PLANT SCIENCE TODAY, 2021
Vol 8(2): 373–379
https://doi.org/10.14719/pst.2021.8.2.871
ISSN 2348-1900 (online)

HORIZON
e-Publishing Group
HePG

Check for updates

OPEN ACCESS

RESEARCH ARTICLE

Evaluation of yield, yield components and nutritive value in intercropping of Barley with Vetch

Bijan Kahraryan[1], Farhad Farahvash[*2], Soleyman Mohammadi[3], Bahram Mirshekari[2] & Varharam Rashidi[2]

[1]Department of Agronomy, Tabriz Branch, Islamic Azad University, Tabriz, Iran
[2]Department of Agriculture, Tabriz Branch, Islamic Azad University, Tabriz, Iran
[3]Seed and plant improvement research Department, West Azerbaijan Agricultural and Natural Resources Research Center, AREEO, Urmia, Iran
*Email: *farahvash@iaut.ac.ir*

ARTICLE HISTORY
Received: 19 July 2020
Accepted: 18 December 2020
Published: 28 April 2021

KEYWORDS
Barley
Dry matter
Forage quality
Intercropping
Vetch

ABSTRACT
To evaluate some agronomic properties and forage characteristics in the intercropping of barley (*Hordeum vulgare* L.) and vetch (*Vicia ervilia* L.), an experiment was conducted during 2014-2016 cropping seasons. A randomized complete block design with four replications was used. Intercropping patterns included 80% barley+ 20% vetch, 60% barley+ 40% vetch, 40% barley + 60% vetch and 20% barley + 80% vetch along with the sole culture of both crops (100% barley and100% vetch). The result showed that the highest value of plant height, grain number, thousand-grain weight, biological yield, grain yield and harvest in barley was observed from 80% barley + 20% vetch intercropping ratio, however, for vetch, it was detected from 100% vetch. Furthermore, the highest land equivalent ratio was obtained from 80% barley+ 20% vetch. Based on the results, the highest crude protein content and dry matter digestibility were observed in sole cropped vetch, whereas the highest neutral detergent fiber and acid detergent fiber were recorded in sole cropped barley. These results suggested that intercropped barley and vetch as 80% barley + 20% vetch ameliorated the grain yield and yield components, and forage quality compared to other intercropping ratios.

Introduction

Intercropping of cereal with legume species is additionally extensive. Intercropping is defined as the simultaneous planting of two or more crops in the same field that gives the feasibility of yield advantage in accordance with the pure system (1, 2). One of the most important advantages of mixed cultivation compared to sole cropping is the increase in production per unit area, which is achieved through the effective use of production resources such as water, nutrients and solar energy (3). The most usually employed intercropping system is to combine the legume crop with non-legume to utilize the legume's potential to fix environmental nitrogen. However, the advantages of intercropping are not limited to legume composition in the mixture (4); it can be the transfer of fixed nitrogen from legumes to associated cereals, and increase in the utilization of the light by providing support to legume and facilitates mechanical harvesting (5, 6).

Mixed sowing of two or more non-legume crops may culminate in yield benefits that may arise due to structural, phenological, physiological and genetic diversity within intercrops that result in advantageous interactions among crops and between crops and environment (7, 8).

In intercropping of vetch with cereal, cereals give architectural support for vetch growth, increasing light penetration, and providing mechanical harvest (9). Various small grain cereals and vetches have been successfully utilized in cereal with legume intercropping systems (10-12). Moreover, cereals are rich in carbohydrates while legumes are rich in proteins, serving a better

To cite this article: Kahraryan B, Farahvash F, Mohammadi S, Mirshekari B, Rashidi V. Evaluation of yield, yield components and nutritive value in intercropping of Barley with Vetch. Plant Science Today. 2021;8(2):373–379. https://doi.org/10.14719/pst.2021.8.2.871

Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, etc.
Full list at http://www.plantsciencetoday.online

digestive and nutritious feed for animals, also cereal-legume intercropping plays a crucial role in soil protection (13). It was reported that Barley intercrops with legumes improved forage quality compared to pure stand of Barley (14).

