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Evaluation of maize (*Zea mays*) based intercropping for productivity, resource-use efficiency and competition indices in the rainfed foothills of northwest Himalayas

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ABSTRACT

A three-year (2009-2011) field experiment was conducted to study competitive behaviour of maize (*Zea mays* L.) + legume/oilseed based additive series paired-row intercropping at the Punjab Agricultural University's Regional Research Station for Kandi Area, Ballowal Saunkhri. The experiment comprised 10 treatments viz. 4 sole plantings of maize, blackgram [*Vigna mungo* (L.) Wilczek], greengram (*Vigna radiata* L.) and sesame (*Sesamum indicum* L.) each, and six intercropping treatments. Among two planting patterns, 100 maize:33 intercrop mix proportion proved superior for maize yield than 100:67 for all the intercrops. The productivity (3.07 tonnes/ha) and sustainability yield index (0.69) were highest when 1 row of greengram was intercropped with maize (2 M:1 G). Inclusion of legumes in intercropping improved both production and rain water use efficiencies with definite yield and economic advantage. The higher land equivalent ratio (1.27) and relative crowing coefficient (20.4) values for 2 M:1 G planting pattern indicated more efficient benefits and maximum maize yield advantage. As per values of aggressivity, greengram (2 rows) proved most competitive (±0.0005) while sesame (2 rows) least competitive (±0.0046) to maize. Among intercrops, the competitive ratio was highest (1.42) for greengram followed by blackgram in both the planting patterns. 2 M:1 G provided 9.8% (actual yield loss=+0.098) yield gain as compared to sole cropping. In the maize+greengram planting patterns, area time equivalent ratio values indicated yield advantages in the range of 19% for 2 M: 1G and 17% for 2 M:2 G. Thus, inclusion of legumes (especially greengram) in maize culture system can achieve a sustainable and economic yield advantage along with shorter system duration compared to their monocultures.

Key words: Blackgram, Competitive indices, Greengram, Maize, Planting pattern, Productivity, Sesame

Uneven and erratic spatio-temporal distribution of rainfall both in occurrence and intensity is the characteristic feature of monsoonal rains in the foothills of Northwest Himalayas of India. Agriculture is mainly rainfed and delayed occurrence of monsoon rainfall coupled with intermittent long dry spells often results in chances of total crop failure. The undulating topography with light textured soils having poor water holding capacity leads to soil and water erosion in general and specifically in the widely spaced crops. Evaporation remains generally higher than precipitation in most part of the year. Stability of crop yield under such situations in the rainfed agro ecosystem practically demands proper crop substitution with intercropping as a biologically acceptable profit oriented production system and insurance mechanism against adverse environmental conditions for efficient soil and water management since the cultivation of sole crop under such conditions is not profitable one especially under severe drought conditions (Sheoran *et al.* 2009).

Traditional systems of mixed cropping as part of the subsistence farming increases domestic food requirements. However, relative yield stability of these farming practices without giving due considerations to spatial arrangements is at low levels with a high probability of crop failures. Maize (*Zea mays* L.), the staple food for the bulk in the region, is a highly adaptive principal rainy season cereal crop (Sheoran *et al.* 2010) while legume like blackgram [*Vigna mungo* (L.) Wilczek] and greengram (*Vigna radiata* L.) and oilseeds like sesame (*Sesamum indicum* L.) are well known for their drought-tolerance. Since maize is a widely spaced crop, inter-row space provides an opportunity to grow component crops. Intercropping in maize with short duration legumes or oilseeds offers the potential to obtain high productivity and profitability at low water use without reducing its own

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yield (Sharma *et al.* 2013) and subsequently offering opportunities to realize higher system productivity, improve soil health, conserve soil moisture and increase total out turn (Padhi and Panigrahi 2006, Singh *et al.* 2008).

In maize based intercropping system, selection of an appropriate intercrop having a desirable plant type and growth pattern assumes greater significance. The crops maturing well before the peak period of maize are ideal. Ideally, crops or cultivars suitable for intercropping should enhance the complementary effects between species and should exhibit intensification in space and time, competition between and among the system components for light, water and nutrients for the proper management of these interactions. A number of competitive indices have been proposed to describe competition within biological and economic advantages of intercropping systems (Yilmaz *et al.* 2008). Yield advantage in the intercropping system may vary depending on the level of competition between component crops and their receptive planting pattern.

