Response of barley cultivars to different combinations and loading systems with Broad bean: growth, yield, and competitive indicators

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Abstract

A field experiment was conducted during the 2024–2025 season in a farmer's field in Al-Jurnaf sub-district, Al-Shirqat district, Salah Al-Din province, Iraq. The site is located at 35.52°N latitude and 43.23°E longitude, 135 .The aim was to evaluate the effect of barley and broad bean loading systems on growth, yield, and some competitive indicators, and to identify the most suitable combinations between varieties and row distribution systems. A split-plot design with three replications was used. The study included three barley cultivars: local Iraqi barley, Ukrainian white barley, and Aldebaran, and two broad bean cultivars: local broad bean and the Spanish Vito cultivar. The treatments included six planting systems: broad bean alone, barley alone, broad bean:barley row, broad bean:two barley rows, broad bean:two barley rows, and two barley:two broad bean rows. The results showed that the single planting of barley was excelled in leaf area (14.067 cm^2), number of branches per plant (6.06 branches.plant $^{-1}$), number of grains per spike (41.68 grains per spike^{-1}), and total yield (9.01 tons ha^{-1}), while the barley:broad bean row system achieved the highest thousand grain weight (33.68 g). At the varietal level, Ukrainian white barley was excelled in leaf area (647.65 cm^2) and number of branches per plant (5.72 branches.plant $^{-1}$), while Aldebaran was superior in number of grains per spike (40.36 grains . spike^{-1}). No significant differences were found between the varieties in number of branches, thousand grain weight, and total yield. The intercropping of Aldebaran with single planting resulted in the highest leaf area (747.57 cm^2), number of grains per spike (42.40 grains . spike^{-1}), and total yield (9.43 t ha^{-1}), while the intercropping of local Iraqi barley with a barley:two broad bean row system resulted in the highest thousand-grain weight (35.86 g). The Land Equivalent Ratio (LER) values ranged from 0.63 to 1.05, with the majority being less than 1, indicating no productivity advantage for intercropping in most combinations. One combination, however, recorded a value of 1.05, suggesting a limited productivity advantage for the intercropping system in that case. The aggressiveness index showed that barley was more competitively dominant in the 1:1 and 1:2 systems, while competitive advantage shifted to broad beans in the 2:1 system, and competition approached equilibrium in the 2:2 system. These results confirm the success of intercropping barley and broad beans. The barley yield depends largely on the ratio of rows and the varietal combination, and maximizing barley yield does not necessarily correspond to maximizing land use efficiency at the agricultural system level.

Keywords: Barley; Broad bean; Intercropping systems; Land Equivalent Ratio; Aggressivity

Introduction:

Intercropping grain and legumes represents one of the pathways for sustainable agricultural intensification, as it combines two crops that differ in morphological characteristics, requirements, and ability to utilize light, water, and nutrients. The success of this system depends on a degree of temporal and spatial integration in resource utilization, ensuring that competition between the two crops does not negate the advantage of system diversity. Recent evidence has shown that the performance of intercropping is not fixed but

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varies depending on the crop type, planting ratios, spatial distribution, fertility, and environmental conditions. Therefore, choosing the row ratio is an agricultural decision no less important than choosing the cultivar [7,11] . Grain-legume systems are of particular importance because grains are typically characterized by rapid initial growth and high light-blocking capacity, while legumes can benefit from biological nitrogen fixation. The relationship between the two species can contribute to improved resource use efficiency under certain management conditions. However, the presence of legumes does not necessarily guarantee an increase in grain yield. Lower barley density in intercropping systems can reduce individual barley yields, while legume yields may partially offset this reduction in land productivity.

Broad beans (*Vicia faba* L.) are among the most important winter legumes, valued for their nutritional content and high protein content. Their ability to fix atmospheric nitrogen makes them a valuable component in production systems aimed at reducing reliance on nitrogen inputs and improving nutrient use efficiency. Recent studies have shown that incorporating broad beans with grain crops can alter nitrogen use efficiency, forage quality, and total yield; however, the response varies considerably depending on the planting ratio, nitrogen level, and environmental conditions [8,10] .

