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Effect of rice (*Oryza sativa*) stubble and nitrogen on performance of tobacco (*Nicotiana tabacum*) in rice-tobacco cropping system

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2001-04 to evaluate the effect of different pre-treatment practices to hasten rice (*Oryza sativa* L.) stubble decomposition and of nitrogen levels on performance of FCV tobacco (*Nicotiana tabacum* L.) in rice-tobacco cropping system in the rainfed Vertisols. The highest mean yields of green, cured and bright leaf of tobacco and grade index were recorded with sprays of 4% urea + cellulose degraders (*Cellulomonas* sp.) on stubbles and incorporation into the soil, which was 16.5, 11.6, 20.7 and 20.0% more, respectively compared with those of the stubbles incorporated without pre-treatment. Sprays of 4% urea + cellulose degraders also increased the leaf-equivalent yield of tobacco, system productivity, profitability, net returns and benefit : cost ratio; the leaf-lamina nitrogen, potassium and nicotine, and reduced sugars, and the sugars : nicotine ratio compared with those of other stubble pre-treatments. Soil-available N and P were significantly higher with sprays of 4% urea + cellulose degraders and application of 21.8 kg P/ha, respectively as compared with other stubble-decomposition methods. The bright leaf yield of tobacco and grade index were comparable with 45 and 60 kg N/ha to tobacco and significantly superior to 30 kg N/ha. Higher leaf-equivalent yield of tobacco, system productivity, profitability, net returns and benefit : cost ratio were obtained with 60 kg N/ha, closely followed by 45 kg N/ha. Benefit : cost ratio was higher with 45 kg N/ha. Leaf lamina concentrations of nitrogen and nicotine increased while sugars, and sugars : nicotine ratio decreased with increase in the level of N from 30 to 60 kg/ha. The soil-available N increased by 6.4% with 60 kg N/ha in comparison with 30 kg N/ha during the 3 years. Nitrogen dose of 45 kg N/ha proved adequate for tobacco when rice stubbles were pre-treated with sprays of 4% urea + cellulolytic bacteria *Cellulomonas* sp. in rice-tobacco cropping system.

Key words : Economics, FCV tobacco, Nitrogen, Productivity, Quality, Rice-tobacco system, Soil fertility, Stubble incorporation

Flue-cured Virginia (FCV) tobacco (*Nicotiana tabacum* L.) is grown traditionally as a mono-crop under conserved soil-moisture conditions during winter (*rabi*) season in Vertisols of Andhra Pradesh. Most of the lands remain fallow in rainy (*kharif*) season because a short period is available for field preparation between rice (*Oryza sativa.* L) harvesting and tobacco planting. Continuous monocropping of tobacco has adverse effect on the soil health, ultimately reducing the crop productivity. Development of a large number of high-yielding, short-duration varieties besides advent of efficient tools and implements for tillage has paved the way to raise a number of *kharif* crops preceding tobacco. The fertility status of soil and annual rainfall of around 1,100 mm received through south-west and north-east monsoons provide ample scope for crop intensification through cultivation of a number of *kharif* crops especially upland rice in 5,815 ha of black soils (Tobacco Board, 2007) preceding tobacco (Kasturi Krishna *et al.*, 2007). Different *kharif* crops exert variable influence on yield and quality of the succeeding FCV tobacco (Kasturi Krishna *et al.*, 2004b). Thus it is imperative to assess the requirement of nutrients, especially nitrogen, for tobacco in rice-tobacco cropping system. The incorporation of rice stubbles not only increases the productivity of the system but also sustains the soil health for a longer period (Singh and Yadav, 2006). However, limited time is available for decomposition of rice stubbles before tobacco planting. Hastening the stubble-decomposition process by inclusion of N, cellulolytic microbes and other decomposing materials at the time of residue incorporation may solve the problems associated with decomposition. As the information regarding rice-stubble decomposition and N requirement of tobacco succeeding *kharif* rice is meagre, the present investigation was carried out to devise appropriate technology for effective *in-situ* management of rice stubbles and to find out the optimum nitrogen dose