Although, maize, blackgram, greengram and sesame are grown in sole as well as in mixed stands because of their diverse morphology, growth rhythm and similar climatic requirements, yet the suitable combination of intercropping pattern and planting density needs to be optimized. Also, paired row intercropping of different crops in the main crop seems the only alternative to compensate the total economic loss due to crop failure under mid and late season's drought and also to get an additional yield benefit in case of the normal crop season. Keeping the above points in view, the present study was designed to assess the agronomic feasibility and to compare the productivity, sustainability and resource use efficiency of the maize+legume/oilseed intercropping system to sole cultures and to study the competitive interactions of these crops in intercropping system for better resources management and higher crop productivity.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (July to October) seasons of 2009, 2010 and 2011 at the Research Farm of Punjab Agricultural University's Regional Research Station for *Kandi* Area, Ballowal Saunkhri (latitude 31°5.87′ N, longitude 76°23.37′ E, altitude 348 m amsl), India which is representative of the foothill rainfed region of Northwest Himalayas. The region witnesses sub-humid climate with hot and dry summer and extremely cold winter. The soil is well drained sandy loam fluventic ustochrept, non-saline (EC 0.13 dS/m) with pH 7.5 (1:2 soil water suspension) and contained 0.25% organic C, 183 kg/ha $KMnO_4$-N, 15.8 kg/ha Olsen P and 338 kg/ha NH_4OAl-K in the surface soil (0-15 cm).

The experiment on additive series paired-row intercropping using maize as main crop while blackgram, greengram and sesame as intercrops in between the paired rows of maize comprising 10 treatments was laid out in a RCBD with three replications. The treatments consisted of four sole crop treatments, viz. (i) sole maize, (ii) sole blackgram, (iii) sole greengram, and (iv) sole sesame; and six intercropping treatments viz. (v) 1 row of blackgram in between paired rows (30/60 cm) of maize (2 M:1 B), (vi) one row of greengram in between paired rows (30/60 cm) of maize (2 M:1 G), (vii) one row of sesame in between paired rows (30/60 cm) of maize (2 M:1 S), (viii) 2 rows of blackgram in between paired rows (30/60 cm) of maize (2 M:2 B), (ix) 2 rows of greengram in between paired rows (30/60 cm) of maize (2 M:2 G) and (x) 2 rows of sesame in between paired rows (30/60 cm) of maize (2 M:2 S).

The sole maize (cv. JH 3459) was planted @ 98 568 plants/ha while sole blackgram (cv. Mash 338), greengram (cv. PAU 911) and sesame (cv. TC 289) were planted @ 333 000 plants/ha each. In case of paired-row intercropping treatments, the population density of maize remained same as that of sole maize but it varied for intercrops. We modified the proportion of the intercrops in the intercropping treatments in two types of mix proportions, i.e. 100:33 (2 M:1 B/G/S) and 100:67 (2 M:2 B/G/S) maize:intercrop, respectively where 100% (98 568 plants/ha) sole maize plus 33% (111,000 plants/ha) and 67% (222 000 plants/ha) population of respective intercrops were grown for each intercropping treatment.

The sowing of the experiment was done on 22, 09 and 05 July during 2009, 2010 and 2011, respectively using a seed rate of 20 kg/ha for maize, blackgram and greengram while 2.5 kg/ha for sesame. The fertilizer schedule was 40:20:10 kg N, P_2O_5 and K_2O/ha for sole as well as intercropped maize. The fertilizer schedule for sole crops of blackgram, greengram and sesame was 12.5:25, 12.5:40 and 35:00 kg N and P_2O_5/ha, respectively. The proportionate fertilizer dose of the respective intercrop was applied depending upon their mix proportion in the mixed cropping. The remaining standard recommended crop management practices were followed as per the package of practices of Punjab Agricultural University, Ludhiana, India.

In sole cropping, maize crop was harvested on 12, 03 October and 26 September; blackgram on 06, 13 and 14 October; greengram on 25, 17 and 14 September; and sesame on 14, 13 and 20 October in the year 2009, 2010 and 2011, respectively. However, in intercropping, harvesting date of maize was delayed (1-2 days) while it was advanced in case of blackgram (3-6 days), greengram (2-3 days) and sesame (2-6 days) depending upon the planting patterns in different years. The economic yield of different crops was converted into maize equivalent yield (MEY) based on the price. The price of maize was $ 208.3, 236.4 and 244.2/tonnes; blackgram $ 747.9, 720.3 and 915.6/tonnes; greengram $ 641.0, 787.8 and 1017.3/tonnes; and sesame $ 854.7, 1193.0 and 1220.8/tonnes in 2009, 2010 and 2011, respectively.

