Indian Journal of Agronomy **53**(1): 70–75 (March 2008)

Productivity, quality and economics of irrigated FCV tobacco (*Nicotiana tabacum*) in relation to spacing, dose and time of nitrogen application

S.V. KRISHNA REDDY*[1], S. KASTURI KRISHNA[1] AND J.A.V. PRASAD RAO

Central Tobacco Research Institute, Research Station, Jeelugumilli, West Godavari, Andhra Pradesh

Received: January 2008

ABSTRACT

A field experiment was conducted during post-rainy season of 2000-01, 2001-02 and 2002-03 at Jeelugumilli to find out optimum spacing, dose and time of N application to flue-cured virginia (FCV) tobacco (*Nicotiana tabacum* L.) in irrigated Alfisols (Northern Light Soils) of Andhra Pradesh. Green leaf yield, cured leaf yield and grade index were significantly higher at a spacing of 100 x 70 cm compared with 100 x 60 cm. Significant increase in green-leaf yield and cured leaf yield was noticed with increase in N level from 90 to 130 kg N/ha. Application of 130 and 110 kg N/ha, being comparable, recorded significantly higher grade index than that of 90 kg N/ha. Application of N in three splits offered significantly higher green leaf yield, cured leaf yield and grade index compared with that of N in two splits. Wider spacing gave higher total N and nicotine levels and lower reducing sugars, equilibrium moisture content (EMC) and filling value of leaf than closer spacing. There was a gradual decrease of sugars and EMC and increase of nicotine, total N and filling value with increased levels of N. Application of nitrogen in three splits gave higher total N, nicotine and filling value and lower reducing sugars and EMC of cured leaf than that of N in two splits. Maximum net returns and benefit : cost ratio accrued when planted at 100 x 70 cm spacing along with 110 kg N/ha applied in three splits. A spacing of 100 cm x 70 cm along with 110 kg N//ha applied in three splits, was found optimum for cv. 'Kanchan' for obtaining higher yield and better grade index with acceptable chemical and physical quality parameters.

Key words: Economics, FCV tobacco, Leaf quality, Nitrogen, Spacing, Yield

Export-quality flue-cured Virginia (FCV) tobacco (*Nicotiana tabacum* L.) is being cultivated on 24,840 ha, producing 48 million kg leaf annually in Alfisols under irrigated conditions, popularly termed northern light soil (NLS) area, comprising East Godavari, West Godavari and Khammam districts of Andhra Pradesh. The recently released cv. 'Kanchan' is the ruling variety with higher yield potential and superior leaf quality characters. The recommended spacing in NLS for the earlier varieties of '16/103' and 'CM-12(KA)' having lower number of leaves which are broader and shorter (than 'Kanchan') was 100 x 60 cm. However, 'Kanchan' with its narrow and long leaf style may respond differently to plant spacing. The effect of spacing (plant population) on leaf usability and quality is far greater than on yield. Closer spacing of plants results in reduced leaf size, body, thickness and weight per unit area of the leaf (Tso, 1999). Nitrogen is the most important element and has a more pronounced effect on the growth and development of flue-cured tobacco plant and the quality of tobacco leaf than any other essential element. Earlier varieties were low yielders with 14-18 curable leaves, having medium N requirement (70-90 kg/ha in two splits) and used to be ready for first priming by 70 days after planting with a total crop duration of 130 days. 'Kanchan' is a high yielder with 24-26 curable leaves, having more N requirement (110-120 kg/ha) and comes to first priming by 90 days after planting with a total crop duration of 165 days. As the soils are light textured and the crop is irrigated, application of entire N in two splits before 35 days after planting exposes the crop to inadequate N availability during grand growth period and afterwards. This results in production of more lemon-yellow grades (pale tobacco in trade parlance) but the trade presently prefers lemon-orange grades. The lemon-orange grades are possible only with adequate N supply during the grand growth period (Collins and Hawks Jr, 1993). Tobacco yield and chemical composition are known to be influenced more not only by the rate of N application but also the time of N supply, because it affects the period of maximum uptake and the N concentration in the leaf at various

***Corresponding author** (Email: krishnakasturi@rediffmail.com)

Present address: [1]Division of Crop Production, Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh 533 105

growth stages. Though 110-120 kg N/ha was recommended based on the earlier and on-going experiments to 'Kanchan', there may be a differential response to dose and time of N application with variation in spacing. Hence the present experiment was conducted to study the response of FCV tobacco cv. 'Kanchan' to spacing, dose and time of N application.

