ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI:** **http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

Growth and yield of Sunflower (*Helianthus annuus*)in additive Intercropping system with Mung bean.

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A B S T R A C T:

Some crops perform better in intercropping systems with other crops relative to their solcropping . Sunflower (*Helianthus annuus* L.) was adopted to be studied in a field experiment within an additive intercropping system with mungbean (*Vigna radiata* L.) in a three rows in combinations (1:3 and 1:4 and 1:5) sunflower-Mung bean intercropped and sole cropped for studding growth , yield components and yield traits during the summer of 2021 at two different agro ecological locations of the governorate of Erbil- Iraq. Experiments were triplicated in a randomized complete block design (RCBD), Each location was a parcel of a local farmers land in the villages of Shamamr (Latitude: 406227, Longitude: 397954 rainfall isocline (350 mm y^{-1})) and Dukalla (Latitude: 358033 m, Longitude: 3993384 m),at the last of the semi insured and the first of the non-insured rainfall zones respectively . Shamamr location suppressed Dukalla location in most of morphological traits at the ages of 20 days after sowing (DAS), nd 60 DAS. Treatment row combination (1:3, 1:4 and 1:5) showed advantages in yield component traits over sole cropping of sunflower might be due to resources gains as solar radiation, conditioning heat environment and space .No advantages of intercropping were observed among cropping systems in seed yield while the treatment (1:5) possessed the highest Harvest index (0.6). Sunflower in Shamamr location is believed to perform better under intercropping system. More planting geometry is recommended to obtain more precise results.

KEY WORDS: Sunflower ,Mung bean ole cropping , row intercropping system
DOI: http://dx.doi.org/10.21271/ZJPAS.34.2.7
ZJPAS (2022) , 34(2);62-74 .

1.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 (Vandermeer ,1992). 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. (Garbo , 2015).

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Article History:
Received: 06/12/2021
Accepted: 31/01/2022
Published: 13/04 /2022

If a crop is unable to compete economically, intercropping may extend opportunities for sustainable farming system (Lithourgidis et al 2011).According to future climate change scenario, it is presumed that winter rainfall may decreases by shifting it partly towards the spring . (jeon et al 2018).It is predicted that future climate change will affect winter crop 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. SF and MB are potential alternatives as spring and summer crops in this area (Bendi and olsen 2011). Early effort was done in this area by Jubr Al-Layla et al. 2012. Growing of two crops or more than two crops is known to the humanity since a long time and defined as intercropping , they either be row intercropping (Mousavi, and Eskandari, 2011). Kahan et al 2020. measured direct seed yield for some intercropped crops and measured Land equivalent ratio of them and found mostly that intercropping performed better in this area . Intercropping is a valuable technique leads to sustainable eco-friend farmland productivity (Anas et al 2017) .intercropping could be beneficial for clearing soil , water and the environment from pollutants , and increase the outcome of farm resources , and to trap beneficial insects (Mousavi, and Eskandari, 2011 and , Anas et al 2017) .Intercropping system could be additive in which the essential crop introduced to the system in a constant rate and the other crops are introduced in varied crop densities (Nawar et al 2020)or in substitutive system as all the contributed constitutes , even the essential crops are grown in a determined total density (Dizayee 2020) . The purpose of this research was to study growth and yield of a local variety of sunflower (SF) as response to four planting treatments , namely : SF sole cropping and three intercropping treatments with Mung bean(MB) crop in intercropping system design with (Sunflower : Mungbean) ratios of (1 SF: 3 MB , 1 SF: 4 MB and 1 SF: 5 MB) in an additive design triplicated at two locations in Erbil governorate under farmers field condition .

2-Materials and Methods,

The response of SF (*Helianthus annuus* L.*)* to intercropping in the semi ensured and non- insured rainfall environment (semi-arid) regions of Erbil regions was studied for growth traits in three intervals of 20 day intervals after planting (DAP) in two farmer fields during the summer season of 2021.

2.1 Climatic Conditions of Erbil Region,

The climate of Erbil district lays within semi-arid environment zones including the three categories of yearly rainfall from insured rainfall at the upper mountainous districts on the northern boarders to semi insured yearly rainfall at the middle districts to non-insured yearly rainfall at the lowermost parts in the boarders with lesser zab river. The meteorological data of both locations are shown in table (1) .

2.2 Field Preparation, Layout, and Cultural Practices,

Two perpendicular plowed row directions were achieved with moldboard after wetting the land and waiting for a suitable soil moisture content for cultivation , then the soil surface was smoothed , graded and moderate for the triplicated experimental units in each location . Planting was done with 10 days aged seedlings to obtain uniform plants in age and population, and to ensure uniform planting to minimize irrigation water use and to avoid the hazardous effects of scarce water availability in this most dryer season in the area since 75 years (Shi, et al 2021) . Only one recommended dosage of N, P, K fertilizer was applied without splitting N fertilizer as usual since the MB can enrich the soil with fixed atmospheric nitrogen. No any chemicals were used as pesticide and herbicide and the weeding achieved manually. SF heads were covered with a mesh cloth to prevent birds, covering were done after pollination.