The sustainability yield index (SYI) of a treatment over a period of years was derived as per Vittal *et al.* (2003). Production efficiency (kg MEY/ha/day) was expressed as the ratio of system productivity (kg MEY/ha) to total duration of the system in days (Patil *et al.* 1995). The rain water use efficiency (RWUE) was computed as a ratio of MEY and crop seasonal and expressed as kg MEY/ha/mm of water used. However, the production efficiency and RWUE in monetary terms were calculated by taking net return (US$/ha) instead of MEY and were expressed as US$/ha/day and US$/ha/mm, respectively.

The benefit of planting patterns and the effect of competition between the main crop and intercrops used in this experiment were calculated using different competition indices. The land equivalent ratio (LER) was calculated using the formula given by Willey (1979). The relative crowding coefficient (K) is a measure of the relative dominance of one species over the other in a mixture (Banik *et al.* 2006). Aggressivity (A) is often used to determine the competitive relationship between 2 crops used in the mixed cropping (Willey 1979). Also, competitive ratio (CR) is another way to assess competition between different species. The CR gives more desirable competitive ability for the crops and is also advantageous as an index over K and AYL (Dhima *et al.* 2007). The next index was the actual yield loss (AYL), which gave more accurate information about the competition than the other indices between and within the component crops and the behaviour of each species in the intercropping system, as it is based on yield per plant (Banik *et al.* 2000). Since none of the above competition indices provide any information on the economic advantage of the intercropping system, the monetary advantage index (MAI) was calculated. Additionally, intercropping advantage (IA) and the area time equivalent ratio (ATER) were also calculated.

One-way analysis of variance (ANOVA) was performed with general linear model on 3-year data set using SPSS version 16.0 statistical software (SPSS 2007). Means between treatments were compared with Turkey HSD test at 5% significance level.

RESULTS AND DISCUSSION

Rainfall and performance of crops

The average annual rainfall of the area is around 1100 mm, of which nearly 80% is received during a short time span of July to mid September which is associated with high relative humidity and comparatively lower solar radiation. The total rainfall received during the cropping period (sowing to harvesting) was 417.6, 585.7 and 769.7 mm in 2009, 2010 and 2011, respectively. The rainfall during the first fortnight of July (SMW 27 and 28); which is the normal time of sowing for maize, blackgram, greengram and sesame; was not quite sufficient for sowing in 2009 and thus delayed the sowing (22 July). However, very good amount of rainfall (SMW 27) was received just before sowing in 2010 and 2011 resulting into timely sowing, i.e. 9 and 5 July, respectively for all the test crops.

In general, the yield of maize, blackgram, greengram and maize equivalent yield (MEY) varied significantly over the years (Fig 1) due to variation in amount and distribution of rainfall. The crop year 2010 was relatively better than 2009 and 2011 for crop growth and development of maize, blackgram and sesame as reflected in their respective

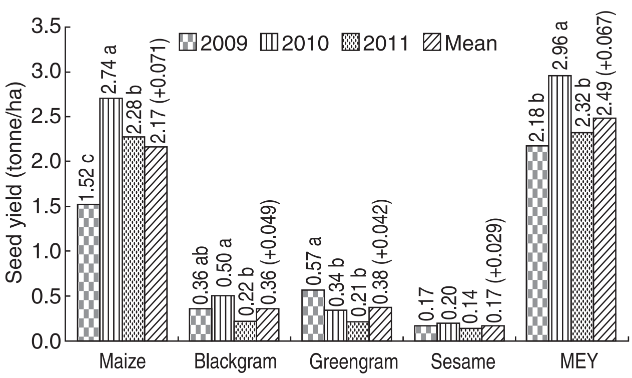

Fig 1 Yield of maize, blackgram, greengram, sesame and maize equivalent yield (MEY) during 2009 to 2011. Bars within a crop sharing the same letters do not differ significantly (Turkey HSD test, significance level = 0.05, within year comparison). Value in parentheses: ± standard error of the difference (sed) in treatment means.

harvested yields owing to adequate and well distributed monsoon rains in 2010 while there was a dry spell (SMW 38 and 39) coinciding reproductive phase in 2009 and heavy storms (SMW 32, 33 and 36) at grand vegetative stage in 2011. However, high rainfall was not favourable for greengram, which performed better in low rainfall year in 2009. In the intercropping culture, the harvesting of maize was slightly delayed (1-2 days) while that of the intercrops was advanced (2-6 days) depending upon the planting patterns in different years when compared to sole culture.

