



Influence of preceding legumes, N levels and irrigation in *rabi* sorghum (*Sorghum bicolor*)

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ABSTRACT

An experiment was conducted during post-rainy seasons of 2012–13 and 2013–14 at Indian Institute of Millet Research, Rajendranagar, Hyderabad to see the effect of preceding legumes, irrigation and N levels on *rabi* sorghum (*Sorghum bicolor* (L.) Moench) productivity and soil quality. Results revealed that the *in situ* incorporation of *Sesbania* during *kharif* significantly increased the grain yield (2511 and 3024 kg/ha) of post-rainy sorghum as compared to *kharif* fallow (2409 and 2930 kg/ha). Further, irrigation at four critical stages, viz. PI, booting, anthesis and milking had significantly out yielded other irrigation levels. Application of 60 kg N/ha produced grain yield on a par with 90 kg N/ha. *Sesbania* green manure incorporated plots contained significantly more population of soil microbes (bacteria, fungi and actinomycetes). The available nutrients (NPK) were significantly higher due to the incorporation of *Sesbania* as compared to the haulms of greengram or stubbles of cowpea.

Key words: Irrigation, Legumes, Nitrogen, *Rabi* sorghum, Soil quality

Sorghum [*Sorghum bicolor* (L.) Moench] is extensively grown both for grain as food and animal feed, and stalks as animal fodder. It is the major cereal of rainfed agriculture in the semi-arid tropics (SAT). Worldwide, grain sorghum is grown on 44.77 million ha area with production of 63.93 million tonnes of grains, and productivity of 1428 kg/ha (FAO STAT 2018). Although India contributes 12.62% in world's sorghum area, it produces only 6.9% due to lower crop productivity (781 kg/ha). In India, it is cultivated in two distinct seasons, viz. from June–October (rainy/*Kharif*) mainly as a rainfed crop with about 85% of the production concentrated in Maharashtra, Karnataka and Andhra Pradesh, and from October–February (post-rainy/*Rabi*). *Rabi* sorghum grains are preferred for human consumption as they mature in rain-free and dry climate. Sorghum grain and fodder yields are low during *rabi* as the crop is normally grown with the stored soil moisture. It often experiences severe terminal moisture stress after flowering due to increasing temperature. Hence, in addition to high yielding cultivars, crop and soil management plays

a major role in sorghum cultivation. Legumes play a major role in the cropping systems of the semi-arid environments. The positive responses of cereals following legumes have been attributed largely to enhanced availability of nitrogen to the cereal crop (Sanginga 2003). Apart from nitrogen, Nielsen and Vigil (2005) indicated that soil moisture was an important factor in determining the residual benefits to cereals grown in rotation with green manure legumes. The low yield potential of *rabi* sorghum is attributed mainly to moisture stress cycles during flowering and grain formation stages. Application of one or two supplemental irrigations during such stress cycles help enhancing the productivity of *rabi* sorghum.

Although the beneficial effect of legumes in cropping systems is widely known, the contribution of preceding (*Kharif*) legumes on N economy and productivity of succeeding *rabi* (post-rainy) sorghum was not adequately investigated. Hence, the present investigation was carried out to study the influence of preceding legumes, N levels and irrigation schedules on the performance of *rabi* sorghum and soil quality.

MATERIALS AND METHODS

A field experiment was conducted during 2012–2013 at the ICAR-Indian Institute of Millet Research, Rajendranagar (17° 31' N, 78° 39' E, and 545 m amsl), Hyderabad to study the effect of preceding legumes, N levels and irrigation schedules on *rabi* sorghum yield and soil quality. The experimental soil was clay loam in texture with pH of 7.7 and EC of 0.38 dS/m, low in organic carbon (0.23%) and

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available N (162 kg/ha), medium in available phosphorus (29.1 kg P₂O₅/ha) and potassium (282.8 kg K₂O/ha). The experiment was laid out in a strip-split design replicated thrice. There were 4 strips in *kharif*, viz. Sesbania, greengram, cowpea and fallow. Sorghum was grown during *rabi* in a split plot layout in each strip with 4 sub plots of irrigation (irrigation at panicle initiation (PI); PI+booting, PI+booting+anthesis; PI+booting+anthesis+milking) and 4 sub-sub plots of nitrogen levels (0, 30, 60 and 90 kg N/ha).