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to tobacco for getting higher productivity, quality and monetary returns of tobacco, as well as to study the changes in soil fertility in the rice-tobacco cropping system.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi* for three consecutive years (2001-04) at the research farm of Central Tobacco Research Institute, Rajahmundry, (16°59' N and 81°48' E at 25.3 m above mean sea-level) in East Godavari district of Andhra Pradesh. It is a hot dry subhumid agro-ecological sub-region (semi-arid tropical climate) with an average annual rainfall of 1,100 mm. The soils are silty clay (sand, silt and clay content in 0-22.5 cm soil layer was 16, 31 and 53% and in 22.5-45 cm it was 15, 31.5 and 53.5% respectively). The Godavari deltaic alluvium-derived Vertisols have slightly alkaline pH (7.76), low in electrical conductivity (0.25 dS/m), available N (190 kg/ha) and organic C (0.47 %) and high in available P (32.0 kg/ha) and K (490 kg/ha). Soil moisture at 33 kPa in 0-22.5 and 22.5-45.0 cm soil layer was 43 and 42.5% (w/w basis), whereas at 1,500 kPa it was 25 and 25.4% (w/w basis) respectively. The bulk density of the respective soil layers was 1.27 and 1.29 g/cc.

The experiment was carried out on permanent lay-out in split-plot design, replicated four times. There were 15 treatment combinations, consisting of five pre-treatment practices to hasten rice stubble decomposition before *in situ* incorporation in main plots viz. sprays of 4% urea on stubbles, spray of cellulose degraders (cellulolytic bacteria, *Cellulomonas* sp) on stubbles, application of 21.8 kg P/ha on stubbles, sprays of 4% urea + cellulose degraders on stubbles and incorporation of stubbles without pre-treatment; and three N levels in sub-plots, viz. 30, 45 and 60 kg N/ha to tobacco. The bacterium *Cellulomonas* sp. was obtained from T. Stanes Co. Ltd., Coimbatore, Tamil Nadu. Phosphorus was applied through single super-phosphate.

Seed of rice 'MTU 1010' (115 days duration) was direct sown 20 cm apart during the second week of July and the crop was harvested in the first week of November. After rice, the treatments were imposed on stubbles and *in-situ* incorporation was done on the next day in the main plots. Each main plot was divided into three sub-plots and N in the form of ammonium sulphate was applied in plough furrows, opened in 70 cm marker lines, and the N dose as per treatment was applied and covered with a levelling plank 15 days before tobacco planting. Tobacco 'VT 1158' was planted in *rabi* at 70 x 50 cm spacing during the last week of November in the plant rows where N was applied. The recommended package of practices was followed to grow rice in *kharif* under rainfed conditions and FCV tobacco in *rabi* with conserved soil moisture.

The rainfall received during *kharif* rice was 566 mm (44 rainy days) in 2001, 453 mm (37 rainy days) in 2002 and 905 mm (53 rainy days) in 2003. The amount of rainfall during *rabi* tobacco was 26 mm (8 rainy days) in 2001-02 and 101 mm (12 rainy days) in 2003-04 seasons. No rainfall was recorded during *rabi* 2002-03 season. During 2002-03 season 25 mm irrigation water was applied from the harvested rain water after harvesting rice to facilitate field preparation and stubble decomposition, as the residual soil moisture was less. Mean maximum and minimum temperatures during *rabi* tobacco were respectively 31.2 and 17.7°C in the first season, 31.1 and 16.8°C in the second season, and 30.6 and 17.7°C in the third season. The soil-moisture content before tobacco planting was 38.4, 40.6, 38.8, 41.0 and 39.2, 41.3% in 0-22.5 and 22.5-45 cm layers, during 2001-02, 2002-03 and 2003-04 seasons, respectively.

