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Article

Cowpea [*Vigna unguiculata* (L.) Walp] herbage yield and nutritional quality in cowpea-sorghum mixed strip intercropping systems

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Abstract:

In traditional row and strip cowpea-sorghum intercropping systems, cowpea forage yield reduces significantly due to intense competition and dominance of sorghum in acquiring growth resources. This field study evaluated novel mixed strip intercropping systems of forage cowpea and sorghum having different number of crops rows arranged under different spatial arrangements. Cowpea was intercropped with sorghum in 8, 12 and 16 rows strips with row-row spacing of 30, 45 and 60 cm. In each strip, equal number of rows of cowpea and sorghum were maintained. Factorial arrangement of randomized complete block design with three replicates was used to execute the field trials during summer seasons of 2013 and 2014. Strips having 12 rows and 60 cm row-row spacing positively affected all agronomic variables of cowpea which led to maximum forage yield (22.2 and 23.7 t ha^{-1} during 2013 and 2014 respectively) and dry matter biomass (6.63 and 6.94 t ha^{-1} during 2013 and 2014 respectively). In contrast, 8-rows strips having line spacing of 30 cm outperformed other intercropping systems by yielding the maximum herbage yield and dry matter biomass of sorghum. The intercropping system comprising of 12-rows strips with 60 cm row-row spacing remained superior in recording the maximum crude protein, fats and total ash along with the minimum fiber content of cowpea. In addition, this intercropping system under rest of spatial arrangements also remained unmatched, while 16-rows strips under all planting geometries remained inferior to other intercropping systems. Thus, cowpea intercropping with sorghum in 12-rows strips having 60 cm spacing offers biologically viable solution to improve biomass and forage quality of cowpea in intercropping with sorghum.

Key words: Animal nutrition, Planting geometries, Row intercropping.

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Introduction

Food security of rapidly increasing human populace demands proportionate increment in milk and meat production globally[1,2]. Under changing climate, production of forages with acceptable nutritional quality occupies central place for obtaining milk production on sustainable basis[3]. Although, many cereals including sorghum provide huge tonnage of biomass but these are unable to provide balanced nutrition to dairy animals[4,5,6]. Resultantly, expensive protein supplements need to be provided which result in slicing of economic returns. In addition, ruminants population is increasing globally which necessitate producing huge quantities of nutritional and cheaper forage throughout the year[7,8]. Thus, intercropping cereals with legumes might lead to achieve the dual purpose of obtaining higher quantities of forage with improved nutritional quality.

Row, mixed and strip intercropping of cereals with legumes have been practiced since long[9,10]. Intercropping forage legumes with cereals diversified the farm resources, preserved and restored soil fertility and improved the efficiency of soil and environmental resources[11,12]. However, serious consideration must be done in choosing the legume intercrops with respect to their compatibility in utilizing resources in spatial and temporal dimensions. Among legume intercrops, cowpea [*Vigna unguiculata* (L.) Walp] could be a good option for having potential to yield considerably higher quantity of nutritious forage in intercropping with sorghum[13,14,15]. In addition, cowpea holds potential to tolerate shade and sustain moderate drought along with fixing atmospheric nitrogen which favor its utilization as an intercrop with cereals[16,17].

However, cowpea intercrop suffered losses in forage yield and nutritional quality owing to dominance of cereals in acquiring growth resources[18,19]. In this way, the type of intercropping becomes pivotal for achieving the added advantage of cowpea intercropping with cereal forages[20]. Thus, in sorghum-cowpea intercropping systems, the real challenge lies in preventing the drastic reduction in the yield and quality of forage cowpea. Various studies have reported contrasting results about the efficacy of strip intercropping system where separate strips of component crops were maintained [8,21,22]. But, there have rarely been any field investigation regarding mixed strip intercropping system entailing rows of component crops in the same strip. In addition, spatial arrangement of component crops also determined the complementarity and competition in cereal-legume intercropping systems[2,14]. However, spatial arrangements must be optimized with respect of intercropping type especially for boosting the productivity of legumes.

Thus, it was hypothesized that optimization of strip intercropping systems and spatial arrangements might lead to improved yield and nutritional value of cowpea forage. The present study aimed primarily to investigate the influence of mixed strip intercropping (strips having rows of both cowpea and sorghum in the same strip) and planting geometries on forage yield of cowpea sown with forage sorghum. Furthermore, another objective was to test the agro-qualitative traits of forage cowpea as influenced by different strip intercropping systems as well as spatial arrangements.