It was demonstrated that the highest crude protein yield belonged to Hungarian vetch + oat intercropping, also shown that sole Hungarian vetch and Hungarian vetch + barley intercropping mixture had the highest protein content (15). Furthermore, the intercropping of barley with annual medic in a 1:1 ratio was excellent compared to any other proportions (16). It was found that both intercropping system of vetch with barley and Hungarian vetch with barley at a seeding proportion of 80% + 20%, had the highest yield compared to other mixtures and pure stands due to land-use efficiency and economic value (17). An increase in yield by 32% was observed from barley and annual medic intercropping when they were planted in a ratio of 2:2 (16).

It has been shown that 60% of grass pea with 40% wheat intercropping ratio had the best results in terms of yield and quality. Furthermore, it was also reported that wheat and grass pea mixtures have more advantages than the pure stand of both species (18). It was demonstrated that the highest forage dry matter (9 t/ha) and LER ratio (1.71) was reported in the barley and vetch intercropping ratio. Similarly, in this study, pure stands cultivation had the highest percentage of forage protein (19).

The previous study just explored the effect of the intercropping system of vetch with barley on forage yield and yield component, but its effect on forage quality has remained unknown. In this regard, the objectives of this study were to assess the effect of intercropping of barley with vetch on forage nutritive value, grain yield and yield components.

Materials and Methods

This field experiment was carried out in 2014 and 2016 cropping seasons at the Agricultural and Natural Resources Research Station of Miandoab (West Azarbaijan Province, Iran 46 °30´W, 36°58´ S altitude 1365 m). This region of Iran is classified as a semi-arid area and is recognized for its short spring and dry summer. Mean temperatures and the total rainfall during growing seasons were 11.8 ºc and 296.50 mm respectively.

To determine the soil properties, the soil samples were taken from a depth of 30 cm. The results of soil analyses are shown in Table 1. The soil was sandy clay soil with (pH 7.20) and had 0.11 % total nitrogen and 1.1% organic matter.

A randomized complete block design with four replications was used. The plant materials included the Iranian barley cultivar (*Hordeum vulgare* cv. Karoon × Kavir, six rows) and native vetch (*Vicia ervilia* L.). Intercropping patterns included of 80% barley + 20% vetch (80B:20V), 60% barley + 40% vetch (60B:40V), 40% barley + 60% vetch (40B:60V), 20% barley + 80% vetch (20B:80V) along with sole culture of both crops (100% barley and 100% vetch). Agronomic practices including ploughing, disk harrowing, field levelling, weed and pest management for each plot were applied equally for all treatments. Planting was done manually in the second week of November. Each block consisted of six plots, the plot size was 5 m^2 and row spacing was 5cm. The 400 and 300 seeds/m^{-2} were planted and each plot was fertilized with a total of 50 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

At the physiological maturity stage, excluding guard rows, 0.5 m^2 of all rows within each plot were hand-harvested for the determination of biomass and grain yield of both crops on the 10 th of July.

Land equivalent ratio (LER) was utilized to quantify the effectiveness of the intercropping treatments.

LER= (Yxy/Yxx) + (Yyx/Yyy)

In the formula, Yxx and Yyy are the yields of sole crops and Yxy and Yyx are the yields of intercrops.

In the second week of April at the pod formation stage (coincided with the milky stage of barley), all sole cropping and intercropping treatments were manually harvested at both years. samples from a randomly selected 1 m^2 area of each plot were cut to ground level.

To determine forage quality, after harvesting 1 kg of green forage, subsamples from each treatment were dried at 70 °C for 48 hrs.

The percentages of forage protein were measured by the Kjeldahl method.

Nitrogen, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)

After measuring the total nitrogen of the sample by applying a coefficient of 6.25, the percentage of crude forage protein in different treatments was calculated. NDF and ADF were analyzed in line with the standard method (9) by adding α-amylase without sodium sulfite and using the ANKOM filter bag system with A220 fiber analyzer (ANKOM Technology, Fairport, NY) and expressed as exclusive residual ash.

Statistical analysis

Statistical analysis was conducted with SAS 9.2 software and the mean of treatments was compared with Duncan's multiple range test (DMRT) at a significant level of 0.01.