Barley (*Hordeum vulgare* L.) is a versatile strategic crop, characterized by its relative adaptability to diverse environmental conditions. Genetic variations among cultivars play a crucial role in determining the rate of vegetative growth, leaf area, number of grains, grain weight, and yield. Recent studies have confirmed that cultivar and cultivation system interact to determine barley's productive traits and quality, and that introducing a legume crop may alter some barley characteristics without necessarily increasing grain yield in all environments[8,11] .The Land Equivalent Ratio (LER) is one of the most important indicators used to evaluate the productivity of intercropping compared to monoculture. It expresses the amount of land required under monoculture to produce the same yield per unit area as an intercropping system. An LER value greater than 1.0 indicates a productivity advantage in intercropping, while a value less than 1.0 indicates no productivity advantage compared to monoculture. Competition indicators, such as aggressiveness, are used to determine the direction and intensity of competition among the species within the intercrop. Recent evidence suggests that intercropping efficiency and LER values are significantly influenced by system composition, species density, spatial distribution, cultivar combinations, environmental conditions, and nutrient management. Therefore, altering the row ratio or cultivar combination can lead to a significant change in productivity advantage and the competitive relationship between crops[6,11,14] . Despite numerous international studies on intercropping of grains and pulses, information regarding suitable cultivar combinations and row ratios for barley and broad beans under the conditions of northern Iraq remains limited. Furthermore, most studies do not simultaneously test more than one cultivar of each crop with multiple intercropping ratios, making the evaluation of the interaction between cultivar and intercropping system essential for arriving at a viable recommendation. Therefore, the current study was designed to test three barley cultivars and two broad bean cultivars under six intercropping systems, focusing on barley characteristics, land use efficiency indicators, and competition. The study hypothesized that changing the row ratio and cultivar combination would alter the degree of competition between barley and broad bean, and that some intercropping systems might achieve a yield advantage per unit area even when barley yield is lower than in monocropping. It also hypothesized that the response of barley cultivars to intercropping systems is not uniform, The study aimed to evaluate intercropping systems of barley and broad beans to determine the best

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combinations and ratios for increasing land use efficiency, and to establish that the most productive cultivar in monocropping is not necessarily the best cultivar in an intercropping system.

Materials and Methods:

Experimental Location and Design:

A field experiment was conducted in a farmer's field in the Al-Jurnaf sub-district of Al-Shirqat district in Salah al-Din Province during the 2024-2025 growing season. The site is located at 35.52°N latitude and 43.23°E longitude. The land was prepared by two perpendicular plows, then leveled and smoothed, and divided into experimental units according to a randomized complete block design (RCBD) using a split-split plot system. The experimental unit measured 2 x 3 m (6 m^2) and had three replicates. Loading systems were placed in the main plots, barley varieties in the sub plots, and broad bean varieties in the subsub plots.

Table (1) Chemical and physical properties of the study soil

traits	**values**	**units**
Sand	503.00	$g.kg^{-1}$
silt	234.00	$g.kg^{-1}$
Clay	173.00	$g.kg^{-1}$
Soil Texture	Silty loam sandy	SCL
PH	7.2	-
Electrical Conductivity	2.47	$DS.m^{-1}$
Cationic Ion Exchange Capacity	7.9	Centimole . kg^{-1}
Organic Matter	5.69	$g.kg^{-1}$ soil
Carbonate Minerals	203	$g.kg^{-1}$ soil
Gypsum	55.11	$g.kg^{-1}$ soil
Bluk Density	1.39	$g.cm^3$
Available Nitrogen	10.9	$mg.kg^{-1}$
Available Phosphorus	4.7	$mg.kg^{-1}$
Available potassium	96.00	$mg.kg^{-1}$

Plant Materials and Crop Systems:

The study included three barley cultivars: local Iraqi barley, Ukrainian white barley, and

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Aldebaran, and two broad bean cultivars: local Iraqi broad bean and Spanish Vito. The cropping systems included six treatments: single broad bean (1:0), single barley (0:1), broad bean:barley (1:1), broad bean:two barley (1:2), and twoBroad beans: one row of barley (2:1) and two rows of broad beans: two rows of barley (2:2) were planted during November, with a spacing of 40 cm between rows of broad beans, 20 cm between rows of barley, and 20 cm between plants in the broad bean crop.

Studies traits:

Leaf area (cm)

The leaf area of each plant was estimated by multiplying the length of the leaf by its width by 0.95, then multiplying the result by the total number of leaves per plant.

- Number of branches per plant

The total number of branches was calculated for a random sample of five plants selected from the midlines of each experimental unit, and then the arithmetic mean of the number of branches per plant was calculated.

Number of Grains per spike: Five spike were randomly selected from each unit at full maturity. The grains were separated, and the average number was calculated.

Weight of 1000 Grains: A random sample of grains was taken after threshing and cleaning and weighed using a sensitive balance. Total yield: Estimated based on plant yield and plant density and converted to tons per hectare.

Competitive indicators: The Land Equivalent Ratio (LER) was calculated using the relationship: LER = La + Lb,

where La = Yab/Yaa and Lb = Yba/Ybb.

Yab and Yba represent the yields of barley and broad beans in intercropping.

Yaa and Ybb represent their yields in sole cultivation. An LER value > 1 is interpreted as a productivity advantage for the intercropping system, while an LER < 1 indicates no productivity advantage compared to sole cultivation.

Aggressivity (A) was used to determine the direction of competitive dominance. In a 1:1 ratio, the simplified relationship between the two partial equivalents was used.

