Indian Journal of Agronomy **67** (3): 294—303 (September 2022)

Research Paper

Enhancement of productivity, water- and nutrient use efficiency and economics through drip fertigation and tray seedlings in FCV tobacco (*Nicotiana tabacum)* under irrigated Alfisols of Andhra Pradesh

S.V. KRISHNA REDDY[1], C.C.S. RAO[2] AND S. KASTURI KRISHNA[3]

ICAR-Central Tobacco Research Institute Research Station, Jeelugumilli, West Godavari (Dt.), Andhra Pradesh 534 456

Received: June 2021; Revised accepted: July 2022

ABSTRACT

A field experiment was conducted for two consecutive seasons (2014–16) and a bulk trial for one year (2016–17) at ICAR-Central Tobacco Research Institute Research station, Jeelugumilli, West Godavari district, Andhra Pradesh under semi arid tropical climate to study the effect of different combinations of drip irrigation, furrow irrigation, tray seedlings, normal seedlings, drip ferti-gation and soil application of fertilizers at 3rd, 25–30, 40–45 days after planting or 10, 25–30, 40–45 days after planting, on green leaf yield (GLY), cured lead yield (CLY), grade index (GI), leaf nicotine and reducing sugars, water- and fertilizer use efficiency as well as economics in FCV tobacco (*Nicotiana tabacum*). The experiment was laid out in a RBD with five replications, nine treatment combinations and was conducted with specified treatments for the first two years and bulk plots during the following year. Two separate plots, viz. $N_0P_{26.2}K_{99.6}$ (T_{10}) and $N_{120}P_{26.2}K_0$ (T_{11}) were grown for comparison and calculation of N and K use efficiencies during the first two years. T_4 (drip irrigation, tray seedlings, drip fertigation at 3rd, 20–25 and 40–45 DAP) and T_2 (drip irrigation, tray seedlings, drip ferti-gation at 10, 25–30 and 40–45 DAP) recorded increased GLY by 23.87, 16.95, CLY by 16.67, 13.83 and GI by 23.43, 21.46% during first and second years, respectively and also higher leaf nicotine when compared to furrow irrigation, normal seedlings, soil application of fertilizers (T_9) i.e. farmers practice. N, P, K uptake and nitrogen and potassium use efficiencies under different treatments were evaluated. Bulk plots grown with tray seedlings, drip irrigation and drip fertigation accrued additional profit of ₹25,285, benefit: cost ratio of 1.82, WUE of 11.74 kg of cured leaf/ ha-mm of water as compared to 5.77 kg of cured leaf/ha-mm in normal seedlings, furrow irrigation and soil application of fertilizers. Only 57.2% of total quantity of furrow irrigation is required for drip irrigation and there is 203.5% increase in WUE with drip irrigation as compared to furrow irrigation.

Key words: Drip fertigation, Drip irrigation, Furrow irrigation, Normal seedlings, Tobacco productivity, Quality, Tray seedlings

Export-quality flue-cured Virginia (FCV) tobacco (*Nicotiana tabacum* L.) is being cultivated during *rabi* season under irrigated conditions in sands, sandy loams and loamy sands of East and West Godavari districts of Andhra Pradesh and Khammam district of Telangana states in 21,635 ha, producing 43.33 million kg semi-flavourful tobacco leaf annually (Tobacco Board, 2019). FCV tobacco under Northern Light Soil conditions is cultivated by giving 12–13 furrow irrigations to the field crop. The furrow irrigation will not provide optimum soil moisture during all the days between two irrigations. Immediately after irrigation the soil may be having excess soil moisture above field capacity and just before irrigation, the field may have less available soil moisture. Both excess moisture and less available soil moisture will have deleterious effect on crop growth. Furthermore, furrow irrigation is a labour-intensive field operation that necessitates labour each time the field is irrigated, includes high-scale drudgery, and necessitates a larger amount of irrigation water.

The major source of irrigation water in this tract is deep bore wells. Now-a-days the ground water supply is becoming scarce and the water table is depleting day by day. Hence, the ground water should be utilized judiciously for sustained availability. Efficient use of irrigation water is

[1]**Corresponding author's Email:** 65svkreddy@gmail.com
[1]Principal Scientist, (Agronomy), ICAR-Central Tobacco Research Institute Research station, Jeelugumilli, West Godavari (Dt.), Andhra Pradesh 534 456; [2]Principal Scientist & Head (i/c), Crop Chemistry & Soil Science, ICAR-CTRI Rajahmundry; [3]Principal Scientist & Head (i/c), Division of Crop Production, ICAR-CTRI Rajahmundry.

essential for attaining maximum water use efficiency. Drip irrigation is efficient method of providing water directly into the root zone of plants and economizes a lot of water (a scarce commodity) under limited water resources, thereby increasing water use efficiency and it also checks unwanted weed growth. Irrigation efficiency in drip irrigation is as high as 90% compared to 30-50% in surface irrigation besides substantial saving of water to the extent of 40–80%. The method of nutrient application is important in improving the nutrient use efficiency. Fertigation is a method of application of fertilizers through irrigation. Fertigation enables adequate supply of water and nutrients with precise timing and uniform distribution to meet crop requirement to get maximum yield (Chawla and Narda, 2002: Patel and Rajput, 2000). Phene *et al*. (1979) reported 25–50% reduction in fertilizer use requirement using drip system compared to surface broadcasting with no yield reduction. Drip fertigation is considered to be the most efficient in improving the yield and saving of water (Behera *et al*., 2013). Thus, drip irrigation and fertigation provides ample scope to increase water and fertilizer use efficiency by reducing leaching, resulting in higher productivity and better quality. Drip fertigation also facilitates for easy application of required amount and concentration of nutrients suited to the crop according to its stage of development and climatic conditions and decreases fluctuation in nutrient availability and reduces the soil salinization and groundwater pollution. The higher crop yields with considerable saving of water and higher production efficiency in chewing tobacco was reported through drip irrigation system (Kumaresan *et al.*, 2013). When compared to other types of conventional bare rooted seedlings, tray seedlings in the field minimise transplanting shock, have a low percentage of gaps, can be fertilised within 2–3 days of planting, require a shorter establishment period, provide crop uniformity, change crop growth pattern by extending growing season, and make more efficient use of precious land and expensive hybrid seed. Hitherto research work on drip irrigation, fertigation and use of tray seedlings to tobacco is not available. Hence, expansion of drip irrigation in FCV tobacco grown in irrigated alfisols is hindering. Keeping the above in view, it is imperative to study the effect of drip irrigation, fertigation and tray seedlings vis-à-vis furrow irrigation, soil application of fertilizers in dollop method and conventional bare rooted normal seedlings on FCV tobacco cv Kanchan for higher productivity and better quality under irrigated Alfisols.

