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INFLUENCE OF INTERCROPPING IN MAIZE ON PERFORMANCE OF WEEDS AND THE ASSOCIATED CROPS

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Abstract

Field experiments on intercropping in maize crop were conducted during 2008 and 2009 at Agriculture Research Institute, Tarnab Peshawar, Pakistan. The experiments were laid out in a randomized complete block design comprising of 11 treatments, including weed free sole maize (WFMz), weedy check sole maize (WCMz), sole French beans (Fb), sole mung-beans (Mb), sole sunflower (Sf), intercropping maize-1-row+Frenchbean-1-row (MzFb 1:1), maize-1-row+Frenchbean-2-rows (MzFb 1:2), maize-1-row+mungbean-1-row(MzMb 1:1), maize-1-row+mungbean-2-rows (MzMb 1:2), maize-1-row+ sunflower-1-row (MzSf 1:1), and maize-1-row+sunflower-2-rows (MzSf 1:2). The treatments significantly affected the weeds and crop parameters. Weed density (136 weeds m^{-2}) and fresh biomass (2769 kg ha^{-1}) were highest in the WCMz and Mb, respectively. The intercropping treatments resulted in 35-56% reduction in weed population. All the intercropping treatments showed 6.46 to 23.93% increase in the yield of maize over WCMz, except that in MzSf 1:2. Overall highest average grain yield of maize (3886 kg ha^{-1}) was recorded in WFMz with 30.65% increase in yield over the WCMz (2695 kg). Among the intercropping treatments, maize yield was highest (3543 kg ha^{-1}) in MzMb 1:1, where the yield was 23.93% higher than the WCMz; though it was at par with the MzFb 1:1 (3232 kg ha^{-1} with 16.62% yield increase over WCMz). The computed LER ranged between 1.023-1.294. Similarly, the cost benefit ratios (CBRs) ranged between 1.27 and 1.67. Among the intercropping treatments, highest CBR (1.64) was computed for MzSf 1:2, followed by MzMb 1:2 (1.58). Thus, intercropping reduced weed population, boosted maize performance, enhanced land utilization and increased farmers' monitory advantage.

Introduction

Maize is the third most important cereal crop in Pakistan after wheat and rice and has got a great value as a fodder as well as a grain crop. During 2010-11, it was grown at national level on an area of 0.9742 million ha, with a total production of 3.707 million tons giving an average yield of 3805 kg ha^{-1} (MINFA, 2011). Though it is a high yielding crop all over the world, unfortunately the case is not the same in Pakistan. Several biological and environmental factors may be responsible for the lower yields. Weeds are however, the most resilient and persistent pest (Beckett *et al.*, 1988), as annual losses in crop yield and quality due to weeds are greater than those due to insects and diseases (Hassan & Marwat, 2001; Khan *et al*., 2008).

Several weed control methods such as planting density, row spacing (Hussain *et al*., 2011; Hamayun, 2003), herbicides (Iftikhar-ud-Din *et al*., 2011; Ali *et al*., 2003), have been tested in maize but were not that successful. There has always been a need to search out an eco-friendly, non chemical and economical weed control method in maize. Intercropping which is the practice of growing more than one crop simultaneously in alternating rows of the same field (Ahmad *et al*., 2013; Arif *et al.*, 2013; Bilalis *et al.*, 2008; Ennin *et al.*, 2002) is an effective practice in maize production which not only helps reduce the available space for weed growth but also increase the production per unit area. Moreover, in case of a severe disease or insect attack there are least chances of 100% crop loss, as the same disease or insect can't attack two different crops at the same time in the same field.

Crop diversity provides several advantages over monocropping, by giving a higher total return in yield and acting as an insurance against failure or fluctuating market price of single crops (Polthanee & Trelo-ges, 2003). Intercropping is a common practice on small farms in developing countries due to small land holding and subsistence framing. However, in Pakistan this approach is widely neglected for various reasons. Due to continuous growing of cereals, the reduction in soil organic-matter content and nutrients led to nutrients imbalance, poor crop growth, low yield and increasing weed seed bank associated with cereals. Therefore intercropping provides unlimited opportunities to address many issues (Adhikary *et al.*, 2008; Hooper *et al.*, 2009).