Results and Discussion:

Barley Leaf Area:

The results in Table (2) show a significant effect of the planting system on barley leaf area. The single planting system achieved the highest average area of 714.06 cm², while the average decreased to 532.67 cm² in the barley:two broad bean planting system. This decrease can be explained by increased competition between the two species for available growth resources, particularly light, water, and nutrients, as well as the lower relative density of barley in some intercropping systems. Furthermore, varying the row distribution can alter the degree of overlap between the shoot and root systems, thus affecting shoot formation and light interception. Studies on intercropping grains and legumes have shown that changing the ratio and distribution of crop rows can lead to significant differences in growth, competition, and resource use efficiency, even when using the same two species [3,10,11] At the cultivar level, Ukrainian white barley outperformed with an average of 647.65 cm², followed by Aldebaran cultivar with an average of 640.92 cm², and then local Iraqi barley with an average of 600.21 cm², indicating genetic differences in vegetative capacity and response to growing conditions. This finding is consistent with [11] who found a significant difference between two barley cultivars in agricultural performance and varietal response to intercropping systems, confirming that the response to intercropping is not necessarily homogeneous among genotypes. Recent legume-grain studies have also supported the importance of the interaction between cultivar

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and growing system; [1] demonstrated that cultivar selection can influence crop performance under intercropping, and that some cultivar combinations are more suitable for intercropping than others. In the current experiment, the intercropping of Aldebaran with monocropping resulted in the highest leaf area of 747.57 cm², while it decreased to 385.93 cm cultivar ² in one of the local Iraqi barley combinations with the intercropping system. This suggests that the effect of intercropping system may be greater than that of the cultivar in some combinations. This finding is supported by studies showing that spatial distribution and crop ratio can alter the intensity of competition and the response of the crop in the intercropping system. In a study conducted on barley and broad beans under different spatial arrangements, growth and competition indicators changed with the row arrangement, confirming that the success of intercropping depends not only on the presence of the two crops but also on their spatial distribution and ratio within the system [3] From a physiological perspective, a decrease in leaf area under some intercropping systems does not necessarily indicate the failure of the intercropping system; a smaller leaf area may be accompanied by better integration between the two species in light interception or water and nutrient utilization, which cannot be determined based on barley characteristics alone. Therefore, leaf area should be interpreted in conjunction with LER and the total yield of the two crops, and not as a sole criterion for the success of Intercropping.

Table (2) Arithmetic averages for intercropping systems, barley cultivars, and broad bean, and the interaction between them in the leaf area traits of the barley crop

cultivars Broad bean	Intercropping systems	barley cultivars			average Intercropping systems
		Ukrainian white	Local barley	Aldebaran	
MSA	Single barley	742.67 ab	651.93 bc	747.57 a	714.06 a
	Barley row: Broad bean row	633.27 bc	577.67 bc	629.13 bc	613.36 bc
	Two barley rows, two broad bean rows	650.87 bc	566.73 dc	607.33 bc	608.31 bc
	Broad bean row: Two barley rows	667.07 cb	653.60 bc	657.40 bc	659.36 ab
	Barley row: Two broad bean rows	626.53 bc	385.93 E	585.53 bc	532.67 c
	Single barley	711.73 cb	640.20 dac	692.93 cb	681.62 ab
	Barley row: Broad bean row	610.87 bc	607.80 dac	585.63 bc	601.43 bc

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FITO	Two barley rows, two broad bean rows	691.53 cb	616.60 dac	573.93 b.c	627.36 cb
	Broad bean row: Two barley rows	489.33 dE	631.47 dac	698.47 cb	606.42 bc
	Barley row: Two broad bean rows	652.60 bc	670.20 cb	631.27 bc	651.36 ab
	average cultivars	647.65 a	600.21 a	640.92 a	

Number of tillers per Plant in Barley

The results in the table show that the single-plant system for barley (specifically in the companion variety MSA) achieved the highest average number of tillers (6.06 tillers.plant^{-1}), compared to some intercropping systems that witnessed a clear decrease. The (barley row: two broad bean rows) system under the companion variety MSA recorded the lowest average (4.82 tillers.plant^{-1}). The excelled of single-planting and the decrease observed in intercropping are attributed to the change in relative plant density and the increased competitive interaction between the two species. In the single-plant system, a larger land area and direct light exposure are available for each plant, which reduces shared shading and provides sufficient light energy to generate stable tillers. In contrast, in intercropping systems (especially the barley row: two broad bean rows system), the elimination competition for light, water, and nutrients in the root and sub-vegetative zone intensifies, inhibiting the growth of barley lateral buds due to shading or strong competition from the broad bean plants. These interpretations align with the findings of Wang et al. (2025), who concluded that spatial arrangement and row distribution in intercropping alter physiological growth parameters, as competition for resources negatively impacts the growth and emergence of basal shoots in grasses.Regarding the influence of varieties, the results showed a clear and significant effect of barley varieties on the number of tillers per plant. The "Ukrainian White" variety recorded the highest average (5.72 tillers.plant^{-1}), followed by the "Aldebaran" variety (5.44 tillers.plant^{-1}) with a non-significant difference. The "Local Iraqi Barley" variety exhibited the lowest average for this trait (5.10 tillers/plant). The superiority of the two varieties (Ukrainian White and Aldebaran) can be explained by the underlying genetic differences and the expressive capacity of the gene structure that controls the production of plant hormones (such as cytokinins and auxins) responsible for activating basal buds and apical dominance, as well as their variation in metabolic efficiency and the ability of their vegetative system to capture environmental resources and direct metabolic products towards the formation and nourishment of new branches. This result is consistent with what Ali found. The results showed a clear and significant effect of barley varieties on the number of tillers per plant; the Ukrainian White variety recorded the highest average at 5.72 tillers, followed by the Aldebaran variety with 5.44 tillers per plant, though the difference was not significant. The Iraqi Local Barley variety, on the other hand, recorded the lowest average for this trait at 5.10 tillers. The superiority of the Ukrainian White and Aldebaran varieties can be explained by the underlying genetic differences and the expressive capacity of the gene structure that controls the production of plant hormones (such as cytokinins and

