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EFFECT OF SPACING AND FERTILIZER LEVELS ON GROWTH, YIELD, QUALITY AND NUTRIENT UPTAKE OF FCV TOBACCO VAR. FCS-4

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ABSTRACT

The field experiment entitled Effect of spacing and fertilizer levels on growth, yield, quality and nutrient uptake of FCV tobacco var. FCS-4 was conducted at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga during late *kharif* 2024 using Randomized Complete Block Design under factorial concept with twelve treatment combinations consisting of four spacing such as (90 cm × 45 cm, 90 cm × 60 cm, 90 cm × 75 cm and 75 cm × 75 cm) and three NPK fertilizer levels (100 % RDF, 125 % RDF and 150 % RDF) replicated thrice. The results showed that plant height was significantly influenced by spacing, with closer spacing of 90 cm × 45 cm recorded the tallest plants(46.4 cm),While wider spacing of 90 cm × 75 cm showed significantly higher leaf area per plant (30.2 dm^2 $plant^{-1}$) leaf area of X position leaves (893.4 cm^2) leaf area of L position leaves (757.1cm^2).Whereas total uptake of nitrogen(48.3 kg ha^{-1}), phosphorus (11.2 kg ha^{-1}) potassium (93.6 kg ha^{-1}), green leaf yield (10889 kg ha^{-1}) and cured leaf yield (1348 kg ha^{-1}) as compared to other spacing. Among the fertilizer levels, application of 150 % RDF recorded significantly higher plant height (41.1 cm), leaf area per plant (29.0 dm^2 $plant^{-1}$), leaf area of X position leaves (907.4 cm^2), leaf area of L position leaves (758.2 cm^2) total uptake of nitrogen (48.1 kg ha^{-1}), phosphorus (12.4 kg ha^{-1}) potassium (90.5 kg ha^{-1}), green leaf yield (10886 kg ha^{-1}) and cured leaf yield (1290 kg ha^{-1}). The chemical quality parameters of leaf like nitrogen, potassium, nicotine, reducing sugars and chlorides were within the acceptable limits.

***Keywords* :** FCV tobacco, FCS-4, spacing, fertilizer levels, growth, yield quality parameters and uptake.

Introduction

Tobacco (*Nicotiana tabacum* L.) is one of the most important high-value commercial crop cultivated in India, contributing significantly to the agricultural economy through domestic consumption and export earnings. India ranks second in global tobacco production after China, cultivating about 0.45 million hectares and producing around 760 million kg of tobacco leaves annually (Anon., 2024). Among the various types, Flue-Cured Virginia (FCV) tobacco holds a prominent place due to its superior leaf quality and export potential. It is primarily grown in the southern transition zone of Karnataka, especially in the Karnataka Light Soils (KLS) region, where it occupies about 0.139 million hectares, producing approximately 241 million kg of cured leaves each year (Anon., 2024). The growth, yield and quality of FCV tobacco are largely determined by its agronomic management practices, particularly plant spacing, population density and nutrient management. The crop growth dynamics such as plant height, leaf number, leaf area, and dry matter accumulation are highly responsive to spacing and fertilization levels. Optimum plant spacing ensures proper aeration, light interception and efficient utilization of soil moisture and nutrients. Wider spacing results in larger leaves and a higher proportion of medium to heavy-bodied tobacco, while closer spacing tends to produce smaller, thinner leaves with lower nicotine content (Chaplin *et al*., 1968). Yield performance in FCV tobacco is closely related to plant density and fertilizer management. Increased plant population can enhance the total cured leaf yield per hectare by efficiently utilizing available resources. For instance, Singh *et al.* (1999) reported that increasing plant density to 31,280 plants ha^{-1} resulted in a 37 per cent increase in cured leaf yield. Similarly, adequate and balanced nutrient application, particularly of nitrogen, phosphorus and potassium has been found essential for achieving higher productivity and maintaining leaf quality (Aziz *et al*., 1969). The quality of FCV tobacco is largely determined by the chemical composition and physical attributes of the cured leaf, including nicotine content, sugar concentration, leaf thickness, elasticity, colour, and combustibility. Nitrogen is known to improve leaf size and colour but excessive application can reduce burning quality and delay maturity. Potassium plays a key role in improving leaf elasticity, colour uniformity, and combustibility, while phosphorus supports root development and early growth (Tripathi *et al*., 1987). An appropriate N and K balance is crucial, as potassium enhances nitrogen-use efficiency and overall leaf quality (Elliot, 1975). Nutrient uptake efficiency also serves as a critical determinant of crop performance. Proper nutrient uptake supports optimal physiological processes such as photosynthesis, translocation, and leaf expansion, ultimately influencing both yield and quality. Balanced fertilization ensures efficient nutrient absorption and utilization, while imbalance particularly in nitrogen and potassium can lead to inferior cured leaf quality and reduced economic returns. In summary, the growth, yield, quality, and nutrient uptake of FCV tobacco are interlinked and highly influenced by plant spacing, population density, and nutrient management. Understanding the interaction among these factors is essential for optimizing resource use efficiency, improving cured leaf quality, and maximizing profitability under the rainfed conditions of Karnataka's FCV tobacco-growing regions**.**