The test species of *Sesbania cannabina* as green manure, greengram (LGG 407) for seed and green manure, and cowpea (EC 4216) for fodder were used. *Sesbania* weighing 15.2 t/ha in 2012 and 16.7 t/ha in 2013 was incorporated *in situ* at 46 days after sowing (DAS). It was estimated to contribute 60–64 kg/ha N after complete decomposition under ideal conditions. The greengram pods (with grain yield of 451 and 467 kg/ha) were harvested at 60 DAS for grain and haulms (8.5 and 8.6 t/ha) were then incorporated into the soil. Similarly, the cowpea foliage (11.3 and 13.5 t/ha) was harvested for fodder and the stubbles were turned down into the soil for decomposition. There were no dry spells for more than a week until the sowing of sorghum in *rabi* on 26 September in the first year and 28 September in the second year. There was a rainfall of 584.4 mm in 2012

and 602.6 mm in 2013. Sorghum cultivar Phule Suchitra was sown at a depth of 5 cm with seeds spaced at 15 cm in rows 45 cm apart each year @10 kg/ha seed. Full doses of phosphorus and potash and 1/2 of nitrogen were placed 2–3 cm below the seed as basal at the seeding. Remaining 1/2 nitrogen was applied at 35 days after sowing (DAS). Furadan 3G (@20 kg/ha) was applied in furrows at planting to control the shoot fly (*Atherigona soccata* R). Thinning was done manually at 20 and 30 DAS by removing excess plants. Leaf area index was recorded at 60 DAS, whereas plant height was taken at the harvest. Leaf area of the fourth leaf from the top was measured as:

Leaf area = length × maximum width × 0.75 (Stickler *et al.* 1961)

The leaf area index (LAI) was calculated by dividing leaf area per plant with ground area per plant. At the beginning and conclusion of the experiment, soil samples were collected for estimation of soil physico-chemical and microbiological properties as per the standard procedures.

RESULTS AND DISCUSSION

Effect on growth parameters: The performance of *rabi* sorghum was influenced by preceding legumes, irrigation and nitrogen (Table 1). The decomposing residue of

Table 1 Growth, yield attributes (pooled data of 2 years) and yield of sorghum as influenced by preceding *kharif* legumes, irrigation schedules and N levels

Treatment	Plant height (cm)	LAI	Total dry matter production (kg/ha)	Panicle length (cm)	Grains/panicle	Panicle weight (g)	1000-grain weight (g)	Grain yield (kg/ha)		Stover yield (kg/ha)	
								2012	2013	2012	2013
<i>Preceding legumes</i>											
C1: Sesbania	221	2.20	8674	17.15	1204	46.70	25.95	2511	3024	5686	6127
C2: Greengram	219	2.05	8469	16.90	1166	45.05	25.85	2446	2942	5487	6063
C3: Cowpea	217	1.45	8388	17.05	1137	45.00	26.05	2389	2947	5441	5999
C4: Fallow	213	1.35	8363	17.00	1101	44.65	25.95	2409	2930	5367	6019
SEm ±	1.7	0.15	72.5	0.1	4	0.1	0.45	17	25	8	9
CD (P=0.05)	6	0.5	251	0.2	15	0.4	NS	59	85	27	29
<i>Irrigation schedules</i>											
I1: PI*	206	1.70	8175	15.60	1091	42.85	24.45	2338	2870	5311	5830
I2: PI and booting	214	1.75	8357	16.55	1134	44.7	25.45	2413	2929	5419	5953
I3: PI, booting and anthesis	221	1.80	8593	17.65	1170	45.8	26.5	2477	2997	5570	6141
I4: PI, booting, anthesis and milk stage	230.05	1.70	8771	18.35	1212	48.05	27.4	2528	3047	5681	6286
SEm ±	1.5	0.10	23	0.1	3.85	0.1	0.45	13	6	36	38
CD (P=0.05)	5.15	NS	79	0.20	13	0.35	1.55	46	22	124	131
<i>Nitrogen (kg/ha)</i>											
N1: 0	195	1.6	7340	14.80	981	39.35	22.85	2039	2466	4863	5311
N2: 30	216	1.7	8202	16.35	1108	43.80	25.05	2380	2886	5305	5833
N3: 60	226	1.85	8959	17.70	1215	47.05	27.10	2650	3222	5708	6338
N4: 90	234	1.9	9393	19.25	1305	51.25	28.80	2686	3269	6104	6726
SEm ±	5	0.2	222	0.40	26.6	1.00	1.05	55	57	132	140
CD (P=0.05)	13	NS	622	1.35	92	3.45	2.95	188	199	457	484