2.3 Experimental Design and Treatments,

Randomized complete block design (RCBD) was adopted in three replications, , each replicate contained four Sunflower (SF) : Mungbean (MB) cropping modes (one pure stand or mono-crop of sunflower and three intercropping modes , namely 1 SF: 3 MB , 1 SF: 4MB , and 1 SF: 5 MB , in an additive experimental design . Planting was achieved in east –west directions for both locations on 75 cm spaced between rows and 25 cm within rows for the sunflower , and 25 cm spacing between rows and three types of inter-row namely 25 cm, 20 cm and 15 cm for the mungbean , so that planting densities were about 5.33 plants m^{-2} for SF ,and 15.99, 21.32 and 26.65 plants m^{-2} accordingly Each plot contained four planting lines of SF and eight planting lines of MB within $15m^{-2}$ plots with dimensions of 3m by 5m .The experiment was designed to study the effect of four cropping patterns on the local SF .

2.4 Studied traits

Plant height (cm)

The plant height was measured in centimeter system using a surveyor's ruler scale from the plant stem`s base on the soil surface to the point of stem junction to head.

Stem diameter (mm)

SF diameter was measured in (mm) at three different height levels on equidistance using ImageJ software.

Plant dry stem and leaf weights (g)

Stems, leaves then heads after ripening were detached , samples where dried in oven at 68C^o at ages of 20, 40 , 60 DAS and at maturity . Shoot dry weight was calculated from adding the dry weights ohe different plant constitutes .

Leaf area (cm^2)

The leaf area was determined using the technology of Image j software (Ibramof et al .2004).

Yield and Yield Attributes

Five plants from each planting line of the three replicates were used to estimate the yield and yield components.

Head diameter (cm)

The average diameter of five mature heads were computed in centimeters with measuring scaled ruler passing through the head center in each treatment ..

Head weight (g)

Head weight (g) from five plants for each treatment was recorded and averaged to get single head weight.

Number of full and empty seeds plant^{-1}

The numbers of empty and full seeds were estimated statistically by allocating both of the whole seed containing disk area and the enclosed empty seed containing area using ImageJ software.

100 seed weight (g)

A random sample containing 100 seeds was selected in each treatment , then weighed in a three digit electronic balance and expressed in (g) .

Biological yield (kg ha^{-1})

Biological yield g plant^{-1}) was measured as the above-ground biomass per plant by weighting the whole plants, including seeds and stalks from the plant samples collected during full maturity, expressed in metric grams, then converted by dividing by the number of plants per sample.

Seed yield (g plant^{-1})

The seed weight of the five representative plants was added to net plot seed weight, and later the average of seed yield was converted to g plant^{-1}.

Growth Parameters and Harvesting

As soon as the outer brackets color of the yellowish flower heads turned in brown color as a maturing sign. Heads were harvested manually dried in the sun, seeds detached from the disc by hitting on disc backs and dried in the sun to 10% moisture content. Shamamr and Dukalla locations were planted by SF at 29/5/2021 and 31/5/ 2021 and harvested at 14/7/2021 and 16/7/2021 respectively. Five plants were cut from the base at each treatment to achieve periodic measurements at each 20 days and also at harvesting.

3. RESULTS ,

3.1 Growth traits

Table (3) illustrates the effect of SF:MB intercropping on some growth characters at Shamamer location , plant leaf area (LA) , leaf area index (LAI), above ground plant weight (PLW) which represents the total of stem weight (SW) and leaf weight (LW) , crop growth rate (CGR) and relative growth rate (RGR) at the ages of 20 and 40 days after planting (DAP) refered to as (a) and (b) following each studied trait respectively .All of the studied traits responded significantly to intercropping patterns accept above ground total plant weight at 20 DAP and leaf area index at 40 DAP .LAIa responded highly to the pattern (1 SF : 5 MB) and even transcended its supreme values at both of the patterns (1 SF: 3 and 4 MB) following the same behavior of plant leaf area at both intervals of 20 and 40 DAS. This may be explained by by the increased Mung-bean plant density in the patter(1SF:5MB), which leads to greater amounts of nitrogen fixation as it is a legume plant. SF in pure stand (1SF:0MB) , Leaf area possessed the highest significant superiority at 40 DAS due to non-competition interference with mung-bean sharing higher leaf areas with SF plants at the patterns (1SF: 3MB) and (1 SF: 4 MB). This might be follows the same superior trend of all the traits of leaf weight , stem weight and above ground plant weight at 40 days after sowing as they reached 142.43g , 100.16g and 42.28 g at pure stand, and 123.4g , 91.42g and 31.98g at intercropping pattern (1 SF:3 MB) besides 188.37g, 132.92g and 55.45g respectively .Dealing with Crop Growth and Relative growth Rates (CGR and RGR) , SF recorded higher significant rates at the intercrop pattern (1SF: 3MB) probably cause of higher leaf area and leaf area indices at each of 20 and 40 DAS , while CGRb and RGRb possessed the superior significant values at the pattern (1 SF: 4 MB) with estimates of 1.43 and 0.04 respectively , the situation that could be explained by the superioeity of plant weight and plant leaf area at this age.