Table 1. Soil physical and chemical characteristics of the experimental site

EC ds/m	Saturation%	pH	Lime%	Clay%	Sand%	Organic Matter (%)	Available potassium (ppm)	Available phosphorous (ppm)	Total nitrogen (%)
1.3	49	7.2	17	31	25	1.1	335	4.8	0.11

Results and Discussion

Plant height

Based on the results of variance analysis (Table 2, 3), intercropping had a significant effect($p < 0.01$) on plant height in barley and vetch. Results of this study showed that the highest height of barley was observed under 80B:20V intercropping ratio with an average of 101.12 cm and the lowest plant height was recorded from 20B:80V intercropping ratio (Table 4). Furthermore, the highest plant height of vetch belonged to the intercropping ratio of 20B:80V by average 61.23 cm, although there was no significant difference between this treatment and treatment of 100V (Table 4). The increase in plant height of barley at 80B:20V intercropping ratio can be related to an increase in nitrogen availability, which was fixed by legume and the presence of complementary effects of the intercrop (20). It was also reported in another study that the plant height of cereals was not influenced by the intercropping system, while faba bean height was affected (21). Similarly, in this study, the faba bean height significantly increased under intercropping practice due to its effort to achieve more light (22, 23).

Number of grain

The result showed that intercropping ratio had a significant effect ($p < 0.01$) on grain number per spike in barley and seed number per plant in vetch (Table 2, 3).

As shown in Table 4, the intercropping ratio of 80B: 20V showed the highest number of grain number per spike by 48.11 grains and seeds number per spike by 6.13% compared to pure crop (100B). The lowest amount of grain number per spike, with 40.22 grain per spike was observed under the intercropping ratio 20B:80V.

The maximum and minimum grain number per plant in vetch was achieved from 100V and 80V:20V

Table 2. Combined analysis of variance for barley characteristics

Mean of Squares						
Sov	df	Plant height	Grain number	Thousand-grain weight	Biological yield	Grain yield
Year	1	12.38^{ns}	125.92^{ns}	195.83^{ns}	**6984.17	2971.45^{ns}
E1	6	3.15	130.06	90.51	5871.02	2780.41
Intercropping ratio	5	120.14**	**224.13	**761.80	1675.05**	3073.10**
Year× Intercropping ratio	5	28.4^{ns}	^{ns}104.95	227.31^{ns}	508.55^{ns}	718.05^{ns}
E2	30	19.8	50.37	169.63	341.25	416.55
CV	-	15.81	15.41	10.38	17.54	21.12

ns: Non- significant, * and ** : significant at 5% and 1% probability levels, respectively

Table 3. Combined analysis of variance for vetch characteristics

Mean of Squares						
Sov	df	Plant height	Grain number	Thousand-grain weight	Biological yield	Grain yield
Year	1	60.72^{ns}	173.66^{ns}	80.03^{ns}	7701.25^{ns}	671.1^{ns}
E1	6	25.13^{ns}	51.43	57.3	1250.68	442.8
Intercropping ratio	5	141.94**	90.35**	220.5**	2205.65**	731.3**
Year× Intercropping ratio	5	10.29^{ns}	34.20^{ns}	41.4^{ns}	295.02^{ns}	133.9^{ns}
E2	30	30.07	19.30	59.9	154. 41	56.8
CV	-	19.01	20.15	11.25	15.96	14.12

ns: Non- significant, * and ** : significant at 5% and 1% probability levels, respectively

Table 4. Mean comparisons for yield and yield components of barley and vetch

	Intercropping ratio	Plant height (cm)	Grain number	Thousand-grain weight (g)	Biological yield (ton ha^{-1})	Grain yield (ton ha^{-1})	Harvest Index (%)
Barley	100% barley	89c	45.33b	41.18b	16.94a	5.841b	34.47c
	80% Barley + 20% Vetch	101	48.11a	45.25a	14.67b	6.14a	42.85a
	60% Barley + 40% Vetch	95b	45.19b	44.12a	13.57bc	4.741c	35.29c
	40% Barley + 60% Vetch	78d	44.12b	34.12c	12.43c	4.72c	38.01b
	20% Barley + 80% Vetch	75d	40.22c	40.12b	10.21d	3.56d	35.66c
	100%Vetch	-	-	-	-	-	
Vetch	100% barley	-	-	-	-	-	
	80% Barley + 20% Vetch	49.33c	10.51c	27.18b	1.15c	0.42e	37.21c
	60% Barley + 40% Vetch	54.11b	11.54b	24.12c	1.31bc	0.49d	37.03c
	40% Barley + 60% Vetch	56.35b	12.17b	29.25a	1.51b	0.56c	37.70c
	20% Barley + 80% Vetch	61.23a	14.25ab	30.12a	1.42b	0.705b	50.29ab
	100%Vetch	60.52a	15.83a	28.52ab	1.94a	1.02a	52.57a

