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INTEGRATED NUTRIENT MANAGEMENT FOR PRODUCTIVITY AND QUALITY OF FCV TOBACCO (*NICOTIANA TABACUM*) IN IRRIGATED ALFISOLS

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A field experiment was conducted during the crop seasons of 2002-05, to find out the response of flue-cured Virginia tobacco (*Nicotiana tabacum* L.) to integrated use of organic manures, biofertilisers and inorganic fertilizers in irrigated Alfisols (northern light soils) at Jeelugumilli in Andhra Pradesh. Results pooled over the years showed that addition of dual cultures of *Azotobacter* and *Azospirillum* along with co-inoculation of VAM fungi and PSB to tobacco grown after sunnhemp *in situ* green manuring (GM) with 8.7 kg P/ha and application of 90-8.7-99.9 kg NPK/ha followed by 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray (T_{10}) increased yields of green leaf by 1.46 t/ha (8.50%), cured leaf by 0.15 t/ha (6.78%) and grade index by 0.23 (14.47%); grade index/cured leaf by 5% and cured leaf production efficiency by 0.92 kg/ha/day compared with those of the recommended practice of fertilizer application *i.e.* sunnhemp with 8.7 kg P (*in situ* GM) + 110-17.5-99.9 kg NPK/ha (T_3). Higher content of nicotine, total nitrogen and lower content of reducing sugars in tobacco leaf lamina; higher net returns, B:C ratio, profitability and higher soil available N were recorded in the treatment T_{10} compared to other treatments. Co-inoculation of VAM fungi + PSB cultures to tobacco grown with sunnhemp *in situ* GM saved 8.7 kg P/ha. Dual inoculation of free nitrogen fixing *Azotobacter* and *Azospirillum* to tobacco grown after sunnhemp *in situ* GM showed a saving of 20 kg N/ ha. Foliar spray of 0.2% $ZnSO_4$ (T_{10}) increased yields of green leaf by 0.75 t/ha (4.19%), cured leaf by 0.09 t/ha (3.96) and grade index by 0.12 (7.06%), grade index/ cured leaf by 2.2% and cured leaf production efficiency by 0.55 kg/ha/day compared with those of the treatment without foliar spray of $ZnSO_4$ *i.e.* T_9. It was concluded that treatment (T_{10}) saved 8.7 kg P and 20 kg N/ha and produced higher cured leaf yield, grade index, better chemical quality in lamina, accrued higher net returns and improved soil available N.

Key words: FCV tobacco, INM, NLS, Productivity

INTRODUCTION

Flue-cured Virginia (FCV) tobacco (*Nicotiana tabacum* L.) is an important excise and foreign exchange earning commercial crop of India grown mainly in the states of Andhra Pradesh and Karnataka. Semi-flavorful to flavorful FCV tobacco required for domestic as well as international markets is being cultivated in an area of around 26000 ha, producing nearly 55 million kg of tobacco leaf annually in Alfisols under irrigated conditions, popularly termed as Northern Light Soil (NLS) area, comprising East Godavari, West Godavari and Khammam districts of Andhra Pradesh (Tobacco Board, 2008). Long-term fertilizer effects show that a total dependence on inorganic fertilizer alone has a deleterious effect on soil health by damaging physical and chemical properties, besides leading to nutrient imbalances in soil which consequently reduced crop productivity. Application of organic matter to soil increases the water holding capacity of soil besides adding major and micronutrients and reducing the leaching losses of nitrogen. Organic manures such as farmyard manure, filter press cake, sunnhemp [*Crotalaria juncea* (L.) Rotar and Joy] *in situ* green manuring also improve the body, aroma, pliability and other quality parameters in tobacco. Biofertilizers like *Azotobacter* (Narasimha Rao *et al.*,1995) and *Azospirillum* (Harishu Kumar *et al.*,1991) are known to improve the nitrogen economy by assimilating free atmospheric nitrogen in FCV tobacco. Vesicular arbuscular mycorrhizal (VAM) fungi are known to improve the availability of P and Zn by absorption of P and Zn from soil by fungal hyphae, translocation and transfer to host and phosphate solubilising bacteria (PSB) are apparently known to increase the plant availability of native and applied phosphorus (Yadav *et al.,* 2008). Although chemical fertilizers will continue