At the second location (Dukalla) and as shown in table (4) the following traits responded significantly to intercropping. Neither of leaf area values at the three growing periods possessed significant differences, rather than leaf area at 20 DAS in the intercrop patterns of 1 SF ; 3 MB , and 1 SF: 4 MB as equaled statically to leaf area value at SF Mono crop (1003.3 g) .

Table (5) shows also that leaf area index reached its maximum significant level in Dukalla location at the ages of 40 and 60 DAS possessing the values of 1.6 and 2.46 respectively. SF inter crop with MB decreased SF crop growth rate at cropping pattern 1 SF: 5 MB inversely to the maximum significant value of relative growth rate RGR with value of 21.64 g m^{-2} day^{-1} after 60 DAS from the intercrop pattern (1SF: 4 MB), as a result from the highly significant plant weight of 282.96 g in the same intercropping pattern.

Tables (6,7 and 8) depicting the combined effect of location , intercropping and their interaction on the studied growth traits of intercropped SF with three different patterns of SF- MB intercropping .The maximum values of 643.17 cm2 and relative growth rate 0f 0.1 gm^{-2} d^{-1} . While the traits of plant weight, stem weight leaf weight and crop growth rates possessed their highest values in Shamamr location at age of 20 DAS as they reached 23.18g , 19.32g, 12.86g and 0.8 g day^{-1} .

Most of the studied traits didn’t offered significant differences in their mean values between locations at the period 40 DAS, mostly because of the higher degrees of temperature the halts the growth to minimum values. Crop growth rate was among the fewer traits that over yielded in Dukalla location (3.256 g d^{-1}).

With relation to growth rate traits at 60 DAS , Shamamr location over yielded in each of stem weight (147.441 g) , leaf weight (63.588 g) and crop growth rate (9.957 g d^{-1}) , while Dukalla location possessed the highest mean values in each of above ground plant weight (202.457 g, Leaf area index (LAI = 2.204) , Relative growth rate (RGR= 14.632 g m^{-2} d^{-1}) .

3.2 The combined effect of cropping patterns on some growth traits of SF

Combining effect of cropping patterns in both of the locations, Shamamr and Dukalla at the ages of 20, 40 and 60 DAS are pooled in table (6) as the non-significance effect was predominant among the mean values of plant, stem and leaf weights in addition each of crop and relative growth rates at age 60 DAS probably due to following of the non-significance effects of the same traits in each of the due to rising temperature effects as depicted in the meteorological table (1) . Regarding to pooled effects of the locations at the ages 20 and 40 DAS, none of the cropping patterns could exceed the performance of sole cropping of SF in plant leaf area (784.33 cm^2) at 20 DAS and plant dry weight (129.03g) at 40 DAS. while most of the intercropping systems could achieve superior trait mean values at both growing ages of 20 and 40 DAS. Exhibition of significance effects among mean trait values are presented in table 7 , at both of the age stages 20 and 40 DAS as combined effect of cropping pattern in the studied areas ,where as the highest mean values of plant weight (21.72 g) , stem weight (9.59 g) leaf weight (12.13 g) and relative growth rate 0.77 g m^{-2} d^{-1} were recorded in intercropping pattern (1SF: 3MB) at the age of 20 DAS which in return caused the determination of the highest significant leaf area index (1.18) for cropping pattern (1 SF: 5 MB). Leaf area index of SF at 40 DAS and for all of the three cropping patterns exceeded their value in sole cropping reaching 2.13 in the cropping pattern (1 SF: 5 MB). As regarded to cropping patterns for combined effects of sites at the age of 40 DAS, the same table depicts superior values of plant weight (168.33 g) , leaf weight (50.33g) and crop growth rate (2.97 g d^{-1}) recorded for SF intercropped to MB in the pattern (1 SF: 4MB).

3.2.2 The combined effect of interaction among locations and cropping patterns on some growth traits of SF

Table (8) shows the effect of interaction between location and cropping patterns on some growth characters of SF at three growth periods 20 DAS , 40 DAS , and 60 DAS , whereas the interaction between Shamamr location and first intercropping pattern (1 SF: 3 MB) possessed the highest mean values of Crop growth rate (1.079 g m^{-2} d^{-1}) as a result of higher significant values of plant , stem and leaf weights (31.27g , 13.89g and 17.38 g) ,as well as LAI reached its maximum significant value (1.34) in the interaction Shamamr and the second intercropping pattern (1 SF: 4 MB) . Dukalla location in the other hand resulted in higher values of leaf area (1003.3 cm^2) and RGR (0.104 g.m^{-2} d^{-1}) its interaction with sole cropping at 20DAS , in addition to producing higher significant values of LAI (1.13) and RGR (0.105 gm^{-2} d^{-1}) in the combined interaction effect of Dukalla location and the cropping patterns 1 SF: 4 MB and 1 SF: 5 MB respectively .