MATERIALS AND METHODS

A field experiment was conducted during winter season (*rabi*) 2000-01, 2001-02 and 2002-03 at the research farm of Research Station, Central Tobacco Research Institute, Jeelugumilli (17°11'30" N and 81°07'50" E at 150 m above mean sea-level), West Godavari district in Andhra Pradesh under semi-arid tropical climate. The soil was sandy loam (0-22.5 cm) and deeper layers (22.5-45 cm) were sandy clay classified Typic Haplustalfs, with pH 6.3 (1:2.5) and electrical conductivity 0.20 dS/m (1:2.5). The available soil N, P and K were: 118.5, 20.5 and 75.5 kg/ha, respectively. The soil chlorides were 24 mg/kg.

Treatments comprised combination of two plant spacings, viz. 100 x 60 and 100 x 70 cm, and three N levels, viz. 90,110 and 130 kg N/ha as main plots; and two times of N application, viz. two splits at 7-10 and 25-30 days after planting (DAP) in 1:1 proportion and three splits at 7-10, 25-30 and 45-50 DAP in 1:2:1 proportion in subplots. The treatments was replicated four times in split-plot design. Sunnhemp [*Crotalaria juncea* (L.) Rotar & Joy] seed @ 50 kg/ha was sown in the first week of June and incorporated *in situ* before flowering in the first week of August. The gross plot size was 6.0 x 8.4 m and net plot size was 4.0 x 7.2 m for 100 x 60 cm and 4.0 x 7.0 m for 100 x 70 cm. The tobacco seedlings of 60 days were transplanted in the first week of October in all the three years. Nitrogen was applied as per the treatment. Phosphorus and potassium were applied @ 26.2 kg and 99.9 kg/ha, respectively. In basal dose, first split of N and full dose of P in the form of diammonium phosphate and 50% K in the form of potassium sulphate were applied 10 days after planting. In basal dose calcium ammonium nitrate was applied to supply higher levels of N (above 26.2 kg P/ha through diammonium phosphate, i.e. <23.4 kg N/ha). In top-dressing, second split of N was given through calcium ammonium nitrate along with remaining 50% K in the form of potassium sulphate at 25-30 days after planting. The remaining 25% N was applied 45-50 DAP. All the fertilizers were applied through dollop method at a spacing of 10 cm away and at a depth of 10 cm on either side of the plant by making holes with pointed sticks or spades.

The crop was raised with recommended package of practices except the inputs applied as treatments. The crop was topped at 24 leaves stage. Decanol 4% was applied @ 10-15 ml/plant for preventing the sucker growth immediately after topping. The first priming was done 90 days after planting. Mature green leaves were harvested by priming and flue cured in the barn. The total rainfall received during the crop season was 61 mm (3 rainy days) in 2001, 188 mm (19 rainy days) in 2002 and 236 mm (10 rainy days) in 2003. Mean maximum and minimum temperatures were respectively 32.1 and 19.2°C in the first season, 31.4 and 19.0°C in the second season, and 31.3 and 18.3°C in the third season.

The data on green leaf and cured leaf of tobacco were recorded and grade index was calculated. The cured-leaf samples collected from lugs and cutters (X) and leaf (L) positions were analysed for chemical quality characters (reducing sugars, nicotine, total N and chlorides) and physical quality parameters [Equilibrium moisture content (EMC) and filling value (FV)] as per the standard procedures. Economics was calculated on the basis of prevailing market prices of inputs and produce. The data were statistically analysed and results of individual years and pooled analysis were presented.

