Pak. J. Bot., 50(5): 1991-1997, 2018.

BIO-AGRONOMIC EVALUATION OF FORAGE SORGHUM-LEGUMES BINARY CROPS ON HAPLIC YERMOSOL SOIL OF PAKISTAN

MUHAMMAD AAMIR IQBAL[*1], ASIF IQBAL[2], MUZAMMIL HUSSAIN SIDDIQUI[1] AND ZAHID MAQBOOL[3]

[1]*Department of Agronomy, The University of Poonch Rawalakot (AJK), Pakistan*
[2]*Department of Agronomy, University of Agriculture Faisalabad, Pakistan*
[3]*Department of Soil and Environmental Sciences, The University of Poonch Rawalakot (AJK), Pakistan*
[*]*Corresponding author's email: muhammadaamir@upr.edu.pk*

Abstract

The proportionate share of binary crops in mixed intercropping systems is crucial for boosting the productivity and nutritional quality of forage. This field trial aimed to investigate the response of seed blended crops of forage sorghum and legumes (soybean, cowpea and cluster bean) to varying seed proportions (100:35, 100:65 and 100:85), while their solitary crops were planted for comparison. Agronomic, physiological and agro-qualitative traits were taken as the experimental variables. Sorghum sown as a binary crop with legumes resulted in a significant ($p<0.05$) decrease of green biomass yield (15-38%) compared to the solo sorghum. In intercropping, soybean recorded 44% less yield, while green forage biomass of cowpea was decreased by 27%. However, the seed blended crop of sorghum-cowpea in 100:65 seed proportion recorded significantly ($p<0.01$) higher biomass (30%) than the mono culture of sorghum. The mixed seeded crop of sorghum and soybean in 100:85 seeding ratio was instrumental in improving the crude protein and lowering the crude fiber content of mixed forage. Sorghum-cowpea binary crop gave the maximum ether extractable fat and total ash of mixed forage, while the solo sorghum had the lowest nutritional quality. Thus, seed blending of sorghum and cowpea in 100:65 seed blending ratio may be suggested owing to higher productivity in irrigated Haplic Yermosols soil under semi-arid climatic conditions.

Key words: Agronomic management, Forage quality, Planting geometry, Mixed intercropping, Solitary cropping.

Introduction

Erratic weather conditions especially extreme heat during the summer months cause severe shortage of forage which reduces the milk and meat production (Promkhambut *et al*., 2010). Global warming, frequent droughts and declining soil fertility owing to unsustainable farming practices have further deteriorated the animal feed resources including forages. Sorghum (*Sorghum bicolor* L.) is a member of grass family and is known for heat and drought tolerance (Iqbal *et al*., 2015; Iqbal & Iqbal, 2015; Hakan *et al*., 2008). It has the potential to thrive well under the moisture and nutrients limited conditions, which makes it suitable for the arid and semi-arid areas of the world (Omari & Nhiri, 2015). Although edaphic and climatic conditions are excellent for sorghum production in Pakistan, but inappropriate sowing time, substandard methods of cultivation, low forage yielding varieties, sub-optimal plant population, poor crop establishment (Iqbal *et al.,* 2017a) and malnutrition (Iqbal *et al.,* 2017b) cause drastic reduction in forage biomass (Iqbal, 2015; Iqbal & Iqbal, 2015). However, sorghum is poor on animal nutrition scale due to low protein and therefore could not meet dietary requirement of large ruminants (Iqbal *et al*., 2015).

Sorghum-legumes mixed intercropping entailing non-distinguishable rows of component crops can increase green forage yield and nutritional quality of mixed forage (Iqbal *et al*., 2018; Maughan *et al*., 2009). Seed blending of cereals and legumes offere diversification of farm resources and enhance the productivity per unit area and time (Jeyabal & Kuppuswamy, 2001). In addition, it assists in achieving the equitable and judicious utilization of resources including irrigation water, solar radiation (Allen *et al*., 2007) fertilizers and labor (Marer *et al*., 2007). Cereal-legumes mixed seeding improved soil fertility and resulted in efficient utilization of applied nutrients (Maingi *et al*., 2001). Besides the type of intercropping systems, seed proportion of component crops may also influence the productivity of intercropping systems by switching from complimentary to competitive relationship.

In addition, the choice of component crops is also crucial for boosting the productivity of mixed intercropping systems. Cowpea (*Vigna unguiculata* L.) and cluster bean (*Cyamopsis tetragonoloba* Taub.) are best suited to be intercropped with forage sorghum due to their potential to tolerate shade, heat and drought (Ahmad *et al.,* 2007; Iqbal, 2015). Soybean (*Glycine max* L.) is another leguminous crop that can be intercropped with forage sorghum. Though, soybean has not been found at par to cowpea and cluster bean for drought and shade tolerance, but its higher potential to fix atmospheric nitrogen makes it suitable to be intercropped with sorghum (Parasad & Brook, 2005).

