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Effect of Sole and Conjunctive Applications of Plant Residues and Inorganic Nitrogen on Growth, Yield and N Uptake of Sorghum

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ABSTRACT: Conjunctive use of organic and inorganic sources of nitrogen is a pragmatic approach for increasing crop productivity while maintaining or improving soil quality. Field experiments were conducted to optimize the conjunctive use of sorghum straw and gliricidia loppings with urea for supplying nitrogen to sorghum grown in dryland Alfisols during the *kharif* seasons of 1994 and 1995 with 13 treatments and 3 replications in a randomized block design. Treatments consisted of sole and conjunctive applications of urea and plant residues, viz. sorghum straw and gliricidia loppings to supply N equivalent to the recommended dose of 60 kg ha^{-1} to rainfed sorghum. Crop growth, yield and N uptake were recorded. In the initial stages of crop growth, drymatter production was higher with 100% N through urea treatment, but with the progress of crop age, urea + gliricidia treatments produced equal or greater drymatter and grain yield. Application of sorghum straw caused reduction in drymatter production and grain yield. Nitrogen uptake by the crop also showed similar trends. Nitrogen uptake at maturity was distinctly higher with gliricidia treatments compared to 100% N through urea. Agronomic efficiency and apparent recovery of applied N were higher with gliricidia treatments and lower with sorghum straw at equivalent N level. Negative efficiency and recovery were observed with 100% N through sorghum straw treatment. The results indicate that gliricidia can be used as a source of N to crops, solely or in combination with inorganic N, whereas sorghum straw can not be used as a source of N, even in combination with inorganic N.

Key words: Conjunctive use, nitrogen, inorganic, sorghum straw, gliricidia, sorghum, yield, N uptake

Soils of drylands in India are poor in fertility and successful crop production on these soils is not possible without application of nutrients, foremost amongst, which is nitrogen. The resource poor farmers who cultivate these soils cannot invest on expensive chemical fertilizers. This situation calls for the use of inexpensive indigenous sources of nutrients. Plant residues, including crop residues and tree prunings are the main sources of nutrients under dryland conditions. However, use of plant residues alone as sources of nutrients can lead to loss of productivity. Therefore, the logical alternative would be to use a combination of chemical fertilizers and plant residues. Such an approach ensures that crop nutrient requirements are met, while soil fertility is maintained or restored (Palm *et al.*, 1997). Many researchers have worked on the conjunctive application of plant residues and chemical fertilizers (Patil *et al.*, 1993; Deshmukh *et al.*, 1995; Sharma and Srinivas, 1997). However, their work focused on conjunctive use of 50% of N through plant residues and 50% through chemical fertilizer, irrespective of the quality characteristics of the plant residues. Cereal straws and other crop residues with wide C/N ratios do not permit high levels of organic N substitution whereas, legume straws and green leaf manures with narrow C/N ratios permit such substitution. The proportions of plant residue N and chemical fertilizer N have to be optimized for individual plant residues, if the conjunctive use system is to succeed. The present investigation was aimed at determining the optimal combination of sorghum residue N and gliricidia loppings N with urea N for sorghum grown on dryland Alfisols.

Materials and Methods

The field experiment was conducted at Hayathnagar Research Farm (HRF) of the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad for two years during the *kharif* seasons of 1994 and 1995. The soil of the experimental site was a red sandy loam belonging to the family of mixed isohyperthermic Typic Haplustalfs. Salient properties of the soil are: sand-80.5%, silt - 3.7%, clay - 15.8%, bulk density - 1.64 Mg m^{-3}, water retention at 0.03 MPa - 10.3%, 1.50 MPa - 6.4%, pH - 5.53, EC - 0.51 dS m^{-1}, CEC - 10.52 C mol (p^+) kg^{-1}, organic carbon - 0.54%, total N - 0.056%, available P - 19.9 kg ha^{-1}, available K - 164.7 kg ha^{-1}.

The experiment was conducted in a randomized block design with three replications and thirteen treatments. Sorghum (CSH-6) was grown during the *kharif* seasons of 1994 and 1995 with recommended package of practices. Treatments were applied when the crop was 15 days old by opening furrows between crop rows. Freshly cut gliricidia loppings and air-dry sorghum straw were used for supplying N in the organic and conjunctive treatments. The C and N contents of the two residues were analysed by flash combustion - gas chromatography in a solid sample CNS analyzer (NA 1500 N, Carbo Erba Strumentazione, Italy). The C and N contents and C:N ratios of the materials used for treatment imposition in 1994 and 1995 are shown in Table 1.