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auxins) responsible for basal bud activation and apical dominance. Furthermore, they differ in photosynthetic efficiency and the ability of their vegetative systems to capture environmental resources and direct metabolic products towards the formation and nourishment of new shoots. This result is consistent with what Ali and Hussain (2024) found: a highly significant genetic variation among barley varieties and structures in their ability Branching depends on environmental suitability. Barley structures have a branching capacity that depends on environmental suitability.

Table (3) Arithmetic averages for intercropping systems, barley cultivars, and broad bean, and the interaction between them in Number of tillers per Plant in Barley

cultivars Broad bean	Intercropping systems	barley cultivars			average Intercropping systems
		Ukrainian white	Local barley	Aldebaran	
MSA	Single barley	6.40 a	5.40 b..e	6.40 a	6.06 a
	Barley row: Broad bean row	5.06 e..c	4.80 gf	5.13 e..g	5.00 bc
	Two barley rows, two broad bean rows	5.80 e..d	4.80 Gf	5.13 e..g	5.24 bc
	Broad bean row: Two barley rows	5.80 e..d	5.26 e..g	5.53 e..d	5.53 ab
	Barley row: Two broad bean rows	5.26 e..g	4.40 G	4.80 gf	4.82 C
FITO	Single barley	6.06 ab	5.46 e..d	6.06 ab	5.86 a
	Barley row: Broad bean row	5.06 e..c	5.00 e..f	4.86 e.f	4.97 C
	Two barley rows, two broad bean	6.00	4.86	4.73	5.20

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	rows	cb	e.f	gf	bc
	Broad bean row: Two barley rows	6.40 a	5.13 e..g	6.40 a	5.97 a
	Barley row: Two broad bean rows	5.40 e.c	5.86 c..d	5.33 e..g	5.53 ab
	average cultivars	5.72 a	5.10 B	5.44 a	

Number of grains .spike:

The results in Table (4) show that single-cropping resulted in a higher number of grains .spike, averaging 41.68 grains .spike^{-1}, compared to 35.62 grains .spike^{-1} in the barley:two broad bean row system. The decrease in this trait under the intercropping system can be explained by increased competition between barley and broad beans for limited growth resources, particularly light, water, and nutrients, during the critical stages of spike formation and grain count determination. Furthermore, the reduced relative density of barley and the altered spatial distribution of plants may affect the size of the vegetative mass and its capacity to provide the necessary metabolites to support grain formation. This finding is consistent with those of [10] who found that the cropping and fertilization system interacted to influence the number of grains .spike and barley yield, and that single-cropping achieved higher grain yields than intercropping under certain conditions, partly due to the increased number of spikes and grain weight. This result is clearly linked to the vegetative characteristics observed in the current study; the single-plant system also recorded the highest leaf area (714.06 cm^2) and the highest leaf area index (LAI) (7.07), compared to the lower levels in the barley:two-broad bean system. The correlation between the increased leaf area and LAI with the higher number of grains .spike suggests that the increased vegetative mass in the single-plant system may have provided greater radiation interception and photosynthesis capacity during the pre- and post-flowering stages, which could support spike formation and grain retention. However, this correlation should be interpreted as a possible physiological relationship rather than a direct causal relationship, as the number of grains in barley is also influenced by spike weight, fruiting efficiency, and genetic and environmental factors. At the cultivar level, Aldebaran had the highest grain-per-head count, averaging 40.36 grains^{-1}, followed by local Iraqi barley at 38.98 grains^{-1}, and then Ukrainian white barley at 37.43 grains^{-1}. The highest value, 42.40 grains^{-1}, was recorded when Aldebaran was intercropped with monocropping. This variation suggests genetic differences among cultivars in their ability to form and maintain grains, which aligns with recent evidence indicating that the determining factors for grain count in barley vary in importance depending on the genetic makeup. On the other hand, recent evidence does not suggest that intercropping necessarily leads to a decrease in grain-per-head count under all

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conditions. A study by [5] On barley and peas, the number of grains .spike was affected by the year and planting system, and the differences between monoculture and intercropping were clearly evident in one year, while they were not significant in others. This confirms that the response of yield components to intercropping depends on environmental conditions, the ratio of crops, spatial distribution, and the degree of competition between the two species.Furthermore, the results of the current study are consistent with the concept that changing the row arrangement can alter the intensity of competition between barley and broad beans. Studies on barley and broad beans have shown that the spatial arrangement of the two species affects growth, nutrient uptake, and competition indicators, and that some intercropping ratios may be more favorable than others. In the study by [3] different spatial arrangements led to a clear difference in system efficiency and competition between barley and broad beans, with some combinations showing superiority in yield indicators and nitrogen utilization.

