

Production efficiency, forage yield, nutrient uptake and quality of sorghum sudan grass hybrid (*Sorghum bicolor* × *Sorghum sudanense*) + cowpea (*Vigna unguiculata*) intercropping system as influenced by sowing methods and varying seed rates of cowpea

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ABSTRACT

A field experiment was carried out at Palampur, Himachal Pradesh, during the rainy (*kharif*) seasons of 2012 and 2013, to study the effect of sowing methods and varying seed rates of cowpea [*Vigna unguiculata* (L.) Walp.] on forage yield of sorghum sudan grass hybrid [*Sorghum bicolor* (L.) Moench. × *Sorghum sudanense* (Piper) Stapf.] and cowpea. Broadcast sowing of sorghum sudan grass hybrid (SSGH) with 75% recommended seed rate of cowpea (33.75 kg/ha) realized significantly higher plant height, shoot number, SSGH and cowpea dry-matter accumulation, total green forage yield (34.18 t/ha), dry forage yield (10.08 t/ha) and production efficiency. Broadcast sowing of SSGH with recommended seed rate of cowpea resulted in significantly higher N (195.17 kg/ha), P (21.52 kg/ha) and K (56.86 kg/ha) uptake. Further, broadcast sowing of SSGH with 75% recommended seed rate of cowpea gave highest net returns (₹32,001/ha), benefit: cost ratio (1.57), SSGH-equivalent yield (SSGHEY) and was followed by broadcast sowing of SSGH with recommended seed rate of cowpea.

Key words : Broadcast sowing, Green fodder yield, Intercropping system, Nutrient uptake, Sorghum sudan grass hybrid

Livestock plays an important role in rural economy of India by providing employment and supplementing family income, which contributes about 21% of the total agriculture income of the family (Sharma *et al.*, 2009). Fodder requirement of livestock is generally met through low quality crop residues and degraded grasslands, which are not enough for maintenance of animal health and productivity. In Himachal Pradesh too, the feed and forage resources are able to meet partial requirement of the livestock. Green herbage in addition to energy also provides vitamins, minerals with better dry-matter digestibility (Surve *et al.*, 2012). Among cultivated fodder crops, sorghum [*Sorghum bicolor* (L.) Moench.] is an important rainy (*kharif*) season crop, grown mainly under rainfed conditions. Recently, sorghum sudan grass hybrid [*Sorghum bicolor* (L.) Moench. × *Sorghum sudanense* (Piper) Stapf.], a cross between male-sterile grain sorghum with sudan

grass, is becoming popular among the farmers owing to its quick growth, succulence, better palatability and low levels of HCN (Prussic acid) compared to sorghum. Cowpea [*Vigna unguiculata* (L.) Walp.] is an important quick-growing drought-tolerant *kharif* legume, produces sufficient quantity of biomass in a short span. Cowpea is tolerant to moderate shade and can be successfully grown in combination with maize, sorghum, pearl millet etc. to get nutrient-rich green fodder (Thomas, 2003). Sorghum sudan grass hybrid (SSGH) and cowpea are the potential *kharif* fodder crops, which can provide higher fodder yields with better quality, when grown in association; further, it may also be beneficial for improving the fertility of the soil. The type of inter/ mixed crop and spatial arrangement in inter/ mixed cropping have important effects on the balance of competition between the component crops and their productivity. Hence to get the best results, a rational approach is required for obtaining information on appropriate plant population of inter/ mixed crop stand. Since information on performance of a new crop SSGH with forage cowpea is lacking, the present investigation was planned to assess the effects of variable seed rates of

