Research Article

Sole and intercropping Sunflower-Mungbean for spring cultivation in Peshawar

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ABSTRACT

Yield of some crops performs better in the intercropping than sole cropping system. Sunflower (*Helianthus annuus* L.) canopy is fragile providing a lot of ground cover, hence, therefore, has a great potential to intercrop with a short stature and/or duration crop making it comparable for the better net return in a cropping system. Field experiment was, therefore, expressly conducted to study the mungbean (*Vigna radiata* L.) in sunflower intercropped on different sowing dates (same sowing date with sunflower, one, two and three weeks delay in sowing from the main sunflower) and rows in combinations (1:1 and 1:2) sunflower-mungbean as intercrop and sole crop of each species for to study yield and yield traits during spring 2011 and 2012 crop growth seasons. Experiments were conducted in randomized complete block design (RCBD), replicated four times at Agronomy Research Farm, the University of Agriculture Peshawar, Pakistan. Data were recorded on plant phenology, yield and yield traits of the main (sunflower) and companion (mungbean) crops. Intercropping did not influence any of the observed morphological traits, yield contributing traits or grain yield of the main sunflower crop. Companion mungbean crop also did not show any advantage ($p < 0.05$) on sole mungbean due to resources competition i.e. solar radiations, nutrients, water and space in the canopy on the ground area. Treatment row combination i.e. 1:1 and 1:2 (sunflower : mungbean) also did not show any advantage in grains yield and/or any of the observed yield trait of mungbean which exhibited sufficient space under the sunflower canopy for mungbean growth and development as additional crop for sustainable soil fertility. Different sowing dates i.e. about a month in delay sowing of intercrop from main sunflower crop did not show any significant ($p < 0.05$) loss in yield or yield contributing traits. The study suggested that mungbean (Cv. Chakwal mung-06) can expectantly be intercropped in sunflower hybrid (Hysun-33) to make it competitive with any other crop of the cropping system in region subject to working on an appropriate planting geometry for sunflower and potential variety of the sunflower to be intercropped.

Keywords: Mungbean intercrop, different sowing date, competitive indices

Introduction

Intercropping is developing two crops together on a piece of land for a season, has improved farming system by efficiently utilizing the natural resources and markedly increasing yield [1]. Yield advantage of intercrop on sole crop is often attributed to the fact that different crops can complement each other avoiding risk of crop failure and stress indices due to any natural factor beyond control of growers. If a crop is unable to compete economically, intercropping may extend opportunities for sustainable farming system. In Khyber Pakhtunkhwa (KP), wheat-maize is successfully grown. Wheat is planted from October to late November subject to rainfall availability. According to future climate change scenario, it is presumed that winter rainfall may decrease by shifting it partly towards the spring [2]. This would badly affect wheat cultivation in Pakistan in general and in KP in particular where wheat is already short by 76% of total demand of local production in KP. It is predicted that future climate change will affect wheat cultivation through acute

water shortage in early autumn. Alternative has to be explored for spring plantation in region with a relatively higher frequency and amount of future rainfall in spring. Sunflower and mungbean are potential alternatives as spring and summer crops in this area. Domestic edible oil production meets only 23% of the country demand [3] with import bill of 2.84 million tons edible oil amounting US \$2.611 billion each year to Pakistan's economy (Rs. 224 billion). Since 1947 to late sixties, canola and cotton have contributed in the local edible oil production. Sunflower (*Helianthus annuus* L.) and soybean (*Glycine max* L.) were introduced but recently sunflower only contributing 32% in domestic edible oil production [4]. Massive population expansion has the demand for more edible oil in future. Pakistan is already paying more, which will become harder to sustain in near future. Opportunity of local oil seed production has to explore at par with expected future climate changes.