Tobacco leaves were harvested at maturity, at 7-8 days interval by priming, and cured in the flue-curing barn. About 2-3 matured leaves were harvested at each time and on an average eight primings were done to complete the harvesting of tobacco. After curing and bulking, leaves were graded based on colour and blemish. The data on cured-leaf and bright-leaf yield were recorded and grade index was calculated as per the formula suggested by Gopalachari (1984). Economics analysis was done based on the prevailing market prices of the inputs and produce. Profitability was calculated on net returns. The tobacco leaf-equivalent yield was computed by converting the *kharif* rice yield (grain and straw) to tobacco cured leaf yield on the basis of market prices, i.e. tobacco cured leaf @ Rs 42,000/t, rice @ Rs 6,150/t and straw @ Rs 5,000/ha. The tobacco leaf was analysed for different chemical quality parameters. Soil samples were collected from 0-22.5 cm depth at pre-sowing and post-harvest, and used to determine organic C, and the available N, P and K contents following standard procedures.

RESULTS AND DISCUSSION

Rice productivity

Grain yield of rice during rainy seasons of 2001, 2002 and 2003 was 3.38, 3.20 and 3.80 t/ha, respectively with a mean of 3.46 t/ha. The grain yield was by 0.18 t/ha (5.33%) less and 0.42 t/ha (12.43%) more in the second and third years, respectively compared with that in the first year. Straw yield was 5.29, 5.22 and 5.70 t/ha (mean 5.40 t/ha) and harvest index was 39, 38 and 40% (mean 39%) in the first, second and third seasons respectively. This variation in productivity could be attributed mainly to the differences in quantity and distribution of rainfall during *kharif*. In the second year the receipt of 20% less (113 mm) rainfall reduced the available soil water to rice, thus giving lower rice yield, whereas in the third year the receipt of 60% more (338 mm) rainfall increased the rice productivity due to availability of sufficient soil moisture during the rice-growing period compared with that in the first season (566 mm rainfall).

Tobacco productivity

Sprays of 4% urea + cellulose degraders (*Cellulomonas* sp.) recorded significantly higher yields of green leaf, bright leaf and grade index compared with other methods (Table 1). This was followed by spray of 4% urea of cellulose degraders, and application of 21.8 kg P/ha. Cured-leaf yield with 4% urea + cellulose degraders was comparable with 4% urea but significantly higher than other decomposition methods. Stubble incorporation without pre-treatment recorded lower tobacco yields. Sprays of 4% urea + cellulose degraders increased the yields of green leaf, cured leaf, bright leaf and grade index by 16.5, 11.6, 20.7 and 20.0% respectively compared with those on incorporation of stubbles without pre-treatment. The higher tobacco yield on incorporation of rice stubbles after sprays of 4% urea + cellulose degraders could be due to narrow C : N ratio as a result of urea spray and readily acting cellulose degrading bacteria. This resulted in proper decomposition and release of nutrients as per the need of the tobacco crop compared with wider C : N ratio under other decomposition-hastening methods (Singh and Yadav, 2006).

There was a significant increase in green-leaf and cured-leaf yields with increase in N level from 30 to 60 kg N/ha. Bright-leaf yield and grade index showed significant increase up to 45 kg N/ha and were comparable with those at 60 kg N/ha. Application of 45 and 60 kg N/ha increased the yields of green leaf by 9.5 and 13.8, of cured leaf by 8.4 and 11.7, of bright leaf by 13.9 and 14.8 and the grade index by 11.4 and 13.0% respectively compared with that of 30 kg N/ha. The increase in N dose from 30 to 45 kg resulted in 0.17 t/ha increase in cured-leaf yield, but the same increment of N from 45 to 60 kg/ha showed only 0.08 t/ha increase in its yield. The increase in yield with successive addition of N was progressively smaller, because the agronomic-use efficiency of N decreases with increase in N level. These results corroborate the findings of Krishna Reddy *et al.* (2003, 2006).