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cowpea under different methods of cropping on the performance of SSGH under mid-hill rainfed conditions of north-western Himalayas.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*khari*) seasons of 2012 and 2013 at Fodder Section, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32.4° N and 76.3° E and 1,227 m altitude) on silty clay loam soil in mid-hills of North-Western Himalaya, having sub-humid climate. The rainfall received during the growing period of crop was 1,308.0 mm in 2012 and 1,607.5 mm in 2013. The experimental soil was acidic in reaction (5.5), high in organic carbon (1.01%), low in available nitrogen (271.0 kg/ha), medium in available phosphorus (11.0 kg/ha) and available potassium (281.0 kg/ha). The experiment was laid out in randomized block design with 3 replications. Total 10 treatments comprised all possible combinations of 2 sowing methods (line and broadcast sowing) and 3 seed rates of cowpea (50, 75 and 100% of recommended seed rate) + sole stands of SSGH and cowpea in line, and broadcast sowing were: line sowing of sorghum sudan grass hybrid + cowpea with 50% recommended seed rate, line sowing of SSGH + cowpea with 75% recommended seed rate, line sowing of sorghum sudan grass hybrid + cowpea with recommended seed rate, broadcast sowing of sorghum sudan grass hybrid + cowpea with 50% recommended seed rate, broadcast sowing of sorghum sudan grass hybrid + cowpea with 75% recommended seed rate, broadcast sowing of sorghum sudan grass hybrid + cowpea with recommended seed rate, line sowing of sorghum sudan grass hybrid, broadcast sowing of sorghum sudan grass hybrid, line sowing of cowpea, broadcast sowing of cowpea. The SSGH was sown using recommended package of practices. Recommended seed rate of SSGH was 40 kg/ha and of cowpea 45 kg/ha. Cowpea was sown as per treatments in additive series with SSGH in line sowing, whereas in broadcast sowing, seed of both crops was mixed and sown by broadcast. Fertilizer dose of N, P₂O₅ and K₂O for cowpea was 20 : 60 : 30 kg/ha and was adjusted according to seed rate used in respective treatment, while for SSGH the recommended dose of N, P₂O₅ and K₂O was 90 : 60 : 30 kg/ha. The crops were raised on 23 June 2012 and 17 June 2013.

Green and dry fodder yields were computed cut-wise as well as total yield of all the cuts of SSGH and cowpea. In all, 2 cuts of SSGH and 1 of cowpea were taken. The crop from net plot was harvested and weighed. The total yield for each plot was adjusted by including the fresh weight of samples, taken for various observations. In order to work out the most profitable treatment, the economics of each

treatment was worked out on the basis of prevalent market prices of the inputs and output. Data for 2 seasons were pooled for final statistical analysis. Plant samples in each treatment were taken based on per cent proportion of each species in the mixture and were subjected to chemical analysis following standard procedures. The cowpea fodder yield was converted to Sorghum Sudan Grass Hybrid Equivalent Yield (SSGHEY) with the following relationship:

$$\text{SSGHEY (t/ha)} = \frac{\text{Price of cowpea per kg} \times \text{Yield of cowpea (t/ha)}}{\text{Price of sorghum sudan grass hybrid fodder/kg}}$$

The per cent crude protein content was calculated by multiplying % nitrogen in plant sample obtained with a constant factor of 6.25. Crude fibre content (%) was worked out by Soxhlet extraction procedure. The crude protein and crude fibre yields were computed by multiplying their respective contents with dry-matter yield. Land-equivalent ratio (LER) was calculated as per the standard procedure.

RESULTS AND DISCUSSION

Growth and development

Broadcast sowing of crops resulted in significantly taller plants and more dry-matter accumulation of SSGH. Plant height of cowpea and plant population of both the crops was not significantly influenced by methods of sowing, but cowpea has better dry-matter accumulation in line sowing (Table 1). In line sowing, close plant spacing within row might have offered more competition for SSGH, a tillering crop for growth resources which ultimately has its effect on growth of the plant. Plants with similar growth habit have more competition among themselves for growth resources (Grof, 1981). However, under broadcast sowing proper distribution of plant population resulted in optimum utilization of growth resources by each and every plant and helps in better growth of the plants (Kumar, 2006). Among seed rates of cowpea, 50% recommended seed rate, remaining at par with 75% recommended seed rate, resulted in significantly taller plants and higher dry-matter accumulation of SSGH. Shoot numbers of SSGH were not influenced significantly by variable seed rates of cowpea. Cowpea had more number of plants with more height and dry-matter accumulation with recommended seed rate. The population of cowpea increased proportionately with the increase in seed rate. The reduction in plant height of SSGH with increasing seed rate of cowpea may be attributed to more inter specific competition offered by increased plant population of cowpea. These results corroborate the findings of Babu *et al.* (1994). Significantly taller plants in sole broadcast-sown SSGH resulted in significantly more dry-matter accumulation. Sowing methods have no effect on shoot number of