Material and methods

Description of experimental site

To evaluate the impact of mixed strip intercropping and planting geometries on the productivity of cowpea intercrops, a field experiment was conducted during summer months of 2013 and 2014 at the research area of University of Agriculture, Faisalabad (30.35-41.47°N and 72.08-73.40°E) situated at an attitude of 184 m(14). The climate of the experimental area falls into Koppen's class of semi-arid, while the soil of the experimental site is classified as Haplic Yermosols as per FAO soil classification system. The meteorological data for crop growing seasons of cowpea were obtained from the meteorological center located closer (about 1 km) to research fields (Table 1).

Table 1: Meteorological data for crop growing seasons of cowpea in 2013 and 2014 along with 10 years mean (10YM) values

Month	Temperature (°C)			Rainfall (mm)			Relative humidity (%)		
	2013	2014	10YM	2013	2014	10YM	2013	2014	10YM
June	40.3	41.5	40.1	44	40	40	60	64	59
July	39.5	38.6	41.0	106	102	101	65	72	62
August	35.0	37.8	34.7	77	68	72	58	69	65
Mean/Total	38.2	39.3	38.6	227	210	213	61.0	68.3	65.3

Experimental treatments and design

Cowpea and sorghum were sown in different strip intercropping systems and three spatial arrangements as follows: T_1A_1= 8 rows strips (cowpea-sorghum in 4-4 rows in the same strips) with 30 cm row-row spacing, T_1A_2= 8 rows strips (cowpea-sorghum in 4-4 rows in the same strip) with 45 cm row-row spacing, T_1A_3= 8 rows strips (cowpea-sorghum in 4-4 rows in the same strip) with 60 cm row-row spacing, T_2A_1= 12 rows strips (cowpea-sorghum in 6-6 rows in the same strip) with 30 cm row-row spacing, T_2A_2= 12 rows strips (cowpea-sorghum in 6-6 rows in the same strip) with 45 cm row-row spacing, T_2A_3= 12 rows strips (cowpea-sorghum in 6-6 rows in the same strip) with 60 cm row-row spacing, T_3A_1= 16 rows strips (cowpea-sorghum in 8-8 rows in the same strip) with 30 cm row-row spacing, T_3A_2= 16 rows strips (cowpea-sorghum in 8-8 rows in the same strip) with 45 cm row-row spacing, T_3A_3= 16 rows strips (cowpea-sorghum in 8-8 rows in the same strip) with 60 cm row-row spacing.

In this way, a total of 9 treatment combinations were tested in factorial arrangement of randomized complete block design (RCBD) with three replications. The strip × strip distance for all intercropping systems was kept at 70 cm. Cowpea rows were adjacent to sorghum rows in subsequent strips. There was no consideration for plant × plant distance. In total, there were 27 experimental plots which were homogeneously maintained for testing the proposed treatments.

Agronomic management plan

In order to formulate the soil fertility management plan, pre-sowing physico-chemical analysis was performed from soil samples collected from 15 and 30 cm depth (Table 2). The seedbed preparation was started with a pre-sowing irrigation of 12 cm and 3 tractor mounted cultivations each followed by planking was done. Cowpea (cv. P-51840 at kg ha^{-1}) and sorghum (cv. Hegari at 80 kg ha^{-1}) were intercropped in 30 cm spaced rows using a hand drill. Recommended dose of nitrogen (50 kg ha^{-1}) (urea) was applied in two splits (at the time of sowing and with first irrigation 12 d after sowing) while total phosphorous (single super phosphate) (40 kg ha^{-1}) was applied as basal dose. Three flood irrigations were applied at 12, 33 and 50 d after sowing. Manual hoeing was done thrice (12, 22 and 32 d after sowing) to keep weed infestation at bay. Cowpea intercrops were harvested using hand sickle at complete flowering.

