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Full Length Research Paper

Effect of fertilizer in controlling weeds under intercropping of pearl millet and red bean in Sistan region, Iran

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This experiment was conducted at the Agriculture Research Center of Zabol University during 2007 cropping season. The experimental design was split plot, using randomized complete block design with three replications. The factors included were, main factors: unfertilized (F_1), 100% fertilizer (F_2), 100% manure (F_3), 50% fertilizer + 50% manure (F_4) and five sub factors: sole crop of millet (I_1), 75% millet + 25% bean (I_2), 50% millet + 50% bean (I_3), 25% millet + 75% bean (I_4) and sole crop of bean (I_5). The plants were planted as replacement method. The results showed that the lowest dry matter for crops and total dry matter of weeds was achieved from 50% fertilizer + 50% manure treatment. Also, the highest total dry matter of millet and bean was obtained from this treatment. The highest dry matter of millet and bean was obtained from the sole crop of millet and bean. Further, the highest total dry matter of millet and bean was achieved from the intercropping treatments. The land equivalent ratio (LER) for most of the intercropping treatments was greater than one which indicated that intercropping had advantage over sole crop. Comparing the performance of sole crop and intercrop treatments, the results indicated that intercropping combinations were more advantageous in terms of weed control.

Key words: Intercropping, pearl millet, red bean, weeds, land equivalent ratio, yield.

INTRODUCTION

Weed management is a critical component of any farming system. Liebman (1989), Morrish (1995), Champion et al. (1996) and Cosser et al. (1996) suggested a number of biological, physiological and mechanical practices offering opportunities for (1) reducing a heavy reliance on agriculture herbicide and (2) for potentially improving farm profitability and environmental quality. Examples of such practices are weed-suppressive cover crops, soil fertility management, crop rotation and intercropping.

Intercropping has been used successfully in a number of zonal cropping systems to improve weed control (Bulson, 1997; Haymes, 1999). Farmers commonly use cereal-legume intercropping practices to establish legume for hay (Hall, 1991; Moreira, 1989). Legume crops are weak competitors with weeds, while the cereal crop component helps to suppress weeds in intercropping systems (Liebman and Dyck, 1993; Mohler and Liebman, 1987). Carr et al. (1995) and Bulson et al. (1997) found a greater weed biomass in sole cropped legumes than in sole cropped cereals. Recent research efforts suggested that intercropping legumes with cereals can have potential for weed suppression and may decrease the need to use herbicides (Haymes, 1999). Moynihan et al. (1996) reported that annual medic-barley intercropping reduced weed mass by an average of 65% across environments, compared with the fertilizer sole crop. Neto (1993) stated that the intercropping system can have important and beneficial effects on weed management.

Canopies formed by intercrops prevent weed from deve-

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loping beneath, such as the intercropping of barley and field pea (Libman, 1989) and sorghum-legume intercrops (Abraham and et al., 1984). Carr et al. (1995) concluded that weed biomass production was reduced by intercropping lentil with wheat, compared with a sole cropping of lentil and sometimes compared with sole-cropped wheat. They suggested that intercropping was suited to crop production system where herbicides are used sparingly, if at all. Mohler and Libman (1987) stated that weed control was improved by intercrops. Dyke and Barnard (1979) found in three years of experiments in England that intercropping red clover with barley reduced growth of quackgrass by 42 to 62% when compared with barley sole crop treatments. Bulson et al. (1997) found that weed control was improved by intercrops. Consequently all intercrop density combinations had a lower weed biomass than the lowest level in the sole cropped beans.

This field experiment was conducted with pearl millet and red bean intercropping in combination with chemical fertilizer and farmyard manure (FYM) to find out effect of intercropping on weeds control.