MATERIALS AND METHODS

A field experiment was conducted for two consecutive seasons in fixed plots during *rabi* seasons in 2014–15 and 2015-16 and bulk plots were grown during 3rd year (2016-17) at the research farm of ICAR-Central Tobacco Research Institute research station, Jeelugumilli, (17° 11' 30" N and 81° 07' 50" E at 150 m above mean sea-level, average annual rainfall 1100 mm), West Godavari district, Andhra Pradesh under semi arid tropical climate. The soil of the experiment was Typic Haplustalfs with sandy loam surface (0–22.5 cm) and sandy clay sub surface (22.5–45.0 cm) with slightly acidic pH (1:2.5) 6.25, low electrical conductivity (1:2.5) 0.21 dS/m, chlorides 28 mg/kg, organic C (0.20%), available N (148 kg/ha), medium in available P (23 kg/ha) and K (228 kg/ha). The textural and physical properties of soils are presented in Table 1.

The experiment consisted of 9 treatments replicated five times in RBD with different combinations of drip irrigation, furrow irrigation, tray seedlings, normal (conventional) seedlings, drip fertigation and soil application of fertilizers at 3, 25–30, 40–45 days after planting or 10, 25–30, 40–45 days after planting (DAP). The nine treatments were 1. Drip irrigation, tray seedling, soil application of fertilizers at 10, 25-30 and 40-45 DAP; 2. Drip irrigation, tray seedling, drip fertigation at 10, 25–30 and 40–45 DAP; 3. Drip irrigation, tray seedling, soil application of fertilizers at 3, 20-25 and 40-45 DAP; 4. Drip irrigation, tray seedling, drip fertigation at 3, 20–25 and 40–45 DAP; 5. Drip irrigation, normal seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; 6. Drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40-45 DAP; 7. Furrow irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; 8. Furrow irrigation, tray seedling, soil application of fertilizers at 3, 20–25 and 40–45 DAP; 9. Furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25-30 and 40-45 DAP. Two separate plots, viz. $N_0P_{26.2}K_{99.6}$ (T_{10}) and $N_{120}P_{26.2}K_0$ (T_{11}) were grown with furrow irrigation, normal seedlings and soil application of fertilizers, at 10, 25–30 and 40–45 DAP for calculation of N and K use efficiencies.

Sunnhemp [*Crotalaria juncea* (L.) Rotar and Joy] seed @ 50 kg/ha was sown in the first week of June and *in situ* incorporation was done before flowering i.e. in first week of August. The incorporated dry matter of sunnhemp was about 4.0 t/ha with N content of 2.15% (on oven dry weight basis) in 2 years. The gross plot size was 6 m × 6 m (60 plants) and the net plot size was 4 m × 4.8 m (32 plants) with spacing of 100 cm × 60 cm. About sixty-day-old tobacco cv 'Kanchan' Normal (conventional) and Tray seedlings were planted on 13th November, 2014 and 25th October, 2015 as per the treatment during first and second seasons, respectively. Bulk plots were grown during third year on 16th November, 2016. The experiment was grown with a fertilizer dose of 120 kg N, 26.2 kg P and 99.6 kg K/ha.

Nitrogen and potassium were applied in three splits in

Table 1. Properties of soil and moisture in field

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	*p*H
0–9	89.29	4.30	6.40	Sandy Loam	6.31
9–39	76.01	4.66	19.33	Sandy clay loam	5.30
39–100	62.41	4.34	33.25	Sandy clay	5.21

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Available soil moisture (%)	Bulk density (g/cc)
0–22.5	7.71–9.39	2.26–3.60	5.45–5.79	1.49–1.52
22.5–45	11.52–13.59	4.02–5.29	7.50–8.30	1.28–1.36

1:2:1 proportion at 3, 20–25 and 40–45 DAP; or at 7–10, 25–30 and 45–50 DAP as per the treatment. Phosphorus was applied @ 26.2 kg P/ha. In basal dose, first split of N and full dose of P in the form of diammonium phosphate and 25% K in the form of potassium sulphate were applied at 3 or 10 days after planting. In basal dose, ammonium sulphate @ 6.6 kg N/ha was applied to supplement N in addition to DAP. In top-dressing, second split (50%) of N and K were given through urea and sulphate of potash at 25–30 days after planting. Remaining 25% each of N and K as ammonium sulphate and K_2SO_4 were applied at 45–50 DAP. Fertilizers in soil application treatments were applied by dollop method at 10 cm away and at a depth of 10 cm on either side of the plant by making holes by either sticks (*Gasika*) or spades. Fertilizers in drip-irrigation treatments were applied through drip fertigation. The crop was raised with assured irrigation using furrow method or drip irrigation and recommended package of practices except the inputs applied as treatments. The crop was topped at 24 leaves at bud stage. Decanol (n-deconol, a fatty alcohol based suckericide) 4% was applied @ 10–15 ml/plant immediately after topping for preventing the sucker growth. The first priming was done at 80 days after planting. Mature leaves were harvested by priming and flue cured in the barn.