However, there has been no systematic and in-depth research for assessing the performance of component crops and their proportionate share in sorghum-legumes mixed intercropping systems on HaplicYermosols soils. We had formulated a hypothesis that one or more legumes may perform better than others and binary crops perform differently under varying seed proportions. Thus, the objective of this field investigation was to assess the comparative performance of sorghum as solitary and mixed seeded crop with forage legumes under varying seed proportions, to sort out the most appropriate forage legume to be intercropped with forage sorghum and to develop a highly sustainable and productive sorghum based mixed intercropping system suitable to dairy farmers for increasing the milk and meat production on sustainable basis.

Materials and Methods

Experimental environment: The experiment was conducted at the Agronomic Research Area of the University of Agriculture Faisalabad, Pakistan during 2013-2015 for three consecutive years. The experimental site lies at 30.35-41.47°N and 72.08-73.40°E with an altitude of 184 m (Iqbal *et al*., 2016). Koppen climate classification system categorizes the experimental site as semi-arid, while FAO soil classification scheme describes the local soil as Haplic Yermosols (Iqbal *et al*., 2017). The experimental soil was sandy clay loam and was deficient in nitrogen, phosphorous and organic matter with pH of 7.5-7.8 as per pre-sowing physico-chemical analyses (Table 1). During the crop growing seasons, there was relatively lesser precipitation during 2014 and 2015 compared to 2013, while the mean daily temperatures during 2014 and 2015 were comparatively on higher side in comparison to 2013, as per records of the meteorological observation center situated at 1 km distance from the experimental area.

Table 1. Physico-chemical analysis of experimental blocks conducted before sowing.

Characteristics	Values		
Mechanical analysis	**2013**	**2014**	**2015**
Sand (%)	57.0	58.0	60.0
Silt (%)	19.0	18.5	18.0
Clay (%)	24.0	23.5	22.0
Textural class	Sandy clay loam	Sandy clay loam	
Chemical analysis	**2013**	**2014**	**2015**
pH	7.9	8.0	7.6
EC (ds m^{-1})	1.51	1.53	1.49
Organic matter (%)	0.69	0.65	0.71
Total nitrogen (mg kg^{-1})	382.7	393.2	399.3
Available phosphorous (mg kg^{-1})	6.80	6.33	6.17
Available potassium (mg kg^{-1})	178.3	171.9	168.2

Experimental treatments and design: Binary crops of sorghum and three legumes (cowpea, cluster bean and soybean) were sown in different seed proportions including 100:35, 100:65 and 100:85. Sorghum and legumes were also sown as solitary crops for the comparison. In this way, there were 13 treatments (9 seed blended crops and 4 pure stands) in total. The experiment was laid out in a randomized complete block design (RCBD) and was replicated thrice with net plot size of 3.9 × 13.0 m. The row to row distance was maintained at 30 cm, while the plant-plant spacing was given no consideration.

Agronomic management: Uniform seedbed preparation was done in all experimental units during three years of field investigation. Pre-sowing irrigation of 10 cm was applied through flood irrigation method and when soil had attained an appropriate moisture level, the seedbed was prepared by giving three cultivations with the help of a tractor-mounted cultivator, each followed by planking. The cultivation was done to a depth of 12 cm. Sorghum (cv. JS-2002) was sown with a single row hand drill in 30 cm apart rows using a seed rate of 75 kg ha^{-1}. Forage legumes including soybean (cv. Ajmairi), cowpea (cv. P-518) and cluster bean (cv. BR-99) were intercropped with forage sorghum. The seed rate of soybean was 100 kg ha^{-1}, while that of cowpea and cluster bean was 40 kg ha^{-1}. Recommended doses of fertilizers (80 kg N as urea in two equal splits and 60 kg P_2O_5 ha^{-1} as single super phosphate in a single dose) were applied. No additional inputs were applied for legume intercrops. Four irrigations of 7.5 cm each were given at 10, 25, 40 and 50 days after sowing (DAS) during the entire growth period of the crops. The crops were harvested manually at 50% heading stage (67 DAS) with a hand sickle.

Data recordings: The physiological parameters of sorghum were recorded as described by Iqbal *et al.*, (2016).

$$\text{Leaf area index} = \frac{\text{Leaf area of crop in m}^2}{\text{Area of land in m}^2} \quad (1)$$

$$\text{Leaf area duration (days)} = (\text{Leaf area index}_1 + \text{Leaf area index}_2)(\text{Time}_2 - \text{Time}_1)/2 \quad (2)$$

where, LAI_1 = Leaf area index recorded at first harvesting, LAI_2 = Leaf area index recorded at last harvesting, $time_1$ =

Date of taking first leaf area and $time_2$ = Date of taking last leaf area.

$$\text{Crop growth rate (g m}^{-2}\text{ d}^{-1}) = \frac{\text{Dry weight}_2 - \text{Dry weight}_1}{\text{Time}_2 - \text{Time}_1} \quad (3)$$

where, dry $weight_1$ and dry $weight_2$ are the dry weights of sorghum taken at times t_1 and t_2, respectively.

$$\text{Net assimilation rate (g m}^{-2}\text{ d}^{-1}) = \frac{\text{Total dry matter biomass}}{\text{Leaf area duration}} \quad (4)$$

