FORAGE YIELD AND QUALITY IN PEARL MILLET-SESBANIA INTERCROPPING SYSTEM UNDER VARIOUS GEOMETRICAL PATTERNS

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ABSTRACT:- Intercropping of cereal and legume forages following proper planting geometry is an important strategy to achieve higher yield of quality forage. A field experiment was performed to evaluate agro-qualitative response of forage pearl millet sown as a base crop and sesbania as intercrop under different geometrical patterns (line sowing of sole pearl millet, line sowing of sole sesbania, cross planting of pearl millet and sesbania, blended seed sowing of pearl millet and sesbania, sesbania intercropping in 30 cm apart rows of pearl millet, sesbania intercropping in 45 cm apart two-row strips of pearl millet, and sesbania intercropping in 75 cm apart four-row strips of pearl millet) at Agronomic Research Area, University of Agriculture, Faisalabad. Sesbania intercropping reduced pearl millet growth. Nonetheless, least decrease in height (23%), leaf area (42%) and number of leaves (16%) of pearl millet was occurred by intercropping sesbania in 45 cm apart two-row strips of pearl millet, as compared to sole cropping of pearl millet. Total green forage yield (60%) was increased by sesbania intercropping over sole-cropping of pearl millet and the intercropping of sesbania in 45 cm apart two-row strips of pearl millet was most beneficial. Intercropping improved quality of fodder mixture, compared to sole-cropping. Crude protein (84%) was improved most by cross planting over sole pearl millet, while, crude fiber (36%) and ash contents (20%) were improved by blended seed sowing, as compared to sole cropping of sesbania. Potential benefits of forage pearl millet can be acquired by intercropping with sesbania and following the planting geometry of sesbania intercropped in 45 cm apart two-row strips of pearl millet.

Key Words: Pearl millet, Sesbania, Intercropping, Growth, Forage Yield, Quality

INTRODUCTION

Intercropping is the growing of more than one crop species or cultivar simultaneously in the same field during a growing season (Armstrong et al., 2008). Crop scien-tists all over the world are facing the alarming situation, resulting from intensive use of chemical fertilizers and they are trying to overcome this condition by exploring alternative sources which are cost effective and environmentally safe (Mia et al., 2010). Intercropping may positively impact on the future food problems in developing countries. It has many advantages, mainly related to the complementary use of environmental resources by the component crops which results in

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increased and more stable yields, better nutrient recycling in the soil, better control of weeds, pests and diseases and an increased biodiversity (Crews and Peoples, 2004).

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries (Tsubo et al., 2005; Khan et al., 2015). Legume crops are rich in protein content (Murtaza et al., 2014). Intercropping of cereals with legumes has been a popular practice in tropics (Hauggard-Nielson et al., 2001) and rainfed areas of the world, due to its various advantages (Agegnehu et al., 2006). Land's used for monocropping are being depleted of soil fertility. Legumes can transfer fixed nitrogen to inter-cropped cereals during their joint growing period and this N is important source for associated cereal crop (Shen and Chu, 2004). In addition, there is evidence that cereals are benefitted by the transfer of nitrogen from the living legume concluding that intercropping helps in exploiting the land and environmental resources in a profitable way (Vasilakoglou et al., 2005). So the approach of mixed cropping can be a solution to maintain soil fertility.

Cereals and legumes, both for forage and grain, are the most common inter-crops. Numerous studies have confirmed more fodder produced from the combined production of cereal and legume intercrops, with further adding the additional benefits of high provisions of quality portions, as measured against alone use of cereal in fodder (Balabanl et al., 2010; Karadag and Buyukburc, 2003). Mixed cropping especially with legumes can improve the forage quality and yield (Ahmad, 2007). It has been reported by Javanmard (2009) that forage quality and quantity of maize-legume intercropping can be increased to great extent. In particular mixed cropping can bring an improvement in forage yield and quality (Ahmad et al., 2007).

The spatial and temporal distribution of plants may have substantial effects on radiation interception (Matthews and Saffell, 1987). In this regard the planting geometry is of utmost importance. Row spacing as well as row orientation are crucial in the determination of growth and yield pattern of crops. Fodder yield of baby corn increased with suitable planting geometry because of effective utilization of applied nutrients, increased sink capacity and higher nutrient uptake by the crop (Thavaprakaash et al. 2005).

Pearl millet (*Pennisetum americanum* L.) is a cereal crop be-longing to family Poaceae and is a good quality fodder having high crude fiber. Sesbania (*Sesbania sesban* L.) is a leguminous crop and belongs to family Leguminosae. It fixes atmospheric nitrogen and also is a good fodder having high protein content. For obtaining a good fodder yield of better quality, an appropriate sowing technique for a non-legume and legume mixture is essential. Also, there is an opportunity to develop a unique planting technique which might provide optimum forage yield as well as meeting the nutritional requirements of animals. The present study was undertaken to increase the quantity and improve the quality of forage pearl millet by growing the sesbania as intercrop and to find out suitable planting pattern for forage pearl millet and sesbania intercropping.