RESULTS AND DISCUSSION

Yield characters

Pooled results for all the years showed that the green-leaf yield, cured leaf yield and grade index were higher at 100 x 70 cm spacing than at 100 x 60 cm spacing (Table 1). Green-leaf yield at 100 x 70 cm spacing was significantly higher by 1.2 t/ha (6.9%) than at 100 x 60 cm spacing. Cured-leaf yield at 100 x 70 cm spacing was significantly higher by 0.13 t/ha i.e. 5.99% than with 100 x 60 cm. The production efficiency of cured-leaf at 100 x 70 cm was 0.79 kg (6.0%) more than at 100 x 60 cm (Table 3). Grade index was also significantly more at 100 x 70 cm spacing by 0.13 t/ha (8.61%) compared with that at 100 x 60 cm. The reason may be that the leaf length of 'Kanchan' was more than 80 cm (X and L- Positions) and the tips of the leaves of plant grew beyond the stem of neighbouring plants (because the intra-row spacing was 60 cm). Hence an increase in the intra-row spacing from 60 to 70 cm might have provided opportunity to intercept more photosynthetically active solar radiation, thereby increasing the photosynthetic assimilation and carbohydrate synthesis, thus contributing to increased yield per plant and in turn higher productivity and grade index under higher spacing. The reduction in yield at 100 x 60 cm spacing may be due to adverse effects of mutual shading on plant growth owing to higher population at lower spacing. These results are in agreement with the reports of Flower (1999).

There was linear and significant increase in green leaf yield with increase in N level from 90 to 130 kg/ha. Green leaf yield at 130 and 110 kg N/ha was higher by 2.56 (15.50%) and 1.88 t/ha (11.39%) respectively than at 90 kg/ha. Cured-leaf yield increased progressively and substantially with increase in N level from 90 to 130 kg/ha. Cured-leaf yield at 130 and 110 kg N was significantly higher by 0.22 (10.4%) and 0.15 t/ha (7.1%), respectively than at 90 kg N/ha. This follows the Mitscherlich's equation, which states that the increase in growth with each successive addition of element in question was progressively smaller. The efficiency of cured-leaf production increased progressively from 12.79 to 14.12 kg/ha/day with increase in N dose from 90 to 130 kg/ha, and was higher by 10.4 and 7.1%, with application of 130 and 110 kg N/ha respectively compared with that of 90 kg N/ha. The grade index with 130 and 110 kg N/ha was comparable and both were significantly superior to 90 kg N/ha. Grade index with 130 and 110 kg N was significantly higher by 0.10 (6.62%) and 0.08 t/ha (5.29%) respectively than at 90 kg N/ha. The 20 kg N increment from 90 to 110 kg increased the grade index by 0.08 t/ha but N increment from 110 to 130 kg increased it by 0.02 t/ha only. These results are in agreement with those of Krishna Reddy *et al.* (2003, 2006).

Pooled analysis revealed that the green leaf yield with three splits of N application was significantly higher by 0.98 t (5.6%) compared with that in two splits. Cured leaf yield with three splits of N application was significantly higher by 0.09 t (4.11%) than that in two splits. The efficiency of cured-leaf production with N application in three splits was higher by 0.55 kg (4.1%) compared with that in two splits. Grade index was also more by 0.10 t (6.6%) with three splits of N compared with its two splits. This reveals that application of N in three splits resulted in more efficient use of N in light soils under irrigation (Krishnamurthy and Ramakrishnayya, 1994), and the longer duration of 'Kanchan' too showed a similar effect.

Quality parameters

The leaf lamina samples from X and L positions of 2000-03 seasons were analysed for chemical characters viz. total N, reducing sugars, nicotine and chlorides. The physical characters such as EMC and FV were also determined (Table 2). Wider spacing (100 x 70 cm) gave higher total N and nicotine levels and lower reducing sugars, EMC and filling value than closer spacing (100 x 60 cm) in both X and L positions of cured leaf. It can be attributed to the availability of more soil area per plant, facilitating increased root growth in the plant, leading to

Table 1. Green leaf yield, cured leaf yield and grade index of FCV tobacco as influenced by spacing, dose and time of N application