Sunflower is a quality source of edible oil with a great potential to adjust in the cropping system with

limited growth period (110 days) as either spring or summer crop [5]. By its plant height and fragile canopy volume, it can successfully be intercropped with grain legumes (i.e. mung, mash, cowpea, ground nuts etc.) and also for fodder (summer clovers), which are extremely short in Pakistan. Average diet of human beings and animals are acute short of available protein [6]. Mungbean (*Vigna radiata* L.) is known as green gram, an integral part of diet consumed boiled or fried, drought tolerant, short duration, and enhanced soil fertility by N fixation [7, 8]. Seed of mungbean is a rich source of edible protein (20-25%) and famous as poor man's meat [9]. N-fixation is important for production system to meet N requirement of the companion crops and following crops in the cropping system [10, 11]. Imbalance nutrient application with poor soil fertility due to higher fertilizer cost is major constraints limiting production of the developing countries [12]. Effective- and/or a successful intercropping system depend on species selection of compatible crops that address future need, market demand and more or less competitive with higher returns than crops already in cultivation in the cropping system. We, therefore, focused to improve understanding of sunflower as intercrop with mungbean as spring crop.

Materials and Methods

Experimental site

Field experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar during spring 2011 and repeated in spring 2012. The experimental site is located 34°01' N latitude and 71°35' E longitude with altitude of 359 m above sea level. The environmental conditions at research farm are warm to hot, semi-arid subtropical, continental climate, with a mean annual rainfall of less than 360 mm. Soil is a deep silt clay loam, alkaline with a pH of about 7.5–7.8, and deficient in total N (<0.5 g kg⁻¹). Rainfall and seasonal temperatures (maximum and minimum) for the crop growth periods are shown in Fig. 1.

Experiment details

To study mungbean intercropped in sunflower on different sowing dates (SD) and row combinations (RC), experiment was conducted in spring 2011 and repeated in spring 2012. Sunflower hybrid (Hysun-33) and mungbean (Cv. Chakwal mung-06) were used in a randomized complete block (RCBD), replicated four times. The experimental unit was 3.10 m in length and 5.4 m in width, accommodating 6 rows of sunflower at 0.90 m. The sole mungbean was planted at 0.45 m space to accommodate 12 rows. For intercrop treatments, alternate one and two rows of mungbean were planted in between sunflower rows. Urea and Single Super Phosphate (SSP) were used to yield basal nutrients of N (90 kg ha⁻¹) and P₂O₅ (60 kg ha⁻¹), respectively. Nitrogen and P were applied as band application in close proximity to sunflower crop. All P was applied at sowing time and N in two splits: half at sowing and remaining half 30 days after

sowing (DAS). Plant populations were maintained by manual thinning after sunflower emergence (20 DAS) by leaving plants at uniform distance of 15.5 cm and 10 cm within rows of sunflower and mungbean (36 DAS), respectively. Mungbean was intercropped in sunflower on four different dates (same date with sunflower, one, two and three weeks after sunflower sowing) by accommodating single (1:1) and double rows (2:1) in sunflower. Details of treatments are shown below.

Treatment structure

T₁= Mungbean-sunflowers (1:1) same planting date

T₂= Mungbean-sunflower (1:1) a week after sunflower planting

T₃= Mungbean-sunflower (1:1) two weeks after sunflower planting

T₄= Mungbean-sunflower (1:1) three weeks after sunflower planting

T₅= Mungbean-sunflower (2:1) same date planting

T₆ = Mungbean-sunflower (2:1) a week after sunflower planting

T₇ = Mungbean-sunflower (2:1) two weeks after sunflower planting

T₈ = Mungbean-sunflower (2:1) three weeks after sunflower planting

T₉ = Sole crop of sunflower (0.90 m spacing)

T₁₀ = Sole crop of mungbean (0.45 m spacing)

Experiment was planted manually in early March using single row hand drill keeping rows spacing of mungbean and sunflower as already explained above. Recommended seed rates were used for sunflower (6 kg ha⁻¹) and mungbean (24 kg ha⁻¹) for the sole and the intercrop treatment. Uniform recommended agronomic practices and plant protection measures were adopted during crop growth and development to keep fields free from seasonal weeds, insect pests and diseases etc.