Regarding to the growth trait responses at 40 DAS , Table 7 shows also the superiority of plant weight (188.37 g) , stem weight (132.92g) and leaf weight (55.45 g) cause of interaction with the cropping pattern (1 SF: 4 MB) .these two patterns achieved the highest CGR (4.517 g d^{-1}) and RGR (0.037 g m^{-2} d^{-1}) in their interaction effect with Dukalla location. The location which interact with the third cropping pattern in achieving highest LAI (3.107) at 40 DAS.

At 60 DAS , the only second and third patterns of intercropping achieved the highest significant values of the most studied traits as a response to their interaction with Dukalla location where the mean values of plant weight (282.92g) , CGR (6.733 gd^{-1}) and RGR(21.62 g m^{-2} d^{-1}) in interaction with 1 SF: 4 MB pattern . LAI (3.447) was the only superior value achieved by the pattern 1 SF: 5 MB was from interaction with Dukalla location at 60 DAS.

Generally it is clear to observe that the interaction between cropping pattern and experimental locations caused superiority of intercropping over sole or (mono) cropping since the minimum values of LAI (0.303) , RGR (0.074 g m^{-2} d^{-1}) and CGR (1.017 g d^{-1}) at Shamamr location during 20 DAS for the first two values and 40 DAS . while sole cropping of SF was inferior to intercropping in each of LAI(0.547) at 40 DAS and (0.637) at 60 DAS.

3.3 Plant height , stem diameter , yield components and yield response :

Plant height and stem diameter were not included in the previous tables cause they were measured at harvesting after physiological growth stage of the SF crop.

Results showed on table (9) emphasis that SF pure stand in Shamamr location achieved higher significant mean values only in number of seeds per head (417.79 seeds) and the above ground biomass (149.56 g) . While all of the three intercrop treatments outperformed the pure stand in all the traits of number of seeds per head, one hundred seed weight, and above ground biomass . While the treatment (1 SF: 5 MB) achieved the highest harvest index (0.60) followed by the treatment (1 SF:3 MB) valued 0.42%.

Table (10) shows that the only two traits that possessed significant difference in Dukalla location was in plant height and harvest index, as sun flower in the pure stand possessed the highest values of plant height (152.33 cm) sharing the intercropping treatment (1 SF: 5 MB), but the only recessive trait that possessed the minimum significant value was harvest index (0.26) for the intercrop (1 SF: 4 MB).

Table (11) shows that the two locations hadn’t imposed any significant effects on the studied traits except plant height as Shamamr location possessed the highest significant value of plant height (176.13 cm) . While Dukalla location produced significant thicker stems with diameter of (30.57 mm) .

Table (12) depicts that intercropping had significant effects on most of the studied traits except stem diameter in both locations as the pure SF stand resulted in superior mean values of the traits plant height (165.08 cm) , number of seeds per head (388.71 seeds) , above ground biomass (135.49 g) and plant seed weight (41.93 g $plant^{-1}$) sharing the treatment (1 SF: 3 MB) in plant height , above ground biomass and plant seed yield and the treatment (1 SF: 4 MB) in plant height (161.05 cm) and one hundred seed weight (13.82 g) . While the superiority in one hundred seed weight (13.85 g, aboveground biomass (176.75 g) and per plant seed weight (42.48 g) were achieved with the treatment (1SF: 3MB) . The (1 SF: 5 MB) was the only treatment that possessed the highest harvest index (0.55) .

Most of the combined effects of location * cropping system possessed higher performance in the values of most studied traits as shown in table (13) as the pure stand produced higher values of number of seeds per head (417.79 seeds) and per plant seed yield (43.87 g) in Shamamr location and the highest value of stem diameter (35 mm) in Dukalla location , while location one possessed the tallest plants (183 cm) with cropping system 1 and the highest values of one hundred seed weight (14.97 g) , aboveground per plant biomass (197.79 g) and per plant seed yield (45.43 g) with the second cropping system , and the highest harvest index (0.60) with the third cropping system .

4. Discussions ,

` Growing of two crops or more than two crops is known to the humanity since a long time and defined as intercropping , they either be row intercropping (Mousavi, and Eskandari, 2011). The benefits of sunflower : mungbean intercropping comes from the fixation of aerobic nitrogen by the deep roots of the mungbean that could also bring back the percolated irrigation water and from the strong ,tall and heavy hairy coated sunflower stems and wide leaves that protected the mungbean from the wormer irradiance , the benefits of intercropping were less than the expected based on the previous studies , that can be mostly to the abnormal water scarcity and temperature of the fields under consideration .

5. Conclusion and recommendations

The experiment showed some irregular results comparing to similar experiments around the studied area due to the extra ordinary changes in climate , however intercropping showed significant differences in growth ,many yield components and yield traits , but resulted in advantages harvest index at intercropping treatment 1:5 sunflower – mungbean combination which encourages the hope of expecting more advantages when more intercropping treatments introduced to the next studies in this area .