to be the main components for meeting the increased crop nutrition needs, agronomic practices involving integrated use of fertilizers, organic manures and biofertilizers is required to reduce the application of chemical fertilizers and cost of cultivation besides being an eco-friendly approach. This approach also helps in sustaining moderate to high productivity and profitability of the field crops and at the same time restores soil health by improving physical and chemical properties of soils. Keeping these points in view, the present experiment was conducted to assess the impact of conjunctive use of organic manures, biofertilisers and chemical fertilizers through soil and foliar application on the yield, quality, economics of FCV tobacco cv. Kanchan and soil health in terms of soil organic C, N, P and K content under irrigated Alfisols of Andhra Pradesh.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* 2002-03, 2003-04 and 2004-05 at the research farm of Central Tobacco Research Institute Research Station, Jeelugumilli, West Godavari district, Andhra Pradesh. The top soil (0-22.5 cm) was sandy loam and deeper layers (22.5-45 cm) were sandy clay, classified as Typic Haplustalfs with slightly acidic pH {(1:2.5) 6.30}, low electrical conductivity {(1:2.5) 0.22 dS/m}, chlorides (32 mg/kg), organic C (0.24%), available N (150 kg/ha), high available P (25 kg/ha) and medium available K (209 kg/ha).

The experiment consisted of 12 treatment combinations *viz.*, T_1= FYM (10 t/ha) + 110-26.2-99.9 kg NPK/ha; T_2 = FPC (10 t/ha) + 110-26.2-99.9 kg NPK/ha; T_3 = Sunnhemp with 8.7 kg P {*in situ* green manuring (GM)} + 110-17.5-99.9 kg NPK/ha; T_4 = Sunnhemp with 8.7 kg P (*in situ* GM) + 110-8.7-99.9 kg NPK/ha + VAM fungi; T_5 =T_4 + PSB; T_6 = Sunnhemp with 8.7 kg P (*in situ* GM) + 90-17.5-99.9 kg NPK/ha + *Azotobacter*; T_7 =T_6 + *Azospirillum*; T_8 = Sunnhemp with 8.7 kg P (*in situ* GM) + 90-8.7-99.9 kg NPK/ha + VAM fungi + PSB + *Azotobacter* + *Azospirillum*; T_9 = T_8 + 0.2% $MgSO_4$ spray; T_{10} = T_9 + 0.2% $ZnSO_4$ spray; T_{11} = FPC (10 t/ha)+ 90-17.5-99.9 kg NPK/ha + All biofertilisers + 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray; T_{12} = FYM (10 t/ha) + 90-17.5-99.9 kg NPK/ha + All biofertilisers + 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray; replicated three times in a randomized block design on a permanent layout.

Sunnhemp seed @ 50 kg/ha was sown in the first week of June and *in situ* incorporation was done before flowering in first week of August. The incorporated dry matter of sunnhemp was about 4.0 t/ha with N content of 3.40% (on oven dry weight basis). Farmyard manure (FYM) and filter press cake (FPC) @ 10 t/ha were applied one month before expected date of tobacco planting and incorporated into the soil after spreading uniformly as per the treatment. N, P and K content of FYM was 0.48, 0.20 and 0.48 and those of FPC were 0.75, 0.30 and 0.60%, respectively. In treatments having biofertilizers viz., *Azospirillum*, *Azotobacter* and 'phosphate-solubilizing bacteria' (PSB) or phosphobacteria (*Pseudomonas striata*) slurry was prepared by mixing 250 g of respective culture and 5 liters of water. The roots of the tobacco seedlings were dipped in this slurry for 30 minutes and then transplanted. Vesicular arbuscular mycorhizal (VAM) fungi (*Glomus fasciculatum*) were mixed with sand in 1:10 proportion and the mixture was applied and mixed uniformly in the planting places in the plots having VAM fungi treatment. The biofertilisers were obtained from Agricultural Research Station, Amaravathi (ANGRAU), Guntur district, Andhra Pradesh. The gross plot size was 6 X 6 m (60 plants) and the net plot size was 4 X 4.8 m (32 plants). Sixty-day-old seedlings of tobacco cv Kanchan were planted with a spacing of 100 X 60 cm in the first week of October. Nitrogen, phosphorus and potassium were applied as per the treatments. Nitrogen was applied in three splits in 1:2:1 proportion at 10, 30 and 45 days after planting. First split of N and full dose of P in the form of di-ammonium phosphate and 50% K in the form of potassium sulphate were applied 10 days after planting as basal dose. Second split of N was given through calcium ammonium nitrate along with remaining 50% K in the form of potassium sulphate at 30 days after planting. Remaining 25% N was top dressed at 45 days after planting adopting dollop method. Foliar spray of 0.2% $MgSO_4$ and 0.2% $ZnSO_4$ was done twice with 600 liters of spray fluid at 35 and 45 days after planting as per treatment. The recommended package of practices was followed to grow tobacco crop except the inputs applied as treatments. The crop was topped at 24