Table 2: Pre-sowing physico-chemical analysis of experimental soil in 2013 and 2014

Soil characteristics	2013	2014
Mechanical analysis:		
Sand, %	57.0	54.5
Silt,%	17.5	19.3
Clay, %	25.5	26.2
Textural class	Sandy clay loam	Sandy clay loam
Chemical analysis:		
Ph	7.9	7.6
EC, dSm^{-1}	1.68	1.64
Organic matter, %	0.75	0.78
Available nitrogen, ppm	6.1	6.4
Available phosphorous, ppm	0.96	0.91
Available potassium, ppm	117	112

Data recordings

All agronomic attributes of cowpea were recorded at the time of harvesting by following the prescribed methods. Ten plants were harvested from middle rows of each replication and then their average was taken. Plant height was recorded with the help of tailor’s measuring tape from base of the plant to the tip of the highest leaf. Stem girth was taken by using vernier caliper. Electric balance was used to take fresh weight per plant while spring balance was used to record green forage yield per plot which was then converted into tons per hectare. The agro-qualitative attributes of forage cowpea were determined by using methodologies given in Table 3.

Table 3: Procedure adopted for measuring agro-qualitative traits of cowpea as suggested by AOAC (2003)

Quality attributes	Methodology
Crude protein	Macro-KJeldahl method and subsequently multiplying nitrogen percentage with a constant of 6.25
Crude fiber	H_2SO_4 and NaOH digestion method
Ether extractable fat	Soxhlet extraction method
Total ash	Ashing at 600 ˚C using muffle furnace technique

Statistical analysis

Statistical analyses of the recorded data were done through employing analysis of variance (ANOVA) using the statistical program "Statistix 8.1". The means were grouped for conducting orthogonal contrasts on following basis; (a) intercropping system versus year, (b) spatial arrangement versus year, (c) intercropping system versus spatial arrangement and (d) intercropping system versus spatial arrangement *versus* year at 5% probability level. The data were also subjected to correlation analysis in order to sort out the relationship (linear or inverse) between yield attributes and forage yield of cowpea.

Results and discussion

Plant height and stem diameter

The agronomic variables of forage cowpea were significantly improved during 2014 probably owing to higher precipitation and moderate temperatures in comparison to 2013. The interactive effect of strip intercropping systems and spatial arrangements was significant for plant height (189** and 203** during 2013 and 2014 respectively) and stem girth (88* and 98** during 2013 and 2014 respectively) of cowpea (Table 4). The tallest cowpea plants (110.3 ± 0.57 and 117.9 ± 0.83 cm during 2013 and 2014 respectively) with greatest stem girth (2.87 ± 0.67 and 2.94 ± 0.69 cm during 2013 and 2014 respectively) were recorded by cowpea sown in 12-rows strips with 60 cm spaced rows (T_2A_3), while 16-rows strips having 45 cm line-line spacing (T_3A_2) resulted in the lowest plant height (78.0 ± 0.38 and 83.1 ± 0.82 cm during 2013 and 2014 respectively) as well as stem girth (2.32 ± 0.81 and 2.53 ± 0.41 cm during 2013 and 2014 respectively) (Table 5). Correlation analysis revealed that there was linear correlation between plant height and stem girth of cowpea as depicted in Figure 1. These results are in complete confirmation with another study[(23)], where legumes plant height and stem diameter were influenced planting geometries of cereal-legume intercropping systems. Simultaneous cultivation of component crops in row and mixed intercropping systems intensified inter-species competition for farm applied resources which led to reduced plant height and stem girth of legumes compared to their monocultures. But when cowpea was sown in 12-rows strips (cowpea-sorghum in 6-6 rows), it might have reduced sorghum dominance in acquiring growth resources. Varied root lengths of cowpea and sorghum might be attributed as the probable reason for reducing competition for growth resources which was further supported by wider strip spacing[(24)].

Number of leaves and leaf-stem ratio

The interactive effect of intercropping systems and spatial arrangements was significant for the number of leaves (93* and 112* during 2013 and 2014 respectively) and leaf-stem ratio (83* and 96* during 2013 and 2014 respectively) (Table 4). Sorghum and cowpea 12-rows strip intercropping in 60 cm spaced lines (T_2A_3) resulted in higher number of leaves per plant (29.1 ± 0.57 and 29.9 ± 0.31 during 2013 and 2014 respectively) and leaf to stem ratio (0.59 ± 0.19 and 0.69 ± 0.21 during 2013 and 2014 respectively) (Table 5). These results corroborate with the findings of other studies(2,3,25), where it was concluded that closely spaced rows of legumes recorded minimum number of leaves and leaf-stem ratio despite exploring varied soil horizons for absorbing moisture and nutrients by sorghum and legumes, still the intra-species competition was severe enough to drastically reduce the growth of legume intercrops. Furthermore, shading effect rendered by sorghum was also found to be an important factor in reducing photosynthesis of legume plants particularly in adjacent rows with sorghum which leads to less number of leaves per plant.