Plots of 8 m x 5 m (40 m^2) size were divided and marked to enable plot-wise application of treatments and collection of samples. Fifteen days after sowing, furrows were opened between crop rows with a bullock drawn plough and required quantities of urea, fresh gliricidia loppings and sorghum straw as per treatments were applied in the furrows. The residues were chopped to a size of around 10-15 cm prior to application. A uniform dose of phosphorus @ 13 kg P ha^{-1} was applied in the furrows in all the plots, irrespective of treatments. Subsequently, the furrows were closed manually.

Plant samples were collected at floral initiation (33 days after sowing (DAS)), anthesis (66 DAS) and maturity. At floral initiation and anthesis, 10 randomly selected plants from each plot were cut close to the base. The sample plants were dried under shade, and subsequently in a forced draft hot air oven at 65°C. Their weights were recorded and dry matter yields per hectare were calculated assuming a plant population of 2.08 lakhs ha^{-1}. At harvest, net plots of 6 x 3 m (18 m^2) were

Table 1. Carbon and N contents (g kg^{-1}) and C:N ratios of the residues used in the experiment

Residue	1994			1995		
	C	N	C:N ratio	C	N	C:N ratio
Sorghum straw	396.0	5.84	67.8	402.0	5.47	73.5
Gliricidia loppings	384.0	26.53	14.5	376.0	27.26	13.8

marked in the centre of each of the 8 x 5 m plots. The earheads were harvested first followed by the straw close to the base. The straw was air dried and plotwise straw weights were recorded. Samples of straw were taken for analysis. Earheads were sun dried and threshed manually. Plot-wise grain weights were recorded and sampled for analysis. Grain and straw samples were dried in a forced draft hot air oven at 65 °C, ground in a Willey type mill and stored in plastic boxes for subsequent analysis. Nitrogen in plant material was determined by kjeldahl digestion and distillation (Jackson, 1973).

Results and Discussion

Dry matter accumulation and yield

At floral initiation in 1994, the highest dry matter production was observed with 100% N through urea (T_5) treatment (Table 2), which is attributable to the availability of mineral N in the soil due to application of urea. The dry matter levels were higher than control with inorganic N treatments, gliricidia treatments and also sorghum straw treatments. The notable exception in this regard was 100% N through sorghum straw treatment (T_9). Higher dry matter production with all treatments except T_9 was a consequence of higher availability of soil mineral N to plants. The lower dry matter production with sorghum straw alone treatment (T_9) compared to control is attributable to deficiency of N resulting from immobilization of N by soil microorganisms. In this severely N limiting environment, microorganisms probably competed with the crop plants for whatever little inorganic N was present in the soil, resulting in N stress for plants. Similar trends in dry matter production as observed at floral initiation were evident at anthesis, and with respect to straw yield at harvest.

Grain yield at harvest was higher with all the gliricidia treatments compared to 100% N through urea treatment, perhaps due to extended availability of mineral N in these treatments compared to 100% N through urea. The highest grain yield observed with 75% N through urea + 25% N through gliricidia treatment (T_{10}) was 97.8% higher than control (T_1) and 2.7% higher than 100% N through urea (T_5) treatment. The lowest grain yield, recorded with 100% N through sorghum straw treatment (T_9), was 9.1% lower than that with control. Lower grain yield with 100% N through sorghum straw (T_9) than control (T_1) is probably due to immobilization of N by high C:N ratio sorghum straw for most of the crop growth period. Total dry matter production at harvest was highest with 75% N through urea + 25% N through gliricidia conjunctive treatment (T_{10}) reflecting the combined effect of high early season N availability from urea component and late season N availability from gliricidia component, respectively. Similar to the results of the present study, Sharma and Srinivas (1997) reported higher dry matter production of sorghum with urea and gliricidia conjunctive treatments, and lower dry matter production with sorghum treatments. Several earlier researchers have reported the ability of leguminous residues applied alone or in conjunction with urea to give yields similar to or higher than urea at equivalent N level (Narkhede and Ghugare, 1987; Reddy *et al.*, 1991; Mittal *et al.*, 1992; Deshmukh *et al.*, 1995). The detrimental effect of cereal straw applications on crop yields is well documented (Reddy *et al.*, 1991; Bellakki and Badanur, 1994; Sharma and Srinivas, 1997).