Table 1. Agrometeorological parameters at Shamamr and Dukalla locations 2021

Month	Air Temperature °C				Relative humidity (%)		Average sun hours		Precipitation (mm)	
	Minimum		Maximum							
	Sh*	Du*	Sh	Du	Sh	Du	Sh	Du	Sh	Du
November	9.5	7.8	21	19.8	51	51	8.7	8.5	38.4	34
December	4.9	3.3	15.1	14	64	67	7.5	7.1	53.4	46
January	3.1	1.4	13.3	12	68	72	7.6	7	62.4	51
February	4.6	2.6	15.8	14	65	67	8.7	7.9	57.6	44
March	8.3	6.1	21.3	18.5	59	48	10.2	9.6	54.6	42
April	13.7	11	27.4	24.3	49	36	11.5	11.3	38.4	28
May	19.7	16.6	34.1	31.2	32	24	12.6	12.6	13.2	8
June	25.3	22.4	39.9	38.1	19	16	13.1	13.1	0.6	1
July	28.6	26.2	43.1	41.9	16	17	12.9	12.9	0	0
August	28.1	25.9	42.9	41.7	17	17	12.1	12.2	0	0
September	23.4	21.1	38.1	36.7	21	20	11.2	11.2	0	0
October	17.8	16.1	31	29.5	31	30	10.1	10	0	0

- ***Sh : Shamamr location , and Du: Dukalla location .***

Table 2 . Some physical and chemical analysis of soil at the studied fields.

Physicochemical properties		Locations	
		Shamamr	Dukalla
17Particles	Sand	22,1	4.6
	Silt	52.1	47.1

size Distr34ibution (g k46g^{-1})			
	Clay	**25.8**	**48.3**
	Texture	**Siltyloam**	**Silty clay**
PH		**7.65**	**7.85**
	N%	**0.07**	**0.11**
	P ppm	**10**	**21**
	K ppm	**320**	**142**
ECe Ds m^{-1}		**0.5**	**0.7**
O.M. %		**0.8**	**1.1**

Table (3) Response of some growth traits of SF to intercropping with mung-bean at Shamamr location .

Growth stage	**Cropping / Taits**	**Mono SF**	**1SF:3MB**	**1SF:4MB**	**1SF: 5MB**
20 days after planting (20 DAP)	**LAa cm^2**	565.33 b	293.33 ab	480.00 ab	837.33 a
	LAIa	0.30 b	0.47ab	0.83 b	1.34 a
	PlantWa g	20.60 ns	31.28 a	23.29 ns	17.58 ns
	StemWa g	8.88 b	13.89 a	10.63 ab	7.90 b
	LeafWa g	11.72 b	17.38 a	12.66 b	9.67b
	CGRa	0.710 b	1.078 a	0.738 b	0.606 b
	RGRa	0.074 bc	0.09 a	0.08 b	0.07 c
40 days after planting (40 DAS)	**LAb cm^2**	1272.67 ns	1046.67 ns	1183.33 ns	719.00 ns
	LAIb	0.68 ns	1.68 ns	1.96 ns	1.15 ns
	PlantWb g	142.43 ab	123.40 ab	188.37 a	44.03 b
	StemWb g	100.16 ab	91.42 ab	132.92 a	32.98 b
	LeafWb g	42.28 a	31.98 ab	55.45 a	11.05 b
	CGRb	1.02 ab	0.49 ab	1.43 a	0.04 b
	RGRb	0.033 a	0.033 a	0.037 a	0.013 b
60 days after planting (60 DAS)	**LAc cm^2**	1210.27 ns	1521.20 ns	1303.77 ns	1362.62 ns
	LAIc	.650 b	2.460 a	2.240 a	2.183 a
	PlantWc	204.75 ns	176.56 ns	231.36 ns	131.44 ns
	StemWc	120.49 ns	180.69 ns	138.59 ns	149.99 ns
	LeafWc	50.93 ns	79.20 ns	59.43 ns	64.78 ns
	CGRc	3.116 ns	2.658 ns	2.149 ns	4.370 ns
	RGRc	9.423 ns	9.163 ns	6.883 ns	14.356 ns

- SF ; Sunflowe , MB ; Mung-bean

** means with the same letters don't differ significantly at $p < 0.05$

Table (4) Response of some growth traits of SF to intercropping with mung-bean at Dukalla location .

Growth stage	**Cropping / Taits**	**1SF: 0MB**	**1SF: 3MB**	**1SF: 4MB**	**1SF: 5MB**