MATERIALS AND METHODS

The intercropping pearl millet-red bean experiment was conducted during 2007 cropping season at the Agriculture Research Center of Zabol University. The site lies at longitude 61°29', and latitude 31°2' and the altitude of the area is 487 m above sea level. It had a warm dry climate with the mean minimum; mean maximum and average air temperatures of 18, 41 and 29°C, respectively. The soil characteristics of Agriculture Research Center was sandy loam in texture (pH= 7.4 and EC= 1.8 dS m^{-1}). The experimental design was split plot, using randomized complete block design with three replications. The factors included were, main factors: unfertilized (F_1), 100% fertilizer (F_2), 100% manure (F_3), 50% fertilizer + 50% manure (F_4) and five sub factors: sole crop of millet (I_1), 75% millet + 25% bean (I_2), 50% millet + 50% bean (I_3), 25% millet + 75% bean (I_4), and sole crop of bean (I_5). The plants were planted as replacement method. In this experiment, the density of 250000 plants/ha was used for both of the species equality and the plants were planted on each row. There was about 10 cm distance between every plant. The distances of main plots from each other was 80 cm and the distances of sub plots from each other was 40 cm. Sub plots were established having 8 rows in the long term of 4 m and with distances of 40 cm. Before planting, full dose of 60 ton/ha manure (100% manure) (Table 1), 200 kg/ha P (as triple super phosphate) and 100 kg/ha K (as potassium sulfate) was added to the respective treatments, while N as urea) was applied in split doses; half at planting and the remaining half at 35 days after planting (100% fertilizer).

The yield of millet forage dry matter was measured in the seed doughing stage and bean forage dry matter yield was measured in the flowering stage.

In the intercropping systems, direct comparison is difficult because products are different for the different plant species growing on one piece of land (Beets, 1982). In such cases, crop productivity should be evaluated using a common unit. A widely used method is the land equivalent ratio (LER) (Raji, 2007 a). LER is defined as the total land area required under mono-culture cropping to give the yields obtained in the polyculture cropping system (Mead and Willey, 1990). Total LER (LER_T), including millet partial LER (LER_M) and bean partial LER (LER_B) was calculated as follows:

$$LER_T = LER_M + LER_B = Y_{IM}/Y_{SM} + Y_{IB}/Y_{SB}$$

Where, Y_{IM} and Y_{IB} are mass yields per unit area of intercropped millet kernels and bean seeds respectively; Y_{SM} and Y_{SB} are mass yields per unit area of sole cropped millet kernels and bean seeds, respectively.

If LER_T is greater than one (LERT > 1), intercropping has a yield advantage, while there is a yield disadvantage from intercropping if LER_T is less than one (LER_T < 1) (Raji, 2007a).

Weed dry matter was measured as follows: on the two species of weed dominance (*Portulaca oleracea* L. and *Salsola kali* L.), in additional to other weed species as the third group.

The data were analyzed using MSTAT-C statistical package; mean separation was done using Duncan's test at 5% probability level.

RESULTS AND DISCUSSION

Dry matter of weeds

The different amounts of manure and chemical fertilizer and different ratios of intercropping were significant on the dry matter of *S. kali* and *P. oleracea*; the other sort of weeds and on the total dry matter of the weeds (Table 2). The driest matter of these species was obtained from 100% fertilizer treatment and with the reduction of chemical fertilizers consumption, dry matter of weeds decreased. The least dry matter of weeds was obtained from the lack of fertilizer treatment (Table 5). These result showed that in the chemical fertilizer treatments, weeds as compared with crops produced the higher dry matter by absorbing nutrients better from the soil (Liebman and Robichaux, 1990; Liebman, 2001). Several authors indicated that chemical fertilization decreased crop competition and consequently, increased weeds biomass (Liebman and Robichaux, 1990).

Between intercropping treatments, the highest dry matter of *S. kali* and *P. oleracea*, the other sort of weeds and total dry matter of weeds were obtained from the sole crop of millet and bean (Table 5). The dry matter of weeds was the lower in intercropping, because millet had greater growth rate than bean when they were grown in mixture together. However, on the one hand, millet occupied the upper part of the canopy and cast shadow on bean, and on the other hand, bean in the lower part of the canopy cast shadow on the soil and led to suppression of weeds in this system. Other researchers reported similar results about this matter (Hauggaard-Nielsen et al., 2001; Haymes and Lee, 1999; Jayakumar et al., 2008).

Interaction of fertilizer and intercropping treatments was significant on the dry matter of *S. kali* and *P. oleracea*, and total dry matter of weeds matter was achieved from F_3I_4 treatment (Table 7).

Dry matter yield of millet and bean

The effect of fertilizer and intercropping treatments was

Table 1. Chemical analysis of farmyard manure.

Chemical element	Value
N (%)	21
P (%)	76
K (%)	1.47
Fe (mg/kg)	7431
Zn (mg/kg)	93
Mn (mg/kg)	372

Table 2. Analysis of variance for dry matter of weeds and total dry matter yield of millet+bean.