Plants fresh and dry weights, green forage yield and dry matter biomass

The interactive effect of intercropping system and spatial arrangements was also significant for fresh weight (274** and 297** during 2013 and 2014 respectively) and dry weight (187** and 257** during 2013 and 2014 respectively) per plant of cowpea along with green forage yield (266** and 287** during 2013 and 2014 respectively) as well and dry matter yield (134** and 120** during 2013 and 2014 respectively). The highest fresh weight (188.6 ± 0.67 and 190.5 ± 0.61 g during 2013 and 2014 respectively) and dry weight (59.1 ± 0.67 and 66.3 ± 1.19 g during 2013 and 2014 respectively) per plant (Table 5) were rendered by 12-rows strip having 60 cm apart rows (T_2A_3). Correlation analysis depicted a linear relationship for fresh and dry weights per plant with green forage and dry matter yields (Figure 1). The same intercropping system (T_2A_3) was instrumental in yielding the maximum green forage yield (22.2 ± 0.28 and 23.7 ± 0.34 t ha^{-1} during 2013 and 2014 respectively) and dry matter biomass (6.63 ± 0.26 and 6.94 ± 0.19 t ha^{-1} during 2013 and 2014 respectively) of forage cowpea (Table 6), while it was followed by 12-rows strips sown in 45 cm spaced rows (T_2A_1). In contrast, sorghum-cowpea 8-rows strips having 30 cm row-row spacing (T_2A_1) remained superior as far as green forage biomass and dry matter yield of sorghum were concerned. It was followed by the same intercropping system having row-row spacing of 45 cm, while sorghum-cowpea intercropping systems comprising of 16-rows strips with 60 cm row-row spacing (T_3A_3) remained inferior to rest of intercropping systems and spatial arrangements (Table 6). The T_2A_3 intercropping system resulted in superior agronomic attributes including plant height, stem girth, fresh and dry weights per plant which ultimately enhanced green forage biomass as well as dry matter yield. These findings are in line with others[22,26], who inferred that productivity of cowpea in narrowly spaced (30 and 45 cm) intercropping systems remained below-par to solo cowpea despite well-developed nodulation and fully functional biological nitrogen fixation (BNF). Similar findings were also reported by other researchers[10,27], where cowpea remained recessive in acquiring nutrients and moisture compared to cereals. In addition, legume intercrops suffered losses in productivity owing to their dependence on soil solution for nitrogen before the initiation of BNF after 27-35 d of sowing. Moreover, in strip intercropping systems, cowpea rows adjacent to sorghum confronted lesser competition for growth resources by exploiting different soil horizons but had to face shading effect rendered by taller sorghum plants. Similarly, inner rows of cowpea faced lesser shading effect but competition for growth resources intensified owing to having same root length which led to reduced herbage yield[28].

Crude protein and crude fiber contents

All quality traits were significantly influenced by intercropping systems and spatial arrangements including crude protein (120** and 135** during 2013 and 2014 respectively), crude fiber (142* and 169** during 2013 and 2014 respectively), ether extractable fat (200** and 225*during 2013 and 2014 respectively) and total ash (101* and 109* during 2013 and 2014 respectively) (Table 4).

Protein content occupies vital position in determining the nutritional quality of forage while agronomists as well as animal nutritionist recommend protein-rich forages for boosting the performance of dairy animals. Cowpea-sorghum intercropping in 12-rows strips having 60 cm row-row spacing (T_2A_3) effectively improved crude protein (19.9 ± 0.21 and 19.6 ± 0.37 during 2013 and 2014 respectively) of cowpea forage with the minimum crude fiber (26.1 ± 0.51 and 26.0 ± 0.90 during 2013 and 2014 respectively) contents (Table 6). This was followed by 12-rows strips having 45 cm spacing (T_2A_1), while strips having 16-rows performed below par under all spatial arrangements. Earlier research works[1,14] are in conformity with these findings, as it was reported that substantial enhancement in crude protein of mixed forage could be achieved by intercropping cowpea with cereal forages under optimized spatial arrangements. It was suggested that type of intercropping could influence nitrogen fixed by cowpea which might be attributed for improved crude protein content and reduced fiber as the absorbed nitrogen and protein content were linearly correlated. Type of intercropping and planting geometries as in our research have also been reported to improve the efficacy of applied nutrients which imparted a significant influence on protein and crude fiber contents of forages[14,29].