During the crop season, total rainfall was 113.8 mm (10 rainy days) in the first, 33 mm (5 rainy days) in the second, and 71.4 mm (5 rainy days) in the third season. Mean maximum and minimum temperatures were 32.25 and 19.10°C in the first, 32.96 and 20.76°C in the second and 31.90 and 19.53°C in the third season, respectively.

The data on tobacco green leaf and cured leaf were recorded and grade index was calculated (Gopalachari, 1984). The cured-leaf samples of tobacco collected from primings (P), lugs and cutters (X), leaf (L) and tips (T) positions were processed and analysed for lamina chemical quality characters (reducing sugars, nicotine and chlorides) as per the standard procedures and reducing sugars/nicotine was calculated in the bulk plots. The N, P and K contents were determined in leaf, stem and root of all the treatments. Nutrient uptake (N, P and K) was estimated by multiplying the nutrient content with respective dry weights. Total nutrient uptake was obtained by summing the individual uptakes of leaf, stem and root. Efficiencies of N and K use were calculated (Surekha *et al*., 2008; Krishna Reddy *et al.*, 2017). Economics and water-use efficiency were calculated through bulk plots. The data were statistically analyzed and results were presented.

RESULTS AND DISCUSSION

Yield characters

Significant differences were noticed between the treatments with regard to the yield characters studied (Table 2). Drip irrigation (T_1) alone resulted in increase in green-leaf yield (GLY) by 305, cured-leaf yield (CLY) by 49, and grade index (GI) by 127 kg/ha, when compared to furrow irrigation (T_7) with other factors remaining same. Drip irrigation with tray seedlings and soil application of fertilizers at 3, 20–25 and 40–45 DAP (T_3) increased the GLY by 1030, CLY by 73 and GI by 43 kg/ha, when compared to drip irrigation with tray seedlings and soil application of fertilizers at 10, 20–25 and 40–45 DAP (T_1). Drip fertigation at 3, 20–25 and 40–45 DAP alone (T_4) recorded increase in GLY by 1515, CLY by 158, and GI by 153 kg/ha, when compared to soil application of fertilizers at the same time (T_3).

Drip fertigation at 10, 25–30 and 40–45 DAP (T_2) also resulted in increase in GLY by 1514, CLY by 158 and GI by 158 kg/ha, when compared to soil application of fertilizers in 3 splits at the same time (T_1). Tray seedlings with drip fertigation at 3, 20–25 and 40–45 DAP (T_4) ensued increase in GLY by 1,031, CLY by 72 and GI by 38 kg/ha, when compared to drip fertigation at 10, 25–30 and 40–45 DAP (T_2).

Furrow irrigation and soil application of fertilizers being common, tray seedlings (T_7) showed increased GLY by 706, CLY by 135 and GI by 127 kg/ha compared to normal seedlings (T_9). Tray seedlings with drip irrigation and drip fertigation (T_2) resulted in increase in GLY by 511, CLY by 117 and GI by 133 kg/ha, compared to normal seedlings (T_6) with same factors. Normal seedlings, soil application of fertilizers being common, drip irrigation (T_5) recorded

Table 2. Effect of drip irrigation and tray seedlings on the productivity of flue-cured Virginia tobacco cv. 'Kanchan' in irrigated Alfisols of Andhra Pradesh

Treatment	Green leaf (kg/ha)			Cured leaf (kg/ha)			Grade index (kg/ha)			Green leaf/ Cured leaf			Grade index/ Cured leaf (%)		
	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled	1st year	2nd year	Pooled
T_1	15,148	16,670	15,909	2,532	2,814	2,673	2,079	2,268	2,174	5.98	5.93	5.955	82.0	80.6	81.35
T_2	16,515	18,331	17,423	2,672	2,992	2,832	2,221	2,442	2,332	6.18	6.13	6.155	83.0	81.6	82.35
T_3	16,091	17,787	16,939	2,595	2,896	2,746	2,115	2,319	2,217	6.20	6.14	6.172	81.5	80.1	80.85
T_4	17,457	19,450	18,454	2,735	3,073	2,904	2,254	2,486	2,370	6.38	6.33	6.357	82.4	80.9	81.65
T_5	14,880	16,279	15,579	2,381	2,629	2,505	1,936	2,098	2,017	6.25	6.19	6.221	81.3	79.8	80.55
T_6	16,079	17,744	16,912	2,569	2,861	2,715	2,101	2,297	2,199	6.26	6.20	6.231	81.8	80.3	81.05
T_7	14,885	16,323	15,604	2,490	2,759	2,624	1,963	2,132	2,047	5.97	5.92	5.946	78.8	77.3	78.05
T_8	15,086	16,570	15,828	2,505	2,778	2,642	2,016	2,195	2,106	6.02	5.97	5.995	80.5	79.0	79.75
T_9	14,233	15,562	14,898	2,368	2,609	2,489	1,845	1,994	1,920	6.01	5.95	5.983	77.9	76.4	77.15
SEm±	337	316	231	52.9	53.1	37.5	45.5	44.11	31.7	0.03	0.03	0.02	0.31	0.31	0.3
CD (P=0.05)	934	876	640	147	147	104	126	122	88	0.09	0.08	0.06	0.85	0.86	1.00
Season															
1st year			15597			2539			2059			6.141			84.04
2nd year			17191			2823			2248			6.084			79.57
SEm±			87			11.05			104			0.013			0.1
CD (P=0.05)			284			36.04			34			0.04			0.2

T_1, Drip irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_2, drip irrigation, tray seedling, drip ferti-gation at 10, 25–30 and 40–45 DAP; T_3, drip irrigation, tray seedling, soil application of fertilizers at 3, 20–25 and 40-45 DAP; T_4, drip irrigation, tray seedling, drip fertigation at 3, 20–25 and 40–45 DAP; T_5, drip irrigation, normal seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_6, drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40–45 DAP; T_7, furrow irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_8, furrow irrigation, tray seedling, soil application of fertilizers at 3rd, 20–25 and 40–45 DAP; T_9, furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP

increase in GLY by 681, CLY by 16 and GI by 23 kg/ha, compared to furrow irrigation (T_9).

