed planted, was calculated using the following formula¹⁸:

$$\text{SMR (g/seed)} = \frac{\text{Grain yield (kg/ha)}}{\text{Seeding rate (seed/m}^2\text{)}} \times 10$$

- The weed suppression effect was studied by collecting randomly 0.5 linear meters at the full maturity stage, the number of broad-leaved weeds' stems were counted, and their biomass yield was weighed. The formula used to calculate the number (Nb) of stems per m² is¹⁷:

$$\begin{aligned}\text{Nb. Stems (Stems / m}^2\text{)} &= \frac{\text{Nb. Stems per plot}}{\text{Plot size (m}^2\text{)}} \\ &= \frac{\text{Nb. Stems per 0.5 linear m} \times 2 \times 5 \text{ (m)} \times 4 \text{ (rows)}}{6 \text{ (m}^2\text{)}}\end{aligned}$$

- The formula used to calculate the broad-leaved weeds' biomass yield in kg/ha is¹⁷:

$$\begin{aligned}\text{Biomass yield (kg/ha)} &= \frac{\text{Biomass yield per plot (g/plot)}}{\text{Plot size (m}^2\text{)}} \times 10 \\ &= \frac{\text{Biomass yield per 0.5 linear m} \times 2 \times 5 \text{ (m)} \times 4 \text{ (rows)}}{6 \text{ (m}^2\text{)}}\end{aligned}$$

RESULTS

Effect of crop mixtures on grain and biomass yield: Growing crop mixtures of legumes (*Vicia* sp. and *Lathyrus* sp.) and spring barley (*Hordeum vulgare*) had a significant effect on the legumes' grain yield ($F_{pr} < 0.001$), regardless of the crop. The legumes' grain yield showed a significant decrease ($LSD = 95.44$) when the mixture ratio of the legume crop decreased (Table 3).

Regarding the barley's grain yield, it was also significantly affected by the mixture ratio: The grain yield of barley increased with the increase in the mixture ratio (Table 3).

There was an interaction between the crop and the mixture ratio. vetch and grass pea were both affected by the mixed cropping system ($F_{pr} = 0.002$) where the highest legumes grain yield was observed when vetch and grass pea were planted with pure crop stands (Avg. Yield (vetch) = 981.1 kg/ha; Avg. Yield (grass pea) = 824.0 kg/ha) while the lowest grain yield was observed when the legumes were planted in a 25:75 ratio (Avg. Yield (vetch) = 177.6 kg/ha; Avg. Yield (grass pea) = 168.0 kg/ha). The difference in grain yield was not significant when the legumes were planted in a ratio of [75:25] and [50:50].

Table 3: Average grain yields per mixture ratios

	Mixture ratio				F pr	LSD
	100% legumes	75% Leg.+25% Bar.	50% Leg.+50% Bar.	25% Leg.+75% Bar.		
	Avg. grain yield (kg/ha)					
Legumes	902.6 ^a	468.7 ^b	367.0 ^c	172.8 ^d	<0.001	95.44
Vetch	981.1 ^a	422.4 ^b	312.5 ^b	177.6 ^c	0.022	134.98
Grass Pea	824.0 ^e	515.1 ^f	421.4 ^f	168.0 ^g		
Barley	-	1091 ^a	1453 ^b	1613 ^c	<0.001	141.4

Different lowercase letters within the same row indicate significant differences among mixture ratios according to the Least Significant Difference (LSD) test at $p < 0.05$. Leg. = Legumes, Bar. = Barley, LSD = Least significant difference, F = F-statistic, $p < 0.05$ indicates statistical significance. "-" Indicates that the treatment was not applicable

Table 4: Decrease (in %) of the legumes grain yield in mixed cropping compared to the pure stands

Grain yield decrease	75% Leg.+25% Bar.	50% Leg.+50% Bar.	25% Leg.+75% Bar.
Vetch	-57%	-68%	-82%
Grass pea	-38%	-49%	-80%

:- Sign indicate decrease in percentage

Table 5: Averages of the total grain yields and total biomass yields for the barley and the legume crops