Table 1. Effect of different treatments on plant height, shoot number and dry matter accumulation, green fodder yield and dry fodder yield (pooled data of 2 years)

Treatment	Plant height (cm)		Shoot number (Nos./m ²)		Dry-matter accumulation (g/m ²)		Green-fodder yield (t/ha)		Dry-fodder yield (t/ha)	
	SSGH	Cowpea	SSGH	Cowpea	SSGH	Cowpea	SSGH	Cowpea	SSGH	Cowpea
<i>Sowing method</i>										
Line sowing	250	128	65.9	30.7	853	195	22.1	8.1	7.0	1.9
Broadcast sowing	271	127	67.0	33.1	911	178	27.0	6.9	8.5	1.6
SEM±	2.6	3.3	0.7	0.6	7.2	5.2	0.36	0.31	0.01	0.01
CD (P=0.05)	7.6	NS	NS	NS	21.5	15.5	1.08	0.92	0.27	0.24
<i>Seed rate of cowpea</i>										
50% recommended	269	118	66.6	23.3	909	94	24.6	5.1	8.2	1.1
75% recommended	262	130	66.1	31.8	885	199	26.4	7.9	8.1	1.9
Recommended	250	134	66.7	40.7	852	263	22.8	9.4	7.0	2.2
SEM±	3.1	4.0	0.9	0.7	8.9	6.4	0.44	0.38	0.10	0.14
CD (P=0.05)	9.3	12.0	NS	3.1	26.3	19.01	1.32	1.12	0.33	0.30
<i>Between sole</i>										
Line sowing SSGH	265	-	70.5	-	937	-	25.5	-	8.8	-
Broadcast sowing SSGH	283	-	70.3	-	1028	-	27.3	-	9.4	-
Line sowing cowpea	-	84	-	44.2	-	243	-	11.3	-	2.4
Broadcast sowing cowpea	-	95	-	45.3	-	265	-	11.3	-	2.6
SEM±	4.4	5.7	1.2	1.0	12.5	9.0	0.62	0.53	0.16	0.13
CD (P=0.05)	13.2	NS	NS	NS	37.1	NS	1.87	NS	0.46	NS
<i>Sole vs. other</i>										
Sole	274	90	70.4	44.8	982	254	26.4	11.3	9.1	2.5
Others	261	127	66.5	31.9	882	186	24.6	7.5	7.8	1.7
SEM±	3.6	4.6	1.0	0.8	10.2	7.3	0.51	0.43	0.11	0.13
CD (P=0.05)	10.7	13.8	3.0	3.5	30.4	22.0	1.53	1.30	0.34	0.38

SSGH, Sorghum sudan grass hybrid; NS, non-significant

SSGH. No significant effect of sowing method on plant height, plant number/m² and dry-matter accumulation of cowpea was observed. Interspecific competition in mixture reduced the plant height of SSGH, shoot number and dry-matter accumulation of both the crops. However, cowpea crop in mixture tend to grow upward with SSGH support might have resulted in more plant height.

Yield

Both the crops, SSGH and cowpea, sown with broadcast method resulted in higher green and dry fodder yields of SSGH and total of SSGH + cowpea over line sowing (Table 1). In broadcast sowing, the random crop geometry perhaps provided more space to SSGH to flourish (Allen, 1974), and hence had positive effect on number of shoots and plant height (Table 1). More plant height also favours more number of leaves/plant (Babu *et al.*, 1994). Secondly, in broadcast sowing, better utilization of resources resulted in SSGH plants with more girth thickness (Kumar, 2006). Significantly higher green and dry forage yields of SSGH and total yield of SSGH + cowpea were obtained under SSGH + 75% recommended seed rate of cowpea treatment. The cowpea yield increased continuously with the increasing seed rate of this crop. Among sole stands, broadcast sowing resulted in higher green and dry forage yields of SSGH and SSGH + cowpea, whereas different sowing methods did not have effect on herbage yield of cowpea. Sole stand of both the crops exhibited significantly higher green and dry fodder yields of each crop, as reflected in higher herbage yield of crops in sole stands compared to other crop combinations.