Productivity and sustainability

The results show that yield (mean of 3 years) of maize and intercrops was higher in monocropping as compared to their respective yields in intercropping (Table 1). Among the two planting patterns of intercropping, 100 maize:33 intercrop mixture proved superior for maize yield as compared to the mix proportion of 100:67 in all the intercrops. Maize intercropped with blackgram, greengram and sesame in 100:33 additive series showed yield decreases of 12.2, 12.5 and 17.2%, respectively as compared to sole maize. The corresponding values for 100:67 additive series were 20.0, 20.7 and 27.7%, respectively. Crop intensification with intercropping reduced the yield of main crop due to more interspecific competition (Singh *et al.* 2008) and disturbance of the habitat (Banik *et al.* 2000). The difference in yields of intercrops in both the planting patterns of intercropping was non-significant with 100 maize:67 mixture having little bit edge. The maize equivalent yield (MEY) differed significantly in different treatments and was highest when one row of greengram was intercropped with maize (2 M:1 G). Latha and Prasad (2008) also reported increased system productivity due to paired row intercropping of maize with greengram. The intercropping with sesame (1 or 2 rows) anticipated MEY even lower than that of the sole maize.

The higher sustainability yield index (SYI) values in 2 M:1 G (69%) and 2 M:2 G (68%) planting patterns

Table 1 Yield and sustainability yield index (SYI) for sole stands and intercropping in different planting patterns (pooled mean of 3 years).

Planting patterns*	Mix proportion (%)	Yield (tonnes/ha)					SYI
		Maize	Blackgram	Greengram	Sesame	MEY	
Maize (M) (Sole)	100	2.58a				2.58bc	0.56
Blackgram (B) (Sole)	100		0.64a			2.16de	0.44
Greengram (G) (Sole)	100			0.57a		1.94ef	0.38
Sesame (S) (Sole)	100				0.37a	1.73f	0.33
2 M:1 B	100:33	2.26b	0.17c			2.84ab	0.63
2 M:1 G	100:33	2.25b		0.25c		3.07a	0.69
2 M:1 S	100:33	2.13bc			0.06b	2.42cd	0.51
2 M:2 B	100:67	2.06bc	0.24b			2.91a	0.65
2 M:2 G	100:67	2.04bc		0.30b		3.03a	0.68
2 M:2 S	100:67	1.86c			0.07b	2.17de	0.45
Mean		2.17 (±0.071)	0.36 (±0.049)	0.38 (±0.042)	0.17 (±0.029)	2.48 (±0.067)	
Significance		<0.001	<0.001	<0.001	<0.001	<0.001	

MEY, Maize equivalent yield. *2M:1B/G/S, 2M:2B/G/S, represents planting pattern of maize-blackgram/greengram/sesame, numbers represent number of rows. Value in parentheses: ± standard error of the difference (sed) in treatment means. Significance levels are from one-way ANOVA. Data followed by different lower-case letters differ significantly (Tukey HSD test, significance level = 0.05, within column comparison).

indicated minimum guaranteed yield obtained from intercropping maize with 1 and 2 rows of greengram and they are less affected by seasonal variations (Table 1). Vittal *et al.* (2003) also justified the biological acceptance of intercropping systems yielding a SYI>0.66, can be duly considered as recommendable sustainable practice. However, intercropping with blackgram, sesame (1 row) and sole maize with a SYI between 0.50 and 0.65 are the highly promising ones while the sole crop of sesame is technically undependable viewing SYI<0.33 . Legumes are known to offer special advantage regarding the stability of the intercropping system because of their beneficial effect on soil N balance and wider adaptability to diverse conditions (Bastia *et al.* 2008). Maingi *et al.* (2001) also emphasized the introduction of grain legumes in cereal-based cropping system to achieve food and nutritional security and sustainability.