20 days after planting (20 DAP)	**LAa cm^2**	1003.3 a	624.33 ab	566.33 ab	378.67 b
	LAIa	0.537 ns	1.000 ns	1.130 ns	1.010 ns
	PlantWa g	15.31 ns	12.16 ns	12.78 ns	15.28 ns
	StemWa g	6.29 ns	5.29 ns	5.10 ns	6.35 ns
	LeafWa g	9.02 ns	6.87 ns	7.68 ns	8.93 ns
	RGRa	0.59 ns	0.47 ns	0.49 ns	0.59 ns
	RGRa	0.10 ns	0.10 ns	0.097 ns	0.103 ns
40 days after planting (40 DAS)	**LAb cm^2**	1026.7 ns	953.67 ns	955.67 ns	1165.33 ns
	LAIb	0.55 c	1.52 bc	1.91 b	3.11 a
	PlantWb g	115.63 ns	109.7 ns	148.30 ns	72.53 ns
	StemWb g	81.33 b	79.87 ab	103.10 a	53.43 b
	LeafWb g	34.30 ns	29.87 ns	45.20 ns	19.10 ns
	CGRb	3.34 ns	3.25 ns	4.52 ns	1.91 ns
	RGRb	0.030 ab	0.033 a	0.038 a	0.023 b
60 days after planting (60 DAS)	**LAc**	1188.5 ns	1395.7 ns	1250.82 ns	1290.1 ns
	LAIc	0.637 c	2.237 b	2.496 b	3.447 a
	PlantWc	208.57 ab	190.87 ab	282.96 a	127.47 b
	StemWc	116.27 ns	156.41 ns	128.34 ns	135.94 ns
	LeafWc	48.95 ns	67.97 ns	54.62 ns	67.79 ns
	CGRc	4.65 ab	4.06 ab	2.75 b	6.73 a
	RGRc	14.61 ab	13.62 ab	21.64 a	8.66 b

- SF ; Sunflowe , MB ; Mung-bean

** means with the same letters don't differ significantly at $p < 0.05$

Table (5) Response of some growth traits of SF to intercropping with mung-bean at Dukalla location (re-arranged according to the trait type).

Treatments / Traits	1 SF : 0 MB	1 SF: 3MB	1 SF : 4MB	1 SF : 5 MB
LAa cm^2	1003.3 a	624.33 ab	566.33 ab	378.67 b
LAb cm^2	1026.7 ns	953.67 ns	955.67 ns	1165.33 ns
LAc	1188.5 ns	1395.7 ns	1250.82 ns	1290.1 ns
LAIc	0.637 c	2.237 b	2.496 b	3.447 a
StemWa g	6.29 ns	5.29 ns	5.10 ns	6.35 ns
StemWb g	81.33 b	79.87 ab	103.10 a	53.43 b
StemWc	116.27 ns	156.41 ns	128.34 ns	135.94 ns
LeafWa g	9.02 ns	6.87 ns	7.68 ns	8.93 ns

LeafWb g	34.30 ns	29.87 ns	45.20 ns	19.10 ns
LeafWc	48.95 ns	67.97 ns	54.62 ns	67.79 ns
PlantWa g	15.31 ns	12.16 ns	12.78 ns	15.28 ns
PlantWb g	115.63 ns	109.7 ns	148.30 ns	72.53 ns
PlantWc	208.57 ab	190.87 ab	282.96 a	127.47 b
CGRb	3.34 ns	3.25 ns	4.52 ns	1.91 ns
CGRc	4.65 ab	4.06 ab	2.75 b	6.73 a
CGRa	0.59 ns	0.47 ns	0.49 ns	0.59 ns
RGRa	0.10 ns	0.10 ns	0.097 ns	0.103 ns
RGRb	0.030 ab	0.033 a	0.038 a	0.023 b
RGRc	14.61 ab	13.62 ab	21.64 a	8.66 b

Note a, b and c refer to the ages of 20,40 and 60DAS

- SF ; Sunflowe , MB ; Mung-bean

** means with the same letters don't differ significantly at $p < 0.05$

Table (6) Response of some growth traits of SF to intercropping with mung-bean at the locations Shammamr and Dukalla .

		Shamamr	Dukalla
20 days after planting (20 DAP)	LAa	544.00 b	643.17 a
	LAIa	0.736 ns	0.919 ns
	PlantWa	23.188 a	13.881 b
	StemWa	10.328 a	5.759 b
	LeafWa	12.860 a	8.122 b
	CGRa	0.800 a	0.534 b
	RGRa	0.079 b	0.100 a
40 days after planting (40 DAS)	LAb	1055.4 ns	1025.3 ns
	LAIb	1.365 ns	1.773 ns
	PlantWb	124.558 ns	111.550 ns
	StemWb	89.369 ns	79.433 ns
	LeafWb	35.189 ns	32.117 ns
	CGRb	0.753 b	3.256 a
	RGRb	0.029 ns	0.031 ns
60 days after planting (60 DAS)	LAc	1349.463 ns	1281.299 ns
	PlantWc	186.028 b	202.467 a
	StemWc	147.441 a	134.243 b
	LeafWc	63.588 a	57.391 b
	LAIc	1.883 b	2.204 a
	CGRc	3.074 a	4.546 b
	RGRc	9.957 b	14.632 a

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (7) Pool analysis of response of some growth traits of SF to intercropping with Mung-bean at Shamamer and Dukalla location.