Measurements and observations

Days to emergence were recorded visually counting days from sowing to complete 80% emergence in central rows in an experimental unit. Days to flowering, -inflorescences and -maturity were also recorded from sowing to occurrence of that event. Leaf area index was recorded non-destructively using LI-2000 plant canopy analyzer (LI-COR, USA) at anthesis. The machine was initially calibrated on day of reading to provide single mean reading of LAI through multiple samplings one above and three below the crop canopy. All readings were simultaneously stored in a data logger and transferred to computer. The reading was made in a day between 11-13 h. Plant height (cm) was measured on ten representative randomly selected samples a week before the crop harvesting. Reading was recorded manually taking measurements on individual plant

from base to the top edge of collar disc of sunflower and terminal node of mungbean. Data on plant population per unit area (m^{-2}) was recorded by counting plants in two central rows in a plot a week before harvesting and converted to m^{-2} . Heads diameter of sunflower was measured on ten selected representative samples from two central rows. Number of pods plant^{-1} in mungbean was manually counted by harvesting all pods in ten randomly selected plants. Number of grains head^{-1} (sunflower) and pod^{-1} (mungbean) were counted manually in ten selected plants by shelling grains from sunflower heads and mungbean pods. Thousand grains weight (g) was recorded from threshed clean grains of a treatment by taking random samples and counting grains and independently weighting at a precise digital balance. Two central rows of an experimental unit were harvested, sun dried in field for two weeks and weighed for a total biomass and yield. Harvest Index (%) was estimated as ratio of grains and total biomass including grains.

The yield advantage of intercropping could determine according to methods already described in literature [13]. Different indices have been used to evaluate productivity and efficiency of land for intercropping [14].

$$LER_{Sf} = Y_{Sf}/Y_{Sf} + Y_{Mb}/Y_{Mb} \dots \dots \dots (Eq. 1)$$

Where, Y_{Sf} = sole crop yield of sunflower (Sf), Y_{Mb} = sole crop yield of Mungbean (Mb), Y_{Sfi} = intercrop yield of sunflower (Sf) in combination with Mungbean (Mb) and Y_{Mbi} = intercrop yield of mungbean (Mb) in combination with sunflower (Sf).

$$ATER = \{(LER_{Sf} \times t_{Sf}) + (LER_{Mb} \times t_{Mb})\} / T \dots \dots \dots (Eq. 2)$$

Where' LER_{Sf} & LER_{Mb} is partial LER of crops Sf & Mb respectively, t = time duration (days) for crop Sf or Mb taken in monoculture as checks and T is the time duration (days) of intercropping system. Aggressivity (A) value was calculated as:

$$A_{Sf} = \{Y_{Sfi} / (Y_{Sf} \cdot Z_{Sf,Mb})\} - \{Y_{Mbi} / (Y_{Mb} \cdot Z_{Mb,Sf})\} \dots \dots \dots (Eq. 3)$$

$$A_{Mb} = \{Y_{Mbi} / (Y_{Mb} \cdot Z_{Mb,Sf})\} - \{Y_{Sfi} / (Y_{Sf} \cdot Z_{Sf,Mb})\} \dots \dots \dots (Eq. 4)$$

For Sunflower

$$CR_{Sf} = \{(LER_{Sf} / LER_{Mb}) \times (Z_{Mb,Sf} / Z_{Sf,Mb})\} \dots \dots \dots (Eq. 5)$$

For Mungbean

$$CR_{Mb} = \{(LER_{Mb} / LER_{Sf}) \times (Z_{Sf,Mb} / Z_{Mb,Sf})\} \dots \dots \dots (Eq. 6)$$

Where $Z_{Mb,Sf}$ = proportion of species 'Sf' grown in association with species 'Mb'; $Z_{Mb,Sf}$ = proportion of species 'Mb' grown in association with species 'Sf'. Species 'Sf' main crop and species 'Mb' intercrop.