Resource-use efficiencies

One row of greengram intercropped with maize (2 M:1 G) registered the highest production efficiency (PE) (35.67 kg MEY/ha/day) and rain water use efficiency (RWUE) (5.55 kg MEY/ha/mm) closely followed by 2 M:2 G with corresponding values of 34.56 kg MEY/ha/day and 5.53 kg

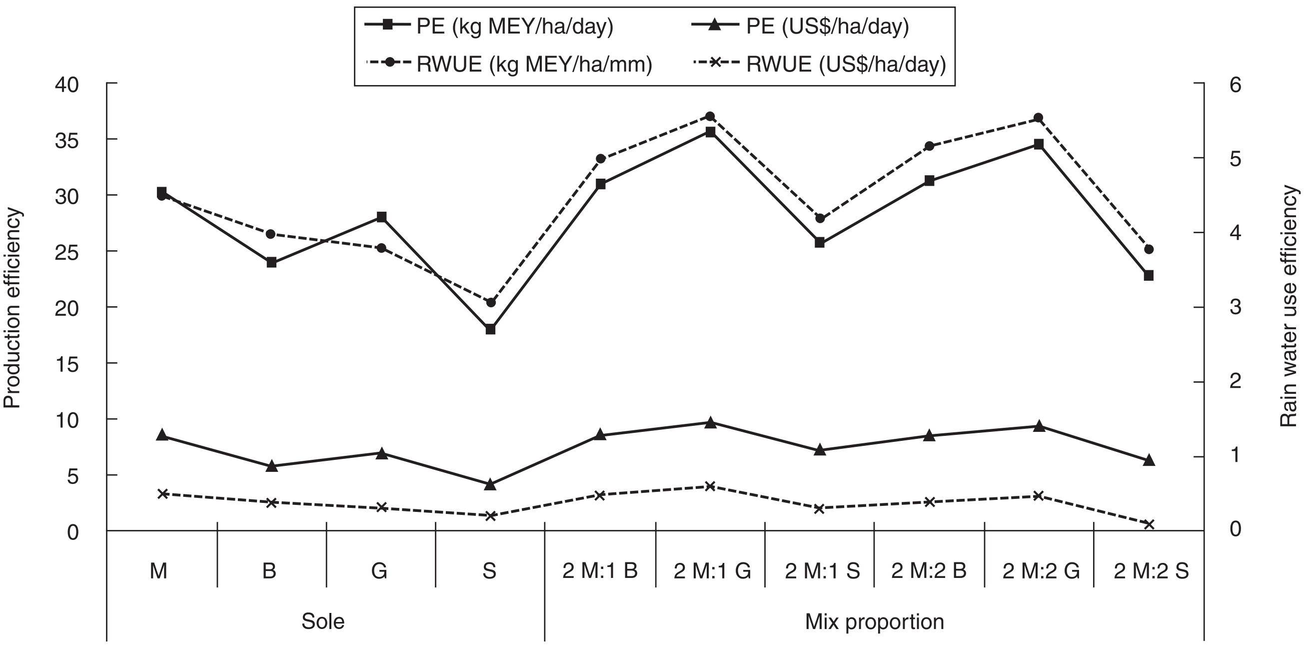

Fig 2 Resource-use efficiencies in different sole and intercropping planting patterns

MEY/ha/mm (Fig 2). Higher system productivity along with shorter length of growing period (LGP) was mainly responsible for the higher PE and RWUE of the system. The lowest PE and RWUE were obtained with sole sesame and one row of sesame intercropped with maize. The longer duration taken by the sesame in maturity with lower productivity was mainly responsible for it. From the point of view of economic efficiency, the 2 M:1 G planting pattern gave the highest PE (8.53 US$/ha/day) and RWUE (0.601 US$/ha/mm) followed by 2 M:2 G for PE and sole maize for RWUE. Sheoran *et al.* (2010) has also reported higher sustainability yield index and production efficiencies due to intercropping of legumes in maize as compared to monoculture.

Land equivalent ratio and relative crowding coefficient

The partial LER_{maize} in different intercropping planting patterns was less than unity (1) which varied significantly and the mix proportion of 100 maize:67 intercrop recorded comparatively higher partial LER_{maize} than 100:33 in all the 3 intercrops (Table 2). Similarly, the partial LER for intercrops was higher in the mix proportion of 100:67. As expected, partial LER_{maize} decreased while $LER_{intercrops}$ increased as the proportion of intercrops increased in the mix-proportions. Among the intercrops, partial LER for legumes was higher than oilseed with highest being in greengram. The LER_{total} differed significantly across planting patterns and its values were higher than 1 when legumes were intercropped with maize indicating more efficient benefits of plant growth factors by intercrops compared to sole crops and favouring the growth and yield of the species. However, intercropping of sesame in maize resulted in LER_{total} values below 1, consequently negatively affecting the growth and yield of plants grown in mixtures (Dhima *et al.* 2007). Thus, it may be inferred that inclusion of legumes (especially greengram) in the maize culture system can achieve a yield advantage compared to maize or legumes in monocultures. These results are in close conformity with that of Dahmardeh and Rigi (2013).