Modern weed control in maize is an integrated program involving tillage, cultivation and herbicides. No fruitful work is yet done on intercropping in maize. Therefore, keeping in view the above mentioned aspects, an experiment was designed with the objectives to find out the best crop for intercropping in maize that might help in sufficient reduction of weed population with least negative impact on maize grain yield and to compare the effect of intercropping with the mono-crops; which may become a part of the integrated weed management program in maize crop.

Materials and Methods

The experiments were conducted at Agriculture Research Institute (Tarnab) Peshawar using an open pollinated variety "Azam" sown in a plot size of 5m x 4.5m for each treatment (experimental unit); each consisting of seven rows, each row was 5m long and 0.8m apart. The seed bed was prepared with a mold board plough followed by a couple of planking for proper leveling. The maize sowing was done in the mid of June

2008 and 2009 with seed drill while the intercrop sowing was carried out with the help of hand hoe. Harvesting took place in the first week of October 2008 and 2009. Sowing of mung beans, French-beans and sunflower as sole crops and intercrops was done on the same day after maize sowing. Intercropping was accomplished in two ways. First, there was one intercrop row between two adjacent maize rows, and second, there were kept two intercrop rows between two rows of maize crop. The row to row distance of maize crop was kept the same for all treatments of intercropping. The plant to plant distances of French-bean, mung-bean and sunflower were kept as per their recommended requirements. Full dose of the fertilizer Phosphorus (P) in form of Single Super Phosphate (SSP) and half of Nitrogen (N) in form of Urea was applied on the day of seed bed preparation as per recommended requirement of 150 kg N and 90 kg P ha^{-1}; whereas the remaining half of N was applied with the first irrigation. The crop was irrigated six times in the total growing season. Insects were controlled as necessary. All the procedures were kept the same in the experiments during both the years.

The experiments were laid out in a randomized complete block design and comprised of 11 treatments replicated four times. Dahmardeh *et al*., (2010) remarked that the main crop and the intercrop should have positive effects on each other; they must have different root systems, nutrients requirements, leaf morphology etc. Moreover, they should have seasonal and climatic similarity. Keeping these points in mind, sunflower, mungbean and French beans were selected for intercropping in maize crop. The treatments included were weed free sole maize (WFMz), weedy check sole maize (WCMz), sole French beans (Fb), sole mung-beans (Mb), sole sunflower (Sf), intercropping maize-1-row+Frenchbean-1-row (MzFb 1:1), maize-1-row+Frenchbean-2-rows (MzFb 1:2), maize-1-row+mungbean-1-row(MzMb 1:1), maize-1-row+mungbean-2-rows (MzMb 1:2), maize-1-row+ sunflower-1-row (MzSf 1:1), and maize-1-row+sunflower-2-rows (MzSf 1:2).

The data on weed density m^{-2} was collected with the help of a quadrate of size 1 m^2 thrown three times randomly in each treatment and then averages were computed. The French-bean crop was harvested 70 days after sowing (DAS), sunflower 80 days and mungbean 85 DAS. The yield data of the intercrops were recorded after their harvesting. In the end, maize crop was harvested, dried, and threshed separately after which the maize grain yield data was collected. Three rows of maize crop from sole treatments and three rows from intercropped treatments were harvested at black layer formation. For economic analysis, the gross income, cost of production, net income ha^{-1} and cost benefit ratio (CBR) were also computed as per prevailing rates in summer season of 2008 and 2009. The efficiency of an intercropping system can be evaluated by the land equivalent ratio (LER), defined as the total area required under sole cropping to produce the equivalent yields obtained under intercropping (Ibrahim *et al*., 2013; Willey and Rao, 1980). The LER values were calculated by the formula:

$$\mathrm{LER} = \left(\frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}\right) \qquad \mathrm{OR}$$

$$\mathrm{LER} = \left(\frac{\text{Grain yield of intercropped maize}}{\text{Grain yield of sole maize}} + \frac{\text{Yield of intercropped legume}}{\text{Yield of sole legume}}\right)$$

All the recorded data were analyzed as a blocked one-way ANOVA with MSTATC; whereas appropriate means were separated by least significant difference (LSD) at the $p = 0.05$ level (Jan *et al*., 2009). For confirmation, both the statistical computer softwares, MSTATC (Michigan State University, USA) and STATISTIX 8.0 were applied for computing both the ANOVA and LSD.