Agronomic parameters of sorghum were recorded by harvesting 10 plants randomly from the middle 3 rows of each plot. Plant height was recorded from the base to tip of the highest leaf with a measuring tap, while the stem diameter was measured using a vernier caliper. Fresh weight per plant was determined by using an electrical balance, while dry weight per plant was estimated by chopping plants with an electric cutter and then 200 g sample was placed in an oven at 74 °C until the caseation of fluctuation in weight. Green forage yield of binary crops was estimated by separating both crops and measuring these by using a spring balance. Mixed forage yield was recorded by following the Equations 5 and 6;

$$\text{Mixed green forage yield (t ha}^{-1}) = \text{Sorghum green forage yield} + \text{legume green forage yield} \quad (5)$$

$$\text{Mixed dry matter biomass (t ha}^{-1}) = \text{Sorghum dry matter biomass} + \text{legume dry matter biomass} \quad (6)$$

Statistical analyses: Barlett's test (p<0.05) showed a non-significant interaction effect of the experimental treatments and year as the variances of all three years were homogenous and ultimately pooling of three years data was done for combined statistical analyses. Then, the data were analyzed statistically using Fisher's analysis of variance technique with the help of a statistical program "Statistix version 8.1" (Iqbal *et al*., 2016). For statistically significant treatments, orthogonal contrasts were employed at 5% probability level to compare and separate the treatments means.

Results and Discussion

Physiological growth parameters of forage sorghum: Leaf area index (LAI) and leaf area duration (LAD) are important growth parameters for determining the total biomass production. A significant reduction in LAI and LAD of sorghum was recorded when it was sown as a binary crop with soybean, cowpea and cluster bean compared to its solitary crop. The binary crop of sorghum and cowpea in 100:65 seed proportion (M_5) gave the highest LAI and LAD; however these were lesser than the pure stand of sorghum (M_{10}) by 14 and 8% respectively. The binary crops of sorghum and soybean in 100:85 seed blending ratio resulted in 32% and 24% lower LAI and LAD respectively in comparison to sole sorghum (Fig. 1a,b). Similarly, the crop growth rate (CGR) and the net assimilation rate (NAR) can also be used to precisely estimate and project the green forage yield of binary crops. Both CGR and NAR witnessed a significant reduction when sorghum was sown as a seed blended crop with all three legumes in comparison to sorghum alone. However among binary crops, M_5 remained unmatched but still a reduction of 13 and 7% in CGR and NAR respectively was recorded in comparison to M_{10} (Fig. 1c,d). It was followed by seed blended crop of sorghum and cluster bean in 100:65 seed proportion (M_8) where the decrease in CGR and NAR was 21 and 6% respectively. Furthermore, there existed a linear correlation among all physiological growth attributes and green forage yield of sorghum (Fig. 2). Sorghum sown alone performed better due to lesser degree of competition for growth resources and resultantly higher leaf growth resulted in higher leaf area index and leaf area duration which led to considerably higher biomass accumulation over the period of time. These results are in complete confirmation with those of Akhtar *et al*., (2013) and Akunda (2001), who reported a significant reduction in the physiological growth traits especially CGR of cereal forages in intercropping with legumes owing to the dependence of legumes on soil solution for nutrients before N contributions from the biological nitrogen fixation process (Kadam & Baig, 2008).