	Mixture ratio				F pr	LSD
	100% legumes	75% Leg.+25% Bar.	50% Leg.+50% Bar.	25% Leg.+75% Bar.		
Total yields (kg/ha)						
Grain yield	946 ^a	1532 ^b	1691 ^b	1684 ^b	<0.001	239.6
Biomass yield	7974.49 ^a	10899.36 ^b	11513.29 ^b	10983.04 ^b	<0.001	8.492

Different lowercase letters within the same row indicate significant differences among mixture ratios according to the Least Significant Difference (LSD) test at $p < 0.05$. The effect of mixed cropping legumes with barley on the total grain yield and the total biomass yield was not affected by the biomass-yielding potential of the crop since there was no significant interaction between the mixture ratio and the biomass-yielding potential ($F_{pr(\text{Grain yield-leg.})} = 0.642$, $F_{pr(\text{Grain yield-bar.})} = 0.804$, $F_{pr(\text{Grain yield-tot.})} = 0.951$, $F_{pr(\text{Total Biomass Yield.})} = 0.932$)

There was an interaction between the crop and the mixture ratio. vetch and grass pea were both affected by the mixed cropping system ($F_{pr} = 0.002$) where the highest legumes grain yield was observed when vetch and grass pea were planted with pure crop stands (Avg. Yield (vetch) = 981.1 kg/ha; Avg. Yield (grass pea) = 824.0 kg/ha) while the lowest grain yield was observed when the legumes were planted in a 25:75 ratio (Avg. Yield (vetch) = 177.6 kg/ha; Avg. Yield (grass pea) = 168.0 kg/ha). The difference in grain yield was not significant when the legumes were planted in a ratio of [75:25] and [50:50].

When comparing the grain yield between the two legumes crops, the decrease in grain yield was more important in vetch than in grass pea where the vetch grain yield decreased by 57% for the [75:25] ration, 68% for the [50:50] ratio and 82% for the [25:75] ration, compared to a 38%, 49% and 80% of decrease in the grain yield for the [75:25], [50:50] and [25:75] ratios respectively (Table 4).

Mixed cropping of legumes with barley revealed to have a significantly positive effect on the total grain yield (sum of the grain yield of both barley and the legume crop) and the total biomass yields (sum of the biomass yield of both barley and the legume crop) ($F_{pr} < 0.001$). Total grain yields and total biomass yields were significantly lowest in the pure crop stands, while both yields increased with the introduction of barley in the mixed crop-ping. In addition, the yields were not statistically different between the different mixture ratios. Whether we substituted 25%, 50%, or 75% of the legume's seeds by barley seeds, the difference in the total grain yields and biomass yields remained statistically the same (Table 5).

Effect of mixed cropping on the seed multiplication ratio (SMR): The seed multiplication ratio (SMR) for both legume crops and barley was significantly affected by the mixed cropping system ($F_{pr} < 0.001$). While the SMR for the grass pea remained statistically similar across all the mixture ratios, the SMR for the

Table 6: Average seed multiplication ratios for the different crops and mixture ratios

SMR (legumes)	Mixture ratio				F pr	LSD
	100% legumes	75% Leg.+25% Bar.	50% Leg.+50% Bar.	25% Leg.+75%Bar.		
Vetch	1.1031 ^a	0.6254 ^b	0.6918 ^b	0.6601 ^b	0.046	0.219
Grass pea	0.9433 ^a	0.7764 ^a	0.9505 ^a	0.8033 ^a		
Barley	-	0.485 ^a	0.939 ^b	2.073 ^c	<0.001	0.1854
Total	1.053 ^a	0.525 ^b	0.866 ^a	1.723 ^c	<0.001	0.18182

Different lowercase letters within the same row indicate significant differences among mixture ratios according to the Least Significant Difference (LSD) test at $p < 0.05$

Table 7: Average biomass yields and number of stems of broad-leaved weeds per mixture ratio

Broad-leaved weeds	Mixture ratio				F pr	LSD
	100% legumes	75% Leg.+25% Bar.	50% Leg.+50% Bar.	25% Leg.+75% Bar.		
Biomass yield (kg/ha)	986.1 ^a	509.4 ^b	317.7 ^b	328.5 ^b	<0.001	259.6
Nb. Stems/m ²	89.96 ^a	33.46 ^b	22.19 ^b	25.05 ^b	<0.001	1.582