Table 5. LER of barley and vetch grain yield

Intercropping ratio	Total	Vetch	Barley
80% Barley + 20% Vetch	1.43	0.38	1.05
60% Barley + 40% Vetch	1.25	0.44	0.81
40% Barley + 60% Vetch	1.31	0.50	0.81
20% Barley + 80% Vetch	1.24	0.63	0.61

intercropping ratios, respectively (Table 4). Since grain number per spike at intercropping was more than barley monoculture treatment, therefore, it can be concluded that intraspecific competition harmed this character and vetch had poor compatibility compared to barley. This can be due to the competition between barley plants and vetch for light and other resources such as water and chemical fertilizer, sole cropping of vetch had the highest seed number per pod (24).

Thousand-grain weight

Thousand-grain weight of barley and vetch was significantly ($p < 0.01$) affected by different intercropping ratios (Table 2, 3).

In barley, the highest thousand-grain weight (45.25 gr) was gained from the 80B:20V intercropping ratio which had no statistical difference with the 60B:40V intercropping ratio (Table 4). The lowest thousand-grain weight was observed under 40B:60V treatment which showed a 46.14% reduction in thousand-grain weight compared to 80B:20V intercropping ratio (Table 4). However, in vetch, the highest thousand-grain weight was detected under 20B:80V intercropping ratio with an average of 30.12 gr, while we could not observe a significant difference between it and the sole culture of vetch and 40B:60V treatment. The lowest one was recorded from 60B:40V (27.18 gr) intercropping ratio which showed a 15.42% reduction in thousand seed weight compared to pure vetch (100V). Therefore, this means that thousand-grain weight was more affected by genetic factors than environmental factors, and partial differences in a thousand -grain weight of 20B:80V intercropping ratio can be to plant density and less intraspecific competition at the intercropping system. However, under normal conditions, a more light reception and access to water, nutrients and solar radiation sole cropping of vetch may let the high performance of photosynthesis and sequentially improve yield components (25).

Biological yield

As presented in Tables 2 and 3, we observed that different intercropping ratios had a significant ($p < 0.01$) effect on barley and vetch biological yield. The maximum barley biological yield was recorded from a pure culture of barley (16.94 ton ha^{-1}) while the minimum one was gained from 20B:80V (10.21 ton ha^{-1}) intercropping ratio.

The highest biological yield in vetch was observed from a pure culture of vetch (100V) (1.94 ton ha^{-1}) was probably due to the higher unit area of land, while the minimum one was recorded from 80B:20V intercropping ratio (1.15 ton ha^{-1}) which showed a 40.81% reduction in biological yield compared to a pure stand of vetch (100V) (Table 4). The decrease in barley's biological yield can be associated with land use efficiency compared to the barley pure stand since by increasing plant density, interactions between land use will be increased, leading to a significant decrease in total dry matter and biological yield. Similarly, it has been demonstrated that intercropping of barley with alfalfa reduced the biological yield of barley 6 to 76 % compared to sole culture (26). Furthermore, it was reported that the highest biological yield of barley was observed in the pure culture of barley (27).

Grain yield

Our result revealed that grain yield in barley and vetch was significantly ($p < 0.01$) affected by the different intercropping ratio (Table 2, 3).

The highest grain yield in barley was gained under 80B:20V treatment (by 6.14 ton ha^{-1}), while the lowest one (by 3.56 ton ha^{-1}) was recorded under 20B:80V treatment (Table 4).