Results

Weed density m^{-2}: The problematic weeds found in the experimental sites during the two years study were *Amaranthus viridis, Digitaria sanguinalis, Digera arvensis*, *Echinochloa crus-galli, Cyperus rotundus, Sorghum halepense, Convolvulus arvensis, Cynodon dactylon, Dactyloctenium aegyptium,* and *Trianthema portulacastrum.* Overall the weed densities in the intercropping treatments were less than the weed densities in the sole treatments. Highest weed density (136 weeds m^{-2}) was observed in the weedy check sole maize (WCMz) which was however at par with the sole Frenchbean and sole mungbean treatments. The lowest density of 60 weeds m^{-2} was recorded in the MzSf 1:2 treatments (i.e. intercropping of maize and sunflower at ratio of 1:2). The rest of the intercropping treatments were statistically similar to each other. In comparison to the weedy check (WCMz), the highest reduction in weed population (91.9%) was though found in WFMz (sole); however, the intercropping treatments also resulted in a significant reduction in weed population, ranging between 34-55%.

Fresh weed biomass (kg ha^{-1}): Weed biomass is an important tool to record the impact of weed control treatments on the crops and their associated weeds. Rao (2000) stated that generally one kilogram of weeds in a field will correspond to one kilogram loss of crop yield. Statistical analysis of the data showed that the applied treatments also significantly affected the fresh weed biomass (Table 1). The overall weed biomass observed in the intercropping treatments ranged between 1105-1656 kg ha^{-1} as compared to the WCMz (2427 kg ha^{-1}). The mean data showed that highest fresh weed biomass of 2769 kg ha^{-1} was found in Mungbean sole treatment (Mb), followed by French bean monoculture (2519 kg ha^{-1}) and WCMz (2427 kg ha^{-1}). Overall minimum fresh weed biomass was found in WFMz (132 kg ha^{-1}) and among the intercropping treatments the minimum weed biomass was recorded in the MzSf 1:2 treatments.

Grain yield of maize (kg ha^{-1}): The agricultural experiments are mostly aimed at improvement in the quality and quantity of the crop yields. Here the results of intercropping effect on maize yield and net income from the given land have been discussed. It is evident from the results given in Table 2 that all the intercropping treatments had a better net effect on crops yields as compared to the sole crops. The intercropping treatments were compared with weed free maize monoculture (WFMz) and weedy maize monoculture (WCMz). The highest maize yield of 3886 kg ha^{-1} with 30.65% increase over WCMz treatments was recorded in WFMz plots. However, among the intercropping treatments, the maize yield was highest (3543 kg ha^{-1}) in MzMb 1:1 followed by MzFb 1:1 (3232 kg ha^{-1}) and MzMb 1:2 (3026 kg ha^{-1}). All these three treatments were statistically at par. The increase in yield of maize over WCMz due to these three treatments was 23.9, 16.62 and 10.49%, respectively (Table 2).

Table 1. Weed density m^{-2}, weed population reduction (%) and fresh weed biomass (kg ha^{-1}) As affected by different treatments (average of the two years, 2008-09).