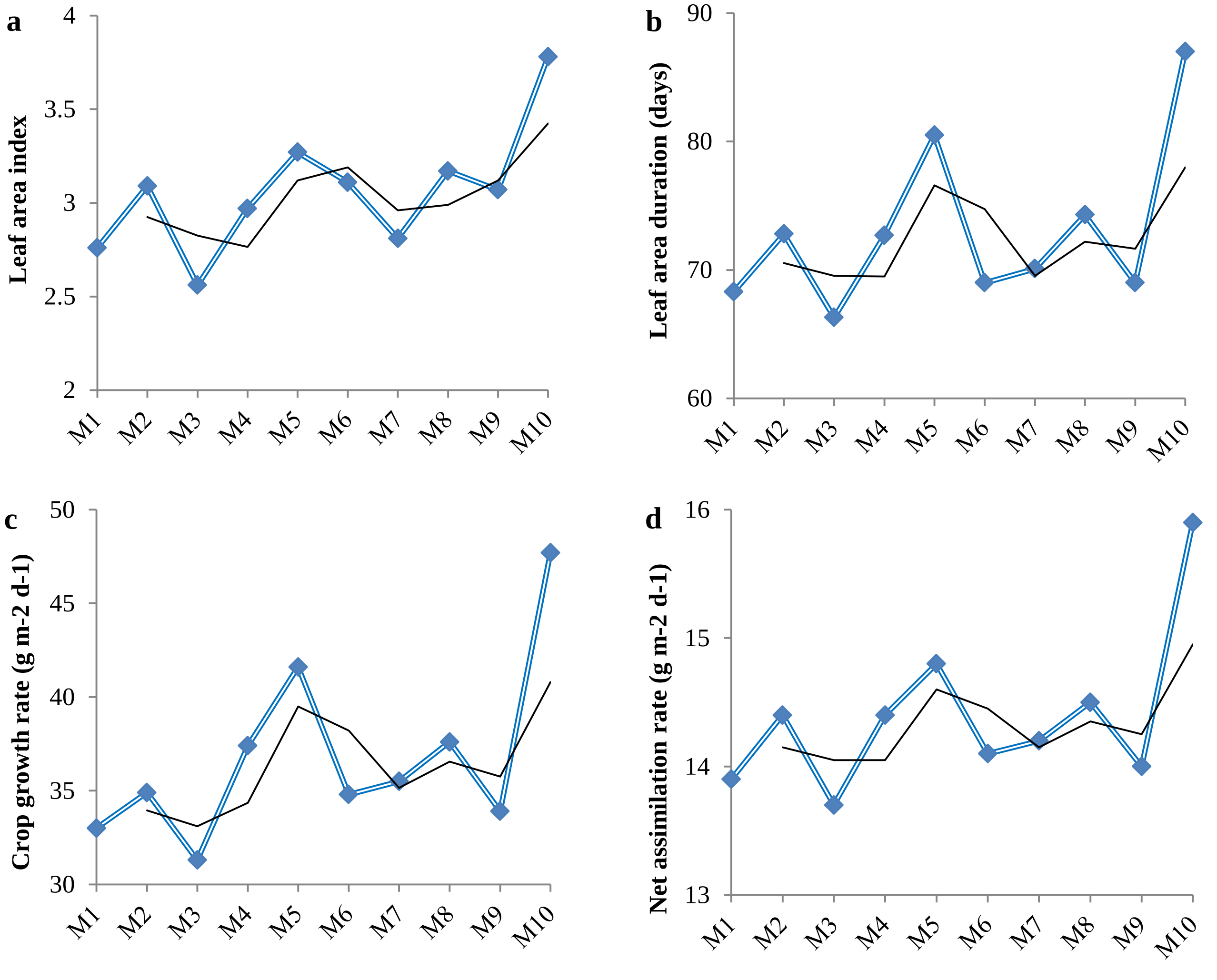

Fig. 1. Physiological growth of forage sorghum sown in mixed intercropping with legumes in varying seed proportions.