Ether extractable fat and total ash contents

Fats are pivotal quality attribute of forages as these secrete higher amounts of energy during metabolism than proteins. Similarly, mineral constituents of forages required to perform various metabolic processes are measured as ash. The intercropping system (T_2A_3) resulted in the maximum fat (1.91 ± 0.17 and 1.95 ± 0.29 % during 2013 and 2014 respectively) and total ash (11.78 ± 0.16 and 11.7 ± 0.21 % during 2013 and 2014 respectively) (Table 6), 16-rows strips registered the minimum fat and ash contents without any regard to spatial arrangements. Strips having 8-rows under all planting geometries performed better in terms of forage quality than 16-rows strips but it remained below par to cowpea sown with forage sorghum in 12-rows strips. These findings also match with a previously conducted study[30], which revealed that considerably higher herbage yield with improved quality attributes could be obtained by optimizing intercropping type and spatial arrangement of component crops.

Conclusions and implications

This study reports novel mixed strip intercropping systems to check the drastic reduction in forage yield cowpea while in intercropping with forage sorghum. As far as green forage yield and agro-qualitative traits of cowpea were concerned, it could be inferred that 12-rows strips (cowpea-sorghum in 6-6 rows) (T_1A_2) remained unmatched particularly when row-row spacing was maintained at 60 cm. Moreover, better growth of cowpea was observed in rows adjacent to sorghum rows in subsequent strips in comparison with cowpea rows adjacent to sorghum rows in the same strip. Strips having 16-rows irrespective of planting geometry could not come at par to rest of the strips probably due to higher intra-species competition for growth resources. However, these encouraging results necessitate further field investigations regarding mixed strip intercropping of cereal forages and legumes for boosting legumes yield under varied agro-climatic and agro-ecological conditions.

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Table 4: Analysis of variance (ANOVA) for all experimental variables under study of cowpea sown with sorghum under different spatial arrangements during 2013 and 2014

SOV	Plant height (cm)		Stem girth (cm)		Leaves per plant		Leaf-stem ratio		Fresh weight per plant (g)		Dry weight per plant (g)		Cowpea green forage yield (t ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
T	213**	288**	73*	85*	109*	100*	74*	89*	287**	234**	166**	183**	244**	280**
A	134**	111**	66*	71*	81*	123*	33*	57*	132**	141**	211**	137**	112*	89*
T×A	189**	203**	88*	98**	93*	112*	83*	96*	274**	297**	187**	257**	266**	287**

SOV	Cowpea DMY (t ha^{-1})		Sorghum GFY (t ha^{-1})		Sorghum DMY (t ha^{-1})		Crude protein (%)		Crude fiber (%)		Ether extractable fat (%)		Total ash (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
T	123**	116**	97	110**	88*	104**	91**	109**	237**	250**	233**	240*	134*	103*
A	91*	75*	132	103*	145*	74*	51*	74*	88*	122**	75*	111*	90*	87*
T×A	134**	120**	114	139*	137*	92*	120***	135**	142*	169**	200**	225*	101*	109*
T×Y=NS				A×Y=NS			T×A×Y=NS							

SOV= source of variance; T= Type of strip intercropping, A= Spatial arrangements, Y=Year. *(P<0.05) ** (P<0.01).

Table 5: Plant height (PH), stem girth (SG), number of leaves (NL), leaf-stem ratio (LSR), fresh weight (FW) and dry weight (DW) per plant of cowpea sown with sorghum under different planting times and spatial arrangements