$$K_{Sf} = [(Y_{Sfi} \cdot Z_{Mb,Sf}) / \{(Y_{Sf} - Y_{Sfi}) \cdot Z_{Sf,Mb}\} \dots \dots \dots (Eq. 7)$$

$$K_{Mb} = [(Y_{Mbi} \cdot Z_{Sf,Mb}) / \{(Y_{Mb} - Y_{Mbi}) \cdot Z_{Mb,Sf}\}] \dots \dots \dots (Eq. 8)$$

Where $Z_{Sf,Mb}$ is sown proportion of (Sf) in mixture of (Mb) and $Z_{Mb,Sf}$ is sown proportion of (Mb) in mixture of (Sf). The product of two coefficients ($K_{Sf} \cdot K_{Mb}$) = k

Significant part of intercrop study is cost: benefit ratio, i.e. total profit e.g. yield of all crops in different intercropping systems vs. sole crop and their economic return in terms of monetary value. It was calculated as:

$$MAI = (P_{Sfi} \times P_{Mbi}) \times \{(LER-1) / LER\} \dots \dots \dots (Eq. 9)$$

Where, $P_{Sfi} = P_{Sf} \times Y_{Sfi}$ and $P_{Mbi} = P_{Mb} \times Y_{Mbi}$, P_{Sf} = Price of species 'Sf' and P_{Mb} = Price of species 'Mb'.

Statistical Analysis

Data on recorded parameters were subjected to analysis of variance (ANOVA) according to the methods already published [15] and treatment means, where found significant, were separated using the least significant difference (LSD) at $P \leq 0.05$.

Results

Main crop

Different parameters measured viz., days to emergence, flowering, maturity, leaf area index (LAI), plant height (cm), plants population at harvest, head diameter (cm), number of grains head^{-1} , grain yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (HI) of sunflower crop did not differ by treatments or their possible interactions (Table 1). As expected and evident from crop data, the cropping system (CS) i.e. mungbean intercrop in sunflower on different dates (SD) and row combinations (RC) 1:1 and 1:2 of mungbean in sunflower did not influence any morphological trait, yield contributing traits and/or yield (Table 2). Canopy LAI, recorded non-destructively as a total canopy green area index observed higher in intercrop vs. sole crop.

Companion crop

Sowing dates means i.e. same dates and subsequent delay for four weeks of mungbean within the sunflower (Table 3), row combinations means i.e. 1:1 and 1:2 and cropping systems means i.e. sole vs. intercrop (Table 4), competitive indices (Table 5) and the possible interactions are presented separately. Data regarding phenology (i.e. days to emergence, days to flowering and days to maturity) were significantly ($p < 0.05$) decreased when planting of mungbean was delayed in the sunflower as spring season crop on two years average basis (Table 3). Mungbean sown in sunflower on the same date took more days compared to every subsequent delay in sowing a week with a significant ($p < 0.05$) reduction in days to emergence, days to flowering and days to maturity. Maximum LAI was observed for three weeks delay sown mungbean in sunflower with a non-significant change in same date of sowing.

Fig. 1. Weather data of mean monthly rainfall (mm) and temperature ($^{\circ}\text{C}$) from March to June of two years experiment duration (2011-12).

Fig. 2. Interactive effect of sowing dates (SD) and Row combinations (RC) on (a) harvest index and (b) leaf area index of mungbean. Vertical bars show $\pm$ SE of the mean.

Table 1. Analysis of variance for different growth, yield and yield traits observed on mungbean sole and intercropped in spring sunflower (2011-2012).