Growth stage	Cropping Taits	1 SF : 0 MB	1 SF: 3MB	1 SF : 4MB	1 SF : 5 MB
20 days after planting (20 DAP)	LAa cm^2	784.33 a	458.83 b	523.17 ab	608.00 ab
	LAIa	0.42 b	0.74 ab	0.98 ab	1.18 a
	PlantWa g	17.96 b	21.72 a	18.04 b	16.43 b
	StemWa g	7.59 b	9.59 a	7.87 b	7.13 b
	LeafWa g	10.37 ab	12.13 a	10.17 ab	9.30 b
	RGRa	0.65 b	0.77 a	0.65 b	0.60 b
	RGRa	0.089 ns	0.093 ns	0.089 ns	0.088 ns
40 days after planting (40 DAS)	LAb cm^2	1149.7 ns	1000.17 ns	1069.50 ns	942.17 ns
	LAIb	0.61 b	1.60 a	1.94 a	2.13 a
	PlantWb g	129.03 a	116.57 ab	168.33 a	58.28 b
	StemWb g	90.75 b	85.64 ab	118.01 b	43.21 b
	LeafWb g	38.29 ab	30.92 bc	50.33 a	15.08 c
	CGRb	2.18 ab	1.87 ab	2.97 a	1.00 b
	RGRb	0.031 ns	0.037 ns	0.033 ns	0.018 ns
60 days after planting (60 DAS)	LAc cm^2	0.030 ab	0.033 a	0.037 a	0.023 b
	LAIc	0.65 b	2.46 a	2.24 a	2.18 a
	PlantWc g	204.8 ns	176.56 ns	231.36 ns	131.44 ns
	StemWc g	120.5 ns	180.69 ns	138.59 ns	149.99 ns
	LeafWc g	50.93 ns	79.20 ns	59.43 ns	64.78 ns
	CGRc	3.12 ns	2.65 ns	2.15 ns	4.37 ns
	RGRc	9.42 ns	9.16 ns	6.88 ns	14.36 ns

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (8) Pool analysis of response of some growth traits of SF to interaction between intercropping and location at Shamamer and Dukalla .

Trait	Interaction of location * cropping patterns							
	Shamamr location				Dukalla location			
LA	Sole SF 0 MB	1SF: 3MB	1SF: 4MB	1SF: 5MB	Sole SF 0 MB	1SF: 3MB	1SF: 4MB	1SF: 5MB
LAa_{20}	565.33 a	293.33 a	480.00 a	837.33 a	1003.33 a	624.33 a	566.33 a	378.67 a
LAIa	0.303 c	0.470 bc	0.83 abc	1.340 a	0.537 bc	1.000 ab	1.130 a	1.010 ab
PlantWa	20.603 bc	31.277 a	23.293 b	17.577 cd	15.310 de	12.157 e	12.780 de	15.277 de
StemWa	8.883 bc	13.893 a	10.630 b	7.903 cd	6.293 de	5.290 e	5.103 e	6.350 de
LeafWa	11.720 bc	17.383 a	12.663 b	9.673 cd	9.017 cd	6.867 d	7.677 d	8.927 cd
CGRa	0.710	1.079 a	0.803 b	0.606 cd	0.589 cd	0.468 d	0.492 d	0.588 cd
RGRa	0.074 d	0.090 ab	0.081 bc	0.071 cd	0.104 a	0.096 ab	0.096 ab	0.105 a
LAb	1272.667 ns	1046.667 ns	1183.333 ns	719.000 ns	1026.667 ns	953.667 ns	955.667 ns	1165.333 ns

LAIb	0.677 cd	1.677 b	1.957 b	1.150 bcd	0.547 d	1.523 bc	1.913 b	3.107 a
PlantWb	142.433 ab	123.400 abc	188.367 a	44.033 c	115.633 abc	109.733 abc	148.300 ab	72.533 bc
StemWb	100.157 ab	91.420 ab	132.917 a	32.983 b	81.333 ab	79.867 ab	103.100 ab	53.433 b
LeafWb	42.277 ab	31.980 abc	55.450 a	11.050 c	34.300 abc	29.867 abc	45.200 ab	19.100 bc
CGRb	1.017 c	0.487 c	1.427 c	0.083 c	3.343 ab	3.253 ab	4.517 a	1.910 bc
RGRb	0.033 ab	0.033 ab	0.037 a	0.013 c	0.030 ab	0.033 ab	0.037 a	0.023 bc
LAc	1210.267 ns	1521.200 ns	1303.767 ns	1362.617 ns	1188.523 ns	1395.763 ns	1250.820 ns	1290.090 ns
LAIc	.6500	2.4600	2.2400	2.1833				
PlantWc	204.753 ab	176.563 ab	231.357 ab	131.440 c	208.567 ab	190.870 ab	282.960 a	127.470 c
StemWc	120.487 ns	180.697 ns	138.590 ns	149.990 ns	116.277 ns	156.407 ns	128.340 ns	135.947 ns
LeafWc	50.933 ns	79.200 ns	59.433 ns	64.783 ns	48.957 ns	67.797 ns	54.620 ns	58.190 ns
LAIc	0.650 c	2.460 b	2.240 b	2.183 b	0.637 c	2.237 b	2.497 b	3.447 a
CGRc	3.116 b	2.658 b	2.150 b	4.370 ab	4.647 ab	4.057 ab	6.733 a	2.747 b
RGRc	9.423 b	9.163 b	6.883 b	14.357 ab	14.623 ab	13.620 ab	21.620 a	8.663 b

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (9) shows the effect of additive cropping system on plant height , stem diameter , yield components and SF seed yield in Shamamr location.