Tray seedlings and soil application of fertilizers being common, drip irrigation (T_3) enhanced the GLY by 2,041, CLY by 104 and GI by 297 kg/ha, when compared to the furrow irrigation with (T_8) tray seedlings. Normal seedlings with drip fertigation (T_6) enhanced GLY by 1,333, CLY by 210 and GI by 182 kg/ha, compared to normal seedlings with soil application of fertilizers (T_5).

Tray seedlings with soil application of fertilizers at 3, 20–25, and 40–45 days after planting (T_3) showed enhanced GLY by 1,360, CLY by 240 and GI by 200 kg/ha, compared to normal seedlings with soil application of fertilizers at 10, 20–25 and 40–45 days after planting (T_5), drip irrigation being common. Tray seedlings with drip fertigation at 3, 20–25 and 40–45 days after planting (T_4) enhanced the GLY by 1,542, CLY by 189 and GI by 171 kg/ha, when compared to normal seedlings with drip fertigation at 10, 20–25 and 40–45 days after planting (T_6). Soil application of fertilizers at 3, 20–25 and 40–45 days after planting (T_8) enhanced the GLY by 224, CLY by 18 and GI by 59 kg/ha, when compared to soil application of fertilizers at 10, 20–25, and 40–45 days after planting (T_7) with tray seedlings and furrow irrigation being common.

When leaf yields were compared to individual factors in the treatments, it is clear that drip irrigation was found superior to furrow irrigation, tray seedlings yielded more than normal seedlings, and fertigation yielded more than soil application of fertilizers; further, tray seedlings with fertigation or soil application of fertilizers at 3, 20–25, and 40–45 days after planting yielded slightly more than application of fertilizers; and tray seedlings with fertigation or soil application of fertilizer at 10, 25–30 and 40–45 days after planting. Considering combination of 2 factors in a treatment at a time, drip irrigation with tray seedlings performed better than drip irrigation with normal seedlings, furrow irrigation with tray seedlings performed better than furrow irrigation with normal seedlings, drip irrigation with normal seedlings resulted in better yields than furrow irrigation with normal seedlings and drip irrigation with tray seedlings gave better yield than furrow irrigation with tray seedlings. Tray seedlings and normal seedlings with fertigation performed better than soil application of fertilizers.

When the treatment with all the 3 factors as a single unit is taken into consideration drip irrigation, tray seedlings, drip fertigation at 3, 20–25 and 40–45 DAP (T_4) recorded higher GLY, CLY and GI, followed by the drip irrigation, tray seedlings, drip fertigation at 10, 25–30 and 40–45 DAP (T_2), when compared to the other treatments. Treatments T_4 (drip irrigation, tray seedlings, drip fertigation at 3, 20–25 and 40–45 DAP) and T_2 (drip irrigation, tray seedlings, drip fertigation at 10, 25–30 and 40–45 DAP) recorded increased GLY by 3,556, 2,525 and GI by 450, 412 kg/ha, respectively, when compared to furrow irrigation, normal seedlings, soil application of fertilizers (T_9), i.e. farmers practice. Green leaf/ cured leaf was higher in T_4 treatment and grade index/cured leaf was higher in T_2 treatment when compared to all the other treatments. These results corroborate with the findings of Kumaresan *et al.* (2013).

Bulk plots grown to calculate the economics of tray seedlings, drip irrigation and drip fertigation vis-a-vis normal seedlings, furrow irrigation and soil application of fertilizers (Table 3). Per cent increase in GLY, CLY, GI and grade index/ cured leaf with tray seedlings, drip irrigation and drip fertigation was 17.6, 16.5, 23.5 and 4.3, respectively, as compared to normal seedlings, furrow irrigation and soil application of fertilizers and this shows the additional benefit of tray seedlings, drip irrigation and drip fertigation over the furrow irrigation, normal seedlings and soil application of fertilizers.

Chemical quality characters

In general mean nicotine concentration increased from P to T position and mean reducing sugars concentration increased from P to L position and thereafter decreased from L to T position (Table 3). The increase in nicotine content from P to T position with increased plant (leaf) height was due to the fact that the nicotine is synthesized in the roots and its rate of synthesis was accelerated after the plants are topped. Nicotine was concentrated in to the remaining tissues after the tobacco is topped and desuckered. Thus, the degree of nicotine accumulation is directly related to the duration the leaves remained on the plants after topping. As the FCV tobacco in irrigated Alfisols is topped and complete sucker control is practiced, top leaves at the tip of the plant remain for a longer period on the plant and thus the nicotine concentration is increased from P to T position with increase in stalk position (Collins and Hawks, 1993).

Lamina nicotine concentration was higher in drip irrigation, tray seedlings, drip fertigation at 10, 25–30 and 40–

Table 3. Effect of drip irrigation and tray seedlings on the nicotine and reducing sugars concentration of flue-cured virginia tobacco cv. 'Kanchan' in irrigated Alfisols of Andhra Pradesh (pooled)

Treatment	Nicotine (%)				Reducing sugars (%)			
	P	X	L	T	P	X	L	T
T_1	1.22	1.34	1.52	2.09	17.46	20.18	20.62	17.69
T_2	1.32	1.58	1.77	2.36	14.40	17.16	18.16	14.66
T_3	1.28	1.53	1.70	2.28	15.24	17.99	18.92	15.49
T_4	1.30	1.57	1.74	2.34	14.69	17.44	18.40	14.90
T_5	1.21	1.46	1.64	2.19	15.85	17.99	19.63	16.11
T_6	1.17	1.42	1.60	2.16	15.90	17.44	19.70	16.17
T_7	1.19	1.44	1.63	2.20	15.89	18.64	19.23	16.20
T_8	1.13	1.36	1.56	2.12	18.24	20.98	20.29	18.44
T_9	1.04	1.27	1.45	2.05	18.84	21.59	20.83	19.13
SEm±	0.01	0.02	0.02	0.02	0.16	0.15	0.16	0.15
CD (P=0.05)	0.03	0.05	0.05	0.05	0.44	0.41	0.44	0.43
Season means								
2013–14	1.35	1.52	1.84	2.54	14.74	16.36	19.30	15.94
2014–15	1.06	1.36	1.40	1.85	17.82	21.29	19.77	17.13
SEm±	0.01	0.01	0.01	0.01	0.11	0.11	0.10	0.14
CD (P=0.05)	0.02	0.04	0.04	0.04	0.35	0.35	0.33	0.45