SOV	d.f	DTE	DTF	DTM	PPM	PHT	LAI	NPPP	NGPP	TGW	BY	GY	HI
Year (Y)	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y(Rep)	6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments	8	**	**	**	**	**	**	**	**	**	**	**	NS
Sole (S) VS. Intercrop	(1)	**	**	**	**	**	**	**	**	**	**	**	NS
Sowing dates (SD)	(3)	**	**	**	NS	*	NS	NS	NS	NS	NS	NS	NS
Row Combination (RC)	(1)	NS	NS	NS	**	**	**	NS	NS	**	NS	NS	NS
SDx RC	(3)	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Y x Treatments	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x S vs. Intercrop	(1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x SD	(3)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x RC	(1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x SDx RC	(3)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	48	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total	71												

DTE= Days to emergence, DTF= Days to flowering, DTM= Days to maturity, LAI= Leaf area index, PHT= Plant height (cm), PPM = Plants m⁻²,
 NPPP= No. Pods plant⁻¹, NGPP= No. Grains pod⁻¹, TGW= thousand grains weight (g), BY= Biological yield (kg ha⁻¹), GY= Grain yield (kg ha⁻¹), HI= Harvest Index (%)

Table 2. Study of plant phenology, yield and yield traits of spring sunflower (sole and intercrop) at Research Farm, the University of Agriculture, Peshawar. Each value is mean of two years average.

Treatments	Means (2011-12)												
	DTE	DTF	DTM	LAI	PHT	PPM	BY	HD	NGPH	TGW	GY	HI	OC
Cropping system (CS)													
Sunflower sole	11	81	110	3.43 b	223.1	7	11255	18.94	991	51.56	2815	25.02	43.98
Sunflower intercropped with mungbean	11	81	110	3.66 a	222.79	7	10975	18.73	985	50.71	2751	25.09	43.37
Significance	ns	ns	ns	0.001	ns	ns	Ns	ns	ns	ns	ns	ns	ns

Means in same column followed by a different letter are significantly different from one another at 5 % level of probability

Table 3. Study of plant phenology, yield and yield traits (averaged across row combinations, sole and intercrop) of spring mungbean crop at Research Farm of the University of Agriculture, Peshawar. Each value is mean of two years average.

Treatments	Means (2011-12)											
	DTE	DTF	DTM	LAI	PHT	PPM	NPPP	NGPP	TGW	GY	BY	HI
Sowing dates (SD)												
Same sowing date with sunflower	18 a	70 a	89 a	3.60 ab	10	30.16	3	5	22.21	22.45	255.6	8.79a
One week after sunflower sowing	11 b	63 b	80 b	3.58 b	11	31.06	3	5	22.29	20.34	260.36	7.81b
Two weeks after sunflower sowing	8 c	60 c	77 c	3.56 b	10	29.99	3	6	22.06	18.76	261.66	7.20b
Three weeks after sunflower sowing	4 d	54 d	70 d	3.74 a	11	31.07	3	5	22.27	18.76	266.87	7.05b
LSD	0.632	1.11	1.18	0.16	ns	ns	Ns	ns	ns	ns	ns	

Means in same column followed by a different letter are significantly different from one another at 5 % level of probability.

DTE = Days to emergence
PHT = Plant height
GNPH = number of grains pod⁻¹
NGPH= Number of grains head⁻¹

DTF = Days to flowering
PPM = Plants m⁻²
TGW = 1000 grains weight (g)
HD= Head diameter (cm)

DTM = days to maturity
BY = Biological yield (kg ha⁻¹)
GY = Grain yield (kg ha⁻¹)

LAI = Leaf area index
NPPP = No. of pods plant⁻¹
HI = Harvest index

Table 4. Study of plant phenology, yield and yield traits (averaged across sowing dates) of spring mungbean intercropping as row combinations (RC) and cropping system (sole vs. intercrop) at Research farm, the University of Agriculture, Peshawar. Each value is mean of two years average.