Treatment	Plant height (cm)	Stem diameter (mm)	Seed No. per head	Weight of 100 seeds (g)	Above ground biomass g plant^{-1}	Plant seed weight g plant^{-1}	Harvest index %
Pure stand SF	177.8 ns	21.17 ns	417.79 a	10.43 b	149.56 ab	43.87 ns	0.32 b
1 SF: 3 MB	183.0 ns	20.57 ns	345.8 ab	13.58 ab	129.57 ab	45.37 ns	0.42 ab
1 SF:4 MB	163.8 ns	17.43 ns	306.9 ab	14.97 a	197.79 a	45.43 ns	0.24 b
1 SF: 5 MB	179.8 ns	23.10 ns	199.93 b	14.00 ab	46.24 b	27.40 ns	0.60 a

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (10) shows the effect of additive cropping system on plant height, stem diameter, yield components and SF seed yield in Dukalla location.

Treatment	Plant height (cm)	Stem diameter (mm)	Seed No. per head	Weight of 100 seeds (g)	Above ground biomass g plant^{-1}	Plant seed weight g plant^{-1}	Harvest index %

Pure stand SF	152.33 a	35.00 ns	359.64 ns	11.27 ns	121.42 ns	40.00 ns	.36 ab
1 SF: 3 MB	126.16 b	29.37 ns	279.23 ns	13.20 ns	115.22 ns	36.40 ns	.33 ab
1 SF:4 MB	133.57 b	29.90 ns	312.45 ns	12.73 ns	155.71 ns	39.53 ns	.26 b
1 SF: 5 MB	142.26 ab	28.00 ns	273.32 ns	13.63 ns	76.16 ns	36.47 ns	.49 a

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (11) shows the pooled effect of location on plant height , stem diameter , yield components and SF seed yield in additive cropping system.

Site	**Plant height (cm)**	**Stem diameter (mm)**	**Seed No. per head**	**Weight of 100 seeds (g)**	**Above ground biomass** g plant^{-1}	**Plant seed weight** g plant^{-1}	**Harvest index %**
Shamamr	176.13 a	20.57 b	317.6 ns	13.25 ns	130.79 ns	40.52 ns	0.39 ns
Dukalla	138.56 b	30.57 a	306.2 ns	12.71 ns	117.13 ns	38.10 ns	0.36 ns

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (12) shows the pooled effect of additive cropping system on plant height , stem diameter , yield components and SF seed yield in Shamamr and Dokalla locations.

Treatment	**Plant height (cm)**	**Stem diameter (mm)**	**Seed No. per head**	**Weight of 100 seeds (g)**	**Above ground biomass** g plant^{-1}	**Plant seed weight** g plant^{-1}	**Harvest index %**
Pure stand SF	165.08 a	28.08 ns	388.71 a	10.85 b	135.49 a	41.93 a	0.34 b
1 SF: 3 MB	154.6 ab	24.97 ns	312.53 b	13.39 ab	122.40 ab	40.88 ab	0.38 b
1 SF:4 MB	148.67 b	23.67 ns	309.7 bc	13.85 a	176.75 a	42.48 a	0.25 b
1 SF: 5 MB	161.05 a	25.55 ns	236.62 c	13.82 a	61.20 b	31.93 b	0.55 a

- SF ; Sunflowe , MB ; Mung-bean

** Means with the same letters don't differ significantly at $p < 0.05$

Table (13) shows the effect of interaction between location and additive cropping system on plant height, stem diameter, yield components and SF seed yield pooled in the locations Shamamr and Dukalla .

*** Treatment**	**Plant height (cm)**	**Stem diameter (mm)**	**Seed No. per head**	**Weight of 100 seeds (g)**	**Above ground biomass** g plant^{-1}	**Plant seed weight** g plant^{-1}	**Harvest index %**
10.00	177.8 ab	21.17 cd	417.79 a	10.43 b	149.56 ab	43.87 a	0.32 bc
11.00	183.00 a	20.57 d	345.83 ab	13.58 ab	129.57 abc	45.37 a	0.42 abc
12.00	163.8 bc	17.43 d	306.93 b	14.97 a	197.79 a	45.43 a	0.24 c
13.00	179.83	23.1 bcd	199.93 c	14.00 ab	46.24 c	27.40 b	0.60 a

	a						
20.00	152.3 cd	35.00 a	359.64 ab	11.27 ab	121.42 abc	40.00 ab	0.36 bc
21.00	126.16 f	29.37 ab	279.23 bc	13.20 ab	115.22 abc	36.40 ab	0.33 bc
22.00	133.51ef	29.90 ab	312.45 ab	12.73 ab	155.71 ab	39.53 ab	0.26 c
23.00	142.3 de	28.0 abc	273.32 bc	13.63 ab	76.16 bc	36.47 ab	0.49 ab

- Tens numbers refer to locations (10 = Shamamr, 20 = Dukalla) while ones refer to cropping system (0 = SF purestand , 1 = 1 SF:3 MB , 2= 1 SF:4 MB , and 3= 1SF :5 MB)

**SF; Sunflowe , MB ; Mung-bean

*** Means with the same letters don't differ significantly at $p < 0.05$

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