MATERIALS AND METHOD

A field experiment was carried out to assess the yield and quality advantage of pearl millet-sesbania intercropping under different geometrical patterns at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan, during 2013. The experimental site was located at 31.25° N latitude, 73.09° E longitude, 184 m above sea level elevation above sea level. The experimental soil was sandy loam with 8.1 pH, 1.08% organic matter, 0.05% nitrogen, 7.1 ppm available phosphorus and 80 ppm available potassium contents.

Pearl millet was taken as base crop while sesbania as intercrop. The experiment was comprised of intercropping of pearl millet and sesbania under different geometrical patterns viz. line sowing of sole pearl millet, line sowing of sole sesbania, cross planting of pearl millet and sesbania, blended seed sowing of pearl millet and sesbania, sesbania intercropping in 30 cm apart rows of pearl millet, sesbania intercropping in 45 cm apart two-row strips of pearl millet, and sesbania intercropping in 75 cm apart four-row strips of pearl millet. The experiment was carried out using randomized complete design with three replications and net plot size of 7 m × 3.6 m. Line sowing of both pearl millet and intercrop was carried out by using single row hand drill on well prepared seed bed.

Line sowing of sole pearl millet and sesbania crops was carried out in 30 cm apart rows. In intercropping systems, intercrop was sown in 30 cm apart rows of pearl millet in cross planting, blended seed sowing, and sesbania intercropping in 30 cm apart rows of pearl millet. In case of sesbania intercropping in 45 cm apart two-row strips of pearl millet and sesbania intercropping in 75 cm apart four-row strips of pearl millet, two and four row strips of sesbania intercrop was sown in between two and four row strips of pearl millet, respectively, where the distance between rows of pearl millet and sesbania was kept 15 cm.

Pearl millet cultivar FB-822 and sesbania cultivar Rohi was selected for this study. Recommended seed rate of 15 kg ha^{-1} for pearl millet and 20 kg ha^{-1} for sesbania was used. Nitrogen in the form of urea at the rate of 60 kg ha^{-1} and phosphorus in the form of single super phosphate at the rate of 60 kg ha^{-1} was applied. Half of the nitrogen and whole of the phosphorus was applied by broadcast method at sowing, while the remaining half nitrogen was applied at second irrigation. In all, four irrigations were applied during the whole cropping season excluding soaking irrigation. All other agronomic measures were kept same for all the treatments. Crop was harvested 75 days after sowing considering it as full mature crop to feed animals. Growth and yield attributes were recorded after harvesting the crop. Growth attributes of pearl millet viz. plant height, stem diameter, leaf area per plant and number of leaves per plant were recorded at maturity. Total plant population and total forage yield of pearl millet and sesbania per hectare was noted. The dry matter percentage was calculated by formula given below;

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

The amount of protein, crude fiber and ash contents in the sole and mixed feed sample of pearl millet and sesbania were calculated by methods given by A.O.A.C. (1984). Total land equivalent ratio (LER) was calculated using the formula described by Willey (1979);

$$LER = L_a + L_b = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

where,

L_a and L_b are the LERs for the individual crops.

Y_{aa} = Pure stand yield of crop "a"

Y_{bb} = Pure stand yield of crop "b"

Y_{ab} = Intercrop yield of crop "a" intercropped with crop "b"

Y_{ab} = Intercrop yield of crop "b" intercropped with crop "a"

Data collected was analyzed statistically by using Fisher's analysis of variance technique and least significant difference (LSD) test was used to compare the treatments' means at 0.05 probability level (Steel et al., 1997).

RESULTS AND DISCUSSION

Effect of Pearl Millet-sesbania Inter-cropping on Pearl Millet Growth

Intercropping of sesbania in pearl millet with different planting geometries decreased the growth of pearl millet. However, there was an increase in total plant population per unit area by sesbania intercropping in pearl millet and maximum increase was observed by sesbania intercropping in 45 cm apart two-row strips of pearl millet when compared to sole cropping of each crop (Table 1). There was a reduction in plant height, stem diameter, leaf area and number of leaves of pearl millet by sesbania intercropping. Nonetheless, sesbania intercropping in 45 cm apart two-row strips of pearl millet caused a mini-

Table 1. Effect of pearl millet-sesbania intercropping under different geometrical patterns on growth of pearl millet