*PI: Panicle initiation

Sesbania green manure improved the vegetative growth of sorghum. Plants grew significantly taller due to irrigation at PI, booting, anthesis and milk stages. Application of high dose of 90 kg/ha N being at par with 60 kg/ha resulted in significantly taller plants. The *in situ* incorporation of *Sesbania* significantly increased the total dry matter (TDM) at harvest (8197 and 9151 kg/ha), than other preceding legumes. Possible reasons for this were due to the fact that *Sesbania* harvested at the beginning of flowering was succulent with high moisture content, maximum nutrient accumulation in the foliage and expected optimum C: N ratio of about 25. This was ideal for early decomposition. Furthermore, the haulms of greengram were less succulent and more lignified because of their late incorporation after harvesting of pods. The stubbles of cowpea added the least biomass to the soil. Confirming the positive role of residual effect of legumes, Mahadkar and Saraf (1988) recorded significant improvement in the dry matter production of sorghum by the incorporation of blackgram haulms in the preceding season. Increase in number of irrigations significantly increased the plant height of sorghum. However, the significant response of N to plant height was observed up to 60 kg/ha only. Leaf area index, however did not vary significantly due to increase in irrigations and nitrogen levels.

Effect on yield attributes: The green manure of *Sesbania* was most effective among all preceding season treatments as it helped to produce longer panicles, more number of grains per panicle and higher weight of panicle. The 1000-grain weight, however, did not vary significantly. Sorghum grown after the preceding fallow land produced significantly less number of grains per panicle. Significantly longer panicles, more number of grains per panicle, higher panicle weight and 1000-grain weight were observed when the crop received irrigations at four critical stages (Table 1). Henadez *et al.* (1992) reported that the ear head weight decreased due to moisture stress at all the critical stages, except when stressed at physiological maturity. Nitrogen improved the yield components remarkably. Increase in N levels up to 90 kg/ha significantly increased the yield attributes of winter sorghum.

Effect on grain and stover yields: Significantly higher grain and stover yields were harvested due to *Sesbania* green manure incorporation during both the years than other preceding crops and fallow. Maximum grain yield (2528 and 3047 kg/ha) was obtained by irrigating the crop at panicle initiation, boot leaf, anthesis and milking stage of grain during both the years. Additional mean grain yield of 67, 133 and 184 kg/ha, respectively was obtained due to two, three and four irrigations over one. Mishra *et al.* (2011) also reported that green manure of *Sesbania* increased the production of sorghum compared to the yield from fallow-sorghum. In an earlier investigation, Pawar and Bhogi (2009) reported that the legumes differed in their influence on the relative performance of sorghum. Similarly, the stover yield increased from 5311–5419 kg/ha by irrigating the crop at panicle initiation and boot leaf stage in the first year and from 5830–6286 kg/ha in the second year. More quantity

of 5570 and 6141 kg/ha stover was obtained by irrigation at panicle initiation, boot leaf and anthesis stage. Maximum stover yield of 5681 and 6286 kg/ha (Table 1) was obtained when the soil was not deprived of moisture stress at panicle initiation, boot leaf, anthesis and milk stage of grains. Grain and stover yields of *rabi* sorghum went on increasing with increasing levels of N from unfertilized control, reaching significantly higher values at 90 kg/ha. However, N applied @90 and 60 kg/ha were at par and produced 32% and 13% higher grain yield over control and 30 kg N/ha, respectively. Similarly, it was 26 and 15% higher in case of stover yield.

Effect on microbial population and SMBC: The data on microbial population (Table 2) indicated that irrespective of treatments, the total bacteria, fungi and actinomycetes were found in large number in the soil during *kharif* 2013 than 2012. *Sesbania* green manure incorporated plots contained significantly more population of bacteria (61 and 74×10^6 CFU/g of soil), fungi (12 and 15×10^4 CFU/g of soil) and actinomycetes (26 and 33×10^3 CFU/g of soil) besides SMBC (464 and 468 $\mu\text{g/g}$) during both the years. The microbial population directly influenced the microbial biomass carbon in the soil and nutrient uptake which in turn probably was due to the faster decomposition of *Sesbania*. The green manure incorporation provided the substrate for different microflora and inorganic compounds. Marked increase in microbial biomass following incorporation of crop residues was also reported by Sridevi *et al.* (2003). The lowest microbial population was recorded when the soil was left fallow preceding to *rabi* sorghum. Beare *et al.* (1996) also reported increase in microbial population with incorporation of green manure crops. Application of green manuring increased the organic carbon content of soil, and directly influences the microbial growth (Tamboli *et al.* 2011). The results further revealed that irrespective of year of experimentation, the rhizosphere soil of sorghum had significantly higher number of microbes, i.e. bacteria (57 and 66×10^6 CFU/g of soil), fungi (12 and 14×10^4 CFU/g of soil), actinomycetes (24 and 28×10^3 CFU/g of soil) and microbial biomass carbon (427 and 416 $\mu\text{g/g}$) when the crop received four irrigations, i.e. at PI, booting, anthesis and milk stage. This could be due to avoidance of drought and presence of sufficient moisture content in the soil during crop growth period which in turn helped for proliferation of microbes thus SMBC (Rangaswami and Venkatesam 1964). Though the microbial population and SMBC in rhizosphere of sorghum increased significantly with the addition of nitrogen from 0–60 kg/ha, further increase in N dose failed to bring out any significant improvement.