Treatments	Weed density m^{-2}	Weed population reduction (%)	Fresh weed biomass (kg ha^{-1})
WFMz (sole)	11 d	91.91	132 f
WCMz (sole)	136 a	---	2427 ab
Frenchbean (Fb) (sole)	133 a	2.20	2519 a
Mungbean (Mb) (sole)	121 a	11.02	2769 a
Sunflower (Sf) (sole)	93 b	31.60	1734 c
MzFb 1:1 (IC)	87 b	36.03	1634 cd
MzFb 1:2 (IC)	75 b	44.85	1254 de
MzMb 1:1 (IC)	89 b	34.56	1427 d
MzMb 1:2 (IC)	72 b	47.05	1252 de
MzSf 1:1 (IC)	81 b	40.44	1656 cd
MzSf 1:2 (IC)	60 c	55.88	1105 e
$LSD_{0.05}$	26.0	---	304

MzFb 1:1 (Maize 1 row + French bean 1 row), MzFb 1:2 (Maize1 row +French bean 2 rows),
MzMb 1:1 (Maize 1 row + mungbean 1 row), MzMb 1:2 (Maize 1 row + mungbean 2 rows),
MzSf 1:1 (Maize 1 row + sunflower 1 row), MzSf 1:2 (Maize 1 row + sunflower 2 rows)

Table 2. Average grain yield of maize (kg ha^{-1}) and yield increase over weedy check (WC) as affected by different treatments (2008 and 09).

Treatments	Grain yield (kg ha^{-1})	Yield increase over WC (kg ha^{-1})	% increase in yield over WC
WFMz (sole)	3886 a	1191	30.65
WCMz (sole)	2695 d	---	---
MzFb 1:1	3232 bc	537	16.62
MzFb 1:2	2997 c	302	10.08
MzMb 1:1	3543 b	848	23.93
MzMb 1:2	3026 c	331	10.49
MzSf 1:1	2881 c	186	6.46
MzSf 1:2	2249 e	- 446	---
LSD	328		

MzFb 1:1 (Maize 1 row + French bean 1 row), MzFb 1:2 (Maize1 row +French bean 2 rows),
MzMb 1:1 (Maize 1 row + mungbean 1 row), MzMb 1:2 (Maize 1 row + mungbean 2 rows),
MzSf 1:1 (Maize 1 row + sunflower 1 row), MzSf 1:2 (Maize 1 row + sunflower 2 rows)

Pod yield of French beans (kg ha^{-1}): Perusal of the data showed that yield of French beans was significantly affected by the treatments. Mean values of data in Table 3 indicated that French-bean yield was highest in its sole treatments (2930 kg ha^{-1}); while in intercropping treatments its yield was 812 and 1533 kg ha^{-1} in MzFb 1:1 and MzFb 1:2 treatments, respectively.

Grain yield of mung beans (kg ha^{-1}): Mungbean is an important crop and has been found very impressive for intercropping with maize crop. Data regarding grain yield of mungbean are shown in Table 3, indicating that grain yield of mungbean was significantly affected by the applied treatments of its sole and intercropping with maize at the two different combinations. The grain yield of mungbean was higher in its sole plots (1956 kg ha^{-1}) than those of intercropped treatments i.e. MzMb 1:1 (648 kg) and MzMb 1:2 (910 kg ha^{-1}); however, both were statistically at par.

Achene yield of sunflowers (kg ha^{-1}): The achene yield of sunflower was also significantly affected by the treatments (Table 3). Lowest achene yield (524 kg ha^{-1}) was recorded in intercropped sunflower with maize at the ratio of 1:2; while the highest achene yield of 1593 kg ha^{-1} was obtained in sunflower sole treatments. The yield in the treatment of MzSf 1:1 was 708 kg ha^{-1}.

Table 3. The effect of maize (Mz), frenchbean (Fb), mungbean (Mb), and sunflower (Sf) grown in monoculture (sole) or intercrops (IC) on yields and land equivalent ratio (LER).