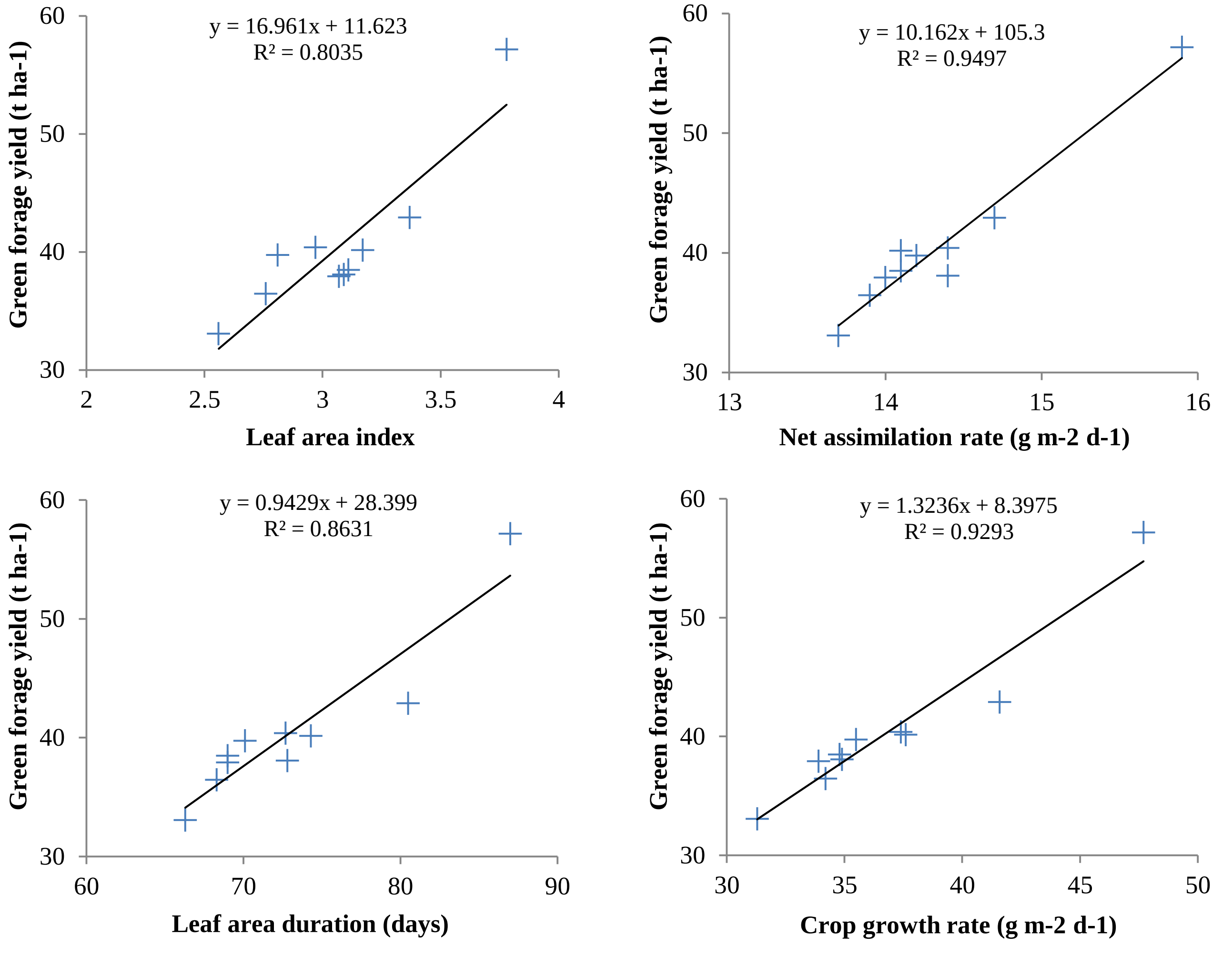

Fig. 2. Correlation analysis of physiological growth attributes with the green forage yield of sorghum sown in mixed intercropping with legumes in varying seed proportions.

Forage sorghum yield components and forage yield: Pure stand of sorghum was found to be outstanding in terms of agronomic variables and forage yield in comparison to the mixed seeded crops. Among binary crops, the maximum plant population at harvest was recorded for seed blended crop of sorghum and cowpea in 100:65 seed ratio and it was followed by mixed seeded crop of sorghum and soybean in 100:35 seed ratio. Sorghum sown as a mixed seeded crop with cowpea in 100:65 seed proportion recorded the highest plant height which was 5% less than the pure stand of sorghum and 11% higher than sorghum-soybean mixed crop in 100:85 seed proportion. Stem diameter and the number of leaves per plant of sorghum were not influenced by the intercropping and seed proportions (Table 2). These results are in contradiction to those of Ahmad *et al.,* (2007), who report that plant population of forage sorghum is not effected by different intercropping systems. However, Rathore *et al.,* (2012) and Ghosh *et al.,* (2007)found that sorghum was more competitive in acquiring the growth resources than legumes but its plant height and stem diameter were significantly reduced in row intercropping owing to the reduced share from the divisible pool of the nutrients and moisture. Contrary to our findings, Carruthers *et al.,* (2000) reported that stem diameter of cereal forages in intercropping was reduced, while Rana *et al.,* (2001) concluded that the number of leaves was a genetically controlled attribute and intercropping had no effect on it.

In addition, sorghum-cowpea binary crop was instrumental in recording the highest leaf area, fresh and dry weights per plant of forage sorghum in 100:65 seed proportion. Sorghum-soybean mixed cropping in 100:85 seed blending ratio resulted in the reduced leaf area, fresh and dry weights per plant of sorghum by 17, 25 and 19% respectively in comparison to the solitary crop of sorghum (Table 2). As forage yield is the sum total of all agronomic variables, thus higher leaf area, fresh and dry weights per plant led to significantly higher green biomass yield (45.9 t ha^{-1} which was 15% less than sole sorghum) and dry matter biomass (13.8 t ha^{-1} which was 18% less than sole sorghum) of seed blended crop of sorghum-cowpea sown in 100:65 seeding ratio than other binary crops. Sorghum performed better as binary crop with cluster bean than sorghum-soybean mixed seeded crop but it was not found to be at par to the mixed seeded crop of sorghum and cowpea in all seeding proportions. Haken *et al.*, (2008) also reported similar findings where soybean was found to be more competitive in acquiring moisture and nutrients than other legumes and the net results was drastic reduction in leaf area, fresh and dry weights per plant of cereal forages in comparison to their pure stands.

Table 2. Plant population (PP), plant height (PH), stem diameter (SD), number of leaves (NL), leaf area (LA), fresh weight (FW), dry weight (DW), green forage yield (GFY) and dry matter biomass (DMB) of sorghum sown as seed blended crop with legumes during 2013-2015 (3-years pooled data with combined analysis).

Treatments	PP (m^{-2})	PH (cm)	SD (cm)	NL	LA (cm^2)	FW (g)	DW (g)	GFY (t ha^{-1})	DMB (t ha^{-1})
M_1=Sorghum + soybean in 100:35 seed proportion	60.1c	254.6g	2.89	10.8	1886.3f	176.3de	56.0ef	34.1ef	11.0e
M_2=Sorghum + soybean in 100:65 seed proportion	54.7e	260.1e	2.92	10.5	1911.5e	170.2e	55.7f	35.4e	11.2e
M_3=Sorghum + soybean in 100:85 seed proportion	50.0f	242.5h	2.94	10.9	1841.9g	161.9f	55.0f	32.9f	10.7f
M_4=Sorghum + cowpea in 100:35 seed proportion	61.9b	268.7cd	2.90	10.6	2085.9b	187.3c	59.7c	37.4de	13.2c
M_5=Sorghum + cowpea in 100:65 seed proportion	60.0c	271.4b	2.97	11.2	1980.7c	198.9b	61.9b	45.9b	13.8b
M_6=Sorghum + cowpea in 100:85 seed proportion	58.9d	262.1ef	2.94	10.7	1973.0cd	181.0d	57.9d	40.0c	12.0d
M_7=Sorghum + cluster bean in 100:35 seed proportion	60.7c	266.4d	2.90	11.1	1977.4c	185.0cd	58.4d	38.1d	12.6cd
M_8=Sorghum + cluster bean in 100:65 seed proportion	57.4d	269.9c	2.91	10.9	1965.8d	184.1cd	57.7e	39.6c	13.0c
M_9=Sorghum + cluster bean in 100:85 seed proportion	54.7e	257.2f	2.95	11.0	1923.0de	182.9d	58.0d	36.9e	11.7de
M_{10}=Sole sorghum	63.3a	283.9a	2.98	11.3	2229.3a	216.4a	67.6a	53.7a	16.9a
Significance	*	**	NS	NS	**	**	*	**	**