Table (4) Arithmetic means for Intercropping systems, barley cultivars, and Broad bean, and the interaction between them in the trait of number of grains per spike for barley crop

cultivars Broad bean	Intercropping systems	barley cultivars			average Intercropping systems
		Ukrainian white	Local barley	Aldebaran	
MSA	Single barley٥	41.20 a	41.46 a	42.40 a	41.68 a
	Barley row: Broad bean row	37.26 bc	38.40 b.a	38.26 bc	38.13 b.c
	Two barley rows, two broad bean rows	30.03 bc	38.33 bc	40.73 a	36.36 bc
	Broad bean row: Two barley rows	40.80 a	41.40 a	41.80 a	41.33 ba
	Barley row: Two broad bean rows	38.86 b.c	29.26 d	38.73 b.c	35.62 c
FITO	Single barley	39.73 ba	41.53 a	42.20 a	41.15 ba
	Barley row: Broad bean row	37.13 bc	29.26 bc	37.93 bc	37.53 b.c
	Two barley rows, two broad bean rows	40.33 ?	41.33 a	42.20 a	41.00 ba
	Broad bean row: Two barley rows	30.53 b.c	41.06 a	41.00 a	37.53 b.c

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	Barley row: Two broad bean rows	38.40 b.c	39.00 b.c	39.20 ba	38.86 b.c
	average cultivars	37.430 b	38.98 ba	40.36 a	

Weight of 1000 grains:

The results in Table (4) show that the response to 1000-grain weight differed from the responses to vegetative characteristics and the number of grains .spike. The barley:broad bean row system achieved the highest average weight of 1000 grains, reaching 33.68 g, compared to 30.57 g in the monoculture system. This pattern suggests a possible compensatory mechanism among the yield components, whereby a decrease in the number of grains or reduced competition for fewer storage locations may lead to an increase in the amount of nutrient available to the remaining grains during the filling stage, thus allowing for the formation of heavier grains. This relationship is important in explaining the components of grain yield. Recent studies in barley have shown that grain count and yield components do not necessarily respond in the same way to environmental and genetic factors. The determination of grain count is strongly linked to spike weight during earlier stages, while grain components are influenced during later stages of grain growth and filling (2023). It appears that monoculture resulted in the highest leaf area and leaf area index, as well as the highest number of grains .spike, while the barley:bow row system achieved the highest 1000-grain weight. This discrepancy suggests a possible trade-off between grain count and grain size. A higher grain count may increase internal competition among downstream locations for nutrient content during the filling stage, while a lower grain count may allow a greater share of resources to be directed to fewer grains, thus increasing their weight. Therefore, a higher 1000-grain weight in the intercropping system does not necessarily mean higher productivity, as grain weight is one yield component that must be interpreted in conjunction with the number of spikes, the number of grains, and the final yield, not in isolation. This interpretation aligns with the findings of recent studies on intercropping grains. Regarding legumes, [10] demonstrated that the response of barley and field beans to intercropping varies with nitrogen levels, and that nitrogen management affects grain yield and system efficiency, indicating that resource availability can alter the dry matter distribution among yield components. A very recent study by [8] also showed that intercropping of barley and field beans can alter grain quality characteristics and nitrogen response. Intercropped barley exhibited higher crude protein concentrations compared to monocropped barley across different nitrogen levels, while monocropped barley required high nitrogen levels to achieve similar protein levels. These results confirm that the relationship between intercropping and barley nitrogen feeding cannot be reduced to a simple direct transfer of nitrogen from legumes to barley, but is influenced by competition and complementarity in resource uptake and the level of nitrogen application.On the other hand, the variation in thousand-grain weight between cultivation systems may also be related to differences in genetic makeup, as cultivars differ in their ability to maintain grain growth during the filling stage. A recent study in barley showed that genetic and environmental factors influence the components determining grain count differently, and that fruiting efficiency is a component more closely linked to genetic variations, while spike weight was an important component in explaining environmental influences. Regarding the interaction between cultivar and cultivation system, local Iraqi barley, when grown in a

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barley:two-broad bean row system, recorded the highest thousand-grain weight of 35.86 g, while Ukrainian white barley, grown in single planting, recorded the lowest value of 28.83 g. This variation indicates the different ability of cultivars to respond to the intercropping system and the row ratio, reflecting the importance of the interaction between genetic makeup and cultivation system in determining grain filling efficiency. Recent studies in grain-legume systems support the importance of selecting the appropriate cultivar combination for the cultivation system. Studies have shown that crop performance in intercropping can vary depending on genetic makeup and the cropping system, and that a cultivar's response under monocropping does not necessarily reflect its performance when intercropped with another crop. In a recent study on barley and broad beans, an intercropping system led to changes in barley grain characteristics and quality compared to monocropping, and the response varied according to nitrogen levels. This confirms that barley performance in intercropping is determined by the interaction of cultivar, environment, and resource management, and not solely by its performance in monocropping[8,10] . Therefore, the superior 1,000-grain weight of local Iraqi barley under a barley:broad bean row system, compared to the lower 1,000-grain weight of Ukrainian white barley under monocropping, indicates that a cultivar's suitability for intercropping should be evaluated in light of its response to intercropping ratios, competition, and spatial distribution, rather than relying solely on its performance in monocropping. This view is consistent with experimental evidence that has shown that genetic combinations can differ in their performance between solitary and intercropping, and that some cultivars may be more suited to intercropping as a result of differences in their competitiveness and resource utilization
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Table (5) Arithmetic means for Intercropping systems, barley cultivars, and Broad bean, and the interaction between them in the 1000 grain weight trait of barley