Based on the results, by increasing the vetch ratio in the intercropping system, the grain yield in vetch reduced, and the highest grain yield was obtained from 100V (by 1.02 ton ha^{-1}), while the lowest one was recorded in 80B:20V intercropping ratio (by 0.42 ton ha^{-1}) (Table 4). This can be related to the availability of overall nitrogen in intercropping of vetch with barely, and also, it increased the yield and yield components in vetch, and also increased the yield of a single plant, barley (3). The other advantage reasons for intercropping methods is the better use of light, water and soil nutrients in the intercropping methods than a monoculture method. This can be due to lower competition in the intercropping systems, and the competition in intercropping systems is interspecific (occur within different species) and is less than the intraspecific (occur between similar species). In harmony with our results, several researchers showed that cereal-legumes intercropping gave greater yield, stability and lower risks than monoculture (27).

Land Equivalent Raito (LER)

In the present study, the LER values were observed to be higher than 1 for all intercropping ratios of barley and vetch. The highest LER was detected in 80% barley + 20% vetch (1.43) intercropping ratios, which indicated that 43 percent more-unit land area would be required to create the same amount in a sole cropping system. After the mentioned ratio, the ratios 40% barley + 60% vetch, 60% barley + 40% vetch and 20% barley + 80% vetch were in the next positions with the values of 1.31, 1.25 and 1.24, respectively. The mean LER values were always greater than 1.0. Also, the advantage from nonlegume–legume intercropping systems have been reported previously in faba bean with barley (28), Smooth vetch with barley (19), barley and lentil (29). High values of the LER index have also been reported by other researchers (9, 12).

Forage quality

Dry Biomass

The effects of the intercropping ratio ($p < 0.01$) were significant on dry biomass (Table 6).

The results indicated that the maximum dry biomass was recorded from the 80% barley + 20% vetch and 100% barley by 6.90 and 6.19 ton/ha, whereas the minimum one was gained from the 20% barley + 80% vetch and 100% vetch by 4.53 and 4.23 ton/ha (Table 7).

Table 6. Combined analysis of variance of forage quality for barley and vetch characteristics

	Mean of Squares						
	Df	Dry biomass	(CP)	(ADF	(NDF	(DMD)	(WSC)
Year	1	98.12ns	55.97^{ns}	44.88^{ns}	9.26^{ns}	54.40^{ns}	55.42^{ns}
E1	6	36.84	160.74	36.11	21.94	52.74	24.58
Intercropping ratio	5	32.97**	368.28**	109.98**	177.39**	386.28**	129.98**
Year× Intercropping ratio	5	10.18^{ns}	133.5^{ns}	51.30^{ns}	23.36^{ns}	171.12^{ns}	41.81^{ns}
E2	30	6.05	75.11	28.06	45.11	98.93	30.12
CV							

ns: Non- significant, * and ** : significant at 5% and 1% probability levels, respectively

Table 7. Mean comparisons forage quality of barley and vetch

Intercropping ratio	Dry biomass (t/ha)	(CP%)	(ADF%)	(NDF%)	(DMD%)	(WSC%)
100% barley	6.19ab	17.56c	52.23a	58.42a	47.75c	19.13b
80% Barley + 20% Vetch	6.90a	20.04b	50.94ab	53.11b	47.77c	21.23a
60% Barley + 40% Vetch	5.55bc	21.35b	48.82abc	48.61c	51.47b	19.13b
40% Barley + 60% Vetch	5.09c	22.32ab	39.62c	45.81cd	53.11b	17.2c
20% Barley + 80% Vetch	4.23d	24.07a	35.45cd	42.28d	59.37ab	16.48c
100%Vetch	4.53d	25.18a	30.48d	39.21e	62.39a	12.71d

Means in each column with the same letter are not significantly different at P<0.05.
CP: crude protein, DMD: dry, NDF: neutral detergent fiber, ADF: acid detergent fiber,

The results showed that the dry matter yield in intercropping treatments was higher than the sole barley and vetch cropping system.

In an intercropping system, an attempt is made to minimize the degree of competition among crop species, which might negatively influence yield and quality, while creating competition by the intercrop to suppress weeds (20), thus maximizing yield.

The highest dry matter yield was recorded from the faba bean– barley 2:1 intercrop, followed by a pure culture of barley (28). In another study, the highest dry matter yield was assigned to a mixture of barley and vetch under 200 seeds/m².

Crude Protein (CP)

The results (Table 6) indicated that the effects of intercropping ratio ($p < 0.01$) on the crude protein was significant.