T_1, Drip irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_2, drip irrigation, tray seedling, drip ferti-gation at 10, 25–30 and 40–45 DAP; T_3, drip irrigation, tray seedling, soil application of fertilizers at 3, 20–25 and 40-45 DAP; T_4, drip irrigation, tray seedling, drip fertigation at 3, 20–25 and 40–45 DAP; T_5, drip irrigation, normal seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_6, drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40–45 DAP; T_7, furrow irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_8, furrow irrigation, tray seedling, soil application of fertilizers at 3rd, 20–25 and 40–45 DAP; T_9, furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP

P, Primings; X, lugs & Cutters; L, Leaf; T, Tips

Table 4. Effect of drip irrigation and tray seedlings on the quality parameters of NLS tobacco (bulk plots 2016–17)

	Tray seedlings, drip fertigation				Normal seedlings, furrow irrigation			
	P	X	L	T	P	X	L	T
Nicotine (%)	1.42	1.53	1.69	2.09	1.29	1.34	1.48	1.92
Reducing Sugars (%)	16.97	22.14	23.51	16.25	18.18	18.96	20.89	19.36
RS/Nicotine	11.95	14.47	13.91	7.78	14.09	14.14	14.11	10.08
Chlorides (%)	0.69	0.74	0.74	0.78	0.74	0.78	0.79	0.84

P, Primings; X, lugs & Cutters; L, Leaf; T, Rips RS, Reducing Sugars

45 DAP (T_2), followed by drip irrigation, tray seedlings, drip fertigation at 3, 25–30 and 40–45 DAP (T_4) and drip irrigation, tray seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP (T_3) in all the positions when compared to rest of the treatments. The lowest concentration of lamina nicotine was recorded in furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP (T_9), when compared to rest of the treatments. Lamina reducing sugars were higher in T_9 treatment, followed by T_8 and T_1 treatments in all the plant positions, when compared to rest of the treatments.

The lamina chemical quality parameter nicotine was higher and reducing sugars, RS/ nicotine and chlorides were lower in bulk plots of tray seedlings, drip irrigation and drip fertigation as compared to normal seedlings, furrow irrigation and soil application of fertilizers. The higher nicotine concentration in bulk plot of drip fertigation was attributed to more efficient utilization of applied nutrients (N) as compared to furrow irrigation (Table 4). The lower concentration of RS and RS/nicotine in drip fertigation might be due to dilution effect of these contents as a result of increased cured-leaf yield.

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. 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 nitrate-reductase activity and the 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 N-use efficiency, increased the concentration of total nitrogen and nicotine and decreased the sugars in tobacco cured leaf. Lower levels of sugars were associated with higher levels of nitrogen. These results are in conformity with the findings of Kasturi *et al*., (2009, 2016) and Krishna *et al*., (2008).

Chlorides are well within the acceptable limits (data not given here) of good quality (<1.5%) in all the treatments. Our results confirmity the findings of Kasturi Krishna *et al*., 2009). The chemical quality characters were within the acceptable limits of good-quality leaf. Distribution of nicotine and reducing sugars in lamina in different plant positions of cured leaf of tobacco followed the normal trend in all the treatments (Gopalachari, 1984).

Nutrient uptake

Significant differences were noticed between the treatments with regard to N, P and K uptake (Table 5). Drip irrigation, tray seedlings, drip fertigation at 3, 25–30 and 40–45 DAP (T_4) showed the highest N, P, K uptake in leaf, stem, root and total, followed by drip irrigation, tray seedlings, drip fertigation at 10, 25–30 and 40–45 DAP (T_2), drip irrigation, tray seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP (T_3) and drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40–45 DAP (T_6). Higher proportion of N, P, K uptake was recorded in leaf followed by stem and root in proportion to their biomass. The lowest N, P, K uptake was recorded in T_9 among the treatments. The proportion of N uptake in leaf, stem and root in the first year were 58.2, 24.5 and 17.3 and in the second year 56.9, 23.9 and 19.2%, respectively.

The proportion of P uptake in leaf, stem and root in the first year was 69.5, 18.2 and 12.3 of total 8.66 kg/ha and in the second year it was 69.8, 17.5 and 12.8% of total 10.81 kg/ha respectively. The proportion of K uptake in leaf, stem and root in the first year was 65.4, 20.94 and 14.55 and in the second year it was 64.8, 20.75 and 14.4%, respectively. The total quantum of N, P, K uptake was higher in the second year than that of the first year owing to the higher productivity. Mean N, P and K accumulation in leaf was higher followed by stem and root. The more proportion of N, P and K accumulation in leaf owing to higher dry-matter accumulation in leaf. Moustakas and Nizanis (2005) also reported similar pattern of uptake and distribution of N and P in plant parts. When we consider, mean total of N, P and K uptake, the proportion of K uptake was slightly higher (48.2%) than N (47.1%) and the P uptake (4.7%) is the lowest. The K uptake was 1.02 and 10.26 times higher

Table 5. Effect of drip irrigation and tray seedlings on nitrogen, phosphorus and potassium uptake (kg/ha) of flue-cured Virginia tobacco cv. 'Kanchan' in irrigated Alfisols of AP (pooled)