Treatment	Yield (kg/ha)					Partial LER				Total LER
	Mz	Fb	Mb	Sf	Total	Mz	Fb	Mb	Sf	
WFMz (sole)	3886 a				3886					
WCMz (sole)	2695 d				2695					
Frenchbean (Fb) (sole)		2930 a			2930					
Mungbean (Mb) (sole)			1956 a		1956					
Sunflower (Sf) (sole)				1593 a	1593					
MzFb 1:1 (IC)	3232 bc	812 c			4044	0.85	0.28			1.13 b
MzFb 1:2 (IC)	2997 c	1533 b			4530	0.77	0.52			1.29 a
MzMb 1:1 (IC)	3543 b		648 b		4191	0.91		0.33		1.24 a
MzMb 1:2 (IC)	3026 c		910 b		3936	0.78		0.47		1.25 a
MzSf 1:1 (IC)	2881 c			524 b	3405	0.74			0.33	1.07 bc
MzSf 1:2 (IC)	2249 e			708 b	3657	0.58			0.44	1.02 c
LSD (P = 0.05)	328.0	528.7	313.3	252.5						0.09

Means in each columns followed by different letters are significantly different from each at p≤ 0.05

Land equivalent ratio (LER): The LER values were greater than one in all intercropping treatments, which indicated yield benefit of intercropping over sole maize crop (Table 3). The highest LER value of 1.29 was computed for MzFb 1:1 (i.e. maize one row intercropped with two rows of mungbean) which was however statistically similar to MzMb 1:2 (1.25) and MzMb 1:1 (1.24). On the other hand, minimum LER i.e., 1.02 was recorded in MzSf 1:2. The results expressed that intercropping of maize with frenchbean and mungbean has got higher land use efficiency than sunflower crop.

Cost benefit ratio (CBR): Agro-economic feasibility of an intercropping system can be determined by its net monetary gain. In the present study, the cost benefit ratio (CBR) of maize intercropping with French bean, mungbean and sunflower was determined to know the economic benefits of intercropping. Highest CBR of 1.64 was observed in MzSf 1:2 treatments, followed by MzMb 1:2 (1.58), and MzFb 1:2 (1.4). However, it should be known that all the treatments had a CBR in the range from 1.27 to 1.64. Moreover, our results in Table 4 also indicated that the net income from all the intercropping treatments was more as compared to the sole cropping.

Table 4. Cost benefit ratio (CBR) of maize (Mz), frenchbean (Fb), mungbean (Mb), and sunflower (Sf) grown in monoculture (sole) and intercrops (IC).

Treatments	Yield (kg ha^{-1})	Gross income PKR ha^{-1}	Total cost PKR ha^{-1}	Net income ha^{-1}		CBR (GI/NI)
				PKR	USD	
WFMz (sole)	3886	155440	67572	92868	1086	1.67
WCMz (sole)	2695	107800	27307	80493	942	1.34
Frenchbean (Fb) (sole)	2930	117200	24870	92330	1080	1.27
Mungbean (Mb) (sole)	1956	117360	30415	86945	1017	1.35
Sunflower (Sf) (sole)	1593	95580	25935	69645	815	1.37
MzFb 1:1 (IC)	3232 + 812	129280 + 32480	27307 + 12435	120018	1404	1.35
MzFb 1:2 (IC)	2997 + 1533	119880 + 61320	27307 + 24820	129023	1510	1.40
MzMb 1:1 (IC)	3543 + 648	141720 + 38880	27307 + 15207	138088	1616	1.31
MzMb 1:2 (IC)	3026 + 910	121040 + 36600	27307 + 30415	99918	1169	1.58
MzSf 1:1 (IC)	2881 + 524	115240 + 34060	27307 + 12967	109026	1276	1.37
MzSf 1:2 (IC)	2249 + 708	89960 + 46020	27307 + 25935	82738	968	1.64

Prices of maize @ Rs. 40, French bean @ Rs. 40, mungbean @ Rs. 60 and sunflower seeds @ Rs. 65 kg-1
Labor charges @ Rs. 300 day^{-1} (1 USD = 85.46 PKR during 2010)

Discussion

The intercropping of sunflower was most successful among the rest of the intercropping treatments in terms of weed population reduction (55%) because of the effective competition with weeds for space. In addition, sunflower growth was also found quicker than weeds which added to its effectiveness in intercropping. However, there was some negative effect found on maize yield. The weed population reduction in mungbean intercrop was less than sunflower because of the relatively smaller size and less rapid growth. The French bean crop among the intercropping treatments was the last in weed population reduction. However, all the intercropping treatments were significantly different from the sole weedy maize in minimizing the weed density.