IS	2013						2014					
	PH (cm)	**SG (cm)**	**NL**	**LSR**	**FW (g)**	**DW (g)**	**PH (cm)**	**SG (cm)**	**NL**	**LSR**	**FW (g)**	**DW (g)**
T_1A_1	94.5 ± 0.27^{c}	2.60 ± 1.16^{d}	22.7 ± 0.55^{cd}	0.50 ± 0.18^{bc}	172.5 ± 0.83^{cd}	50.8 ± 0.21^{cd}	96.2 ± 0.67^{d}	2.63 ± 0.33^{e}	24.3 ± 0.27^{d}	0.52 ± 1.19^{c}	173.0 ± 0.65^{d}	52.6 ± 0.66^{de}
T_1A_2	90.7 ± 0.64^{cd}	2.64 ± 0.51^{cd}	21.2 ± 0.67^{d}	0.44 ± 0.27^{d}	170.1 ± 0.67^{d}	48.4 ± 0.37^{d}	94.7 ± 0.51^{de}	2.67 ± 0.57^{d}	23.0 ± 0.53^{de}	0.50 ± 0.35^{cd}	173.9 ± 0.25^{d}	50.8 ± 1.15^{e}
T_1A_3	94.3 ± 0.37^{c}	2.68 ± 0.94^{c}	24.0 ± 0.34^{c}	0.52 ± 0.30^{b}	174.5 ± 0.31^{c}	52.3 ± 0.25^{c}	97.2 ± 0.28^{d}	2.71 ± 1.17^{c}	26.5 ± 0.49^{cd}	0.55 ± 0.82^{bc}	177.0 ± 0.37^{c}	54.1 ± 0.96^{d}
T_2A_1	102.7 ± 0.29^{b}	2.74 ± 0.56^{b}	28.9 ± 0.67^{ab}	0.53 ± 0.28^{b}	185.1 ± 0.44^{ab}	58.5 ± 0.50^{a}	108.4 ± 0.19^{b}	2.87 ± 0.94^{b}	29.0 ± 0.72^{b}	0.57 ± 0.93^{b}	186.2 ± 0.24^{b}	61.4 ± 0.67^{b}
T_2A_2	100.0 ± 0.33^{b}	2.70 ± 0.42^{bc}	26.6 ± 0.90^{b}	0.52 ± 0.64^{b}	181.5 ± 0.58^{b}	55.9 ± 0.41^{b}	101.6 ± 0.43^{c}	2.73 ± 0.35^{c}	27.3 ± 0.60^{c}	0.55 ± 0.24^{bc}	184.6 ± 0.51^{b}	58.3 ± 0.29^{c}
T_2A_3	110.3 ± 0.57^{a}	2.87 ± 0.67^{a}	29.1 ± 0.57^{a}	0.59 ± 0.19^{a}	188.6 ± 0.67^{a}	59.1 ± 0.67^{a}	117.9 ± 0.83^{a}	2.94 ± 0.69^{a}	29.9 ± 0.31^{a}	0.69 ± 0.21^{a}	190.5 ± 0.61^{a}	66.3 ± 1.19^{a}
T_3A_1	83.5 ± 0.41^{d}	2.35 ± 0.31^{ef}	21.5 ± 0.87^{d}	0.45 ± 0.22^{cd}	169.9 ± 0.29^{d}	44.9 ± 0.59^{ef}	89.9 ± 0.67^{ef}	2.58 ± 0.52^{g}	22.5 ± 0.29^{e}	0.48 ± 0.17^{d}	171.2 ± 0.20^{de}	46.0 ± 0.88^{fg}
T_3A_2	78.0 ± 0.38^{e}	2.32 ± 0.81^{f}	18.8 ± 0.66^{e}	0.41 ± 0.37^{e}	164.2 ± 0.21^{e}	41.7 ± 0.32^{f}	83.1 ± 0.82^{f}	2.53 ± 0.41^{h}	21.9 ± 0.40^{f}	0.45 ± 0.29^{e}	165.3 ± 0.19^{f}	43.8 ± 0.60^{g}
T_3A_3	91.1 ± 0.24^{cd}	2.39 ± 0.92^{e}	21.4 ± 0.37^{d}	0.48 ± 0.40^{c}	166.0 ± 0.34^{de}	46.2 ± 0.19^{e}	92.4 ± 0.97^{e}	2.60 ± 0.60^{g}	24.4 ± 0.69^{d}	0.51 ± 0.33^{cd}	170.9 ± 1.11^{e}	48.7 ± 0.37^{f}
$LSD_{0.05}$	3.80	0.06	2.93	0.04	4.23	3.89	5.29	0.15	0.47	0.03	4.01	3.87

Data presented here is average of 3 replications. IS= Intercropping systems, T_1= 8-rows strips (cowpea+sorghum in 4-4 rows), T_2= 12-rows strips (cowpea+sorghum in 6-6 rows), T_3= 16-rows strips (cowpea+sorghum in 8-8 rows)

A_1= 30 cm spaced strips, A_2= 45 cm spaced strips, A_3=60 cm spaced strips.

[abcdef] Values followed by different letters within columns differ (P<0.05), ± represents standard deviation increase or decrease.