Values having similar lettering did not differ at $p<0.05$. *= significant at $p<0.05$, **= significant at $p<0.01$, NS= non-significant at $p<0.05$

Table 3. Legumes green forage yield (LGFY), legumes dry matter biomass (LDMB), mixed green forage yield (MGFY), mixed dry matter biomass (MDMB), crude protein (CP), crude fiber (CF), ether extractable fat (EEF) and total ash (TA) of seed blended crops of sorghum and legumes during 2013-2015 (3-years pooled data with combined analysis).

Treatments	LGFY (t ha^{-1})	LDMB (t ha^{-1})	MGFY (t ha^{-1})	MDMB (t ha^{-1})	CP (%)	CF (%)	EEF (%)	TA (%)
M_1=Sorghum + soybean in 100:35 seed proportion	10.4f	5.1f	44.5f	16.1e	14.8e	25.0d	1.88c	10.67g
M_2=Sorghum + soybean in 100:65 seed proportion	12.7e	5.9de	48.1e	17.1d	15.0de	24.8de	1.92b	10.74f
M_3=Sorghum + soybean in 100:85 seed proportion	11.6ef	5.6e	44.5f	16.3e	15.6d	24.1e	1.96ab	10.81e
M_4=Sorghum + cowpea in 100:35 seed proportion	19.1de	7.5d	59.1b	20.7b	13.8fg	26.9c	1.81de	10.84de
M_5=Sorghum + cowpea in 100:65 seed proportion	23.9c	9.9bc	69.8a	23.7a	14.1f	27.4b	1.87c	10.91d
M_6=Sorghum + cowpea in 100:85 seed proportion	20.1d	8.4c	60.1b	20.4bc	14.6ef	27.7b	1.90bc	11.05c
M_7=Sorghum + cluster bean in 100:35 seed proportion	18.3e	7.0	56.4c	19.6c	13.0h	26.8c	1.78e	10.81e
M_8=Sorghum + cluster bean in 100:65 seed proportion	19.7d	7.9cd	59.3b	20.9b	13.4gh	27.3b	1.83d	10.85de
M_9=Sorghum + cluster bean in 100:85 seed proportion	19.0de	7.4d	55.9cd	19.1cd	13.7g	27.9b	1.86c	10.89d
M_{10}=Sole sorghum	-	-	53.7d	16.9d	8.8i	29.3a	1.71f	10.69f
M_{11}=Sole soybean	20.7cd	8.2c	20.7i	8.2h	21.7a	23.7e	1.98a	11.09c
M_{12}=Sole cowpea	32.4a	11.3a	32.4g	11.3f	19.1b	24.9de	1.91b	11.87a
M_{13}=Sole cluster bean	28.9b	10.4b	28.9h	10.4g	18.3c	26.6c	1.84	11.13b
Significance	**	*	**	**	**	*	*	**

Values having similar lettering did not differ at $p<0.05$. *= significant at $p<0.05$, **= significant at $p<0.01$, NS= non-significant at $p<0.05$.

Legumes biomass production and mixed (sorghum + legumes) forage yield: Forage yield of legume intercrops is important to be maintained for achieving the added advantage of intercropping. Among solitary crops, cowpea remained unmatched and it was followed by cluster bean while soybean recorded the minimum forage biomass. Among binary crops, cowpea remained outstanding in 100:65 seeding ratio with sorghum, however it yielded 27% less forage than pure stand of cowpea (Table 3). Soybean sown in seed blending with sorghum in 100:85 seed proportion suffered a drastic reduction in green forage yield (44%) in comparison to solo soybean. although the binary crops of sorghum and legumes could exploit different soil horizons by virtue of different root types and root penetration depths for extracting the moisture and nutrients, but legumes were dominated by cereal forages which caused a decrease of 24-56% compared to their mono cropping (Sani *et al*., 2011). The shading effect of taller cereal forages was also reported to reduce legumes forage yield by 12-19% because of less photosynthesis (Satheeshkumar *et al*., 2011; Oseni & Aliyu, 2010). Similarly, the binary crop of sorghum and cowpea in 100:65 seeding ratio was instrumental in yielding 30% higher mixed green forage than the exclusive crop of sorghum. It was followed by mixed seeded crop of sorghum and cowpea in 100:85 seeding ratio which in turn was followed by seed blended crop of sorghum-cluster bean in the seed proportion of 100:65 (Table 3). Sorghum-soybean mixed intercropping under all seeding proportions resulted in significantly lower mixed green forage and dry matter biomass. The superior performance of mixed seeded crop of sorghum and cowpea might be attributed to better utilization of soil and environmental resources because of different botanical characteristics of companion crops. Tajudeen (2010) also reported that sorghum-cowpea intercropping gave 45% higher mixed forage in comparison to the solo sorghum owing to higher water and nutrient use efficiency.