Mung-beans apparently had a very friendly combination with maize crop in terms of reduction in weed density as well as maize grain yield (Makinde *et al*., 2009). Mungbean is a 75 day crop and thus harvested before the harvesting stage of maize. Therefore, it suppressed the weed growth in the empty niches in the earlier maize growing season especially during the critical period of weed competition (Hussain *et al.*, 2012; Gomes *et al*., 2007; Buchler *et al*., 2001), ultimately the nutrients that could be utilized by weeds are sucked by the mungbean crop which had least or no impact on maize crop as the requirements of the two crops were physiologically different, which was not the case with the weeds (Din *et al.*, 2013; Santalla *et al*., 2001). On the other hand, the French beans and sunflower intercropping impact was not that effective. The sunflower crop though performed well in weed suppression in the early stages and affected maize performance at the same time, which indicated that there could have been competition for space between maize and sunflower plants in the later stages. Similarly, the French beans intercropping suppressed weed growth to some extent however their growth was also suppressed by maize crop.

It is obvious that when a crop is sown solely the yield will be higher than when it is sown as intercrop, as there is always a competition for the available limited resources. The inter-specific competition and depressive effect of maize, a C_4 species, on French beans, a C_3 crop, as maize have been known to be dominant when intercropped with C_3 crops like soybean etc. Zhuang & Yu-Bi (2013) and Polthanee & Trelo-ges (2003) reported that shading by the taller plants in mixture could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields.

The reason for the lowest yield is in fact the over population in the specified area of the treatments. At one side there is C_4 maize and on the other side the sunflower population is almost double of maize which not only resulted in an inter-specific competition i.e. between maize and sunflower plants but also an intra-specific competition among sunflower plants themselves, in addition to the weed–crop competition for nutrients, light, space and water. Perusal of the data showed that yield of sunflower was significantly affected by intercropping sunflower with maize. Taller plants in mixture do reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields (Zhang *et al.*, 2012). Similarly, crop yields are reduced by intercropping as compared to monoculture (Polthanee and Trelo-ges, 2003).

Researchers like Olufajo (1992) and Agbaje *et al*., (2002) achieved higher land land equivalent ratios in intercropping with maize crop. Efficient use of land resource where land shortage inclines the farmers to grow many crops on small piece of land is one of the rationales of intercropping in the traditional farming systems. Patra *et al*., (1990) achieved higher LER from intercropping of maize with pigeon pea, Mandimba (1995) from intercropping of maize with groundnut, and Kalia *et al*., (1992) from maize intercropped with soybean. Similarly, Ullah *et al*., (2007) in experiments on soybean-maize intercropping achieved highest land equivalent ratio of 1.62 from maize intercropped with soybean. In conclusion, all the intercropping systems have the potential to give substantially higher net income over mono-cropping.

According to Singh & Balyan (2000) and Barik *et al*., (1998), intercropping system is more economical as compared to sole cropping system. The greater income from intercropping treatments is in fact attributed to the efficient use of inputs, soil, and other resources. Intercropping is therefore an economical method of crop growing as shown by net income and CBR in Table 4. The study suggests that intercropping can reduce reliance on the synthetic herbicides for weed management and can decrease the cost of production. In addition it is an environmentally safe way of managing and minimizing the associated weeds.

Conclusions

The treatments of intercropping were all effective in weeds population reduction and increase in income per unit area. Average weed densities m^{-2} were considerably reduced by the intercropping treatments of French bean, mung bean and sunflower in maize, thereby reducing weed populations significantly as compared to weedy check. The intercropping treatments also showed increase in the yield of maize over weedy check sole maize treatments. Similarly, the LER and CBR values indicated fruitful results of the intercropping treatments. Therefore, the practice of intercropping should be encouraged in future as the farmers in Pakistan generally are reluctant of the intercropping particularly in maize crop.

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