Treatment	Nitrogen uptake				Phosphorus uptake				Potassium uptake			
	Leaf	Stem	Root	Total	Leaf	Stem	Root	Total	Leaf	Stem	Root	Total
T_1	55.65	23.40	17.69	96.75	6.57	1.65	1.23	9.45	64.15	20.52	14.16	98.83
T_2	60.95	25.80	19.59	106.34	7.53	2.02	1.41	10.96	69.67	22.73	15.93	108.33
T_3	57.99	24.47	18.54	101.00	7.02	1.83	1.26	10.11	66.72	21.63	14.79	103.13
T_4	64.25	27.29	20.78	112.32	8.30	2.20	1.56	12.07	73.47	24.27	17.02	114.76
T_5	50.90	21.30	16.06	88.27	5.91	1.43	0.96	8.29	59.62	18.72	13.05	91.39
T_6	57.07	24.05	18.20	99.32	6.95	1.80	1.25	9.99	65.43	20.99	14.50	100.92
T_7	54.38	22.82	17.24	94.44	6.45	1.62	1.20	9.27	62.99	19.88	13.88	96.74
T_8	54.73	22.99	17.37	95.09	6.49	1.63	1.16	9.28	63.40	20.00	13.98	97.37
T_9	50.56	21.13	15.93	87.62	5.87	1.42	0.95	8.23	59.23	18.57	12.94	90.73
T_{10}	6.88	3.39	2.68	13.0	2.81	1.02	0.55	4.38	22.7	4.71	2.61	30.0
T_{11}	26.8	13.3	10.9	51.0	5.10	1.94	1.15	8.19	19.1	7.23	4.22	30.6
Season means												
1st year	52.21	22.01	15.55	89.28	6.82	1.57	1.06	8.66	61.51	19.71	13.70	94.13
2nd year	60.34	25.38	20.31	106.03	7.55	1.89	1.38	10.81	68.42	21.91	15.24	105.58

T_1, Drip irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_2, drip irrigation, tray seedling, drip ferti-gation at 10, 25–30 and 40–45 DAP; T_3, drip irrigation, tray seedling, soil application of fertilizers at 3, 20–25 and 40-45 DAP; T_4, drip irrigation, tray seedling, drip fertigation at 3, 20–25 and 40–45 DAP; T_5, drip irrigation, normal seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_6, drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40–45 DAP; T_7, furrow irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_8, furrow irrigation, tray seedling, soil application of fertilizers at 3rd, 20–25 and 40–45 DAP; T_9, furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_{10}, N_0 $P_{26.2}$ $K_{99.6}$ & T_{11}, N_{120} $P_{26.2}$ K_0

than N and P uptake, respectively. Krishnendu Bay (2020) reported that, N uptake was significantly higher (16.77%) with 150% recommended dose of fertilizer (RDF) than that of RDF in the hybrid maize.

Higher total K uptake than N by the tobacco crop indicates the importance of K in the mineral nutrition of FCV tobacco. The soils of the experimental plot was low in N and K status, hence application of N and K might have increased the uptake of N and K by the crop (Harder *et al.,* 2000; Kasturi-Krishna *et al*., 2016; Krishna Reddy *et al*., 2017). Tanmoy Paik *et al.* (2020) concluded that, application of 150% RDF resulted in the highest yield, net returns and nutrient-use efficiency in wheat.

Nitrogen and potassium-use efficiency indices

Nitrogen-and potassium-use efficiencies under different treatments were evaluated (Table 6) in terms of agronomic efficiency (AE_N, AE_K), physiological efficiency (PE_N, PE_K), harvest index (HI_N, HI_K), internal utilization efficiency (IUE_N, IUE_K), partial factor productivity (PFP_N, PFP_K) and apparent recovery efficiency (ARE_N, ARE_K).

The AE_N, PE_N, IUE_N and PFP_N values ranged from 14.26 to 17.72, 22.01 to 23.81, 25.91 to 28.47 and 25.85 to 28.41 kg/kg; ARE_N and HI_N values ranged from 60.1 to 80.7 and 57.23 to 57.76%, respectively. The AE_K, PE_K, IUE_K and PFP_K values ranged from 5.91 to 9.38, 12.93 to 14.51, 25.31 to 27.42 and 25.30 to 27.43 kg/kg; and ARE_K and HI_K values ranged from 46.17 to 66.19 and 64.03 to 65.27%, respectively.

The indices except ARE_N and ARE_K, HI_N and HI_K were lower in all the treatments. The HI_N and HI_K remained more or less same (57.23 to 57.76% for N and 64.03 to 65.27% for K) across all the treatments. This implied that, about 57.23–57.76% of total N uptake and 64.03–65.27% of total K uptake was translocated to economic part (i.e. leaf) in all the treatments. Drip irrigation, tray seedling and drip fertigation resulted in higher nutrient uptake and the nutrient-use efficiencies (T_4 and T_2) and the furrow irrigation, normal seedlings, soil application of fertilizers (T_9) recorded lower nutrient uptake and nutrient-use efficiencies. These findings are consistent with those of Krishna Reddy *et al.* (2017).

Uptake N and K nutrients and nutrient-use efficiencies were higher with treatments T_4 and T_2 and lower with treatment T_9 as reflected in cured-leaf

Table 6. Effect of drip irrigation and tray seedlings on nitrogen and potassium-use efficiency indices of flue-cured Virginia tobacco