Results showed that in all intercropping ratios, crude protein was enhanced with an increasing vetch ratio (from 20 to 80 %) in the intercropping ratios (Table 7). In special, the 20B:80V intercropping ratio had the highest crude protein (24.07 %) followed by the 40B:60V (22.32 %) intercropping ratio. Sole cropping of barley (100B), showed the lowest crude protein (17.56 %) compare to other cropping ratios.

Improved wheat CP in intercropping systems compared to sole cropping systems was a result of a higher N uptake (30). The spatial interspecific complementarity in bi-cropping systems may have played a greater role in enhancing N-use ability (31, 32).

Other researchers also reported an increase in the crude protein in intercropping cereal with the legume (9, 27, 33), which is consistent with the results of the present study. Among all intercropping of annual legumes and barley treatments, the maximum protein content was reported in pure stands of vetch and grass pea. In a study, the maximum and the minimum crude protein were recorded in 100% grasspea and 100 % wheat, respectively (34). Furthermore, it has been reported that among bean with barley intercropping treatments the highest Crude Protein content (CP) was in the faba bean monocrop (28).

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)

Based on the results of the analysis of variance (Table 6), the Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) were significantly affected by intercropping ratios ($p < 0.01$).

Results revealed that as a proportion of vetch increased in intercropping ratios, the ADF and NDF content of the forage reduced. The minimum NDF was observed from vetch sole culture (39.21%), whereas the maximum value was obtained from barley monoculture (58.42%) followed by 20B:80V (42.28%) intercropping ratio (Table 7). It was demonstrated that the presence of cereals in mixed culture increased the ADF and NDF content of forage (17). It is stated that The highest ADF and NDF content was reported from the pure wheat stand while the lowest NDF content has belonged to the pure grass pea stand during two years (34).

Dry matter digestibility (DMD)

The results of this study indicated that the effects of intercropping ratios ($p < 0.01$) on dry matter digestibility (DMD) were significant (Table 6).

Results showed that the maximum value of DMD was recorded from vetch monoculture (100% vetch) by 62.39 % and followed by 20B:80V treatment. Also, the lowest DMD has observed in 100B and 80B: 20V treatments by 47.75 and 47.77%, respectively (Table 7). It was found that the sole culture of the annual medic had higher DMD than barley, and the mixture of barley with annual medic decreased DMD of the mixed forage (33).

Water Soluble Carbohydrates (WSC)

The results of the analysis of variance indicated that the effects of intercropping ratios ($p < 0.01$), on the water-soluble carbohydrates (WSC) was significant (Table 6).

The maximum value of WSC has obtained under 20B:80V treatment and the lowest WSC was observed in 100% vetch treatment (Table 7). For this experiment, WSC concentration was enhanced in the intercrop system compared to the sole culture of vetch. In agreement with our results, it was found that WSC concentration in the barley-bean intercropping system was increased compared to the sole bean (35). Furthermore, it was reported that intercropping had a positive effect on WSC in corn-soybean combinations (36).

Conclusion

According to the results of the present study, the grain yield and its components in barley and vetch improved by adopting certain intercropping patterns. The estimated LER exceeded unity in intercropping ratios, which indicated that these intercrops were beneficial due to the higher exploitation of the limited environmental sources. Also, as it matches the end of the growing season, it is particularly suggested for local farmers in the northwest of Iran who have not been able to provide sufficient forage during the growing season. Furthermore, the intercropping of vetch with barley increased the yield and quality of forage. In this study, the ratio of 80% barley + 20% vetch intercropping ratio was identified as the best combination of forage yield and forage quality. Therefore, this combination is recommended for improving the quantitative and qualitative characteristics of forage in barley and vetch intercropping system.

Acknowledgements

Thanks to Dr. Fatemi for his valuable comments.