System productivity

Broadcast sowing of crops either in intermixed cropping or as sole stands resulted in higher SSGH green fodder-

equivalent yield (Table 2). Recommended seed rate of cowpea @ 75% resulted in significantly more SSGH green fodder-equivalent yield. Association of SSGH with cowpea gave higher SSGH green fodder-equivalent yield than pure crops. The SSGH green fodder-equivalent yield decreased and cowpea green fodder yield increased with the increasing seed rates of cowpea (Table 1), but more yield of cowpea at higher seed rate and its more price of fodder (₹2,000/t) compared to SSGH (₹1,500/t) contributed to increase in the equivalent yield in the treatments with recommended seed rate and made it comparable with 75% recommended seed rate. In pure stand, low yield of cowpea and contribution of cowpea with more price put mixed/intercropped treatments on upper hand than sole stand in term of SSGH green fodder-equivalent yield.

On dry-weight basis, proportion of SSGH was higher in broadcast sowing than in line sowing (Table 2). Better growth in broadcast sowing (Table 1) increased the dry-matter accumulation of SSGH which in turn resulted in higher proportion of this crop, whereas in cowpea reverse trend was observed. The proportion of cowpea crop increased with increasing seed rates of cowpea and reverse trend was observed in SSGH. Increased seed rate of cowpea improved growth and development of this crop, whereas increase in population of cowpea suppressed SSGH growth and development. This effect of treatments on growth and development of crops was reflected on proportion of each crop in respective treatments.

Production efficiency

Broadcast sowing of crop; 75% recommended seed rate of cowpea with SSGH showed the highest production efficiency (PE) of the system (Table 2). Broadcast sowing has 10.29% more production efficiency than line sowing. Sowing of SSGH with 75% recommended seed exhibited 17.90% and 4.08% more production efficiency than 50% recommended seed rate and recommended seed rate respectively. Intercropping of SSGH and cowpea revealed best results for production efficiency as compared to sole cropping. Sheoran *et al.* (2010) also reported higher production efficiencies of intercropping of legumes in maize as compared to monoculture of crops.

Land-equivalent ratio

No significant effect of sowing methods was observed on land-equivalent ratio (LER) of SSGH and cowpea (Table 2). However, among seed rates of cowpea, 75% recommended seed rate remaining at par with recommended seed rate resulted in significantly higher land-equivalent ratio of 1.70 than the lowest seed rate of cowpea. The result indicated that multiple cropping systems have resulted in better utilization of land in comparison to

pure cropping (Barik and Tiwari, 1996).

Quality

Sowing methods had no effect on crude protein and crude fibre content of forage; however, higher dry-matter yield in broadcast sowing (Table 1) resulted in significantly better crude protein and crude fibre yields. Dhar *et al.* (2006) also reported same results owing to better dry matter yield under broadcast sowing. Recommended seed rate of cowpea resulted in production of herbage with highest crude protein content, whereas the crude fibre content was higher with 50% recommended seed rate of cowpea. Higher proportion of SSGH and low proportion of cowpea (Table 2) support these findings which might have redefined its effect on crude protein content, as cowpea being legume is rich in crude protein content than SSGH. Higher crude fibre content was observed in monoculture than intercropping systems. Sowing of SSGH with 75% recommended seed rate resulted in higher crude protein yield, whereas highest crude fibre yield was obtained when SSGH was sown with 50% recommended seed rate of cowpea. These results are in line with those reported by Krishna *et al.* (1998). Sole stand of SSGH and cowpea had higher crude protein and crude fibre yields over intercropped treatments. Kumar and Bhanumurthy (2001) also found high crude protein yield in sole cowpea as compared to other systems. The difference in crude protein and fibre yields in all treatments can be ascribed to variations in crude protein content in treatments but more pronouncedly dry matter yield of each crop in different treatments.