cultivars Broad bean	Intercropping systems	barley cultivars			average Intercropping systems
		Ukrainian white	Local barley	Aldebaran	
MSA	Single barley	31.56 e..g	28.83 g	31.33 e..g	30.57 d
	Barley row: Broad bean row	33.43 e..a	31.73 e..g	33.33 e..a	32.83 b.c
	Two barley rows, two broad bean rows	34.50 ba	32.96 e..a	32.16 e..g	33.21 b
	Broad bean row: Two barley rows	30.03 e.f	30.90 e..g	31.73 e..g	30.88 dc
	Barley row: Two broad bean rows	32.63 e..a	35.86 a	33.06 e..a	33.85 a
	Single barley	31.03	29.63	30.73	30.46

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		e..g	gf	e..c	d
FITO	Barley row: Broad bean row	33.86 bc	33.43 e..a	33.76 bc	33.68 a
	Two rows of barley, two rows of broad beans	32.56 e..a	30.23 e..f	29.86 e.f	30.88 dc
	Broad bean row: Two barley rows	33.90 b.a	30.26 e..c	29.96 e.f	31.37 b.c
	Barley row: Two broad bean rows	33.33 e..a	33.00 e..a	31.00 e..g	32.44 bc
	average cultivars	32.68 a	31.68 a	31.69 a	

Total Barley Yield:

The results in Table (6) show that the total barley yield was significantly higher in monocropping, reaching 9.01 tons ha^{-1}, while it decreased to 3.97 tons ha^{-1} in the barley:two-broad bean system. This decrease can be mainly explained by the reduced relative density of barley due to allocating part of the area to the legume crop, along with the potential for increased competition between the two crops for light, water, and nutrients. This competition impacted the yield components and ultimately led to a decrease in barley yield under the intercropping system. This result is consistent with recent findings in intercropping systems. [2] found that monocropping barley achieved the highest grain yield, while changing the row ratio led to a clear change in barley performance and land use efficiency. The barley:clover system with a 2:1 ratio recorded the highest LER value of 1.21. These results indicate that a decrease in the yield of the main crop in intercropping does not necessarily imply a decrease in the overall efficiency of the farming system, as the accompanying crop can compensate for some of the decrease through its contribution to the total yield and the efficient use of land resources.This finding gains further significance when interpreted in conjunction with the growth characteristics and yield components identified in the current study. Barley monoculture exhibited superior leaf area, leaf area index, and number of grains .spike traits that can collectively contribute to determining crop productivity. In contrast, the intercropping system resulted in a decrease in some of these characteristics, while showing an increase in thousand-grain weight, suggesting a change in resource allocation among the yield components. Therefore, the decrease in barley yield in the intercropping system should not be interpreted in isolation from the broad bean response and system efficiency indices, particularly the Land Equivalent Ratio (LER), which combines the contributions of both crops per unit area.Recent evidence suggests that the row ratio is a crucial factor in determining the success of intercropping, as demonstrated by the study by [2] The 2:1 barley-alfalfa intercropping system, while not achieving the highest barley yield compared to monocropping, did achieve the highest LER of 1.21, along with better land use and economic viability indicators. A recent study on barley and peas also showed that changing the intercropping system can affect yield, land use efficiency, and profitability, confirming that judgments on intercropping systems should be based on the overall system performance, not

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just barley yield.From a resource-efficiency perspective, the superior barley yield of monoculture does not necessarily preclude the possibility of a productivity advantage for intercropping. The LER (Low Resource Efficiency Index) measures the area required under monoculture to produce the yield per unit area of the intercrop, and therefore, the intercrop may be more land-efficient even when the barley yield is lower than that of monoculture. Thus, the decrease in barley yield from 9.01 to 3.97 tons ha^{-1} should be interpreted as a response to competition and a change in barley relative density, while the overall productivity viability of the system should be assessed by considering the combined yield of both crops and the competitive and land-use efficiency indices. This view is supported by the recent findings of [8] in a barley-field bean system. Their study showed that intercropping not only altered barley yield and quality but also increased the crude protein concentration in barley grains compared to monoculture across different nitrogen levels, while allowing for the maintenance of grain quality with lower nitrogen inputs. This confirms that the evaluation of intercropping should not be limited to the barley yield alone, but should include the yield of both crops, land use efficiency, grain quality, nutrient use efficiency, and the environmental impacts of the system.