Treatment	Green leaf yield (t/ha)				Cured leaf yield (kg/ha)				Grade index			
	2000–01	2001–02	2002–03	Pooled	2000–01	2001–02	2002–03	Pooled	2000–01	2001–02	2002–03	Pooled
Spacing												
100 x 60 cm	16.12	18.59	17.46	17.39	2.11	2.21	2.20	2.17	1.49	1.58	1.45	1.51
100 x 70 cm	17.19	19.82	18.76	18.59	2.23	2.33	2.34	2.30	1.60	1.72	1.60	1.64
SEm±	0.20	0.26	0.30	0.15	0.02	0.03	0.04	0.02	0.02	0.02	0.02	0.01
CD (P=0.05)	0.61	0.78	0.92	0.41	0.07	0.09	0.11	0.05	0.05	0.06	0.07	0.03
N dose (kg/ha)												
90	15.26	17.67	16.59	16.51	2.05	2.15	2.14	2.11	1.50	1.59	1.44	1.51
110	17.00	19.60	18.57	18.39	2.20	2.29	2.30	2.26	1.56	1.67	1.54	1.59
130	17.70	20.34	19.18	19.07	2.26	2.36	2.37	2.33	1.57	1.70	1.57	1.61
SEm±	0.25	0.32	0.37	0.18	0.03	0.04	0.04	0.02	0.02	0.02	0.03	0.01
CD (P=0.05)	0.74	0.95	1.12	0.41	0.09	0.11	0.13	0.05	0.06	0.07	0.09	0.03
Time of N application												
Two splits	16.27	18.71	17.53	17.50	2.13	2.22	2.21	2.19	1.50	1.60	1.47	1.52
Three splits	17.04	19.70	18.69	18.48	2.21	2.32	2.33	2.28	1.59	1.71	1.56	1.62
SEm±	0.19	0.21	0.21	0.12	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.01
CD (P=0.05)	0.55	0.62	0.63	0.32	0.07	0.07	0.08	0.04	0.05	0.06	0.06	0.03
Season												
2000-01				16.66				2.17				1.55
2001-02				19.20				2.27				1.65
2002-03				18.11				2.27				1.52
SEm±				0.50				0.07				0.05
CD (P=0.05)				1.60				NS				NS

greater absorption of N and synthesis of more nicotine. This is because alkaloids are synthesized in roots of tobacco plant, and with increase in plant population there was a greater degree of root competition resulting in a reduction in alkaloids per plant. As there is a negative relationship of N and nicotine with reducing sugars, sugars were less under wider spacing. Sugars also contributed to more EMC, as they are positively related. There was an increase in filling value with increase in plant population. The rate of increase in leaf mass/unit area (thickness) of flue-cured tobacco is positively related to light intensity. The increase in plant population/unit area caused mutual shading, resulting in lower photosynthetic assimilation due to reduction in available light intensity. This resulted in thin bodied and more fragile leaf, thereby increasing the filling value at closer spacing. These results corroborate the reports of Flower (1999).

There was a gradual increase of nicotine and total N, and decrease in sugars with increase in N level in both X and L positions. It is the interplay of the N and carbohydrate metabolism as influenced by management that predetermines the quality and chemical composition of cured tobacco. Nitrate reductase is an important substrate inducible enzyme, whose activity is affected by the nitrate-N concentration of leaves and therefore the amount of N available in the soil. There is a very good negative relationship between its activity and the accumulation of starch in the leaves (Flower, 1999). Thus in the present study an increase in N level decreased the sugars and increased the nicotine and total N. Lower levels of sugars are associated with higher levels of N (Kasturi Krishna *et al.*, 2004). These results are also in agreement with the findings of Krishnamurthy *et al.* (1996). The EMC decreased and filling value increased with increase in N level. This decrease in EMC could be due to decrease in sugars with increase in N as sugars are positively related to EMC. There was increase in the filling value, because with adequate moisture an increase in the supply of N level facilitates greater expansion of leaf, thereby decreasing the weight per unit area or thickness and thus increasing its fragile nature and in turn resulting in higher filling value (Tso, 1999).