leaves at bud stage. Decanol (n-deconal, a fatty alcohol based suckericide) 4% was applied @ 10-15 ml/plant immediately after topping for preventing the sucker growth.

Tobacco leaves were harvested at maturity and flue-cured. The data on green leaf and cured leaf were recorded and grade index was calculated. Economics was calculated based on the prevailing market prices of the inputs and produce *i.e.* tobacco cured leaf @ Rs 52,000/t. Profitability was calculated on net returns. The tobacco cured leaf samples from primings (P), lugs and cutters (X), leaf (L) and tips (T) positions were collected, processed and analyzed for reducing sugars, nicotine, chlorides, total N, P and K as per the standard procedures. Soil samples were collected from 0-22.5 cm depth at pre-sowing and post-harvest and estimated pH, electrical conductivity (EC), organic C, available N, P and K contents following standard procedures.

RESULTS AND DISCUSSION

Yield characters

Results of pooled data over the years (Table 1) showed that co-inoculation of VAM fungi + PSB cultures to tobacco grown after sunnhemp *in situ* GM with 8.7 kg P/ha and 110-8.7-99.9 kg NPK/ha to tobacco (T_5) improved yields of green leaf by 0.44 (2.56), cured leaf by 0.05 (2.26) and grade index by 0.03 t/ha (1.89%) compared with those of the tobacco grown after sunnhemp *in situ* GM with 8.7 kg P and 110-17.5-99.9 kg NPK/ha (Recommended practice T_3). By co-inoculation of VAM fungi + PSB, 8.7 kg P/ha was saved. The differences in growth response with VAM fungi was attributed to absorption of P and Zn from soil by fungal hyphae, translocation and transfer to the host (Yadav *et al.,* 2008). The beneficial effect of PSB may be due to increased availability of native and applied soil phosphorus to the plant. The use of phosphobacteria and VAM fungi is undoubtedly of value in increasing crop yields (Yadav *et al.,* 2008).

Addition of dual culture of free nitrogen fixing *Azotobacter* and *Azospirillum* to tobacco grown after sunnhemp *in situ* GM with 8.7 kg P and 90-17.5-99.9 kg NPK/ha (T_7) improved yields of green leaf by 0.24 t/ha (1.40%), cured leaf by 0.02 t/ha (0.90%) and grade index by 0.03 (1.89%) compared to recommended practice (T_3), thus showing a saving of 20 kg N/ha. The better response of FCV tobacco for *Azospirillum* dip was mainly due to increased leaf growth which may be attributed to increased N availability through N fixation and secretion of plant growth promoting substances by *Azospirillum* culture compared with no *Azospirillum* treatments (Narasimha Rao *et al.*,1995).

Combined addition of dual cultures of *Azotobacter* and *Azospirillum* along with co-inoculation of VAM fungi and PSB to tobacco grown after sunnhemp *in situ* GM with 8.7 kg P and 90-8.7-99.9 kg NPK/ha (T_8) increased yields compared to the recommended practice (T_3) and showing a total saving of 20 kg N and 8.7 kg P/ha.