In all the intercropping system included in this study, maize appeared to be highly dominant as it had higher value of the relative crowding coefficient (K_{maize}) than the intercrops in different intercropping systems (Table 2). It can be inferred that the intercropped maize utilized the resources more efficiently than its associated crops which appeared to be dominated. The products of the relative crowding coefficient (K_{total}) were always more than unity (1) except for maize + sesame in the 100:67 mix proportion, indicating a definite yield advantage due to intercropping. Among the intercropping systems, the maximum maize yield advantage was obtained from 1 row of greengram intercropped in between paired rows of maize (2 M:1 G) as indicated by the maximum value (20.40) of K_{total}. The highest RCC value of the product of the coefficient was also recorded by Sheoran *et al.* (2009) when maize was intercropped with greengram.

Aggressivity, competitive ratio, and actual yield loss

The component crops did not exhibit equal competitive intensity based on aggressivity (Table 3). Regardless of the planting patterns, there was a positive sign for maize and the negative for intercrops showing thereby that the maize was dominant, while intercrops were dominated. However, in the 2M : 1G planting pattern, greengram (1 row) was dominant. The aggressivity value was the minimum for 2M : 2G planting patterns, which indicated that greengram (2 rows) was the most competitive crop to maize. By contrast, sesame (2 rows) proved to be least competitive to maize. These results are in line with the findings of Ehsanullah *et al.* (2011), Takim (2012) and Yilmaz *et al.* (2008) who reported the dominant effect of maize having a positive “A” value when grown in association with legumes.

Willey and Rao (1980) reported that CR gives a better measure of competitive ability of the crops and can prove a better index as compared with RCC and aggressively. Intercropped maize had higher competitive ratios (CR_{maize}) in all planting patterns except 100:33 mix proportion of 2 M: 1G, thus indicating that maize was more competitive

Table 2 Land equivalent ratio (LER) and relative crowding coefficient (K) for intercropping in different planting patterns (pooled mean of 3 years)

Planting patterns*	Mix proportion	Land equivalent ratio (LER)			Relative crowding coefficient (K)		
	(%)	LER_{maize}	$LER_{intercrop}$	LER_{total}	K_{maize}	$K_{intercrop}$	K_{total}
2 M:1 B	100:33	0.88a	0.26c	1.14b	2.07	1.08	2.57
2 M:1 G	100:33	0.88a	0.41b	1.27a	14.54	2.41	20.40
2 M:1 S	100:33	0.83a	0.17d	0.99c	4.36	0.64	2.60
2 M:2 B	100:67	0.81ab	0.39b	1.18b	4.09	0.96	3.83
2 M:2 G	100:67	0.79ab	0.49a	1.28a	3.42	1.89	5.35
2 M:2 S	100:67	0.73b	0.18d	0.90d	2.46	0.33	0.74
Mean		0.82 (±0.02)	0.32 (±0.02)	1.13 (±0.03)	5.16 (±2.04)	1.22 (±0.15)	5.91 (±2.46)
Significance		<0.001	<0.001	<0.001	NS	NS	NS

*2M:1B/G/S, 2M:2B/G/S, represents planting pattern of maize-blackgram/greengram/sesame, numbers represent number of rows. Value in parentheses: ± standard error of the difference (sed) in treatment means. Significance levels are from one-way ANOVA. Data followed by different lower-case letters differ significantly (Tukey HSD test, significance level = 0.05, within column comparison).

Table 3 Aggressivity (A), competitive ratio (CR), actual yield loss (AYL) and relative yield loss (RYL) for intercropping in different planting patterns (pooled mean of 3 years).