S.O.V	df	*Portulaca oleracea* (kg/ha)	*Salsola kali* kg/ha)	Other species of weed (kg/ha)	Total dry matter of weed (kg/ha)	Total dry matter yield of millet+bean (kg/ha)
		Mean square				
Replication	2	1411.6$^{n.s}$	924.1$^{n.s}$	10213.7$^{n.s}$	7866.4$^{n.s}$	93852.5$^{n.s}$
Fertilizer	3	638421.4**	224716.3**	137541.2**	1319366.9**	4325682.9**
Error a	6	28231.7	8527.9	10231.6	69437.6	725984.7
Intercropping ratio	4	214296.1**	24191.6**	167042.8**	593425.0**	1689863.1*
Interaction	12	71432.5**	7998.6**	33921.1**	144891.3**	768493.6*
Error b	32	15135.5	2654.3	7169.5	25984.8	198876.9
CV (%)	-	19.2	16.9	22.4	14.1	17.6

* and ** significant at 5 and 1% levels of probability, respectively; $^{n.s}$, not significant.

Table 3. Analysis of variance for dry matter yield of millet and bean.

S.O.V	d.f	Dry matter yield of bean (kg/ha)	Dry matter yield of millet (kg/ha)
		Mean square	
Replication	2	412469.6$^{n.s}$	79428.5$^{n.s}$
Fertilizer	3	3199028.4*	1985246.7*
Error a	6	514791.8	568773.9
Intercropping ratio	3	2914599.2*	31154763.4*
Interaction	9	721563.9**	1245229.1*
Error b	24	298622.9	300471.5
CV (%)	-	20.4	27.1

* and ** significant at 5 and 1% levels of probability, respectively; $^{n.s}$, not significant.

significant on dry matter yield of millet and bean (Table 3). The highest dry matter yields of millet and bean were obtained from 50% fertilizer + 50% manure and the lowest dry matter yields of millet and bean were achieved from the unfertilized treatment (Table 4). Application of manure has various advantages such as increasing soil physical properties, waterholding capacity and organic carbon content apart from supplying good quality nutrients. The addition of organic sources could increase the yield through improving soil productivity and higher fertilizer use efficiency (Santhi and Selvakumari, 2000). High and sustained yield could be obtained with balanced fertilization combined with manure (Kang, 1990). The results of this experiment are similar to those of others investigations (Edward and Daniel, 1992; Ghosh et al., 2007; Hati et al., 2001).

Between intercropping treatments, the highest dry matter of millet and bean forage was obtained from the sole crop of millet and bean (Table 6). This result showed that according to the increase of the two species density in the culture, the different systems increased the dry matter. This finding agrees with the report of Liebman and Dyck (1993), Mohler and Liebman (1987) and Hauggaard-Nielsen et al. (2001).

Interaction of fertilizer and intercropping treatments was significant on dry matter of millet and bean forages, so

Table 4. Analysis of variance for forage yield of millet and bean.

S.O.V	d.f	LER
		Mean square
Replication	2	0.019$^{n.s}$
Fertilizer	3	0.211*
Error a	6	0.039
Intercropping ratio	2	0.050*
Interaction	6	0.056*
Error b	16	0.012
CV (%)	-	21.9

* and ** significant at 5% and 1% levels of probability, respectively.

Table 5. Mean comparison of main effects for the dry matter of weeds.

Treatment		*Salsola kali* (kg/ha)	*Portulaca oleracea* (kg/ha)	Other species of weed (kg/ha)	Total dry matter of weed (kg/ha)
Fertilizer+FYM					
Unfertilized		593.6c	711.7c	167.8c	1473.1c
100% fertilizer		744.2a	1111.2a	244.1a	2099.5a
100% FYM		602.4c	727.2c	182.7b	1532.7bc
50% fertilizer + 50% FYM		637.3b	876.4b	203.1b	1696.4b
Intercropping					
Millet	**Bean**				
100	0	751.2a	921.7a	282.3a	1955.2a
75	25	549.9b	804.3b	201.8b	1556.0b
50	50	509.4b	800.2b	190.7b	1500.3b
25	75	474.2b	794.5b	184.8b	1453.5b
0	100	712.3a	896.4a	262.5a	1871.2a

Mean followed by similar letters in each column, are not significantly at the 5% level of probability.

Table 6. Mean comparison of main effects for dry matter yield of millet and bean (kg/ha).

