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

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

| Treatment | Plant height (cm) | LAI | Total dry matter production (kg/ha) | Panicle length (cm) | Panicle length (cm) | Grains/ panicle (g) | 1000-grain weight (g) | Grain yield (kg/ha) 2012 | Stover yield (kg/ha) 2012 |
|-----------|------------------|-----|------------------------------------|---------------------|---------------------|---------------------|----------------------|--------------------------|--------------------------|
| C1: Sesbania | 221              | 2.20 | 8674                               | 17.15              | 1204                | 46.70               | 25.95                | 2511                     | 3024                     |
| C2: Greengram  | 219              | 2.05 | 8469                               | 16.90              | 1166                | 45.05               | 25.85                | 2446                     | 2942                     |
| C3: Cowpea    | 217              | 1.45 | 8388                               | 17.05              | 1137                | 45.00               | 26.05                | 2389                     | 2947                     |
| C4: Fallow    | 213              | 1.35 | 8363                               | 17.00              | 1101                | 44.65               | 25.95                | 2409                     | 2930                     |
| CD (P=0.05)   | 6                | 0.5  | 251                                | 0.2                | 15                  | 0.4                 | NS                   | 59                       | 85                       |

Effect on growth parameters: The performance of rabi sorghum was influenced by preceding legumes, irrigation and nitrogen (Table 1). The decomposing residue of 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 at 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
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 × 10⁶ CFU/g of soil), fungi (12 and 15 × 10⁴ CFU/g of soil) and actinomycetes (26 and 33 × 10³ CFU/g of soil) besides SMBC (464 and 468 µg/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 × 10⁶ CFU/g of soil), fungi (12 and 14 × 10⁴ CFU/g of soil), actinomycetes (24 and 28 × 10³ CFU/g of soil) and microbial biomass carbon (427 and 416 µg/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.
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 its harvest. The available N, P and K then increased due to the addition of fresh mass of the legumes in the second year. The available N, P and K reduced to less than the initial quantity, but higher 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.

### REFERENCES

Beare M H, Cookson W R and Wilson P E. 1996. ‘Effect of straw residue management practices on composition and activity on soil microbial communities and patterns of residue decomposition’. (In) Proceedings of the ASSS and NZSS National Soils Conference. Melbourne, Australia. pp 11–12.

Henadez V A G, Manjarrez S P and Mendoza CLE. 1992. Drought-stress effect on dry matter production and distribution in sorghum plants. Sorghum Newsletter 33: 56.

Kulakarni K R and Pandey P K. 1988. ‘Annual legumes for food as green manure in rice based cropping systems’. (In) Sustainable agriculture-green manure in rice farming. International Rice Research Institute, Los Bonas, Leguna, Philippines. 289–99.

Mahadkar U V and Saraf C S. 1988. Effect of various inputs on yield of urd bean and its residual effects on succeeding fodder sorghum. Journal of Maharashtra Agricultural University 13(3): 293–5.

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**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 (× 10⁶ CFU/g of soil) | Soil actinomycetes (× 10⁵ CFU/g of soil) | Soil fungi (× 10⁴ CFU/g of soil) | Soil microbial biomass carbon (μg/g) | pH | EC (dS/m) | OC (%) | Available nutrients (kg/ha) |
|-----------|-----------------------------------|---------------------------------------|-------------------------------|----------------------------------|----|----------|--------|---------------------------|
| **Preceding legumes** | | | | | | | | |
| 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 |
| CD (P=0.05) | 0.35 | 0.1 | 0.07 | 0.9 | 0.1 | 0.03 | 0.01 | 0.6 | 0.1 | 1.3 |
| **Irrigation schedules** | | | | | | | | |
| 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 |
| CD (P=0.05) | 0.14 | 0.1 | 0.07 | 1.0 | 0.1 | 0.01 | 0.01 | 0.35 | 0.14 | 1.7 |
| **Nitrogen (kg/ha)** | | | | | | | | |
| 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 |
| CD (P=0.05) | 1.34 | 0.7 | 0.28 | 8.2 | 0.18 | 0.01 | 0.01 | 5.0 | 0.6 | 7.9 |

*PI: Panicle initiation*
VS, Lokhande O G, Patel Z N, Thakur N S, Nemade S M, Bhat Spandana Pramod Kumar and Kewalanand. 2011. Sorghum Agronomy: Kharif Report -agm12.doc. Page 1:16.

Nielsen D C and Vigil M F. 2005. Legume green fallow effect on soil water content at wheat planting and wheat yield. *Agronomy Journal* 97: 684–689.

Pawar A D and Bhogi R S. 2009. Effect of green manure and its incorporation methods in rabi sorghum cropping system. *Annals of Plant Physiology* 23(2): 162–64.

Rangaswami G and Venkatesan R. 1964. The rhizosphere microflora of rice plants as influenced by soil depth and root maturity. *Current Science* 33: 181–83

Sanginga N. 2003. Role of biological nitrogen fixation in legume based cropping systems: a case study of West Africa farming systems. *Plant and Soil* 252: 25–39.

Sridevi S, Katyal J C, Srinivas K and Sharma K L. 2003. Carbon mineralization and microbial dynamics in soil amended with plant residues and residue fractions. *Journal of Indian Society of Soil Science* 51:133–39.

Stickler F C, Wearden S and Pouli W. 1961. Leaf area determination in grain sorghum. *Agronomy Journal* 53:187–89.

Tamboli B D, Shelke I R, Bhagawan D V, Indi D V, Kadam J R and Deshpande A N. 2011. Effect of green manuring on dryland Rabi sorghum productivity and soil quality in Vertisol. *Indian Journal of Dryland Agricultural Research and Development* 26(26): 33–7.