Different lowercase letters within the same row indicate significant differences among mixture ratios according to the least significant difference (LSD) test at $p < 0.05$. Leg. = Legumes, Bar. = Barley, LSD = Least significant difference, F = F-statistic, $p < 0.05$ indicates statistical significance. The biomass-yielding potential of the legumes crop did not interfere with the effect of the mixture ratios on the broad-leaved weeds density (F pr = 0.758 and F pr = 0.122 for the biomass yield and number of stems, respectively)

vetch decreased on average by 40% when moving from the pure crop stand planting to the mixture, with no significant difference between the different mixture ratios. On the other hand, the cereal SMR increased significantly when the density of barley increased (Table 6).

The crop mixtures had a significant effect on the SMR independently from the different crops (F pr < 0.001, LSD = 0.18182). The lowest SMR reached a value of 0.525 when the mixture consisted of 75% legumes and 25% barley. When the barley density increased from 25% to 75%, the total SMR increased from 0.525 to 1.723 (Table 6). In addition, the SMR for the pure crop stand planting ($SMR_{[100:0]} = 1.053$) and for the [50:50] mixture ratio ($SMR_{[50:50]} = 0.866$) were not significantly different.

The effect of mixed cropping of legumes with barley on the SMR was not affected by the biomass-yielding potential of the crop since there was no significant interaction between the mixture ratio and the biomass-yielding potential (F pr(SMR-LEG.) = 0.981; F pr(SMR-BAR.) = 0.613; F pr(SMR-TOT.) = 0.604).

Effect of mixed cropping on the broad-leaved weeds: The biomass yield of broad-leaved weeds (main weeds found are wild chamomile, gallium and field bindweed) as well as the number of stems of broad-leaved weeds per unit area was significantly affected by the mixed cropping (F pr < 0.001) (Table 7).

While the weeds' biomass yield and number of stems were not significantly different between the [75:25], [50:50] and [25:75] mixture ratios, the broad-leaved weed density was significantly the highest with the pure crop stands where the weeds biomass yield reached 986.1 kg/ha and the number of stems reached 89.96 stems/m² (Table 7). Compared with the [100:0] ratio, the weeds' biomass yield significantly dropped by 51% with the [75:25] ratio (from 986.1 kg/ha to 509.4 kg/ha), by 68% with the [50:50] ratio (from 986.1 kg/ha to 317.7 kg/ha) and by 67% with the [25:75] ratio (from 986.1 kg/ha to 328.5 kg/ha). On the other hand, the weeds' number of stems significantly dropped by 63% with the [75:25] ratio (from 89.96 kg/ha to 33.46 kg/ha), by 75% with the [50:50] ratio (from 89.96 kg/ha to 22.19 kg/ha) and by 72% with the [25:75] ratio (from 89.96 kg/ha to 25.05 kg/ha) (Table 7).

DISCUSSION

This study aimed to evaluate the effect of mixed cropping vetch (*Vicia* sp.) with barley (*Hordeum vulgare*) and grass pea (*Lathyrus* sp.) with barley on the yield, seed multiplication ratios, and broad-leaved weed suppression. Three mixture [Legume: Barley] ratios ([75:25], [50:50], [25:75]) in addition to the pure stand planting [100:0] were studied.

The legumes grain yields for both vetch and grass pea were negatively affected by the mixed cropping, where the highest grain yield was observed in the legume's pure stands and the lowest with the [25:75] ratio. For the legume crops as well as the barley crop, the grain yield significantly increased with the increase of their relative seeding rate.

These findings suggest that barley has higher competition over the vetch and grass pea crops when grown as mixed crops because pure legume stands produced higher grain yields than mixed cropping systems. This could be attributed to the high adaptability and fast-growing properties of barley^{2,3} in addition to its strong, fibrous root system and its ability to quickly establish during the early stages of growth⁶.

On the other hand, mixed cropping improved the total grain yield and total biomass yield, where the lowest yields were observed in the [100:0] mixture ratio. The mixture ratios did not have a significant effect on yield, and all mixture ratios generated statistically the same yields.