Treatment		Dry matter yield of millet (kg/ha)	Dry matter yield of bean (kg/ha)	Total dry matter yield of millet+bean (kg/ha)
Fertilizer+FYM				
Unfertilized		4985.2c	1986.2c	6971.4d
100% fertilizer		5169.9c	2351.8b	7521.7c
100% FYM		5811.3b	2470.1ab	8281.4b
50% fertilizer + 50% FYM		6320.8a	2671.8a	8992.6a
Intercropping				
Millet	**Bean**			
0	0	6812.7a	-	6812.7b
25	25	6634.4b	1252.2d	7886.6a
50	50	5833.7c	1877.1c	7710.8a
25	75	4229.3d	3311.9b	7541.2a
0	100	-	3418.6a	3418.2b

Mean followed by similar letters in each column, were not significantly at the 5% level of probability.

Table 7. Mean comparison of interaction effects for the dry matter of weeds.

Treatment	*Salsola kali* (kg/ha)	*Portulaca oleracea* (kg/ha)	Other species of weed (kg/ha)	Total dry matter of weed (kg/ha)
F_1I_1	689.2bc	802.7c	234.7ab	1726.6de
F_1I_2	647.7cd	761.4e	184.9cd	1594.0ef
F_1I_3	540.8ef	756.8e	179.3d	1476.9f
F_1I_4	518.2f	751.8e	171.4d	1449.3f
F_1I_5	647.0cd	798.8de	219.2bc	1665.0de
F_2I_1	778.3a	1055.9a	261.3a	2095.5a
F_2I_2	644.2d	976.4ab	223.1bc	1842.7bc
F_2I_3	551.7ef	964.1b	218.8bc	1734.6d
F_2I_4	597.3e	959.0b	201.0c	1757.3cd
F_2I_5	726.1b	958.0b	254.8a	1938.9b
F_3I_1	681.9bc	838.3d	234.5ab	1754.7cd
F_3I_2	572.4e	769.0e	193.8cd	1535.2f
F_3I_3	556.5ef	764.4e	187.1cd	1490.0f
F_3I_4	529.9f	738.4e	18383cd	1451.6f
F_3I_5	771.7a	809.3de	221.0bc	1802.0c
F_4I_1	698.3bc	911.8bc	242.4ab	1852.5bc
F_4I_2	576.8e	839.7d	199.5cd	1636.0e
F_4I_3	660.9c	831.7d	191.9cd	1684.5de
F_4I_4	544.8ef	829.8d	187.6cd	1562.2ef
F_4I_5	673.6c	885.7c	237.3b	1796.6c

Mean followed by similar letters in each column, are not significantly at the 5% level of probability.

that the highest dry matter of the two species were obtained from the sole crop with 50% fertilizer + 50% manure (Table 8).

Land equivalent ratio for dry matter of millet and bean forage

The effect of fertilizer and intercropping treatments was significant on LER of the two species dry matters (Table 4). LER in most of the intercropping different ratios was greater than one (Table 9). The highest LER of the species dry matter was obtained (LER= 1.37) from 50% fertilizer + 50% manure treatment (Table 9). According to the dry matter yield of millet and bean, in this treatment, manure caused improvement in the soil's structure properties and chemical fertilizers improved the nutrients availability which led to the increase of dry matter yield in these species. This finding agrees with the report of Hati et al. (2001) and Edward and Daniel (1992).

In the interrace intercropping treatments, the highest LER was obtained (LER= 1.32) from 25% millet + 75% bean (Table 9). This justifies that the intercropping gave significantly higher combined yield than the monocultures. This might be probably because of the marked morphological difference of the two crops, which facilitated better utilization of more light and other environmental resources that agree with the argument of Jayakumar et al. (2008). The relative yield reduction of millet was very low than that of bean when compared with the combined intercrop yield (Table 9); this is similar with the report of Davis and Garcia (1983), Flesch (1991), Chemeda (1997) and Raji (2007b). This justifies that millet had a higher relative competitive ability when compared with bean, which may be probably due to the shading effect of millet on beans. Furthermore, intercropping of millet-bean indicated better compatibility, because it maintained almost the sole yield of millet which agrees with the report of Habtamu et al. (1996). Millet-bean intercropping showed good compatibility since it maintained almost 46 to 83% sole millet yields. In general, intercropping gave higher yield advantage than monocropping and this agrees with the report of Chemeda (1997).