Nutritional quality of mixed forage: The quality of mixed forage determines and influences the milk and meat production on sustainable basis. Among solitary crops, soybean recorded the highest crude protein and the lowest crude fiber and it was followed by solo cowpea which in turn was followed by the pure stand of cluster bean (Table 3). The monoculture of sorghum yielded the maximum crude fiber which deteriorated forage quality. The binary crop of sorghum and soybean in all seeding proportions resulted in higher protein and lower fiber content than other mixed seeded crops. Solo soybean recorded the highest ether extractable fat and cowpea in pure stand followed it, while sorghum-cluster bean mixed seeding in 100:35 seed ratio gave the lowest fat content. Total ash which represents the mineral constituents of forage was the highest in the solitary crop of cowpea, while the mono culture of cluster bean followed it. Among seed blended crops, sorghum and cowpea sown in 100:85 seeding proportion yielded comparatively higher total ash, while the binary crop of sorghum and soybean gave the lowest total ash (Table 3). Mixed intercropping was instrumental in increasing the crude protein and lowering the crude fiber of mixed forage as legumes particularly soybean was rich in protein and resultantly quality of mixed forage was improved (Marer *et al*., 2007). Similarly, Pal & Sheshu (2001) reported that intercropping of sorghum with legumes was effective in boosting ether extractable fat and ash of mixed forage as compared to sole sorghum. It was concluded that legumes being the rich source of protein, increased the qualitative attributes of mixed forage in sorghum-legumes intercropping systems.

Conclusions

The findings of this field trial were partially in accordance with the postulated hypothesis as forage sorghum yield in mixed intercropping with legumes was decreased by 15-38% as compared to its solitary crop. Soybean sown as mixed seeded crop with sorghum under varying seeding proportions also recorded a significant decrease (24-56%) in forage biomass, while cowpea as a binary crop performed better than other legumes. However, sorghum-cowpea mixed seeding in 100:65 seed ratio remained superior by yielding 30% higher biomass than the solitary crop of sorghum. The binary crop of sorghum and soybean in 100:85 seed proportion remained unmatched by boosting the crude protein and lowering the crude fiber content of mixed forage, while the seed blended crop of sorghum and cowpea resulted in increased ether extractable fat and total ash. These research findings offer one of the most feasible and easy to practice strategies for boosting the biomass production with improved nutritional quality of mixed forage on Haplic Yermosols soils of Pakistan. However, there is a dire need to assess other leguminous forage crops and their cultivars for optimizing the seed proportion of binary crops in order to provide sufficient and nutritious forage on sustainable basis.

Acknowledgements

The principal author extends a sincere gratitude to the Higher Education Commission (HEC) of Pakistan for providing financial assistance under Indigenous Fellowship Scheme (5000-Fellowships-2AV1-215) and International Research Support Initiative Program (IRSIP).

References

Ahmad, A.H., R. Ahmad and N. Mahmood. 2007. Production potential and quality of mixed sorghum forage under different intercropping systems and planting patterns. *Pak. J. Agri. Sci.,* 44(2): 87-93.

Akhtar, M.F., A.U.H. Ahmad, M.S.I. Zamir, F. Khalid, A.U. Mohsin and M. Afzal. 2013. Agro-qualitative studies on forage sorghum (*Sorghum bicolor* L.) sown alone and in mixture with forage legumes. *Pak. J. Sci.,* 65(2): 179-185.

Akunda, E.M.W. 2001. Crop yields of sorghum and soybeans in an intercrop. *The J. Food Technol., Afr.,* 6(1): 2-4.

Allen, V.G., M.T. Baker, E. Segarra and C.P. Brown. 2007. Integrated irrigated crop livestock systems in dry climates. *Agron. J.,* 99: 346-360.

Carruthers, K., B. Prithiviraj, Q. Fe, D. Cloutier, R.C. Martin and D.L. Smith. 2000. Intercropping corn with soybean, lupin and forages: yield component responses. *Eur. J. Agron.,* 12: 103-115.

Ghosh, P.K., K.K. Bandypadhyay, R.H. Wanjari, M.C. Manna, A.K. Mishra, M. Mohanty and A.S. Rao. 2007. Legume effect for enhancing productivity and nutrient use efficiency in major cropping systems-an Indian perspective: a review. *J. Sustain. Agric.,* 30(1): 61-86.

Hakan, G., R. Avcioglu, H. Soya and B. Kir. 2008. Intercropping of corn with cowpea and bean: Biomass yield and silage quality. *Afr. J. Biotechnol.,* 22 (7): 4100-4104.

Iqbal, A., M.A. Iqbal, A. Iqbal and R.N. Abbas. 2018. Spatio-temporal reconciliation to lessen losses in yield and quality of forage soybean (*Glycine max* L.) in soybean-sorghum intercropping systems. *Bragantia*., 77(2). http://dx.doi.org/10.1590/1678-4499.2017043

Iqbal, A., M.A. Iqbal, A. Iqbal, Z. Aslam, M. Maqsood, Z. Ahmad, N. Akbar, H.Z. Khan, R.N. Abbas, R.D. Khan, G. Abbas and M. Faisal. 2017a. Boosting forage yield and quality of maize (*Zea mays* L.) with multi-species bacterial inoculation in Pakistan. *Phy. Int. J. Exp. Bot.,* 86: 84-88.