Authors' contributions

All authors collaborated in the writing and editing of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

References

1. Bhatti IH, Ahmad R, Jabbar A, Nazir M, Mahmood T. Competitive behavior of component crops in different sesame-legume intercropping systems. International Journal of Agriculture and Biology (Pakistan). 2006.
2. Sarkar R, Shit D, Maitra S. Competition functions, productivity and economics of chickpea (*Cicer arietinum*) based intercropping system under rainfed conditions of Bihar plateau. Indian Journal of Agronomy. 2000;45(4):681-86.
3. Parveen S, Qamar I, Ali A, Arshad M. Effect of legume–grass mixture on forage yield and quality in the Pothwar of Pakistan. Online Journal of Biological Sciences. 2001;1:809-11. https://doi.org/10.3923/jbs.2001.809.811
4. Manna M, Ghosh P, Acharya C. Sustainable crop production through management of soil organic carbon in semiarid and tropical India. Journal of Sustainable Agriculture. 2003;21(3):85-114. https://doi.org/10.1300/J064v21n03_07
5. Atis I, Kokten K, Hatipoglu R, Yilmaz S, Atak M, Can E. Plant density and mixture ratio effects on the competition between common vetch and wheat. Australian Journal of Crop Science. 2012;6:498-505.
6. Holland JB, Brummer EC. Cultivar effects on oat-berseem clover intercrops. Agronomy journal.1999; 91: 321–29. https://doi.org/10.2134/agronj1999.00021962009100020023x
7. Kiær LP, Skovgaard IM, Østergård H. Grain yield increase in cereal variety mixtures: a meta-analysis of field trials. Field Crops Research. 2009;114(3):361-73. https://doi.org/10.1016/j.fcr.2009.09.006
8. Atis I, Konuskan O, Duru M, Gozubenli H, Yilmaz S. Effect of harvesting time on yield, composition and forage quality of some forage sorghum cultivars. International Journal of Agriculture and Biology. 2012;14(6).
9. Lithourgidis A, Vasilakoglou I, Dhima K, Dordas C, Yiakoulaki M. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crops Research. 2006;99(2-3):106-13. https://doi.org/10.1016/j.fcr.2006.03.008
10. Dhima K, Lithourgidis A, Vasilakoglou I, Dordas C. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research. 2007;100(2-3):249-56. https://doi.org/10.1016/j.fcr.2006.07.008
11. Karagić Đ, Vasiljević S, Katić S, Mikić A, Milić D, Milošević B, et al. Yield and quality of winter common vetch (*Vicia sativa* L.) haylage depending on sowing method. Biotechnology in Animal Husbandry. 2011;27(4):1585-94. https://doi.org/10.2298/BAH1104585K
12. Lithourgidis A, Dordas C, Damalas CA, Vlachostergios D. Annual intercrops: an alternative pathway for sustainable agriculture. Australian journal of crop science. 2011;5(4):396.
13. Anil L, Park J, Phipps R, Miller F. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. Grass and Forage Science. 1998;53(4):301-17. https://doi.org/10.1046/j.1365-2494.1998.00144.x
14. Strydhorst SM, King JR, Lopetinsky KJ, Harker KN. Forage potential of intercropping barley with faba bean, lupin or field pea. Agronomy Journal. 2008;100(1):182-90. https://doi.org/10.2134/agronj2007.0197
15. Yolcu H, Dasci M, Tan M. Evaluation of annual legumes and barley as sole crops and intercrop in spring frost conditions for animal feeding. I. Yield and quality. Journal of Animal and Veterinary Advances. 2009;8(7):1337-42.
16. Sadeghpour A, Jahanzad E. Seed yield and yield components of intercropped barley (*Hordeum vulgare* L.) and annual medic (*Medicago scutellata* L.). Australian Journal of Agricultural Engineering. 2012;3(2):47.
17. Yilmaz Ş, Özel A, Atak M, Erayman M. Effects of seeding rates on competition indices of barley and vetch intercropping systems in the Eastern Mediterranean. Turkish Journal of Agriculture and Forestry. 2015;39(1):135-43. https://doi.org/10.3906/tar-1406-155
18. Atis I, Acikalin S. Yield, quality and competition properties of grass pea and wheat grown as pure and binary mixture in different plant densities. Turk Journal Field Crops. 2020;25(1):18-25. https://doi.org/10.17557/tjfc.737476
19. Pouryousef M, Oshnood Alizadeh Kh, da Silva T. Smooth vetch (*Vicia dasycarpa* L.) as a suitable crop for mixed planting with barley in semi-arid regions. Maejo International Journal of Science and Technology. 2017;11(03):219-25.
20. Jensen ES. Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic nitrogen in pea-barley intercrops. Plant and Soil. 1996;182(1):25-38. https://doi.org/10.1007/BF00010992
21. Dordas A, Lithourgidis A S. Growth, yield and nitrogen performance of faba bean intercrops with oat and triticale at varying seeding ratios. Grass and Forage Science. 2011:66 (4):569-77. https://doi.org/10.1111/j.1365-2494.2011.00814.x
22. Dhima KV, Lithourgidis Ithourgidis AS, Vasilakoglou asilakoglou IB, Dordas CA. Ompetition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops

Research. 2007:100:249–56. https://doi.org/10.1016/j.fcr.2006.07.008

23. Karlidag Arlidag H, Yildirim ildirim E. The effects of nitrogen fertilization on intercropped strawberry and broad bean. Journal of Sustainable Agriculture. 2007;29:61–74.

24. Jalilian J, Najafabadi A, Zardashti MR. Intercropping patterns and different farming systems affect the yield and yield components of safflower and bitter vetch. Journal of Plant Interactions. 2017;12(1):92-99. https://doi.org/10.1080/17429145.2017.1294712

25. Belel M, Halim R, Rafii M, Saud H. Intercropping of corn with some selected legumes for improved forage production: A review. Journal of Agricultural Science. 2014;6(3):48. https://doi.org/10.5539/jas.v6n3p48

26. Moynihan JM, Simmons SR, Sheaffer CC. Intercropping annual medic with conventional height and semidwarf barley grown for grain. Agronomy journal. 1996;88(5):823-88. https://doi.org/10.2134/agronj1996.00021962008800050023x

27. Mohsenabadi GR, Jahansouz M, Chaeichi M, Rahimian MH, Liaghat A, Savaghebi FGR. Evaluation of barley–vetch intercrop at different nitrogen rates. Journal of Agricultural Science and Technology. 2008;10:22-31.

28. Galanopoulou K, Anastasios S. Lithourgidis, christos A. Dordas B. Intercropping of Faba bean with barley at various spatial arrangements affects dry matter and nitrogen yield, nitrogen nutrition index and interspecific competition. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2019;47(4):1116-27. https://doi.org/10.15835/nbha47411520

29. Dahmardeh M. Intercropping Barley (*Hordeum vulgare* L.) and Lentil (*Lens culinaris* L.): Yield and intercropping advantages. Journal of Agricultural Science. 2013;(4):208- 13. https://doi.org/10.5539/jas.v5n4p209

30. Koohi SS, Nasrollahzadeh S, Raei Y. Evaluation of chlorophyll value, protein content and yield of sorghum (*Sorghum bicolor* L.) mung bean (*Vigna radiata* L.) intercropping. International Journal of Biological Sciences. 2014;4 (8):136-43. https://doi.org/10.12692/ijb/4.8.136-143

31. Bedoussac L, Justes E. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant Soil. 2010;330:19-35. https://doi.org/10.1007/s11104-009-0082-2

32. Chapagain T. Intercropping wheat and barley with nitrogen fixing legume species in low input organic systems. [dissertation]. Vancouver: The University of British Columbia. 2014.

33. Sadeghpour A, Jahanzad E, Esmaeili A, Hosseini M, Hashemi M. Forage yield, quality and economic benefit of intercropped barley and annual medic in semi-arid conditions: Additive series. Field Crops Research. 2013;148:43-48. https://doi.org/10.1016/j.fcr.2013.03.021

34. Atis I, Acikalin S. Yield, quality and competition properties of grass pea and wheat grown as pure and binary mixture in different plant densities. Turkish Journal of Field Crops. 2020; 25(1):18-25. https://doi.org/10.17557/tjfc.737476

35. Kristensen V. The production and feeding of whole-crop cereals and legumes in Denmark. Whole-crop cereals: Chalcombe Publications, Canterbury, UK; 1992. p. 21-37.

36. Baghdadi A, Halim RA, Ghasemzadeh A, Ebrahimi M, Othman R, Yusof MM. Effect of intercropping of corn and soybean on dry matter yield and nutritive value of forage corn. Legume Research-An International Journal. 2016;39(6):976-81. https://doi.org/10.18805/lr.v39i6.6643