Planting patterns*	Mix proportion (%)	Aggressivity (A)		Competition Ratio (CR)		Actual yield loss (AYL)		
		A_{maize}	$A_{intercrop}$	CR_{maize}	$CR_{intercrop}$	AYL_{Maize}	$AYL_{Intercrop}$	AYL_{Total}
2 M:1 B	100:33	0.0010cd	-0.0010bc	1.16cd	0.91b	–0.117a	–0.214b	–0.331b
2 M:1 G	100:33	-0.0034e	0.0034a	0.84d	1.42a	–0.123a	0.220a	0.098a
2 M:1 S	100:33	0.0031ab	-0.0031de	1.77b	0.64c	–0.170a	–0.482c	–0.650d
2 M:2 B	100:67	0.0023bc	-0.0023cd	1.42bc	0.73c	–0.194ab	–0.422c	–0.614d
2 M:2 G	100:67	0.0005d	-0.0005b	1.29bcd	0.96b	–0.207ab	–0.260b	–0.466c
2 M:2 S	100:67	0.0046a	-0.0046e	2.82a	0.38d	–0.274b	–0.731d	–1.007e
Mean		0.0013 (±0.0005)	-0.0013 (±0.0005)	1.54 (±0.11)	0.84 (±0.06)	–0.181 (±0.02)	–0.315 (±0.05)	–0.495 (±0.06)
Significance		0.01	0.01	<0.001	0.01	<0.001	0.003	0.001

*2M:1B/G/S, 2M:2B/G/S, represents planting pattern of maize-blackgram/greengram/sesame, numbers represent number of rows. Value in parentheses: ± standard error of the difference (sed) in treatment means. Significance levels are from one-way ANOVA. Data followed by different lower-case letters differ significantly (Tukey HSD test, significance level = 0.05, within column comparison).

than blackgram (1/2 rows), greengram (2 rows) and sesame (1/2 rows) (Table 3). The CR values of maize increased while that of intercrops decreased as the proportion of intercrops increased in the mixture. Among intercrops, the competitive ratio was highest for greengram followed by blackgram in both the planting patterns. These results suggest that among intercrops, greengram proved to be a better competitor than other crops when grown in association with maize. Sheoran *et al.* (2009) have also reported that greengram with one row was the better competitor than two rows when sown in association with maize.

In general, AYL_{maize} had negative values in all planting patterns and the highest AYL_{maize} value (-0.117) was obtained from 2 M:1 B while the lowest (-0.274) was from 2 M:2 S (Table 3). The highest $AYL_{intercrop}$ value belonged to 2 M:1 G while the lowest value was to 2 M:2 S. Comparing the two planting patterns, 100:33 has had the higher AYL_{maize} as well as $AYL_{intercrop}$ values than that of 100:67. Overall, the 2 M: 1 G with 100:33 mix proportion was the only intercropping system which had positive values for both $AYL_{intercrop}$ as well as AYL_{total}. These results indicate that through the intercropping of 1 row of greengram in maize as an additive series, 9.8% (AYL_{total}=+0.098) yield gain could be obtained as compared to their sole treatments. Many previous studies have reported that a cereal+legume intercropping system can achieve an enhanced biomass over corresponding monocultures (Yilmaz *et al.* 2008, Takim 2012).

Intercropping advantages, monetary advantage index and ATER

The ultimate considerations for selection of the best intercropping system are the advantage and the economics of production (Banik *et al.* 2000). The intercropping advantage (IA), which is an indicator of the economic feasibility of intercropping systems, affirmed that the most advantageous planting pattern was 1 row of greengram intercropped in between paired rows of maize (2 M:1 G) at the mix-proportion of 100:33 with an IA value of +87.7 (Table 4). The values of IA followed the same trend with AYL values. The negative values of IA for the rest of the planting patterns showed that these planting patterns led to

Table 4 Intercropping advantage (IA), monetary advantage index (MAI) and Area time equivalent ratio (ATER) for intercropping in different planting patterns (pooled mean of 3 years).

Planting patterns*	Mix proportion (%)	Intercropping advantage (IA)			Monetary advantage index (MAI)	Area time equivalent ratio (ATER)		
		IA_{maize}	$IA_{intercrop}$	IA_{total}		$ATER_{maize}$	$ATER_{intercrop}$	$ATER_{total}$
2 M:1 B	100:33	-26.4a	-175.1b	-201.5b	94.75b	0.84ab	0.25c	1.09b
2 M:1 G	100:33	-28.0a	115.7a	87.7a	170.59a	0.88a	0.31b	1.19a
2 M:1 S	100:33	-38.2a	-546.6d	-584.8e	-6.33c	0.77b	0.17d	0.94c
2 M:2 B	100:67	-44.3ab	-340.3c	-384.6d	122.17ab	0.76b	0.37a	1.13ab
2 M:2 G	100:67	-46.9ab	-251.9b	-298.8c	169.99a	0.79ab	0.38a	1.17a
2 M:2 S	100:67	-62.6b	-802.4e	-865.0f	-66.27d	0.67c	0.18d	0.85d
Mean		-41.1 (±3.4)	-333.4 (±49.4)	-374.5 (±50.3)	80.82 (±15.8)	0.78 (±0.015)	0.28 (±0.015)	1.06 (±0.022)
Significance		<0.001	<0.001	<0.001	<0.001	0.002	0.01	<0.001