Figure 1: Correlation analysis for yield attributes with green forage yield and dry matter yield of cowpea (combined analysis of pooled data of 2013 and 2014)

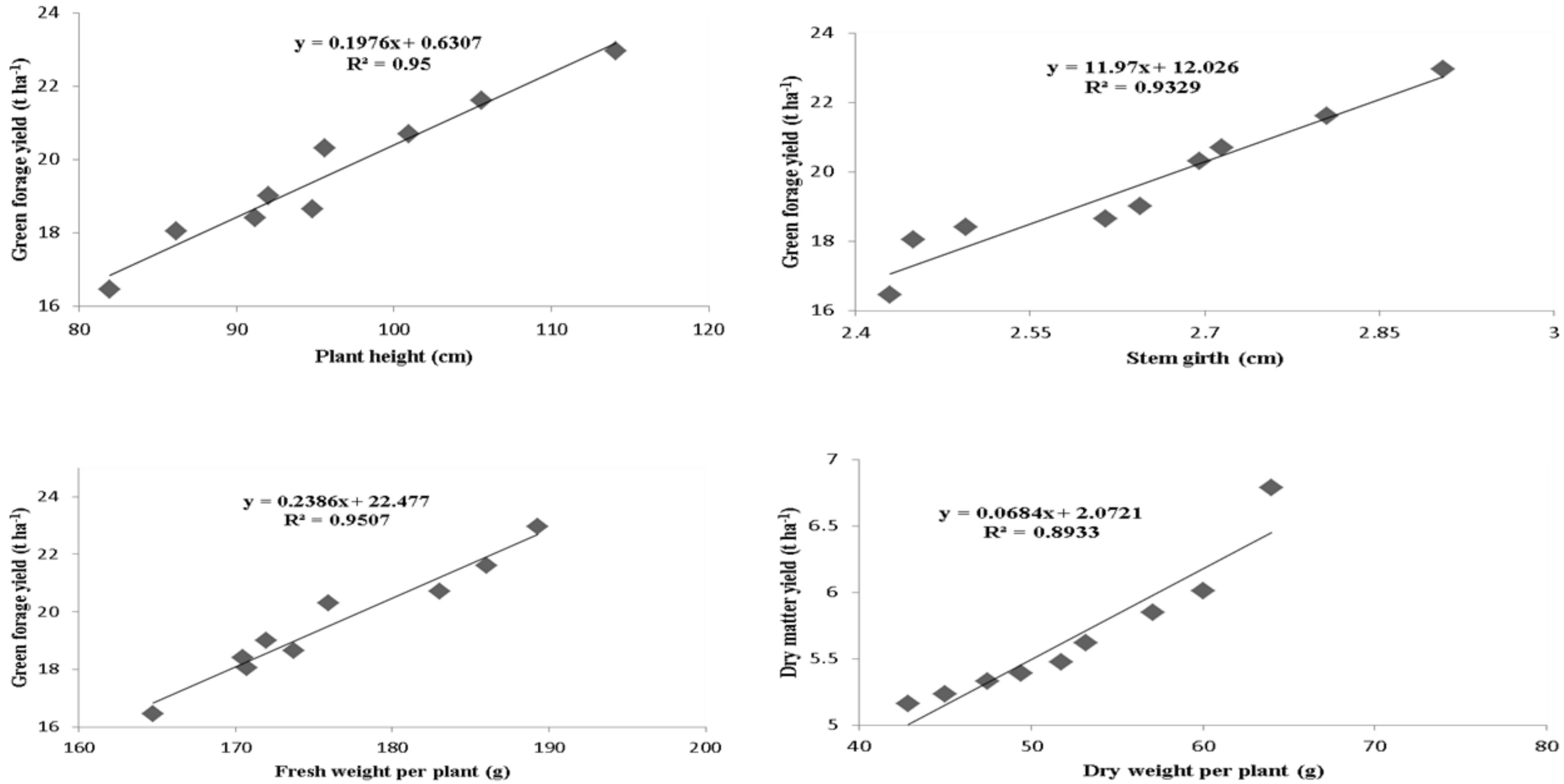

Table 6: Green forage yield (GFY), dry matter yield (DMY), crude protein (CP), crude fiber (CF), ether extractable fat (EEF) and total ash (TA) of cowpea sown with sorghum under different planting times and spatial arrangements in 2013 and 2014