Treatments	Means (2011-12)											
	DTE	DTF	DTM	LAI	PHT	PPM	NPPP	NGPP	TGW	GY	BY	HI
Row combination(RC)												
One row intercropped in sunflower	10	62	79.13	3.50 b	8 b	32.56 a	3	5.37	23.17 a	22.17	259.22	8.57 a
Two rows intercropped in sunflower	10	62	78.91	3.74 a	12 a	29.56 b	3	5.34	21.24 b	17.99	263.02	6.86 b
Significance	ns	ns	ns	0.000	0.000	0.000	Ns	ns	0.000	ns	ns	0.000
Cropping system (CS)												
Mungbean sole crop	18 a	70 a	89 a	3.61	25 a	58.08 a	27 a	11 a	44.21 a	608.75 a	2968.65 a	20.50 a
Mungbean intercrop in sunflower	10 b	62 b	79 b	3.62	10 b	31.06 b	3 b	5 b	22.21 b	20.08 b	261.12 b	7.71 b
Significance	0.000	0.000	0.000	ns	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000

DTE = Days to emergence
PHT = Plant height
GNPH = number of grains pod⁻¹

DTF = Days to flowering
PPM = Plants m⁻²
TGW = 1000 grains weight (g)

DTM = days to maturity
BY = Biological yield (kg ha⁻¹)
GY = Grain yield (kg ha⁻¹)

LAI = Leaf area index
NPPP = No. of pods plant⁻¹
HI = Harvest index

Table 5. Land Equivalent Ratio (LER), Area Time Equivalent ratio (ATER), Competitive Ratio (CR), Aggressivity value (Ag), Relative Crowding Co-efficient (RCC) and Monitory Advantage Index (MAI) of sunflower-mungbean intercropping treated with different sowing dates and row combination.

Treatments	LER	ATER	CR _s	CR _m	Ag _(s)	Ag _(m)	RCC	MAI
Sowing dates (SD)								
Mungbean same sowing date with sunflower	1.02	1.01	19.81	0.105	0.676	-0.676	-7.96	2019
Mungbean one week after sunflower sowing	1.02	1.01	19.18	0.087	0.684	-0.684	62.27	1798
Mungbean two weeks after sunflower sowing	1.01	1.00	21.61	0.083	0.683	-0.683	11.65	697
Mungbean three weeks after sunflower sowing	1.00	0.99	21.22	0.084	0.682	-0.682	23.65	296
Row combination(RC)								
Mungbean one row intercropped in sunflower	1.02	1.01	6.95	0.149	0.417	-0.417	18.01	1959
Mungbean to rows intercropped in sunflower	1.00	1.00	33.96	0.03	0.945	-0.945	26.8	446

CR_s= Competitive ratio (Sunflower), CR_m= Competitive ratio (Mungbean), Ag_(s)=Aggressivity (Sunflower), Ag_(m)= Aggressivity (Mungbean),

Canopy LAI did not show any significant ($p < 0.05$) change with one and two week delay in sowing of mungbean in sunflower. Plant height (cm), plant density, number of grains pod⁻¹ and thousand grains weight (g) of mungbean did not show any significant ($p < 0.05$) changes by delay in sowing a week, two or three from same planting date. Likewise, grain yield and biological yield expressed no statistical changes with sowing dates on mungbean crop. The same sowing date expressed a higher ($p < 0.05$) harvest index when compared with any subsequent delay in planting a week, two or three in sunflower. Harvest index of any subsequent delay sowing from one to three weeks did not differ from each other.