Combined addition of dual cultures of *Azotobacter* and *Azospirillum* along with co-inoculation of VAM fungi and PSB to tobacco grown after sunnhemp *in situ* GM with 8.7 kg P/ha and 90-8.7-99.9 kg NPK followed by 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray (T_{10}) increased yields of green leaf by 1.46 t/ha (8.50%), cured leaf by 0.15 t/ha (6.78%), grade index by 0.23 (14.47%), grade index/cured leaf by 5% and cured leaf production efficiency by 0.92 kg/ha/day compared with those of the recommended practice (T_3). $ZnSO_4$ spray of 0.2% (T_{10}) increased yields of green leaf by 0.75 (4.19), cured leaf by 0.09 (3.96), grade index by 0.12 t/ha (7.06%); grade index/cured leaf by 2.2% and cured leaf production efficiency by 0.55 kg/ha/day compared with those of the treatment T_9. The increase in green and cured leaf yield is not statistically significant. However, grade index increased significantly due to Zn spray. Zinc application contributed to increased yield probably owing to its influence on protein and auxin synthesis and N fixation (Anuradha *et al.*, 2005). Application of FYM and FPC @10 t/ha in lieu of sunnhemp *in situ* GM were not giving comparable tobacco yields and thus sunnhemp *in situ* GM is definitely better than application of organic manures.

Chemical quality characters

Reducing sugars, nicotine, chlorides, total nitrogen, phosphorus, and potassium in leaf lamina are important chemical quality parameters

Table 1: Tobacco yield attributes as influenced by integrated nutrient management (pooled)

Tr.No.	Treatments	Tobacco yield (t/ha)			Green leaf/ cured leaf	Grade index / cured leaf (%)	Cured leaf productivity (kg/ha/day)
		Green leaf	Cured leaf	Grade index			
T_1	FYM (10 t/ha) + 110-26.2-99.9 kg NPK /ha	14.19	1.88	1.34	7.50	71.2	11.53
T_2	FPC (10 t/ha) + 110-26.2-99.9 kg NPK /ha	14.26	1.93	1.37	7.36	71.3	11.84
T_3	Sunnhemp with 8.7 kg P (*in situ* GM) + 110-17.5-99.9 kg NPK /ha	17.18	2.21	1.59	7.73	72.1	13.56
T_4	Sunnhemp with 8.7 kg P + 110-8.7-99.9 kg NPK /ha+ VAM	17.35	2.24	1.60	7.77	71.7	13.74
T_5	T_4 + PSB	17.62	2.26	1.62	7.76	71.9	13.87
T_6	Sunnhemp with 8.7 kg P + 90-17.5-99.9 kg NPK /ha + *Azotobacter*	17.05	2.19	1.59	7.79	72.3	13.44
T_7	T_6 + *Azospirillum*	17.42	2.23	1.62	7.84	72.6	13.68
T_8	Sunnhemp with 8.7 kg P + 90-8.7-99.9 kg NPK /ha + VAM + PSB + *Azotobacter* + *Azospirillum*	17.72	2.25	1.64	7.85	72.6	13.80
T_9	T_8 + 0.2% $MgSO_4$ spray	17.89	2.27	1.70	7.87	74.9	13.93
T_{10}	T_9 + 0.2% $ZnSO_4$ spray	18.64	2.36	1.82	7.47	77.1	14.48
T_{11}	FPC (10 t/ha)+ 90-17.5-99.9 kg NPK /ha + All biofertilisers + 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray	16.21	2.16	1.60	7.47	76.3	13.25
T_{12}	FYM (10 t/ha)+ 90-17.5-99.9 kg NPK /ha + All biofertilisers + 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray	15.69	2.12	1.60	7.48	76.4	13.01
	SEm±	**0.35**	**0.04**	**0.04**	**0.04**	**0.36**	**0.23**
	CD (P=0.05)	**0.97**	**0.11**	**0.10**	**0.12**	**1.00**	**0.64**
	Seasons						
	2002-03	13.26	1.77	1.30	7.47	73.5	10.86
	2003-04	16.76	2.24	1.61	7.50	72.8	13.74
	2004-05	20.29	2.51	1.86	8.07	74.0	15.40
	SEm±	**0.25**	**0.04**	**0.03**	**0.03**	**0.26**	**0.20**
	CD (P=0.05)	**0.85**	**0.14**	**0.10**	**0.11**	**0.88**	**0.68**

Table 2: Chemical composition of FCV tobacco leaf lamina as influenced by integrated nutrient management (pooled)