Treatment	Agronomic efficiency (kg CLY increased/kg nutrient applied)		Apparent recovery efficiency (%)		Physiological efficiency (kg CLY increased/kg nutrient taken up from fertilizer		Nutrient-harvest index or Translocation index (%)		Internal utilization efficiency (kg CLY/ kg nutrient taken up)		Partial factor productivity (kg CLY/ kg nutrient applied)	
	AE_N	AE_K	ARE_N	ARE_K	PE_N	PE_K	HI_N	HI_K	IUE_N	IUE_K	PFP_N	PFP_K
T_1	15.80	7.45	67.70	52.90	23.40	14.19	57.58	64.92	27.70	27.05	27.63	27.05
T_2	17.12	8.78	75.69	60.83	22.68	14.51	57.37	64.31	26.70	26.14	26.63	26.14
T_3	16.4	8.05	71.24	56.50	23.09	14.35	57.47	64.69	27.25	26.62	27.19	26.63
T_4	17.72	9.38	80.70	66.19	22.01	14.23	57.23	64.03	25.91	25.31	25.85	25.30
T_5	14.40	6.05	60.64	46.71	23.81	13.07	57.70	65.24	28.45	27.41	28.38	27.41
T_6	16.15	7.80	69.85	54.65	23.18	14.37	57.52	64.83	27.40	26.90	27.34	26.90
T_7	15.39	7.05	65.77	51.17	23.47	13.88	57.63	81.46	27.86	27.13	27.78	27.12
T_8	15.53	7.19	66.32	51.70	23.49	14.01	57.62	65.11	27.85	27.13	27.78	27.13
T_9	14.26	5.91	60.1	46.17	23.80	12.93	57.76	65.27	28.47	27.42	28.41	27.43

T_1, Drip irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_2, drip irrigation, tray seedling, drip ferti-gation at 10, 25–30 and 40–45 DAP; T_3, drip irrigation, tray seedling, soil application of fertilizers at 3, 20–25 and 40-45 DAP; T_4, drip irrigation, tray seedling, drip fertigation at 3, 20–25 and 40–45 DAP; T_5, drip irrigation, normal seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_6, drip irrigation, normal seedlings, drip fertigation at 10, 25–30 and 40–45 DAP; T_7, furrow irrigation, tray seedling, soil application of fertilizers at 10, 25–30 and 40–45 DAP; T_8, furrow irrigation, tray seedling, soil application of fertilizers at 3rd, 20–25 and 40–45 DAP; T_9, furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP

yield. This is because in the former 2 treatments, drip irrigation, tray seedlings and drip fertigation were used which complemented each other, resulting in enhanced yield and thus nutrient uptake and nutrient-use efficiencies, while lower cured-leaf yield, nutrient uptake and nutrient use were recorded in T_9 treatment. This is because in T_4 and T_2 treatments the leaf yield increased in tune with the nutrient uptake, which resulted in higher values of N-and K-use efficiencies. The decline in nutrient uptake and N-and K-recovery efficiency with T_9 might be due to leaching losses of these nutrients to deeper layers beyond root zone due to the porous nature of sandy soils in furrow irrigation, normal seedlings and soil application of fertilizers. Our results confirm with the findings of Farrokh and Farrokh (2012).

The N:K uptake ratio, i.e. amount of N uptake for each kg of K uptake, remained around 0.98 and there was not much variation among the different treatments as the doses of N and K applied were same for all the treatments. Potassium is essential for plant growth and greatly required during the growth, vegetative and reproductive stages, since it is engaged in osmotic adjustment, stomata mechanism, photosynthesis, enzyme activation and meristematic growth. The total K uptake increase due to N fertilization is attributed to the increase in availability of nitrogen, a potent stimulant of growth. However, to achieve the maximum efficiency in tobacco production an appropriate balance in amounts of N and K must be available in the soil, as there is strong interaction between these 2 nutrients for the growth of the crop.

In FCV tobacco the ARE_N values ranged from 60.3 to 80.7% and ARE_K values between 46.17 and 66.19% under irrigated Alfisols. The ARE_N is only 30–40% in rice and 50–60% in other cereals. The ARE_K varied from 60 to 80% in other crops. These findings corroborated with reports of Brar *et al*. (2011). Prasad and Shivay (2016) also reported that, the fertilizer N-use efficiency is less than 50%.

Economics

Bulk plots were grown to calculate the economics of tray seedlings, drip irrigation and drip fertigation vis-a-vis normal seedlings, furrow irrigation and soil application of fertilizers (Table 7). Additional profit of 25,285 and benefit : cost ratio of 1.82 was realized with tray seedlings, drip irrigation and drip fertigation, though cost of cultivation, gross returns increased over normal seedlings, furrow irrigation and soil application of fertilizers. Jalpa *et al.* (2021) also reported that, sole *bidi* tobacco was the second highest productive and remunerative crop. Water-use efficiency was 11.74 kg of cured leaf/ha-mm of water used in tray seedlings, drip irrigation and drip fertigation, as compared to 5.77 kg of cured leaf/ha-mm in normal seedlings, furrow irrigation and soil application of fertilizers.

Table 7. Effect of drip irrigation and tray seedlings on the productivity and economics of Northern Light Soil for tobacco (bulk plots 2016–17)

Treatment	Tray seedlings, drip fertigation	Normal seedlings, furrow irrigation	Percent increase in Tray seedlings and drip fertigation
GLY (kg/ha)	17,234	14,659	17.6
CLY (kg/ha)	2,935	2,520	16.5
GI (kg/ha)	2,236	1,811	23.5
GL/CL	5.87	5.82	–
GI/CL (%)	76.2	71.9	4.3
Cost of cultivation (₹/ha)	280,153	249,413	
Gross returns @135/kg (₹/ha)	396,225	340,200	
Additional cost of cultivation (₹/ha)	30,740		
Additional gross returns (₹/ha)	56,025		
Additional profit (₹/ha)	25,285		
Benefit : cost ratio	1.823		
Total irrigation water	250 ha-mm	437 ha-mm	Only 57.2% of total quantity of furrow irrigation is required for drip.
WUE* (CL/ha-mm of water)	11.74	5.77	203.5% increase.

GLY = Green Leaf Yield; CLY = Cured Leaf Yield; GI = Grade Index; GL/CL = Green Leaf/ Cured Leaf; GI/CL = Grade Index/ Cured Leaf; WUE Water Use Efficiency

Drip irrigation required only 57.2% quantity of furrow irrigation, and it increased the WUE by 203.5 % to furrow irrigation.