One and two row intercropping of mungbean in sunflower (main crop) did not show any statistical ($p < 0.05$) differences in days to emergence, flowering, maturity and number of pods plant⁻¹ and grains pod⁻¹ (Table 4). Nevertheless, canopy LAI and plant height were observed greater for two rows intercrop in sunflower than single row intercrop. All possible interactions were found non-significant ($p < 0.05$) for crop LAI except the SD x RC (Fig. 2a). It is evident from the data in the figure that LAI decreased for one row by delay sowing for a week and thereafter the crop LAI moderately increased for the third week delay sowing with significant differences between one row and two rows. High reading observed for two rows and a marked increase noted from the same date to first week and further delay in sowing showed a slight increase. Contrary to that plant per unit area and thousand grains weight were observed maximum in one row intercropping when compared with two rows intercropping mungbean in sunflower. Both grain yield and biological yield in mungbean did not differ ($p < 0.05$) at one or two rows intercropping but harvest index was observed greater for one row as compared to two rows intercropping. The only interactions of a treatments combination SD x RC was found significant for harvest index (Fig. 2b). It is evident from the figure that a stable and slight decrease observed in one RC from delay in sowing and marked decrease observed in two RC from same date sowing to delay in sowing for one week and further delay in sowing shows a mild decrease. None of the observed traits were found at par or better in intercropping when compared with sole mungbean (Table 4).

Competitive indices

The treatment SD and RC did not affect land equivalent ratio (LER) on two years averages (Table 5). The value of the LER was almost close to one for SD and RC which indicated no yield advantage of intercrop over the sole crop. The data revealed that ATER for treatments SD and RC were same as reported for the LER on two years averages. Hence there is no additional advantage to an intercrop over

sole crop. Competitive behavior of the companion crop of an intercrop system was determined in terms of Aggressivity (Ag) and Competitive ratio (CR), Relative Crowding Co-efficient (K). The CR values are presented in Table 4. Sunflower crop has more CR value than mungbean crop indicating the competitiveness and dominant behavior of the sunflower on mungbean crop. Maximum CR value of sunflower is observed in treatments that mungbean planted in the sunflower after two weeks delay from the sunflower crop, followed by mungbean sown after three weeks delay in season. The highest reading was recorded for the mungbean sown on same date with sunflower and lowest reading was observed for mungbean sown after a week of sunflower sowing. The CR response to different SD in mungbean was different from sunflower, and maximum CR observed for mungbean planted with sunflower on same date, followed by mungbean sowing a week in delay, mungbean sowing three weeks in delay of sunflower and the minimum for mungbean sowing two weeks delay in sunflower. Higher CR was noted for sunflower in two rows combination over the one row on two years averages. Contrary to sunflower, high CR for mungbean was observed in one row than two rows combination. Aggressivity data revealed that companion crop did not compete equally and sunflower indicated dominant behavior over the intercrop showing the positive (+) sign against negative (-) sign for mungbean (Table 5). Ag was highest for sunflower in all treatments as compared to mungbean. The Ag of sunflower observed on two years average with no difference in Aggressivity values for sunflower that mungbean sown after two and three weeks delay. The Ag decreased by delay in sowing dates from first week to three weeks after sunflower cultivation with a minimum for treatment where mungbean sown in sunflower on same date. However, mungbean as intercropped showed opposite behavior for Ag in intercropping. A negative Ag indicated that mungbean was suppressed during growth period by sunflower. Maximum Ag observed in treatment that mungbean sown with sunflower at same time and a delay in mungbean sowing increased Ag on two years average data. Sunflower showed more Ag values in two rows combination (RC). Contrary to sunflower, mungbean showed more Ag in one row than two rows combination on two years averages data.

The relative crowding co-efficient (k) of an intercrop system is also presented in Table 4. The data indicated that almost all K values were greater than one, which showed that yield of intercrop has advantage over the sole crop. The only negative value for k was reported in treatment when mungbean intercropped with sunflower on same date showed yield disadvantage of the intercrop.

The SD affected k of intercrop system with different fashion. It is evident from the results that maximum k was noted when mungbean sown in sunflower a week delay, followed by three weeks delay, two weeks delay and minimum k value observed when mungbean sown at same date with sunflower. Similarly the k was higher in two rows than single row combination on two years average data. Significant part of study was the cost to benefit ratio more specifically total profit i.e. the monetary value of return (MAI). The yield of all crops combinations in different intercropping systems vs sole crop and their economic return MAI are given in Table 5. The data regarding MAI indicated that MAI were positive showing yield advantages in intercrop over sole crop. It is evident from the data that delay sowing of mungbean in sunflower decreased MAI on two years average. By comparison RC, one row treatment showed higher MAI than two rows.