Total dry matter yield of millet and bean

The effect of fertilizer and intercropping treatments was significant on the total dry matter yield of millet and bean (Table 2). According to the dry matter of the species, the highest total dry matter yield of the species was obtained from 50% fertilizer + 50% manure treatment and the lowest was achieved from the unfertilized treatment (Table 6). In this treatment, the yield increase of the total dry matter of millet and bean under the condition of 50% fertilizer and 50% manure may be attributed to the improvement of the physico-chemical characteristics and

Table 8. Mean comparison of interaction effects for dry matter yield (kg/ha).

Treatment	Dry matter yield of millet (kg/ha)	Dry matter yield of bean (kg/ha)	Total dry matter yield of millet+bean (kg/ha)
F_1I_1	5981.1bc	-	5981.1e
F_1I_2	5647.5c	1676.7f	7324.2bc
F_1I_3	5371.8c	1514.2ef	7086.0c
F_1I_4	4739.3d	2774.5bc	7513.8bc
F_1I_5	-	2799.6bc	2799.6f
F_2I_1	5897.4bc	-	5897.4bc
F_2I_2	5606.2bc	1812.4ef	7618.6b
F_2I_3	5412.2c	1989.6e	7601.8b
F_2I_4	4526.3d	2736.5bc	7262.8bc
F_2I_5	-	2826.4b	2826.4f
F_3I_1	6496.6ab	-	6496.6d
F_3I_2	6261.3b	1861.3ef	8122.6ab
F_3I_3	5719.5c	2041.4e	7760.9b
F_3I_4	4186.6d	2612.9c	7294.5bc
F_3I_5	-	2838.3b	2838.3f
F_4I_1	6611.7a	-	6611.7cd
F_4I_2	6573.4a	1996.9e	8570.3a
F_4I_3	6013.6bc	2367.1d	8380.7a
F_4I_4	5434.9c	3041.2a	8476.1a
F_4I_5	-	3094.7a	3094.7f

Mean followed by similar letters in each column, were not significantly at the 5% level of probability.

Table 9. Land equivalent ratio (LER) for forage yield.

Intercropping ratio	F1 (Unfertilized)			F2 (100% fertilizer)			F3 (100% FYM)			F4 (50% fertilizer+50% FYM)			LER mean for intercropping ratio
	L_m	L_b	LER	L_m	L_b	LER	L_m	L_b	LER	L_m	L_b	LER	
I2	0.61	0.23	0.84	0.79	0.38	1.17	0.69	0.33	1.02	0.83	0.46	1.29	1.08b
I3	0.67	0.45	1.12	0.83	0.49	1.32	0.75	0.51	1.26	0.71	0.67	1.38	1.27a
I4	0.46	0.73	1.19	0.57	0.84	1.41	0.48	0.76	1.24	0.53	0.91	1.44	1.32 a
LER mean for fertilizer+FYM			1.05c			1.30a			1.17b			1.37a	

Mean followed by similar letters in each column, were not significantly at the 5% level of probability. I2, Intercropping 75% millet and 25% bean; Lm, relative yield for millet; I3, intercropping 50% millet and 50% bean; Lb, relative yield for bean; I4,intercropping 25% millet and 75% bean.

soil fertility and also to the improvement of nutrients availability. Other researchers also reported similar results (Edward and Daniel, 1992; Ghosh et al., 2007; Hati et al., 2001; Mohamed Amanullah et al., 2006).

For the interrace intercropping treatments, the highest total dry matters of these species were obtained from intercropping different ratios (Table 6). Intercropping produced higher yield than the sole crops by effective use of more sources (such as light, moisture and nutrients) and also prevented weed's growth. Similarly, Ghanbari (2000) reported that wheat in mixture with bean not only produced greater yield but also controlled weeds.

With due attention to significant effect of interactions of fertilizer and intercropping treatments on total dry matter, it was seen that the highest total dry matter yields of these two species were obtained from F_4I_2 treatment (Table 8).

Conclusion

The results of the present on-farm trials indicated that productivity of the pearl millet + red bean intercropping system could be improved with the application of recommended dose of fertilizers and manure. Pearl millet+red bean intercropping with 50% fertilizer + 50% manure recorded significantly lower weed density and biomass. Overall, the application of fertilizer with manure had the largest and most consistent effect on yield. Some of the benefits associated with intercropping are the increase of soil physical properties, water holding capacity and organic carbon content apart from the supply of good quality nutrients that also improve soil productivity and higher fertilizer use efficiency.

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