Treatment	Total Plant population m^{-2}	Plant height (cm)	Stem diameter (cm)	Leaf area per plant (cm^2)
Line sowing of sole pearl millet	67.67[d]	178.20[a]	1.49[a]	1936[a]
Line sowing of solesesbania	57.33[e]	----	----	----
Cross planting of pearl millet and sesbania	87.33[b]	119.93[c]	1.29[b]	1361[c]
Blended seed sowing of pearl millet and sesbania	67.33[d]	99.37[d]	1.13[c]	1179[e]
Sesbania intercropping in 30 cm apart rows ofpearl millet	72.33[cd]	112.8[cd]	1.15[c]	1357[cd]
Sesbania intercropping in 45 c apart two-row strips of pearl millet	93.33[a]	136.80[b]	1.27[b]	1368[b]
Sesbania intercropping in 75 cm apart four-row strips of pearl millet	77.33[c]	64.33[e]	1.22[b]	1354[d]
LSD at $p \leq 0.05$	5.170	13.57	0.068	5.45

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$

mum reduction in plant height (23%), leaf area (42%) and number of leaves (16%) of pearl millet, while, stem diameter (15%) was decreased least by cross planting of pearl millet and sesbania in intercropping system which produced similar results as produced by intercropping system in which sesbania was inter-cropped in 45 cm apart two-row strips of pearl millet as well as sesbania inter-cropping in 75 cm apart four-row strips of pearl millet as compared to pearl millet sole cropping. The results revealed that plant growth of pearl millet was lowered by sesbania intercropping as compared to mono-cropping and planting geometry, also imposed significant effect on pearl millet growth. Sesbania intercropping in 45 cm apart two-row strips of pearl millet was better in enhancing the plant growth in intercropping system (Tables 1 and 2). Better growth of pearl millet in intercropping system with this geometry may be attributed to better aeration and light penetration. Mass et al. (2007) evaluated the performance of pearl millet in different row spacing and found that wider row spacing resulted in more plant height than narrow row spacing. Intercropping system affected the plant growth of pearl millet which might be due to some competitive effect of sesbania with pearl millet in inter-cropping system. Ayub et al. (2004) found a significant effect of sorghum-rice bean inter-cropping on plant height and number of leaves of both the crops. Similar to our results, Ibrahim et al. (2006) reported a decrease in plant height of maize in maize-cowpea inter-cropping system sown in different seeding ratios.

Effect of Pearl Millet-sesbania Inter-cropping on Forage Yield

Sesbania inter-cropping in pearl millet with different geometrical patterns influenced the forage yield positively. The consequence of inter-cropping was an increase in total green fodder yield and dry fodder yield per unit area when compared to sole cropping, and sesbania inter-cropping in 45 cm apart two-row strips of pearl millet proved most beneficial of all. It was noticed that yield advantage was acquired by sesbania inter-cropping in pearl millet as indicated by land equivalent ratio and inter-cropping sesbania in 45 cm apart two-row strips of pearl millet gave maximum green fodder yield increase (60%) over sole cropping of pearl millet (Tables 2 and 3). Better yield by sesbania inter-cropping in 45 cm apart two-row strips of pearl millet may be attributed to more plant population per unit area as well as more biomass producing ability of sesbania. Many studies have reported a yield increase of forage cereal-legume intercrops relative to cereal sole crops (Ghanbari-Bonjar and Lee, 2003; Carr et al., 2004). Mpairwe et al. (2002) has also reported that intercropping of cereals and legumes produced higher yield than either sole crops. Furthermore, Arya et al. (2000) reported that sorghum + cowpea intercropping yielded significantly more green forage and dry matter of forage crops. In our study it was noticed that dry matter yield was also increased in pearl millet-sesbania intercropping system (Table 2). Similar results were observed by Javanmard et al. (2009) who reported an increase in dry matter yield of forage maize in intercropping system with vetch, bitter vetch, berseem clover and common bean. Results of present study revealed that inter-cropping of sesbania in pearl millet gave a considerable yield advantage over sole cropping which was indicated by land equivalent ratio higher than one in different planting patterns (Table 2 and 3). Dahmardeh et al. (2009) reported similar results that maize-cowpea inter-cropping system resulted in higher land equivalent ratio as compared to sole cropping in different planting ratios. Ahmad et al. (2007) reported that various planting patterns imposed significant effect on mixed, dry and green forage yield of sorghum-cowpea and sorghum-sesbania, and 45 cm spaced double row strips proved better.