Discussion

As expected, no significant changes were observed in yield and any of the yield related traits for sunflower crop. When compared with the companion mungbean as an intercrop, the sunflower was planted under same nutrients, inputs and cultural management to yield a uniform density per unit area and hence has resulted non-significant changes in yield and any of the yield related traits including general plant morphology. These results are in contradiction with the published findings [16] wherein it is reported a higher yield and yield traits in sole sunflower than intercropped with mungbean for the spring season. Taller statured of sunflower canopy did not show change in any of the measured character compared to shorter height intercrop mungbean. These results are in conflicts with published literature wherein plant height, LAI, and grain of sweet sorghum were observed lower in the intercropping as compared to sole crop [17]. Contrary to the sunflower, mungbean as intercropped in the sunflower canopy was completely over shaded for growth and development. The crop LAI was recorded higher for intercropped than sole and one row than two row combinations intercropping [18]. Quite natural when sowing was delayed for a week from the sunflower, days to emergence, flowering and maturity were reduced and hence a significant response was observed for sowing dates of the traits [19]. One and two rows intercropping mungbean in sunflower did not show any statistical change in days to emergence; flowering and maturity because these traits are independent of the unit population rather associated with climate and moisture. Nonetheless, sole than intercrop showed a delay in emergence, flowering and maturity that might be due to the cold temperature in early March that does not suite mungbean crop and delay

in sowing enhance merge, flowering and maturity for mungbean crop. The greater LAI in two RC than one row might be due to more number of plants m^{-2} that promotes dense plant canopy and more vegetation. Plants per unit area did not affected by sowing dates while using the same seed rates with viable seeds have to show similar emergence. These results are in conflicts with published literature [20, 21] stating low stand of plants in early sowing of mungbean. Delay mungbean sowing in season as spring crop was advantageous to increase slightly in temperature and photoperiod, which also favors emergence and hence has resulted a non-significant ($p < 0.05$) response on density of companion crop [18]. However, the sole crop than intercrop showed higher density and likewise did by the one row than two, which proved that increase density per unit area or shading effect has a strong influence on plant survival. The higher will be the crowding and the greater will be the shade effect, the lesser would be the chances of survival or the companion plants in an intercropping. No statistical changes were observed in biological yield and grains yield by delay sowing and one and two rows intercropping of mungbean [22]. However, among yield contributing traits, none of the yield traits showed any change by delay sowing. This might be advantageous of the warmer weather for the spring crop, which brought a non-significant response in yield contributing traits. Thousand grains weight of one row than two rows intercropping were better due to available spaces for the plant canopy in the intercropping [23]. The sole crop than intercrop showed better yield traits, which also confirms that space and microclimate within the crop canopy for intercropping is equally important for better yield. Competitive indices (LER, ATER, CR, Ag, RCC and MAI) did not show any significant changes which inferred that mungbean, intercrop in sunflower as spring crop was not actively responsive. These results are not in agreement with literature [16] reporting a complementary response for the competitive indices. One possible reason might be that relatively mild solar radiation intensity, shorted days and lower temperature were insufficient to produce a significantly ($p < 0.05$) favorable response on growth of the companion crops in the intercrop as spring intercropping system in the area.

Conclusion

This study concluded that sunflower intercropping with mungbean did not reflect any adverse effects on any observed traits in the sunflower. We have not seen any significant changes in the mungbean yield and yield traits by delay planting or adjusting one and two rows in the sunflower. This shows that intercropping of mungbean and sunflower is possible and needs detailed investigation to manage

planting geometry, changes in sowing dates and appropriate mungbean variety that fits with sunflower for a successful intercropping to get maximum benefits of the intercrop than sole crop for grains or biomass yield in addition to the sole crop.

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