Several studies have reached the same conclusion that mixed cropping systems had higher forage yields than pure stands^{19,20}. Turk and Tawaha²¹ reported that mixed cropping of hairy vetch with barley had 96% higher yields than pure stands of legumes. While in our study the three mixture ratios were not significantly different in terms of total yields, Seyedeh *et al.*²⁰ who studied the same mixture ratios, found that the highest yields were obtained with the [50:50] ratio, with no significant difference between the [25:75] and [75:25] ratios.

In addition, some studies that evaluated the nutrient intake of mixed cropping and sole cropping concluded that mixing legumes with barley improved the use of resources and increased nutrient absorption from the soil²⁰⁻²².

Moreover, the fact that vetch and grass pea are both climbing and lodging plants^{23,24} makes mechanical harvestability less effective and results in losses in harvested grains and biomass. In mixed cropping, barley plays the role of physical support for the vetch and grass pea crops and improves their establishment and mechanical harvestability resulting in higher forage yields^{25,26}.

When evaluating the SMR, different trends were observed. When studied separately, the legumes and the barley SMR both increased with the increase of their relative ratios. The highest legumes SMR was observed in the pure stands [100:0] while the legumes' lowest SMR, and the barley's highest SMR, were with the [25:75] ratio. When combining both the legumes and the barley yields, the total SMR had a different trend. The highest SMR was with the [25:75] ratio, and the lowest was in the [75:25] ratio. The pure stand [100:0] and the [50:50] ratio had a statistically similar SMR. This implies that the higher the proportion of barley in the mixture, the higher the SMR.

The significant difference in the SMR emphasizes the synergic effect between the legumes crop and the barley, and the significant effect of the different mixture ratios, even though they had no significant effect on the yields. Several studies have confirmed the significant influence of seed rate on the seed multiplication ratio, where decreasing seed rates significantly increased the SMR with no significant effect on the seed yield^{27,28}.

Weed suppression is another advantage observed in this study of mixed cropping systems. The broad-leaved weeds' biomass yield and the number of stems significantly decreased with the mixed cropping system, compared to the pure stand legumes. However, no significant effect was reported between the different mixture ratios.

Regardless of the mixture ratio, the introduction of barley in the mixture suppressed the broad-leaved weeds. This can be attributed to the barley's fast establishment ability in the early stages of the cycle and competing with the broad-leaved weeds and consequently preventing their early development⁶. The same findings were concluded by²⁷ where mixed-cropped barley and chickpea resulted in a 66% decrease in the total weed density and a 90% decrease in the weed biomass.

CONCLUSION

In conclusion, mixed cropping of vetch and grass pea with barley has an advantage over pure stand crops. Mixed cropping systems lead to an increase in the total forage yield and a decrease in the number of stems and the biomass yield of broad-leaved weeds. The seed multiplication ratio was also influenced by the mixed cropping system.

Based on these findings, the [25:75] legume-to-barley ratio emerges as the most suitable mixture, combining strong forage yield, effective weed suppression, and the highest seed multiplication ratio, making it the most efficient option for both forage production and seed increase programs. Further research is recommended to validate this ratio's performance across a wider range of agroecological zones, soil types, and rainfall regimes, and to evaluate its long-term effects on soil fertility and cropping system sustainability under farmer-managed field conditions.

SIGNIFICANCE STATEMENT

Farmers in dry, low-rainfall regions often struggle to grow enough forage and feed for their animals while also keeping soil healthy and weeds under control. This study shows that growing barley together with vetch or grass pea in the same field, rather than growing each crop alone, offers clear practical benefits. The two legume crops naturally enrich the soil with nitrogen, while barley acts as a physical support that keeps the climbing legumes upright, making harvesting easier and reducing crop losses. Barley also establishes quickly, which helps crowd out weeds that would otherwise compete with the crops for light, water, and nutrients. Testing four different planting ratios over three growing seasons, this research found that mixed cropping consistently produced more total forage than growing any single crop alone, while also producing significantly less weed growth than legumes planted by themselves. It further identified the seed ratio that gave farmers the best return in terms of seed available for future planting. These findings offer farmers and land managers a practical, low-cost strategy to boost forage production, improve soil fertility naturally, reduce reliance on weed control, and secure their own seed supply for the next planting season, supporting more resilient and sustainable farming systems in dry-area environments.

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