Tobacco quality parameters

Due to different methods of hastening stubble decomposition, the sugar content of leaf lamina varied from 16.15 to 15.09% and that of nicotine from 2.19 to 2.58%, whereas sugars : nicotine ranged between 7.6 and 6.0 (Table 2). Higher levels of nitrogen (2.40), potassium

Table 1. Green leaf, cured leaf and bright leaf yields and grade index of FCV tobacco as influenced by decomposition-hastening method of rice stubble and nitrogen application

Treatment	Green-leaf yield (t/ha)				Cured-leaf yield (t/ha)				Bright-leaf yield (t/ha)				Grade index (t/ha)				Tobacco leaf-equivalent yield (t/ha)	System productivity (kg/ha/day)
	2002	2003	2004	Pooled	2002	2003	2004	Pooled	2002	2003	2004	Pooled	2002	2003	2004	Pooled		
Stubble decomposition method																		
Spray of 4% urea	12.3	13.6	12.6	12.8	1.94	2.07	1.89	1.97	0.85	0.85	1.16	0.95	1.35	1.34	1.60	1.43	2.57	10.28
Sprays of cellulose degraders	12.1	13.2	12.1	12.5	1.87	2.00	1.82	1.89	0.81	0.85	1.15	0.94	1.38	1.38	1.54	1.43	2.49	9.96
Application of 21.8 kg P/ha	11.9	12.7	11.9	12.2	1.84	1.96	1.78	1.86	0.81	0.83	1.12	0.92	1.30	1.30	1.49	1.36	2.46	9.84
Sprays of 4% urea + cellulose degraders	12.6	14.2	13.3	13.4	1.95	2.13	1.98	2.02	0.94	0.99	1.32	1.08	1.43	1.52	1.72	1.56	2.62	10.48
Stubble incorporation without pre-treatment	11.2	12.1	11.2	11.5	1.80	1.90	1.73	1.81	0.80	0.81	1.09	0.90	1.26	1.22	1.42	1.30	2.41	9.64
SEm±	0.28	0.26	0.27	0.16	0.05	0.05	0.05	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.03	
CD (P=0.05)	0.85	0.81	0.83	0.43	0.14	0.14	1.14	0.07	0.08	0.07	0.09	0.04	0.10	0.08	0.10	0.05	0.08	
N levels to tobacco (kg/ha)																		
30	11.2	12.2	11.2	11.6	1.78	1.90	1.70	1.79	0.77	0.79	1.05	0.87	1.27	1.25	1.42	1.31	2.40	9.60
45	12.2	13.4	12.4	12.7	1.90	2.05	1.87	1.94	0.86	0.91	1.22	0.99	1.37	1.40	1.60	1.46	2.54	10.16
60	12.7	13.8	13.0	13.2	1.96	2.09	1.95	2.00	0.88	0.90	1.23	1.00	1.39	1.41	1.65	1.48	2.60	10.40
SEm±	0.12	0.12	0.11	0.07	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	
CD (P=0.05)	0.35	0.34	0.32	0.19	0.06	0.05	0.05	0.03	0.03	0.03	0.03	0.02	0.06	0.04	0.05	0.03	0.03	

(0.93), nicotine (2.58) and lower levels of sugars (15.09%) and sugars : nicotine (6.0) were recorded in the treatments where 4% urea + cellulose degraders were applied before stubble incorporation. Lower values of N, K and nicotine, and higher values of sugars and sugars : nicotine were recorded under stubble incorporation without pretreatment. This could be attributed to higher organic matter and residual N in the plots receiving 4% urea + cellulose degraders.