Iqbal, M.A., B.J. Bethune, A. Iqbal, R.N. Abbas, Z. Aslam, H.Z. Khan and B. Ahmad. 2017b. Agro-botanical response of forage sorghum-soybean intercropping systems under atypical spatio-temporal pattern. *Pak. J. Bot.,* 49(3): 987-994.

Iqbal, M.A. 2015. Cluster bean (*Cyamopsis tetragonoloba* L.) germination and seedling growth as influenced by seed invigoration techniques. *Am-Eur. J. Agric. Environ. Sci.,* 15 (2): 197-204.

Iqbal, M.A. and A. Iqbal. 2015. Overviewing forage shortage for dairy animals and suitability of forage sorghum for ensiling. *Global Vet.,* 14(2): 173-177.

Iqbal, M.A., A. Iqbal, M. Ayub and J. Akhter. 2016. Comparative study on temporal and spatial complementarity and profitability of forage sorghum-soybean intercropping systems. *Cust. Agronegocio.*, 12(4): 2-18.

Iqbal, M.A., A. Iqbal, N. Akbar, H.Z. Khan and R.N. Abbas, 2015. A study on feed stuffs role in enhancing the productivity of milch animals in Pakistan- Existing scenario and future prospect. *Global Vet.,* 14(1): 23-33.

Jeyabal, A. and G. Kuppuswamy. 2001. Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping systems and soil fertility. *Heriana J. Agron.,* 15: 153-170.

Kadam, G.L. and I.A.B. Baig. 2008. Studies on different planting patterns of sorghum + soybean intercropping system. *Int. J. Agric. Sci.,* 4(1): 181-187.

Maingi, M.J., A.C. Shisanya, M.N. Gitonga and B. Hornetz. 2001. Nitrogen fixation by common bean (*Phaseolus vulgaris* L.) in pure and mixed stands in semi- arid South East Kenya. *Eur. J. Agron.,* 14: 1-12.

Marer, S.B., B.S. Lingaraju and G.B. Shashidhara. 2007. Productivity and economics of maize and pigeon pea intercropping under rainfed condition in northern transitional zone of Karnataka. *Karnataka J. Agric. Sci.,* 20(1): 1-3.

Maughan, M.W., J.P.C. Flores, I. Anghinoni, G. Bollero, F.G. Fernandez and B.F. Tracy. 2009. Soil quality and corn yield under crop-livestock integration in Illinois. *Agron. J.,* 101: 1503-1510.

Omari, R.E. and M. Nhiri. 2015. Adaptive response to salt stress in sorghum (*Sorghum bicolor*). *Am-Eur. J. Agric. Environ. Sci.,* 15(7): 1351-1360.

Oseni, T.O. and I.G. Aliyu. 2010. Effect of row arrangements on sorghum-cowpea intercrops in the semi-arid savannah of Nigeria. *Int. J. Agric. Biol.,* 12(1): 137-140.

Pal, U.R. and Y. Sheshu. 2001. Direct and residual contribution of symbiotic nitrogen fixation by legumes to the yield and nitrogen uptake of maize (*Zea mays* L.) in the Nigerian Savannah. *J. Agron. Crop Sci.,* 187 (1): 53-58.

Parasad, R.B. and R.M. Brook. 2005. Effect of varying maize densities on intercropped maize and soybean in Nepal. *Exp. Agric.,* 14: 365-382.

Promkhambut, A., A. Younger, A. Polthanee and C. Akkasaeng. 2010. Morphological and physiological responses of sorghum (Sorghum bicolor L.) to waterlogging. *Asian J. Plant Sci.,* 9 (4): 183-193.

Rana, R.S., B. Singh and S.C. Nagi. 2001. Management of maize/legume intercropping under mid-hill sub-humid conditions. *Ind. J. Agric. Res.,* 35: 100-103.

Rathore, R.S., D.D. Nawange, R.S. Solanki and R.P. Singh. 2012. Identification of suitable ideotypes of blackgram (*Vigna mungo* L.) for intercropping with sorghum (*Sorghum bicolor* L.). *Leg. Res.,* 35(1): 72-74.

Sani, B.M., N.M. Danmowa, Y.A. Sani and M.M. Jaliya. 2011. Growth, yield and water use efficiency of maize-sorghum intercrop at Samaru, Northern Guinea Savannah, Nigeria. *Niger. J. Bas. Appl. Sci.,* 19: 253-259.

Satheeshkumar, N., P. Thukkaiyannan, K. Ponnuswamy and P. Santhi. 2011. Effect of sowing and weed management methods and intercrops on weed control and grain yield of sorghum under intercropping situation. *Crop Res.,* 41: 46-51.

Tajudeen, O.O. 2010. Evaluation of sorghum-cowpea intercrop productivity in Savanna agro-ecology using competition indices. *J. Agric. Sci.,* 2(3): 142-151.

(Received for publication: 31 October 2017)