*2M:1B/G/S, 2M:2B/G/S, represents planting pattern of maize-blackgram/greengram/sesame, numbers represent number of rows. Value in parentheses: ± standard error of the difference (sed) in treatment means. Significance levels are from one-way ANOVA. Data followed by different lower-case letters differ significantly (Tukey HSD test, significance level = 0.05, within column comparison).

be disadvantageous in terms of monetary returns. The lowest IA value of -865.0 for the planting pattern 2 M:2 S showed that maximum economic disadvantage for maize was observed with sesame in 100:67 mix proportion due to more yield loss of including sesame in the system.

The values of monetary advantage index (MAI) were relatively higher for maize-legume intercropping than the maize-sesame intercropping. Highest MAI (170.59) was observed with 2 M:1 G being identical to 2 M:2 G intercropping system, implying that as the most economical and advantageous planting pattern (Table 4). The lowest MAI value belonged to the planting pattern 2 M:2 S. The positive values of MAI in maize-legume intercropping systems show definite yield and economic advantages compared to the sole cropping systems tested in the study. These findings are also parallel to those of LER and competitive indices. Dhima *et al.* (2007) and Yilmaz (2008) reported that if LER and K values were higher, there was also an economic benefit expressed with MAI values. Krantz *et al.* (1976) also reported higher monetary returns from systems involving intercropping of legumes and non-legumes compared to sole non-legume cropping which was attributed to better utilization of resources.

The area time equivalent ratio (ATER) provides more a realistic comparison of the yield advantage of intercropping over that of sole cropping than LER as it considers variation in time taken by the component crops of different intercropping systems. In all the planting patterns, the ATER values were smaller than LER values (Table 4), indicating contrary to LER, ATER is free from problems of overestimation of resource utilization. Regarding the planting patterns, the ATER values for maize-legume intercropping were higher than the maize-sesame intercropping indicating a better bio-economic efficiency of greengram and blackgram intercropping in maize over that of sesame intercropping. In the maize+greengram planting pattern, ATER values indicated yield advantages in the range of 19% for 2 M: 1G and 17% for 2 M:2 G. Higher values of ATER in intercropped treatments compared with monoculture of maize were attributed to efficient utilization of natural (land, light and rainfall) and added resources (fertilizer). In maize+sesame planting patterns, ATER values were less than one indicating poor utility of resources. Higher ATER values have also been reported in maize+blackgram (Padhi and Panigrahi 2006) associations compared with monoculture of their component crops.

The study concludes that intercropping of maize with legumes (blackgram, and greengram) positively complimented the seed yield, associated competition between the component crops (maize and intercrops) and monetary returns compared to solitary cropping of the same species. The maize+greengram intercropping at 100:33 mix proportions (2 M:1 G) proved good option viewing yield advantages, optimum exploitation of the environmental resources and relatively better production and rainwater use efficiencies and was less affected by seasonal variations. Intercropping of 1 row of greengram in maize provided 9.8% yield gain as compared to their sole cropping. The greengram (2 rows) proved most competitive one while sesame (2 rows) being least competitive to maize. Similarly, the positive values of MAI in maize-legume based intercropping suggested definite yield and economic advantages.

Since planting pattern and mix proportion significantly affected the efficiency of intercropping and also the farmers in the region are not traditionally reluctant to replace or reduce the plant population of maize because of its preference as food and fodder, legume intercropping in maize can fulfil the diversified needs of concerned growers. Such a biologically and economically feasible cropping system can be easily acceptable and practiced especially by small farmers in the rainfed foothills of Northwest Himalayas. The continuous diffusion of short duration modern varieties can help further in intensification of crop production through intercropping. Therefore, in the current scenario of growing population pressure, changing climate and the need to produce diverse products from the ever shrinking land holdings, inclusion of legumes (especially greengram) in the maize culture system can be a very useful management strategy not only to meet out the food requirements but also to increase profitability for farmers, sustainability of agriculture and conservation of soil health.

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