Treatments	Reducing sugars (%)				Nicotine (%)				Chlorides (%)				Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	P	X	L	T	P	X	L	T	P	X	L	T	P	X	L	T	P	X	L	T	P	X	L	T
T_1	14.05	20.27	16.17	13.68	1.39	1.71	2.59	2.90	0.33	0.41	0.51	0.57	1.51	1.85	2.70	2.97	0.26	0.32	0.26	0.22	1.71	1.92	2.46	2.30
T_2	13.65	20.07	15.95	13.45	1.41	1.73	2.67	2.95	0.32	0.34	0.45	0.51	1.53	1.87	2.77	3.04	0.25	0.31	0.25	0.22	1.67	1.85	2.39	2.23
T_3	12.66	19.18	15.03	12.53	1.55	1.86	2.80	3.11	0.30	0.40	0.52	0.59	1.68	2.00	2.91	3.21	0.25	0.32	0.26	0.23	1.68	1.88	2.46	2.26
T_4	12.05	18.51	14.50	11.93	1.61	1.91	2.86	3.17	0.36	0.36	0.45	0.51	1.74	2.04	2.97	3.27	0.27	0.34	0.28	0.24	1.61	1.84	2.40	2.20
T_5	11.49	17.68	13.73	11.13	1.65	1.96	2.97	3.27	0.35	0.42	0.47	0.53	1.78	2.08	3.07	3.37	0.27	0.34	0.29	0.25	1.60	1.79	2.30	2.11
T_6	12.87	19.65	15.29	12.84	1.51	1.81	2.79	3.09	0.35	0.42	0.46	0.51	1.64	1.96	2.92	3.18	0.26	0.33	0.28	0.24	1.69	1.90	2.48	2.30
T_7	12.41	18.81	14.72	12.13	1.58	1.89	2.84	3.15	0.38	0.38	0.47	0.54	1.71	2.01	2.95	3.24	0.26	0.32	0.27	0.23	1.64	1.85	2.44	2.23
T_8	11.80	18.17	14.12	11.76	1.63	1.94	2.89	3.22	0.38	0.39	0.48	0.54	1.76	2.06	3.00	3.32	0.28	0.35	0.30	0.26	1.61	1.81	2.34	2.14
T_9	11.24	17.47	13.42	11.16	1.67	1.98	3.03	3.34	0.39	0.34	0.48	0.55	1.80	2.10	3.13	3.43	0.28	0.35	0.31	0.27	1.59	1.78	2.29	2.10
T_{10}	10.97	16.58	12.79	10.44	1.69	2.00	3.13	3.44	0.36	0.36	0.46	0.52	1.83	2.13	3.23	3.53	0.29	0.37	0.32	0.28	1.58	1.77	2.27	2.08
T_{11}	13.08	19.76	15.63	13.13	1.47	1.80	2.77	3.07	0.36	0.34	0.45	0.49	1.61	1.94	2.90	3.15	0.24	0.30	0.25	0.21	1.61	1.81	2.47	2.33
T_{12}	13.27	19.94	15.81	13.25	1.46	1.77	2.75	3.04	0.38	0.41	0.46	0.52	1.59	1.92	2.88	3.13	0.23	0.30	0.25	0.21	1.64	1.83	2.48	2.35
SEm±	0.16	0.15	0.17	0.12	0..03	0.02	0.04	0.05	0.01	0.01	0.01	0.01	0.03	0.04	0.05	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.02
CD (P=0.05)	0.44	0.43	0.47	0.33	0..07	0.07	0.11	0.13	0.04	0.04	0.03	0.03	0.08	0.10	0.13	0.09	0.02	0.02	0.02	0.02	0.06	0.06	0.07	0.06
Seasons																								
2002-03	13.05	19.42	15.87	12.93	1.41	1.71	2.64	2.98	0.31	0.34	0.43	0.47	1.52	1.84	2.75	3.07	0.23	0.30	0.26	0.23	1.58	1.77	2.34	2.17
2003-04	12.74	18.99	14.95	12.41	1.55	1.86	2.84	3.18	0.36	0.38	0.47	0.55	1.70	2.00	2.97	3.27	0.26	0.34	0.28	0.24	1.65	1.85	2.40	2.22
2004-05	11.59	18.12	13.47	11.52	1.70	2.02	3.04	3.28	0.41	0.43	0.52	0.58	1.83	2.15	3.14	3.37	0.28	0.35	0.30	0.26	1.69	1.90	2.45	2.26
SEm±	**0.11**	**0.11**	**0.10**	**0.05**	**0.01**	**0.01**	**0.01**	**0.03**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.03**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**
CD (P=0.05)	**0.37**	**0.38**	**0.33**	**0.19**	**0.04**	**0.05**	**0.04**	**0.09**	**0.02**	**0.03**	**0.02**	**0.05**	**0.05**	**0.12**	**0.05**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.04**	**0.03**	**0.06**	**0.04**
Acceptable limits	8.0 -24.0				0.7 – 3.5				<1.5				1.0 - 3.0				0.20 -0.40				1.5-3.0			