IS	2013						2014					
	GFY (t ha^{-1})	**DMY (t ha^{-1})**	**CP (%)**	**CF (%)**	**EEF (%)**	**TA (%)**	**GFY (t ha^{-1})**	**DMY (t ha^{-1})**	**CP (%)**	**CF (%)**	**EEF (%)**	**TA (%)**
T_1A_1	18.4±0.18^{d}	5.36±0.18^{e}	18.8±0.41^{bc}	26.2±0.72^{e}	1.79±0.24^{cd}	11.00±0.15^{d}	18.8±0.58^{d}	5.59±0.16^{d}	18.9±0.33^{c}	26.0±0.98^{d}	1.82±0.18^{c}	11.33±0.11^{c}
T_1A_2	17.7±0.53^{e}	5.29±0.37^{ef}	18.6±0.22^{c}	26.9±0.15^{cd}	1.76±0.17^{d}	11.07±0.37^{d}	17.9±0.28^{e}	5.51±0.34^{d}	18.8±0.92^{c}	26.6±0.62^{c}	1.79±0.11^{cd}	11.07±0.24^{e}
T_1A_3	19.9±0.91^{c}	5.52±0.25^{d}	19.0±0.34^{b}	26.6±0.37^{d}	1.81±0.18^{c}	11.13±0.17^{c}	20.7±0.67^{cd}	5.72±0.84^{c}	19.3±0.53^{b}	25.4±0.37^{e}	1.84±0.23^{c}	11.39±0.15^{bc}
T_2A_1	21.0±1.23^{b}	5.93±0.53^{b}	19.6±0.55^{ab}	26.1±0.51^{e}	1.86±0.29^{b}	11.29±0.28^{b}	22.2±1.09^{b}	6.09±0.50^{b}	19.4±0.20^{b}	26.0±0.90^{d}	1.90±0.15^{b}	11.45±0.37^{b}
T_2A_2	20.4±0.44^{bc}	5.78±0.47^{c}	19.0±0.67^{b}	26.7±0.18^{d}	1.84±0.33^{bc}	11.08±0.34^{d}	21.0±0.77^{c}	5.91±0.77^{b}	19.3±.37^{b}	26.7±1.17^{c}	1.87±0.26^{bc}	11.23±0.38^{d}
T_2A_3	22.2±0.28^{a}	6.63±0.26^{a}	19.9±0.21^{a}	25.9±0.91^{f}	1.91±0.17^{a}	11.78±0.16^{a}	23.7±0.34^{a}	6.94±0.19^{a}	19.6±0.37^{a}	21.5±0.32^{f}	1.95±0.29^{a}	11.78±0.21^{a}
T_3A_1	17.8±0.37^{e}	5.26±0.38^{ef}	18.2±0.79^{d}	27.6±0.27^{b}	1.73±0.23^{de}	10.93±0.28^{e}	18.5±0.59^{d}	5.29±0.61^{e}	18.5±0.40^{d}	27.3±0.67^{b}	1.75±0.20^{d}	11.05±0.16^{e}
T_3A_2	16.1±0.41^{f}	5.16±0.82^{f}	18.1±0.62^{d}	27.9±0.67^{a}	1.70±0.29^{e}	10.55±0.27^{f}	16.7±0.44^{f}	5.10±0.94^{f}	18.0±1.11^{e}	27.8±0.85^{a}	1.71±0.10^{e}	10.58±0.44^{f}
T_3A_3	17.2±0.30^{ef}	5.18±0.21^{f}	18.6±0.63^{c}	27.1±0.41^{c}	1.74±0.37^{de}	11.07±0.18^{d}	17.8±0.69^{e}	5.48±0.26^{d}	18.9±0.91^{c}	27.1±0.71^{bc}	1.79±0.17^{cd}	11.46±0.27^{b}
$LSD_{0.05}$	1.38	0.19	0.40	0.33	0.05	0.13	1.08	0.21	0.20	0.36	0.04	0.10

Data presented here is average of 3 replications. IS= Intercropping systems: T_1= 8-rows strips (cowpea+sorghum in 4-4 rows), T_2= 12-rows strips (cowpea+sorghum in 6-6 rows), T_3= 16-rows strips (cowpea+sorghum in 8-8 rows) A_1= 30 cm spaced strips, A_2= 45 cm spaced strips, A_3=60 cm spaced strips.
^{abcd} Values followed by different letters within columns differ (P<0.05); ± represents standard deviation increase or decrease.