There was a significant increase in N and nicotine content with successive increase in N level up to 60 kg N/ha. Higher leaf-nicotine content (2.56%) was recorded with 60 kg N/ha. The leaf-K content increased from 30 to 45 kg N/ha but decreased at 60 kg N/ha. Reducing sugars and reducing sugars: nicotine were significantly higher with 30 kg N/ha, which decreased gradually up to 60 kg N/ha. It is the interplay of the N and carbohydrate metabolism that predetermines the quality and chemical composition of cured leaf of tobacco. Nitrate reductase is an important substrate-inducible enzyme and its activity is affected by the NO_3-N concentration of leaves, and consequent availability of the amount of N in the soil (Flower, 1999). There is a negative relationship between the activity of nitrate reductase and accumulation of starch in the leaves. Nitrogen is a component of the nicotine molecule and is important in its synthesis in tobacco. The concentration of nitrogen in leaves is positively correlated with nicotine and negatively with starch and sugar concentrations (Flower, 1999). Thus in the present study, an increase in the rate of fertilizer N increased the concentration of total nitrogen and nicotine and decreased the sugar and sugar : nicotine ratio in cured leaf of tobacco. However, lamina K content and sugars: nicotine ratio were in acceptable limits on application of 45 kg N/ha rather than that of 60 kg N/ha. These results are in conformity with the findings of Kasturi Krishna *et al.* (2004a) and Krishna Reddy *et al.* (2006). Phosphorus and chloride content in leaf was not altered by different methods of hastening stubble decomposition and nitrogen levels. All the chemical quality characters were well within the acceptable limits of good-quality leaf.

The climatic conditions influenced the bright leaf yield, grade index and leaf-quality characters, wherein significantly higher bright-leaf yield of tobacco (1.17 t/ha) and grade index (1.55) were obtained during 2003-04 season than during the other two seasons. Lower levels of N, nicotine and chlorides in the leaf and higher levels of sugars and sugars: nicotine were also obtained in this season. This variation in yield and quality in 2003-04 season was mainly due to higher amount of rainfall received during tobacco-growth period, which caused leaching of available soil N, thus reducing their availability to the plant compared with that in the first and second seasons. This leached N causes the early transition of nitrate to carbohydrate metabolism, which results in a larger than normal accumulation of starch and smaller total nitrogen and nicotine (Chandrasekhararao and Reddy, 1998; Flower, 1999)

System productivity and economics

The highest leaf-equivalent yield of tobacco, system productivity (Table 1), profitability, net returns and benefit : cost ratio (Table 3) were obtained with spray of 4% urea

Table 2. Nutrient composition and chemical quality parameters in leaf lamina of FCV tobacco as influenced by decomposition hastening method of rice stubble and nitrogen application (pooled mean of three seasons)

Treatment	N (%)	P (%)	K (%)	Reducing sugars (%)	Nicotine (%)	Reducing sugars : nicotine	Chlorides (%)
Stubble decomposition method							
Spray of 4% urea	2.32	0.23	0.91	15.62	2.52	6.32	1.32
Spray of cellulose degraders	2.22	0.23	0.89	15.82	2.43	6.70	1.37
Application of 21.8 kg P/ha	2.13	0.25	0.87	16.04	2.36	7.00	1.40
Sprays of 4% urea + cellulose degraders	2.40	0.22	0.93	15.09	2.58	6.00	1.28
Stubble incorporation without pre-treatment	2.08	0.22	0.87	16.15	2.19	7.60	1.40
SEm±	0.02	0.01	0.01	0.06	0.01	0.06	0.04
CD (P=0.05)	0.05	NS	0.04	0.21	0.04	0.17	NS
N to tobacco (kg/ha)							
30	2.08	0.24	0.88	17.14	2.25	7.87	1.41
45	2.26	0.23	0.95	15.53	2.45	6.51	1.34
60	2.35	0.22	0.85	14.56	2.56	5.79	1.31
SEm±	0.02	0.01	0.01	0.05	0.01	0.06	0.04
CD (P=0.05)	0.05	NS	0.04	0.14	0.04	0.16	NS
Acceptable limits	1.0–3.0	0.20–0.25 (Vertisols)	≥0.90 (Low in Vertisols)	8.0–24.0	0.7–3.5	6.0–13.0	<1.5

Table 3. Economics and changes in soil-chemical parameters after three crop cycles as influenced by decomposition-hastening method of rice stubble and nitrogen application in rice–virginia tobacco cropping system