P = Primings (first and second harvest from bottom), X = Lugs and cutters (third and fourth harvest), L = Leaf (fifth to 10th harvest) and T= Tips (11th and 12th harvest) @ two leaves per harvest.

influenced by different components of INM (Table 2). Relatively higher contents of nicotine, total nitrogen and lower contents of reducing sugars in tobacco leaf lamina were recorded in all the plant positions in the treatment T_{10} compared to other treatments. This trend could be attributed to higher nitrogen availability and foliar spray of $MgSO_4$ and $ZnSO_4$ in this treatment**.** Lower contents of total N, nicotine and higher content of reducing sugars in tobacco leaf lamina were recorded in all the plant positions in the treatments $T_{1,}$ $T_{2,}$ T_{11} and T_{12} that received FYM and FPC @ 10 t/ha (in addition to other INM components) compared to other treatments that have sunnhemp *in situ* GM with 8.7 kg P/ha (T_3-T_{10}). This might be due to lower N supply from FYM and FPC as compared to sunnhemp *in situ* GM which is evident from lower soil organic C and residual N in these treatments.

There was a gradual increase of nicotine, total N and decrease in sugars with increase in soil available N in all plant positions. It is the interplay of the N and carbohydrate metabolism as influenced by management that predetermines the quality and chemical composition of cured leaf of tobacco. 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 correlated with starch and sugar concentrations (Flower, 1999). Thus in the present study, an increase in the soil available N and organic C increased the concentration of total nitrogen and nicotine and decreased the sugar and sugar: nicotine ratio in tobacco cured leaf. Similar observations were also reported by Kasturi-Krishna *et al.*, (2009) and Krishna-Reddy *et al.* (2008). Although chloride concentration in lamina varied among the treatments, it was well within the normal limits of good quality leaf. Usually leaf chlorides >1.5% is not preferred as the leaf absorbs more moisture, becomes pale and slick and adversely affects leaf burning quality.

The variations in yield parameters and lamina quality characteristics were significant between the seasons. Higher green leaf, cured leaf, grade index and cured-leaf productivity and higher levels of lamina total N, nicotine and lower sugars in all plant positions were recorded during the third season compared with those of the first and second seasons. This was mainly due to the carry over (residual) and cumulative effect of organic manures applied in the first and second season crop and more than the carry over effect, the benefit in improving soil health made it to produce higher tobacco leaf yields, and increased lamina total N and nicotine in third season compared with first and second season (Kasturi-Krishna *et al.*, 2009 and Krishna-Reddy *et al.*, 2009). The study also revealed that the lamina total N, nicotine and potassium contents increased gradually from P to T positions and reducing sugars and P concentrations increased from P to X position and there after decreased gradually up to T position in all the treatments (Table 2). Distribution of nicotine, reducing sugars, total N, P and K in different plant positions followed the normal trend in all the treatments (Gopalachari, 1984). All the chemical quality parameters were within the acceptable limits in all the plant positions.

Economics

The highest net return, B: C ratio and profitability were obtained with $T_{10.}$ foliar sprays of Zn and Mg along with other INM components have improved the cured leaf yields leading to increase in gross returns and hence accrued higher net returns in these treatments. In general, higher net returns were obtained with sunnhemp *in situ* GM due to the higher tobacco cured leaf yields in these treatments as compared to application of FYM and FPC @ 10 t/ha.