Integration of drip irrigation, tray seedlings, drip fertigation at 3, 20–25 and 40–45 DAP increased the green-leaf yield by 3,556 (23.87), cured leaf yield by 415 (16.67) and grade index by 450 kg/ha (23.44%), when compared with furrow irrigation, normal seedlings, soil application of fertilizers at 10, 25–30 and 40–45 DAP. The additional profit accrued due to tray seedlings, drip fertigation plot was 25,285/ha with a benefit: cost ratio of 1.82 and with 57.2% of total furrow irrigation water requirement, thus showing 42.8% saving in irrigation requirement and 203.5% in WUE. Among all the treatments, furrow irrigation, normal seedlings and soil application of fertilizers recoded the lower yields. The tobacco yields were significantly higher during 2015–16 (2 year), owing to early planting and favourable weather conditions.

REFERENCES

Behera, M.S., Verma, O.P., Mahapatra, P.K., Singandsdhupe, R.B. and Kumar, A. 2013. Effect of irrigation and fertility levels on yield, quality and economics of Japanese mint (*Mentha arvensis*) under drip irrigation system. *Indian Journal of Agronomy* **58**(1): 109–113.

Brar, M.S., Singh, Bijay, Bansal, S.K. and Srinivasa Rao, Ch. 2011. Role of potassium nutrition in nitrogen use efficiency in cereals. International Potash Institute. Research findings. *e-ifc* No. 29, December 2011.

Chawla, J.K. and Narda, N.K. 2002. Growth parameters of trickle fertigated potato (*Solanum tuberosum*). *Indian Journal of Agricultural Sciences* **70**(11): 747–752.

Collins, W.K. and Hawks (Jr), S.N. 1993. *Principles of Flue Cured Tobacco Production*, 116 pp. N.C. state University, Raleigh, NC, USA.

Farrokh, A.R. and Farrokh, A. 2012. Effect of nitrogen and potassium on yield, agronomy efficiency, physiological efficiency and recovery efficiency of nitrogen and potassium in flue cured tobacco. *International Journal of Agriculture and Crop Sciences* **4**(12): 770–778.

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

Gopalachari, N.C. 1984. *Tobacco*, 96 pp. Indian Council of Agricultural Research, New Delhi.

Harder, R., Yang, Y.H. and Zhang, F. 2000. Sound agronomic approaches for improved K content and quality of flue-cured tobacco leaf in Yunnam, China. CORESTA *Bulletin,* p. 117.

Jalpa, P., Panchal, K.M. Gedia, Padhiyar, G.M. and Patel, J.N. 2021 Agronomic and economic evaluation of alternative cropping systems for *bidi* tobacco (*Nicotiana tabacum* in middle Gujarat conditions. *Indian Journal of Agronomy* **66**(4): 462–465.

Kasturi, K. S., Krishna R. S.V., Deo Singh, K., Harishu K. P. and Krishnamurty, V. 2009. Effect of organic and inorganic sources of nitrogen on productivity, quality and economics of FCV tobacco (*Nicotiana tabacum*) in irrigated Alfisols. *Indian Journal of Agronomy* **54**(3): 336–341.

Kasturi Krishna, S., Krishna Reddy S.V., Krishnamurthy, V., Chandrasekhara Rao, C. and Anuradha, M. 2016. Effect of N and K levels on growth, yield and nutrient uptake of FCV tobacco cv. Kanchan. *Indian Journal of Agricultural Sciences* **86**(5): 692–696.

Krishna Reddy, S.V., Kasturi Krishna, S. Damodar Reddy, D. Chandrasekhara Rao, C and Nageswara Rao, K. 2017. Productivity, leaf quality and nutrient–use efficiency of FCV tobacco (*Nicotiana tabacum*) genotypes to levels of N and K application under irrigated Alfisols of Andhra Pradesh. *Indian Journal of Agronomy* **62**(4): 510–518.

Krishna Reddy, S.V., Kasturi Krishna, S. and Prasad Rao, J.A.V. 2008. Productivity, quality and economics of irrigated FCV tobacco *(Nicotiana tabacum)* in relation to spacing, dose and time of nitrogen application. *Indian Journal of Agronomy* **53**(1): 70-–75.

Krishnendu Bay, Benerji, Hirak and Bandopadhyaya, Pinto. 2020. Effect of cultivars, levels of nitrogen and potassium on growth yield and nutrient uptake of maize (*Zea mays*) hybrids. Indian Journal of Agronomy **65**(1): 68–76.

Kumaresan, M., Rao, C.C.S. and Murthy, T.G.K. 2013. Effect of drip irrigation on productivity and quality of chewing tobacco. *Indian Journal of Agronomy* **58**(3): 402–407.

Moustakas, N.K. and Nizanis, H. 2005. Dry matter accumulation and nutrient uptake in flue-cured tobacco (*Nicotiana tabacum* L.). *Field Crops Research* **94**(1): 1–13.

Patel, N. and Rajput, T.B.S. 2000. Effect of fertigation on growth and yield of onion. (In) *Proceedings of International Conference on Micro and Sprinkler Irrigation Systems,* held during 8–10 February 2000 at Jalgoan, Maharastra, India, pp. 77.

Phene, C.J., Fouss J.L. and Sander, I.C. 1979. Water, nutrient and herbicide management for potatoes with trickle irrigation. *American Potato Journal* **56**: 51–56.

Prasad, R. and Shivay Y.S. 2016. Deep placement and foliar fertilization of nitrogen for increased use efficiency – An overview. *Indian Journal of Agronomy* **61**(4): 420–424.

Surekha, K., Rao, K.V. and Sam, T.K. 2008. Improving productivity and nitrogen use efficiency through integrated nutrient management in irrigated rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **78**(2): 173–176.

Paik, T., Singh, Y. and Sadhukan, R. 2020. Nutrient management in wheat (*Triticum aestivum*) for improving grain yield, nutrient-use efficiency and profitability. *Indian Journal of Agronomy* **65**(1): 107–110.

Tobacco Board, 2019. *Annual Report*, *2018-19,* 24 and 26 pp. Tobacco Board, Ministry of Commerce and Industry, Government of India. Guntur, Andhra Pradesh.