Similar trends in dry matter production and yield in response to different treatments as observed in 1994, were observed in 1995 also. The highest grain yield in 1995, recorded with 50% N through urea + 50% N through gliricidia

Table 2. Effect of treatments on crop dry matter production and yield (kg ha^{-1}) during 1994 and 1995

Treatment	Floral initiation		Anthesis		Harvest: Straw		Harvest: Grain		Harvest: Total dry matter	
	1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
T 1	219 de	318 fg	1162 cd	1529 cd	1316 de	1626 d	837 d	997 e	2153 cd	2623 e
T 2	267 cd	389 def	1524 bc	1949 bc	1712 bcd	2078 cd	1081 cd	1306 de	2794 bc	3384 de
T 3	306 abc	426 bcde	1729 ab	2199 ab	2072 abc	2361 abc	1284 bc	1585 bcd	3357 ab	3945 bcd
T 4	342 ab	500 abc	2007 a	2600 a	2189 ab	2625 abc	1473 ab	1756 abc	3662 a	4381 abcd
T 5	375 a	548 a	2117 a	2794 a	2412 a	2980 a	1612 ab	1997 ab	4024 a	4977 ab
T 6	326 abc	445 abcde	1787 ab	2264 ab	1942 abc	2289 bc	1280 bc	1543 cd	3222 ab	3832 cd
T 7	270 bcd	394 cdef	1502 bc	1974 bc	1625 cde	2026 cd	1066 cd	1323 cde	2691 bcd	3348 de
T 8	230 de	340 efg	1243 cd	1621 cd	1325 de	1674 d	859 d	1061 e	2184 cd	2734 e
T 9	197 e	280 g	1065 d	1400 d	1177 e	1487 d	761 d	912 e	1938 d	2399 e
T 10	348 a	515 ab	2070 a	2780 a	2400 a	2994 a	1656 a	2048 a	4057 a	5042 a
T 11	331 abc	487 abcd	2011 a	2714 a	2322 a	2935 a	1634 a	2077 a	3955 a	5011 ab
T 12	322 abc	472 abcd	2007 a	2685 a	2327 a	2905 ab	1643 a	2054 a	3969 a	4958 ab
T 13	307 abc	451 abcd	1921 ab	2579 a	2245 a	2833 ab	1612 ab	1991 ab	3857 a	4824 abc
SE ±	30	46	183	247	209	261	145	186	353	446

Values in a column followed by a common letter are not significantly different at P=0.05 according to Duncan's Multiple Range Test (DMRT)

Treatments: T1 - Control (no N), T2 - 25% N through urea, T3 - 50% N through urea, T4 - 75% N through urea, T5 - 100% N through urea, T6 - 75% N through urea + 25% N through sorghum straw, T7 - 50% N through urea + 50% N through sorghum straw, T8 - 25% N through urea + 75% N through sorghum straw, T9 - 100% N through sorghum straw, T10 - 75% N through urea + 25% N through gliricidia loppings, T11 - 50% N through urea + 50% N through gliricidia loppings, T12 - 25% N through urea + 75% N through gliricidia loppings, T13 - 100% N through gliricidia loppings; % refers to % of the recommended dose of 60 kg N ha^{-1}

treatment (T_{11}), was 108.3% and 4.0% higher than control (T_1) and 100 per cent N through urea (T_5) treatments, respectively. The lowest grain yield, recorded with 100% N through sorghum straw treatment (T_9), was 8.5% lower than with control.