Table 2. Effect of pearl millet-sesbania intercropping under different geometrical patterns on pearl millet growth and total forage yield

Treatment	Number of leaves per plant	Total dry matter yield (t/ha)	Total green forage yield (t/ha)	Total land equivalent ratio (LER)
Line sowing of sole pearl millet	11.80[a]	8.73[d]	51.71[f]	----
Line sowing of sole sesbania	----	8.61[d]	50.70[f]	----
Cross planting of pearl millet and sesbania	9.80[bc]	13.94[a]	76.32[b]	1.48
Blended seed sowing of pearl milletand sesbania	9.20[cd]	10.53[c]	58.38[e]	1.13
Sesbania inter-cropping in 30 cm apart rows of pearl millet	9.27[cd]	11.26[bc]	62.77[c]	1.22
Sesbania inter-cropping in 45 cm apart two-row strips of pearl millet	10.17[b]	14.86[a]	82.53[a]	1.61
Sesbania inter-cropping in 75 cm apart four-row strips of pearl millet	8.60[d]	12.15[b]	67.67[c]	1.31
LSD at $p \leq 0.05$	0.791	0.941	3.248	----

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$

Table 3. Effect of pearl millet-sesbania inter-cropping under different geometrical patterns on quality of forage mixture

Treatments	% yield increase over sole pearl millet	Crude protein (%)	Crude fiber (%)	Ash (%)
Line sowing of sole pearl millet	----	7.67[e]	28.68[a]	15.95[a]
Line sowing of sole sesbania	----	19.32[a]	18.69[e]	11.07[e]
Cross planting of pearl millet and sesbania	48	14.15[b]	22.31[d]	11.70[de]
Blended seed sowing of pearl milletand sesbania	13	11.57[d]	25.37[b]	13.25[b]
Sesbania inter-cropping in 30 cm apart rows of pearl millet	21	12.81[e]	24.40[bc]	13.06[bc]
Sesbania inter-cropping in 45 cm apart two-row strips of pearl millet	60	14.15[b]	22.27[d]	12.35[cd]
Sesbania inter-cropping in 75 cm apart four-row strips of pearl millet	31	12.31[cd]	23.73[c]	12.96[bc]
LSD at $p \leq 0.05$	----	0.960	1.321	0.732

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$

Effect of Pearl Millet-sesbania Inter-cropping on Quality of Fodder Mixture

Quality of fodder mixture was decreased by inter-cropping sesbania in different planting geometries. It was noticed that crude protein content in fodder mixture was less than that found in sesbania sole cropping, however, sesbania inter-cropping in pearl millet proved better in respect to protein content as compared to pearl millet sole cropping. There was an increase in crude protein content (84%) in fodder mixture as compared to pearl millet and the sesbania inter-cropping in 45 cm apart two-row strips of pearl millet as well as cross planting of pearl millet and sesbania proved most beneficial among all in improving crude protein content in fodder mixture. Crude fiber and ash content in fodder mixture was found less than pearl millet while more than sesbania when each of these was sown alone. However, blended seed sowing of pearl millet and sesbania showed better results in increasing crude fiber (36%) and ash contents (20%) among all the inter-cropping systems as compared to sesbania sole cropping (Table 3). Cereal-based forages have characteristically high fiber proportion of the dry matter content and are considered low in protein as compared to legumes. So legumes can serve as a source of protein nourishment to animals. Hence possibility exists for the combined production of legumes and cereals, rather than growing them separately (Ross et al., 2004; Lithourgidis et al., 2007). Studies have revealed an improved quality of fodder mixture by intercropping cereals with legumes rather than growing them separately (Yolcu et al., 2009). In our study it was observed that pearl millet was poor in protein content and sesbania was poor in fiber and ash contents when they were sown as sole crops, while, in inter-cropping systems an improvement in protein, fiber and ash contents was noticed in the fodder mixture. In inter-cropping system, the planting pattern also imposed a significant effect on quality of fodder mixture (Table 3). The results of our study are in accordance with Kocer and Albayrak (2012) who found that intercropping pea in oat and barley with different planting ratios resulted in improved fodder quality as compared to monoculture. Similarly, Afzal et al. (2013) reported that different planting methods exerted differential effect on quality of forage sorghum.

CONCLUSION

The results revealed that growth of pearl millet was reduced by sesbania intercropping, while, total green forage yield and dry matter yield was increased than mono-cropping systems. However, minimum reduction in growth and maximum increase in yield was caused by intercropping sesbania in 45 cm apart two-row strips of pearl millet. The quality of fodder mixture was decreased in intercropping system; however, blended seed sowing and intercropping sesbania in 45 cm apart two-row strips of pearl millet resulted in least reduction. Potential benefits of forage pearl millet can be obtained by inter-cropping forage sesbania and following the planting geometry of sesbania intercropping in 45 cm apart two-row strips of pearl millet.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

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1.	Mr. Tassadduq Rasool	Conceived the idea, data collection, data analysis, wrote methodology
2.	Mr. Ali Zohaib	Data analysis, wrote abstract, introduction, results and discussion, overall management of the article
3.	Dr. Ehsanullah	Conceived the idea, technical input at every step
4.	Dr. Riaz Ahmad	Conceived the idea, technical input at every step
5.	Mr. Tasawer Abbas	Data collection, wrote conclusion
6.	Ms. Tahira Tabassum	Data entry in statistical software and analysis, wrote references, paper formatting
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