Treatment	Cost of cultivation ($x10^3$ Rs/ha)		Net returns ($x10^3$ Rs/ha)		B : C ratio	Profitability (Rs/ha/ day)	Changes in soil fertility			
	Tobacco	System	Tobacco	System			Organic C (%)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Stubble-decomposition method										
Spray of 4% urea	52.8	67.5	29.7	40.3	1.59	161.2	0.49	85.0	12.3	214
Spray of cellulose degraders	51.4	66.1	28.0	38.6	1.58	154.4	0.49	83.9	13.3	216
Application of 21.8 kg P/ha	50.8	65.7	27.3	37.9	1.58	151.6	0.48	82.3	17.6	211
Sprays of 4% urea + cellulose degraders	54.1	68.8	30.7	41.3	1.60	165.2	0.50	87.2	14.2	216
Stubble incorporation without pre-treatment	49.7	64.4	26.3	36.9	1.57	147.6	0.48	82.6	12.3	218
SEm±							0.01	0.9	0.2	2
CD (P=0.05)							NS	3.0	0.7	NS
N levels to tobacco (kg/ha)										
30	48.9	63.6	26.4	37.0	1.58	148.0	0.48	81.4	14.1	217
45	52.3	67.0	29.1	39.7	1.59	158.8	0.49	84.6	13.9	215
60	54.0	68.8	29.7	40.3	1.58	161.2	0.50	86.6	13.7	213
SEm±							0.01	0.4	0.1	2
CD (P=0.05)							NS	1.5	NS	NS
Initial soil-test value							0.47	84.8	14.3	219

+ cellulose degraders followed by individual spray of 4% urea. The increase in cured-leaf productivity of tobacco with spray of urea + cellulose degraders on rice stubbles resulted in higher leaf-equivalent yields of tobacco and system productivity, and thus higher net returns and more profitability. The higher monetary returns might be also due to relatively lower productivity cost in this treatment. Lowest leaf-equivalent yield of tobacco, system productivity and economics were recorded with stubble incorporation without pre-treatment. Among the N doses, higher leaf-equivalent yield of tobacco, system productivity, profitability and net returns were recorded with application of 60 kg N/ha, closely followed by 45 kg N/ha. This was due to the higher cured-leaf yield of tobacco in this treatment. However, benefit : cost ratio was higher (1.59) with application of 45 kg N/ha, closely followed by that of 60 kg N/ha (1.58).

Soil fertility

Residual soil fertility indicated significant variation in the available N and P status of soil but there was no change in organic C and available K (Table 3). Available N ranged from 82.35 to 87.25 mg/kg with different practices of hastening stubble decomposition, which was significantly higher (87.25 mg/kg) with sprays of 4% urea + cellulose degraders. This might be due to the combined effect of urea spray and mechanism of action of the cellulolytic microorganisms that are involved in mineralization of organic matter which increased the available soil N. Kumar *et al.* (2004) and Singh and Yadav (2006) also reported an increase in the status of available N of the soil on rice-stubble incorporation in other cropping systems. The lowest available soil N was noticed in stubble incorporation without pre-treatment. Application of 21.8 kg P/ha on stubbles before incorporation significantly increased the available P status of the soil compared with other practices hastening stubble decomposition. This could be due to the application of P on rice stubbles and lower quantity of P removal (5-6 kg/ha) by the succeeding tobacco. Available N status of the soil varied significantly and was higher (86.65 mg/kg) with application of 60 kg N/ha and lower (81.44 mg/kg) with 30 kg N/ha. Average P status of the soil decreased slightly from initial value of soil test, i.e. 14.30 to 13.97 mg/kg. Marked differences were not observed with pH and organic C of soil.

It was concluded that sprays of 4% urea + cellulolytic bacteria *Cellulomonas* sp. on stubbles and incorporation into the soil improve the soil fertility, thereby improving the productivity, quality and monetary returns of the succeeding tobacco, and thus system productivity. Nitrogen dose of 45 kg N/ha was found adequate for tobacco in rice-virginia tobacco cropping system.

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