Nutrient uptake

The SSGH sown with cowpea using broadcast sowing showed significantly higher uptake of N and P (Table 3). Growing of SSGH with cowpea using recommended seed rate and cowpea with 75% recommended seed rate resulted in significantly higher N, P and K uptake by the crops than 50% recommended seed rate of cowpea and sowing methods on K by the crops have no significant effect. All the treatments, comprising SSGH + cowpea resulted in higher uptake of N, P and K over their respective sole stand. On an average, in pure stands broadcast sowing resulted in more uptake of N and P over line sowing. Nutrient uptake is a function of dry-matter yield and content of respective nutrients. The dry-matter yield obtained under different treatments in the present study amply supports nutrient uptake behaviour of the crops in respective treatments.

Soil properties

Different treatments did not show significant effect on

Table 2. Effect of different treatments on sorghum sudan grass-equivalent yield, proportion of crops, production efficiency, land-equivalent ratio and crude protein content, crude protein yield, crude fibre content and crude fibre yield (pooled data of 2 years)

Treatment	SSGHEY (t/ha)	Proportion of crops (%)	Production efficiency (kg/ha/day)	Land equivalent ratio	Crude protein content (%)	Crude protein yield (t/ha)	Crude fibre content (%)	Crude fibre yield (t/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
		SSGH								
<i>Sowing method</i>										
Line sowing	32.7	79.7	340	1.6	14.7	1.18	24.6	2.19	24.8	1.11
Broadcast sowing	36.0	84.0	375	1.6	15.2	1.34	23.8	2.40	32.0	1.57
SEm±	0.46	0.35	4.8	0.02	0.4	0.03	0.3	0.03	0.63	0.03
CD (P=0.05)	1.37	1.04	14.3	NS	NS	0.11	NS	0.10	1.86	0.09
<i>Seed rate of cowpea</i>										
50% recommended	31.1	89.3	324	1.4	12.8	1.09	26.3	2.45	26.2	1.37
75% recommended	36.7	81.0	382	1.7	15.4	1.35	23.6	2.35	31.4	1.42
Recommended	35.3	75.3	367	1.7	16.6	1.34	22.6	2.07	27.6	1.22
SEm±	0.57	0.43	5.9	0.02	0.5	0.04	0.4	0.04	0.77	0.04
CD (P=0.05)	1.68	1.28	17.5	0.08	1.5	0.13	1.0	0.13	2.28	0.11
<i>Between sole</i>										
Line sowing SSGH	26.0	-	271	-	7.6	0.70	31.6	2.77	19.4	1.02
Broadcast sowing SSGH	28.1	-	293	-	9.1	0.92	29.5	2.79	24.9	1.48
Line sowing cowpea	14.5	-	151	-	20.1	0.48	20.6	0.50	2.73	0.12
Broadcast sowing cowpea	15.06	-	157	-	20.0	0.52	21.1	0.55	5.43	0.31
SEm±	1.13	-	11.8	-	1.0	0.09	0.7	0.08	1.54	0.07
CD (P=0.05)	2.38	-	24.8	-	2.1	0.18	1.5	0.08	3.23	0.15
<i>Sole vs. other</i>										
Sole	20.9	-	436	-	14.2	1.31	25.7	3.30	13.1	0.73
Others	34.3	-	358	-	14.9	1.26	24.2	2.29	28.4	1.34
SEm±	0.52	-	5.4	-	0.45	0.04	0.32	0.04	0.70	0.03
CD (P=0.05)	1.54	-	15.9	-	NS	0.12	1.0	0.12	2.08	0.10

SSGH, Sorghum sudan grass hybrid; SSGHEY, Sorghum sudan grass-equivalent yield; NS, non-significant

Table 3. Effect of different treatments on soil organic carbon, pH, available nutrients and nutrient uptake of crops (pooled data of 2 years)