Effect on soil fertility: The data on soil chemical properties (Table 2) revealed that initially the soil was slightly alkaline, low in organic carbon and available nitrogen, medium in available phosphorus and potassium contents. The pH and EC reduced due to the *in situ* incorporation of *Sesbania*. It is considered that the crop residues are important in maintaining the soil resources at optimum level as they are the major sources of carbon inputs. However, the organic carbon content did not change

Table 2 Soil microbial and physico-chemical properties at the conclusion of the experiment as influenced by preceding *kharif* legumes, levels of irrigation and nitrogen

Treatment	Soil bacteria ($\times 10^6$ CFU/g of soil)	Soil actinomycetes ($\times 10^3$ CFU/g of soil)	Soil fungi ($\times 10^4$ CFU/g of soil)	Soil microbial biomass carbon ($\mu\text{g/g}$)	pH	EC (dS/m)	OC (%)	Available nutrients (kg/ha)		
								N	P ₂ O ₅	K ₂ O
<i>Preceding legumes</i>										
C1: Sesbania	74	33	15	468	7.2	0.27	0.28	189.4	30.8	288.5
C2: Greengram	61	28	13	366	7.3	0.28	0.27	157.0	29.2	271.9
C3: Cowpea	53	23	12	360	7.4	0.30	0.25	152.7	26.3	266.5
C4: Fallow	39	21	11	257	7.4	0.31	0.23	155.1	24.7	242.1
SEm \pm	0.35	0.1	0.07	0.9	0.1	0.03	0.01	0.6	0.1	1.3
CD (P=0.05)	1	0.5	0.3	3.0	NS	NS	NS	2.0	0.5	4.5
<i>Irrigation schedules</i>										
I1: PI*	47	24	12	306	7.3	0.28	0.25	162.3	27.4	260.8
I2: PI and booting	51	25	12	339	7.3	0.28	0.26	165.5	27.2	264.9
I3: PI, booting and anthesis	63	28	14	390	7.4	0.29	0.24	169.3	28.3	269.7
I4: PI, booting, anthesis and milk stage	66	28	14	416	7.3	0.28	0.24	166.7	27.8	274.6
SEm \pm	0.14	0.1	0.07	1.0	0.1	0.01	0.01	0.35	0.14	1.7
CD (P=0.05)	0.4	0.4	0.3	3	NS	NS	NS	1.3	0.6	5.9
<i>Nitrogen (kg/ha)</i>										
N1: 0	50	24	12	335	7.4	0.30	0.26	162.6	22.1	259.4
N2: 30	57	26	13	364	7.4	0.30	0.26	167.3	23.4	270.9
N3: 60	60	28	14	389	7.3	0.29	0.25	170.6	22.9	264.3
N4: 90	61	27	13	362	7.4	0.29	0.24	175.8	24.7	259.4
SEm \pm	1.34	0.7	0.28	8.2	0.18	0.01	0.01	5.0	0.6	7.9
CD (P=0.05)	4	2.0	0.9	23.0	NS	NS	NS	13.9	1.8	22.3

*PI: Panicle initiation

before and after harvest of sorghum due to the incorporation of the preceding crops. The lack of response in organic carbon could be ascribed to the tropical climate. The mass of legumes incorporated in the soil increased the available nitrogen to more than the initial value before sowing sorghum during both the years. The legumes depleted the available P and K to less than the initial value. The soil nutrient pool had relatively less quantity of available N, P and K in all the treatments after the harvest of sorghum in the first year. The available N, P and K then increased due to the addition of fresh mass of the legumes in the second year. Sorghum exhausted these nutrients leaving behind relatively low quantities in the soil after its harvest. The available N was significantly higher than the initial quantity due to the incorporation of *Sesbania* when compared to the haulms of greengram or stubbles of cowpea. However, the available P and K reduced to less than the initial quantity, but higher quantity of P and K was present in *in situ* incorporation of *Sesbania*. Incorporation of cowpea preceding to *rabi* sorghum increased the organic carbon and available nitrogen after five years of experimentation (Tamboli *et al.* 2011).

The results clearly indicated that grain and stover yields of *rabi* sorghum and soil quality could be improved

significantly through *in situ* incorporation of *Sesbania* as green manure in *kharif* irrigating sorghum at four critical stages of PI, boot leaf, anthesis and milking stages and application of 60 kg N/ha. Further, a 30 kg mineral N/ha could be saved through *Sesbania* green manuring.

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