Residual soil fertility

Residual soil fertility indicated significant variation in the available N status of soil, but there was no change in pH, EC, organic C, available P and K (Table 3). Available N ranged from 152.3 to 162.9 kg/ha under different treatments. The treatment T_{10} being on a par with the treatments having sunnhemp *in situ* GM i.e.T_3-T_9 showed significantly higher soil available N as compared to other treatments having application of FYM and FPC @10 t/ha (T_1,T_2,T_{11} and T_{12}). Lower values of soil available N was recorded in the treatments that received FYM and FPC in lieu of sunnhemp *in situ* GM. The higher soil available N in sunnhemp *in situ* GM-tobacco system might be the result of enhanced microbial activity due to accretion of

Table 3: Economics and residual soil fertility as influenced by integrated nutrient management after three crop seasons

Tr. No.	Treatments	Economics (x10³ Rs/ha)			B: C ratio	Profitability (Rs/ha/day)	Soil chemical parameters					
		Gross returns	Cost of cultivation	Net returns			pH	EC (dS/m)	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available (kg/ha)
T_1	FYM (10 t/ha) + 110-26.2-99.9 kg NPK /ha	97.76	67.44	30.32	1.45	186.0	6.40	0.23	0.24	152.3	26.1	215
T_2	FPC (10 t/ha)+ 110-26.2-99.9 kg NPK /ha	100.36	68.44	31.92	1.47	195.8	6.37	0.24	0.25	153.2	26.5	216
T_3	Sunnhemp with 8.7 kg P (*in situ* GM) + 110-17.5-99.9 kg NPK /ha	114.92	72.04	42.88	1.60	263.1	6.20	0.23	0.26	158.7	28.0	217
T_4	Sunnhemp with 8.7 kg P + 110-8.7-99.9 kg NPK /ha+ VAM	116.48	72.34	44.14	1.61	270.8	6.20	0.24	0.26	158.0	29.0	214
T_5	T_4 + PSB	117.52	72.79	44.73	1.61	274.4	6.23	0.23	0.27	159.6	29.9	213
T_6	Sunnhemp with 8.7 kg P+ 90-17.5-99.9 kg NPK /ha + *Azotobacter*	113.08	70.73	42.35	1.60	259.8	6.23	0.23	0.25	157.5	28.4	214
T_7	T_6 + *Azospirillum*	115.96	71.58	44.38	1.62	272.3	6.20	0.21	0.26	160.2	28.6	215
T_8	Sunnhemp with 8.7 kg P+ 90-8.7-99.9 kg NPK /ha + VAM + PSB + *Azotobacter* + *Azospirillum*	117.00	71.73	45.27	1.63	277.7	6.20	0.22	0.27	159.2	27.9	212
T_9	T_8 + 0.2% Mg SO_4 spray	118.04	72.53	45.51	1.63	279.2	6.20	0.23	0.28	159.0	27.2	211
T_{10}	T_9 + 0.2% Zn SO_4 spray	122.72	74.73	47.99	1.64	294.4	6.23	0.24	0.28	162.9	27.0	210
T_{11}	FPC (10 t/ha)+ 90-17.5-99.9 kg NPK /ha + All biofertilizers + 0.2% Mg SO_4 spray + 0.2% Zn SO_4 spray	112.32	72.33	39.99	1.55	245.3	6.33	0.24	0.25	153.2	26.7	217
T_{12}	FYM (10 t/ha)+ 90-17.5-99.9 kg NPK /ha + All biofertilizers + 0.2% Mg SO_4 spray + 0.2% Zn SO_4 spray	110.24	71.53	38.71	1.54	237.5	6.40	0.24	0.24	152.3	26.4	216
	SEm±						**0.07**	**0.02**	**0.01**	**1.71**	**0.81**	**2.68**
	CD (P=0.05)						**NS**	**NS**	**NS**	**5.00**	**NS**	**NS**
	Grand Mean						6.27	0.23	0.26	157.2	27.64	214.17
Initial soil test value							6.30	0.22	0.24	150.0	25	209

fresh organic matter with higher N content as a consequence of sunnhemp incorporation into the soil (Krishna Reddy *et al.*, 2007). Perceptible improvement in soil fertility in terms of organic C, available N, P and K was noticed as compared to initial soil test values, though the differences were not significant statistically.

It was concluded that combined inoculation of dual cultures of *Azotobacter* and *Azospirillum* along with co-inoculation of VAM fungi and PSB to tobacco grown after sunnhemp *in situ* GM with 8.7 kg P and 90-8.7-120 kg NPK/ha followed by 0.2% $MgSO_4$ spray + 0.2% $ZnSO_4$ spray (T_{10}) produced higher cured leaf yield, grade index, better chemical quality in lamina, accrued higher net returns and improved soil available N.

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