Treatment	Organic carbon (%)	pH	Available nutrient (kg/ha)			Nutrient uptake (kg/ha)		
			N	P	K	N	P	K
<i>Sowing method</i>								
Line sowing	1.1	5.1	274.2	10.4	294.5	165.8	17.4	49.4
Broadcast sowing	1.2	5.1	270.8	9.2	308.2	194.3	20.9	53.2
SEm±	0.04	–	3.2	0.13	10.1	6.02	0.3	3.02
CD (P=0.05)	NS	–	NS	0.40	NS	13.9	2.8	NS
<i>Seed rate of cowpea</i>								
50% recommended	1.1	5.1	270.1	10.1	286.6	155.3	15.9	43.3
75% recommended	1.2	5.1	267.7	9.7	306.0	189.8	20.0	53.8
Recommended	1.1	5.1	279.7	9.6	311.4	195.2	21.5	56.9
SEm±	0.05	–	3.9	0.16	12.4	7.3	1.2	3.7
CD (P=0.05)	NS	–	NS	NS	NS	17.0	3.4	9.5
<i>Between sole</i>								
Line sowing SSGH	1.0	5.1	243.0	10.1	277.8	134.4	11.5	42.3
Broadcast sowing SSGH	1.0	5.1	244.6	11.9	319.0	149.8	14.5	34.9
Line sowing cowpea	1.1	5.1	283.7	9.3	265.3	77.0	10.8	11.1
Broadcast sowing cowpea	1.1	5.1	271.9	9.1	274.9	86.0	9.9	9.8
SEm±	0.09	–	7.9	0.32	24.9	14.8	2.3	7.4
CD (P=0.05)	NS	–	NS	0.70	NS	24.1	11.5	13.4
<i>Sole vs. other</i>								
Sole	1.1	5.2	260.8	10.1	284.3	111.8	11.7	24.5
Others	1.1	5.1	272.5	9.8	301.3	180.1	19.2	51.3
SEm±	0.04	–	3.6	0.15	11.3	6.73	1.1	3.4
CD (P=0.05)	NS	–	NS	NS	NS	15.5	3.1	8.7
Initial value	1.01	5.5	271.0	11.0	281.0	–	–	–

SSGH, Sorghum sudan grass hybrid; NS, non-significant

soil properties, viz. organic carbon content (%), pH, available N and K (Table 3) was observed. After completion of experiment, a reduction in available phosphorus was observed under broadcast sowing and in sole cowpea compared to sole SSGH. Cowpea being a leguminous crop might have enriched the soil N pool; but at sufficient rate of P application cowpea competes more for P uptake than SSGH (Wahua, 1983). Although, appreciable variation in soil properties was observed after the completion of experiment over initial respective values of different parameter.

Economics

Net returns and benefit: cost ratio (Table 2) calculated to find out the economic viability of different treatments imposed indicated broadcast sowing more profitable in terms of net returns ($32.0 \times 10^3 \text{ ₹/ha}$) and B: C ratio (1.57). Higher herbage yield (Table 1) coupled with low cost of cultivation in broadcast sowing made this treatment more profitable. Sowing of crops using 75% recommended seed rate gave higher net returns ($31.4 \times 10^3 \text{ ₹/ha}$) and B: C ratio (1.42). Broadcast sown monoculture of both the crops resulted in higher net returns and B: C ratio owing to better herbage yield and low cost of cultivation than line sow-

ing. Multiple cropping resulted in better net returns ($28.4 \times 10^3 \text{ ₹/ha}$) and B: C ratio (1.34) over sole crops owing to better herbage yield. The herbage yield gap between 75% recommended and recommended seed rate was less but increased cost of cultivation at higher seed rate indented the difference in net returns among these treatments.

The present study clearly indicates that cultivation of SSGH with cowpea is advantageous from herbage yield, quality, economics and nutrient uptake (NPK) point of view. Broadcast sowing of SSGH with cowpea using 75% recommended seed rate of cowpea was most productive and profitable.

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