N uptake

Nitrogen uptake by the crop exhibited a distinctly sigmoidal pattern in both years (Fig. 1). Roy and Wright (1974) also found that N accumulation by sorghum was slow early in the season, became rapid and reached a peak around 70 days after sowing and decreased subsequently. At floral initiation in 1995, the amount of N taken up was highest with 100% N through urea treatment (T_5), due to increased availability of mineral N in the soil and consequent accumulation of dry matter with this treatment. Nitrogen uptake with 100% N through sorghum straw treatment was lower than control due to immobilization of soil N by applied sorghum straw. Sharma and Srinivas (1997) reported similar results on N uptake by sorghum at early stages of crop growth with identical treatments. By harvest, the amounts of N accumulated in straw, grain and total dry matter were higher with gliricidia treatments compared to the 100% N through urea treatment (T_5), due to extended availability of N to the crop in the gliricidia treatments. Analogous to the findings of the present study, Pathak and Sarkar (1994) reported that N uptake by rice was highest with urea at 30 and 70 days after transplanting, while at harvest N uptake was highest with sesbania + urea treatment. Sharma and Srinivas (1997) also found that while N uptake by sorghum in the initial stages of crop growth was highest with urea, the urea + *Leucaena* (1:1) treatment recorded the highest N uptake at harvest.

The highest N uptake by sorghum at maturity recorded with 25% N through urea + 75% N through gliricidia treatment (T_{12}) was 122.4% and 4.9% higher than the N uptake with control (T_1) and 100% N through urea (T_5) treatments, respectively. Increased N uptake with application of gliricidia residues has been reported earlier in maize (Tian *et al.*, 1993; Handayanto *et al.*, 1997) and sorghum (Reddy *et al.*, 1991; Das *et al.*, 1997). Lowest N uptake at maturity recorded with 100% N through sorghum straw treatment was 12.5% lower than with control. Decrease in N uptake by crops due to application of sorghum straw has been reported in sorghum (Myers, 1983; Das *et al.*, 1997).

The effects of treatments on N uptake by sorghum in 1995 were similar to those observed during 1994. However, the amounts of N taken up

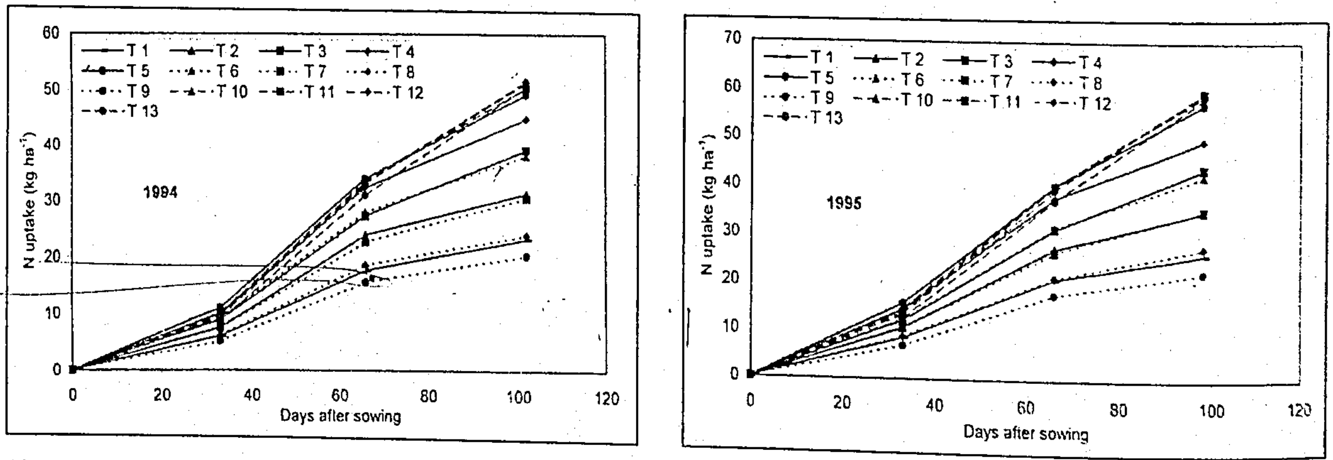

Fig. 1. Nitrogen uptake by sorghum as influenced by treatments during 1994 and 1995

were higher in 1995, due to higher dry matter production. In 1995 also, the highest total N uptake was recorded with the 25% N through urea + 75% N through gliricidia treatment (T_{12}) and it was 129.6% and 4.4% higher than with control (T_1) and 100% N through urea (T_5) treatments respectively. The amount of N taken up by the crop with 100% N through sorghum straw treatment (T_9) was 14.6% lower than that with control.