Table (6) Arithmetic means Intercropping systems barley cultivars and Broad bean and the interaction between them in the trait of total barley yield

cultivars Broad bean	Intercropping systems	barley cultivars			average Intercropping systems
		Ukrainian white	Local barley	Aldebaran	
MSA	Single barley۰	8.29 bc	8.06 e..a	9.43 a	8.59 a
	Barley row: Broad bean row	5.04 h..k	4.62 h..i	4.99 h..k	4.88 cd
	Two barley rows, two broad bean rows	7.13 e..c	6.59 e..g	6.10 e..g	6.60 b
	Broad bean row: Two barley rows	7.87 e..a	7.79 e..a	7.96 e..a	7.87 A
	Barley row: Two broad bean rows	3.82 k	4.01 jk	4.08 jk	3.97 d
FITO	Single barley	9.08 ba	8.55 b.c	9.41 a	9.01 a
	Barley row: Broad bean row	5.18 h..k	5.98 e..g	5.11 h..k	5.42 cb
	Two barley rows, two broad bean rows	7.28 e..a	7.28 e..a	5.96 e..g	6.51 b

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	Broad bean row: Two barley rows	8.53 b.c	8.53 b.a	7.85 e..a	8.22 b
	Barley row: Two broad bean rows	4.58 h..i	4.32 j.i	4.33 j.i	4.41 cd
	average cultivars	6.68 a	6.45 a	6.52 a	

Land Equivalent Ratio (LER:

The results of Table (7) indicate that the overall Land Equivalent Ratio (LER) values in the study ranged between 0.63 and 1.05, and most of the values were less than 1.0, which indicates that the majority of intercropping systems did not achieve a productive advantage in land use compared to single cultivation of the two crops under the experimental conditions. This can be explained in light of the superiority of single-cropping barley in a number of traits related to production, especially leaf area, leaf area index, number of grains per ear and barley yield, while these traits decreased in some intercropping systems. This confirms that the LER does not depend on the yield of the main crop alone, but rather on the balance between the productivity of the two types and the percentage of their presence in the system. Recent studies have shown that the row ratio and spatial arrangement directly affect the productivity of intercropping and the value of LER; It was reported by [2] reported the highest LER reaching 1.21 when growing barley and alfalfa in a 2:1 ratio, despite the superiority of single cultivation in barley grain yield. In the current study, the highest LER value was 1.05 when growing local Iraqi barley with local broad bean in a two-barley row: two barley row system, which is a limited increase equivalent to only about 5% above the limit value of 1.0. Therefore, it should be interpreted as a limited production advantage confined to this combination, and not as evidence of the superiority of intercropping in general [13]. This result is consistent with evidence showing that choosing the crop ratio and spatial arrangement can significantly alter the efficiency of the system; A study on barley and pea showed that changing the spatial arrangement from within-row mixing to alternating rows resulted in a difference in LER from 1.16 to 1.26, confirming the sensitivity of the indicator to system design. A specialized study in barley and broad bean also showed that the 2:1 spatial arrangement was more efficient than some other arrangements in terms of productivity, competition indicators, and nitrogen uptake, which confirms that the relationship between the two crops is largely determined by the ratio of rows and spatial distribution. Hence, a low LER in most parameters does not necessarily mean a lack of agricultural value for intercropping; It may achieve other benefits that are not reflected in the index, such as improving resource utilization and reducing weeds. In this context, a recent study conducted across four field experiments showed that alternating intercropping between Broad Bean and barley achieved a reduction in weed coverage and mass by 2.7% and 76.6%, respectively, compared to Broad Bean alone. Therefore, evaluation of broad bean systems should combine yield, LER, competition indicators, nutrient use efficiency and environmental benefits, rather than relying on barley yield or LER alone [10].

Aggressivity:

The results in Table (8) show that Aggressivity (A) exhibited a clear change in the direction and intensity of competition between barley and broad beans as the row ratios varied. In the 1:1 system, Aab values tended towards