Application of N in three splits resulted in higher total N, nicotine and filling value and lower reducing sugars and EMC than that in two splits. The former reduced the leaching losses (as a result of delayed application of N in smaller proportions) leading to longer availability of N in the soil, facilitating the plant to absorb more N coinciding with grand growth period compared with N application in two splits (Collins and Hawks Jr, 1993). Consequently, N

Table 2. Chemical and physical quality parameters of FCV tobacco as influenced by spacing, dose and time of N application (pooled)

Treatment	Total N (%)		Reducing sugars (%)		Nicotine (%)		Chlorides (%)		EMC (%)		Filling value (cc/g)	
	X	L	X	L	X	L	X	L	X	L	X	L
Spacing												
100 x 60 cm	1.94	2.26	14.29	11.61	2.43	3.05	0.71	0.70	12.16	11.73	3.51	3.31
100 x 70 cm	2.29	2.54	11.66	10.07	2.69	3.27	0.65	0.64	11.84	11.40	3.31	3.14
SEm±	0.01	0.02	0.10	0.05	0.01	0.02	0.01	0.01	0.04	0.04	0.02	0.01
CD (P=0.05)	0.03	0.05	0.26	0.15	0.03	0.05	NS	NS	0.10	0.12	0.05	0.04
N dose (kg/ha)												
90	1.94	2.22	14.82	11.73	2.44	3.03	0.70	0.70	12.11	11.72	3.28	3.10
110	2.12	2.41	13.16	10.72	2.57	3.17	0.68	0.67	11.96	11.53	3.43	3.25
130	2.27	2.58	10.95	10.08	2.67	3.28	0.66	0.64	11.93	11.45	3.53	3.34
SEm±	0.02	0.01	0.12	0.07	0.013	0.02	0.01	0.01	0.04	0.05	0.02	0.02
CD (P=0.05)	0.06	0.03	0.26	0.15	0.05	0.05	NS	NS	0.10	0.12	0.05	0.04
Time of N application												
Two splits	2.06	2.35	14.12	11.26	2.50	3.10	0.70	0.69	12.14	11.67	3.36	3.18
Three splits	2.17	2.45	11.83	10.43	2.62	3.22	0.66	0.66	11.86	11.46	3.47	3.27
SEm ±	0.01	0.013	0.09	0.07	0.013	0.023	0.01	0.01	0.05	0.05	0.01	0.02
CD (P=0.05)	0.03	0.04	0.25	0.19	0.04	0.07	NS	NS	0.14	0.13	0.03	0.04
Season												
2000-01	2.17	2.59	11.97	9.50	3.21	3.33	0.53	0.47	12.00	11.65	3.38	3.21
2001-02	1.92	2.08	14.60	14.64	1.82	2.55	0.68	0.74	11.36	10.90	3.45	3.25
2002-03	2.25	2.54	12.35	8.38	2.65	3.60	0.82	0.81	12.65	12.14	3.41	3.21
SEm±	0.04	0.013	0.11	0.11	0.02	0.04	0.01	0.013	0.06	0.05	0.03	0.01
CD (P=0.05)	0.13	0.04	0.34	0.34	0.06	0.13	0.03	0.04	0.19	0.16	NS	0.03
Acceptable limit	1.0–3.0		8.0–24.0		0.7–3.5		< 1.5		11.0–15.0		3.1–3.8	

Table 3. Cured leaf production efficiency and economics as influenced by spacing, dose and time of nitrogen application (based on three seasons mean)

Treatment	Cured leaf production efficiency (kg/ha/day)	Cost of cultivation (x 10^3 Rs/ha)	Net returns (x 10^3 Rs/ha)	Benefit : cost ratio	Profitability (Rs/ha/day)
Spacing					
100 x 60 cm (16,666 plants/ha)	13.15	69.66	28.35	1.41	594
100 x 70 cm (14,285 plants/ha)	13.94	71.52	34.74	1.49	644
N dose (kg/ha)					
90	12.79	67.73	30.30	1.45	594
110	13.70	71.03	32.53	1.46	628
130	14.12	73.01	31.80	1.44	635
Time of N application					
Two splits (10, 30 DAP)	13.27	69.55	29.44	1.43	600
Three splits (10, 30, 50 DAP)	13.82	71.63	33.65	1.47	638

application in three splits increased the total N, nicotine concentration and filling value and decreased the concentration of reducing sugars and EMC in the leaves. In general, all the physical and chemical quality characteristics were within the acceptable limits of good-quality leaf in all the treatments. The chloride content of the leaf did not vary significantly due to spacing, N dose and time of application, and was within the desirable limit in all the treatments.