Agronomic efficiency and apparent recovery of applied N

The agronomic efficiency of applied N in 1994 decreased with increasing levels of N in the urea alone treatments (Table 3), indicating that each successive increase in the dose of N resulted in progressively smaller increases in grain yield. This is predictable since it is well known that plant response to inputs follows the law of diminishing returns, i.e., successive increments in inputs result in smaller and smaller response (Tisdale *et al.*, 1985). Decrease in agronomic efficiency with increase in N level has been reported by several researchers (Bock, 1984; Harmsen, 1984; Katyal, 1989). The agronomic efficiency of N applied through gliricidia treatments was higher than that of N applied through urea at equivalent N level. This higher efficiency with gliricidia treatments is due to relatively higher yields with these treatments compared to 100% N through urea treatment (T_5) because at equivalent N level, agronomic efficiency is a function of grain yield. Higher efficiency of N applied through gliricidia or gliricidia in conjunction with urea, compared to urea alone has been reported by Reddy *et al.*, (1991) and Sharma and Srinivas (1997). Agronomic efficiency of applied N was low with sorghum straw treatments, being lowest and negative with 100% N through sorghum straw. The negative efficiency observed with sorghum straw was due to the fact that grain yield with this treatment was less than that with control. Sharma and Srinivas (1997) also reported negative response of grain yield to N applied exclusively through sorghum straw. Treatment effects on agronomic efficiency in

Table 3. Agronomic efficiency and apparent recovery of applied N with different treatments during 1994 and 1995

Treatment	Agronomic efficiency (kg grain kg^{-1} N applied)		Apparent N recovery (%)	
	1994	**1995**	**1994**	**1995**
T 2	16.3	20.6	54	60
T 3	14.9	19.6	53	59
T 4	14.1	16.9	48	52
T 5	12.9	16.7	43	52
T 6	7.4	9.1	25	27
T 7	3.8	5.4	12	15
T 8	0.4	1.1	1	2
T 9	-1.3	-1.4	-5	-6
T 10	13.7	17.5	47	55
T 11	13.3	18.0	46	56
T 12	13.4	17.6	47	56
T 13	12.9	16.6	46	54

1995 were similar to those observed in 1994, but with all treatments, the efficiency was higher in 1995 due to higher yields in that year.

Like agronomic efficiency, apparent recovery of applied N also decreased as the levels of N increased in the urea alone treatments. Decrease in apparent recovery of N with increase in N levels has been reported by More and Ghonsikar (1984). Sharma and Srinivas (1997) also found lower recovery of N applied through urea by sorghum at 80 kg N ha^{-1} compared to that at 40 kg N ha^{-1}. The per cent N recovery was higher with gliricidia treatments compared to the 100% N through urea treatment. At equivalent N level, apparent N recovery is a direct function of whole plant N uptake. Accordingly, higher recovery of N with gliricidia treatments is due to higher N uptake. The per cent recovery of applied N was low with sorghum straw treatments. The lowest recovery was observed with 100% N through sorghum straw treatment (T_9). With this treatment, the apparent recovery was negative, indicating that rather than releasing N to plants, sorghum straw caused a locking up of plant available N because of the wide C:N ratio of sorghum straw. Similar results on apparent N recovery by sorghum with treatments involving urea + gliricidia and sorghum straw were reported by Sharma and Srinivas (1997). Hornick and Parr (1987) indicated that N use efficiency of crops increases when fertilizers are added in conjunction with organic manures. Amounts of N recovered with different treatments were higher in 1995 compared to 1994 due to higher N uptake by the crop in 1995 as discussed earlier. Otherwise, treatment effects on apparent N recovery were similar in both the years of study.

Conclusion

Crop growth and yield with gliricidia residues as N source were comparable to inorganic N source. Regardless of the level of N substitution, gliricidia produced yields on par with 100% N through urea. Thus, residues like gliricidia can be used as an alternative source of N to crop, and if sufficient quantities are available, can even replace inorganic N, provided native soil N status meets the needs of the early stages of crop growth. Unlike gliricidia residues, sorghum straw caused reduction in yield when used as a source of N, irrespective of the level of N substitution. Thus, wide C:N residues like sorghum straw are not advised as sources of N to crops but may be used as mulches for soil and water conservation or as organic amendments for building up soil organic matter and improving soil fertility.

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