negative in most combinations, while the competitive trend favoring barley continued in the 1:2 system. In the 2:1 system, however, the values turned positive, indicating a shift in the dominant competitive force as the relative distribution of the two crops changed. In the 2:2 system, some values approached zero, reflecting a convergence in competitive ability between the two crops. This response confirms that competitive dominance is not determined simply by increasing the proportion of one crop, but rather results from the interaction between plant density, spatial distribution, resource utilization capacity, and variations in vegetative and temporal growth between the two crops. This is supported by the findings of [3] The study showed that changing the spatial arrangement of barley and broad beans from 1:1 and 2:2 to 2:1 or mixed planting resulted in a clear difference in competition indices, LER, and system efficiency. The 2:1 treatment was the most favorable combination in terms of dry matter and nitrogen production. This finding is consistent with the pattern of traits recorded in the current study. Some intercropping systems that exhibited stronger competition for barley were associated with higher leaf area, leaf area index, and number of grains .spike, while reduced barley representation in some combinations led to lower levels of these traits and barley yield [4]. This suggests that the variation in aggressiveness indirectly reflects differences in each crop's ability to intercept light, utilize water and nutrients, and form dry matter under different row ratios. Conversely, the higher thousand-grain weight in some intercropping treatments, despite the lower number of grains, indicates the possibility of compensation among yield components. This underscores that the intensity of competition should not be explained by a single trait alone, but rather by the concurrent changes in growth, yield components, and final production. This result is consistent with evidence showing that the spatial arrangement of crops can alter the intensity of competition even when the two crop types are constant. Studies of barley with peas have demonstrated that changing the row order led to a clear difference in system performance and LER values, confirming the importance of spatial distribution in determining the degree of overlap between the two types. A very recent study of a legume-other crop system also showed that Aggressivity values change according to the planting order, and that a positive or negative sign of the index indicates the more competitively dominant side, while values close to zero indicate a convergence of competitive ability between the two types [4,14] . Therefore, the shift in the Aab sign from negative to positive with the change in row ratio in the current study demonstrates that competitive dominance between barley and broad beans was dynamic, not static, and that the selection of the appropriate row ratio should be based on the integration of Aggressivity, LER, yield, and yield components, rather than on the competition index alone.

Table (8) Values of competitive indicators for barley and broad bean crops in intercropping systems compared to the single cultivation of both crops for the economic yield characteristic of the two crops

bearly	Broad bean		Land Equivalent Ratio			Aggressivity
8.29		c	La	Lb	LER	Aab
5.04	11.68	1*1	0.30	0.46	0.77	-0.16
7.76	7.29	2*1	0.62	0.19	0.82	0.43
7.13	9.24	2*2	0.43	0.37	0.80	0.06
3.82	13.64	1*2	0.15	0.72	0.88	-0.57
Competitiveness indicators for the first grade of barley with the first grade of broad beans						
bearly	Broad bean		Land Equivalent Ratio			Aggressivity
9.09		c	La	Lb	LER	Aab
5.19	12.70	1*1	0.29	0.48	0.77	-0.20

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8.53	7.35	2*1	0.63	0.19	0.81	0.44
7.28	8.05	2*2	0.40	0.31	0.71	0.10
4.50	13.83	1*2	0.17	0.70	0.86	-0.53
Indicators of competition between the first grade of barley and the second grade of broad beans						
			?			
bearly	Broad bean		Land Equivalent Ratio			Aggressivity
8.07		c	La	Lb	LER	Aab
4.62	9.24	1*1	0.29	0.44	0.72	-0.15
7.97	7.89	2*1	0.66	0.25	0.91	0.41
6.59	8.35	2*2	0.41	0.39	0.80	0.01
4.01	14.05	1*2	0.17	0.88	1.05	-0.72
Competitiveness indicators for the second barley cultivar with the first broad bean cultivar						
bearly	Broad bean		Land Equivalent Ratio			Aggressivity
8.56		c	La	Lb	LER	Aab
5.98	9.18	1*1	0.35	0.34	0.69	0.01
8.27	8.35	2*1	0.64	0.20	0.85	0.44
6.31	8.26	2*2	0.37	0.30	0.67	0.07
4.32	13.31	1*2	0.17	0.65	0.82	-0.48
Competitiveness indicators for the second barley cultivar with the second broad bean cultivar						
bearly	Broad bean		Land Equivalent Ratio			Aggressivity
9.43		c	La	Lb	LER	Aab
4.99	12.05	1*1	0.26	0.46	0.73	-0.20
7.97	8.08	2*1	0.56	0.21	0.77	0.36
6.10	7.89	2*2	0.32	0.30	0.63	0.02
4.00	14.64	1*2	0.14	0.75	0.89	-0.61
Competitiveness indicators for the third barley cultivar with the first broad bean cultivar						
bearly	Broad bean		Land Equivalent Ratio			Aggressivity
9.41		c	La	Lb	LER	Aab
5.12	12.56	1*1	0.27	0.47	0.74	-0.20
7.86	8.69	2*1	0.56	0.22	0.77	0.34
5.96	8.71	2*2	0.32	0.33	0.64	-0.01
4.34	13.48	1*2	0.15	0.67	0.83	-0.52
Competitiveness indicators for the third barley variety with the second broad bean variety						

Conclusions

Monoculture resulted in superior leaf area, number of tillers, number of grains, and overall yield due to the absence of competition. In contrast, intercropping achieved an increase in 1000-grain weight but did not achieve a land use efficiency advantage (LER = 1.05) except in one limited combination, confirming that increased grain weight alone does not justify the effectiveness of intercropping.

Regarding the performance of varieties and systems, "Ukrainian white barley" excelled in leaf area and number of tillers, while the "Aldebaran" variety excelled in number of grains per spike. The barley-bean row system achieved the highest 1000-grain weight as a compensatory response.

Recommendations: Monoculture of the "Aldebaran" variety is recommended when targeting the highest barley yield. The study also recommends future measurements of

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nitrogen uptake and content to confirm the actual transfer of nitrogen between the two crops, and testing the effect of different fertilization levels on row ratios.

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