Climatic conditions influenced the leaf quality characters significantly during the course of study (Table 2). Lower levels of leaf N and nicotine, and higher levels of sugars were obtained in 2001-02 season. In this season the receipt of 79% rainfall (143 mm in 13 rainy days) coincided with the period of fertilizer application during October and November. As a result, some of the applied N could have leached into the deeper layers of soil, thus reducing the soil availability of N to tobacco during grand growth period, leading to lower total N, nicotine and higher sugars in the second season. In 2000-01 season, only 40 mm rainfall was received in October-November, whereas in 2002-03 season, 79% of rainfall (187.3 mm in 7 rainy days) was received in October before the application of second dose of fertilizer and the remaining 21% (49 mm) was received in February and March at the end of the crop season.

Economics

Higher net returns (Rs 34,740/ha), benefit : cost ratio (1.49) and profitability (Rs 644/ha/day) were achieved at 100 x 70 cm spacing than 100 x 60 cm (Table 3). Profitability increased with increase in N level from 90 to 130 kg N/ha. However, higher net returns (Rs 32,530/ha) and benefit : cost ratio (1.46) accrued at 110 kg N compared with that from 90 and 130 kg N/ha. Application of N in three splits recorded higher net returns (Rs 34,740/ha), benefit : cost ratio (1.49) and profitability (Rs 638/ha/day).

It was concluded that a spacing of 100 x 70 cm with N dose of 110 kg/ha applied in three splits at 7-10, 25-30 and 45-50 days after planting in 1:2:1 proportion would be optimum for 'Kanchan' for getting higher yield and better grade index with acceptable chemical and physical quality parameters under irrigated northern light soil conditions of Andhra Pradesh.

REFERENCES

Collins, W.K. and Hawks Jr, S.N. 1993. *Principles of flue Cured Tobacco Production,* pp 103-106. N.C. State University, Raleigh, N.C. USA.

Flower, K.C. 1999. Field practices. In: *Tobacco: Production, Chemistry and Technology,* pp 77-82. Davis, D.L. and Nielsen, M.T. (Eds). Blackwell Science Ltd., University Press, Cambridge, Great Britain.

Kasturi Krishna, S., Krishna Reddy S.V. and Krishnamurthy, V. 2004. Effect of spacing, levels of nitrogen and topping on yield and quality of irrigated *natu* tobacco (*Nicotiana tabacum*) grown in Alfisols of Andhra Pradesh. *Indian Journal of Agronomy* **49**(2): 124–127.

Krishnamurthy, V. and Ramakrishnayya, B.V. 1994. Nitrogen and potassium balance in flue cured tobacco in irrigated Alfisols. *Tobacco Research* **20**(1): 71–73.

Krishnamurthy, V., Chandrasekhararao, C. and Ramakrishnayya, B.V. 1996. Chemical quality characteristics of flue-cured tobacco as affected by different levels of N and K fertiliza-

tion in irrigated Alfisols. *Journal of Potassium Research* **12**(4): 391–399.

Krishna Reddy, S.V., Kasturi Krishna, S. and Krishnamurthy, V. 2006. Productivity, quality and economic returns in FCV tobacco (*Nicotiana tabacum*) with conjunctive use of organic manures and nitrogen under irrigated Alfisols of Andhra Pradesh. *Tobacco Research* **32**(1): 25–31.

Krishna Reddy, S.V., Kasturi Krishna, S. and Prasad Rao, J.A.V. 2003. Effect of nitrogen and level and time of topping on productivity and quality of FCV tobacco variety K 326 (NLS 4) grown in irrigated Alfisols of Andhra Pradesh. *Tobacco Research* **29**(2): 148–154.

Tso, T.C. 1999. Seed to smoke. In: *Tobacco : Production, Chemistry and Technology,* pp. 12-13. Davis, D.L. and Nielsen, M.T. (Eds). Blackwell Science Ltd. University press, Cambridge, Great Britain.