FCS-4 is a recently developed tobacco variety released in 2024 by the All India Network Project on Tobacco, Shivamogga. It is characterized by a semi-erect growth habit with a conical canopy structure and leaf angle orientation ranging from 45° to 89°.The variety is well adapted to the southern transition zone of Karnataka and is moderately resistant to black shank and frog eye leaf spot diseases, which are among the major production constraints in this region. In order to exploit the full genetic potential of the FCS-4 variety the major agronomic practices like spacing and fertilizer requirement. Hence, the present study was undertaken to evaluate the effect of spacing and fertilizer levels on growth, yield, quality parameters and nutrient uptake of FCV tobacco var. FCS-4.

Material and Methods

A field experiment was conducted during late *kharif* season of 2024 at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga. It lies under 13º 58' N latitude, 75º 34' E longitude with an altitude of 650 m above the mean sea level in Southern Transition Zone of Karnataka (Zone-7). The prevailed weather conditions during the cropping period provided favourable circumstances for the growth and yield of FCV tobacco var. FCS-4. The crop received rainfall of 232.6 mm during the cropping period. The mean maximum and minimum air temperature 33.4 °C and 21.5°C was recorded. The soil of the experimental site was sandy loam in texture with PH 5.6, Electrical conductivity (EC) 0.9 dSm^{-1} and organic carbon (OC) 4.7 g kg^{-1} content. The experiment was laid out in RCBD (factorial concept) with twelve treatment combinations consist of four spacing such as (90 cm × 45 cm, 90 cm × 60 cm, 90 cm × 75 cm and 75 cm × 75 cm) with three different level of NPK fertilizers(100 % RDF 40:30:80 kg $N:P_2O_5:K_2O$ ha^{-1}, 125 % RDF 50:37.5:100 kg $N:P_2O_5:K_2O$ ha^{-1} and 150 % RDF 60:45:120 kg $N:P_2O_5:K_2O$ ha^{-1}) replicated thrice. Periodical observations were recorded. The data so obtained were subjected to statistical analysis as per the standard procedures given by Gomez and Gomez (1984).

Results and Discussion

Effect of spacing and fertilizer levels on growth parameters and yield on FCV tobacco var. FCS-4

Among different spacing 90 cm × 45 cm recorded significantly higher plant height this might due to the higher plant population (24,691 plants ha^{-1}) at 90 cm × 45 cm spacing, which led to greater competition among plants for light, nutrients, and moisture. This crowding effect encouraged plants to grow taller in order to intercept sunlight, but it restricted branching and stem thickness. Individual plants in treatments with narrow spacing did not get an opportunity to proliferate laterally due to less lateral space, which is in agreement with the findings of Patel *et al.* (2002). Wider spacing of 90 cm × 75 cm recorded significantly higher leaf area plant^{-1}, leaf area of X position leaves and leaf area of L position leaves (Table 1). It might also be due to the variation in plant spacing markedly influenced the available area per plant, which in turn affected leaf parameters. The wider spacing of 90 cm × 75 cm (6750 cm^2) provided 66.7 per cent more area per plant compared to 90 × 45 cm (4050 cm²), 25 per cent more area than 90 cm × 60 cm (5400 cm^2) and 20 per cent more area than 75 cm × 75 cm (5625 cm^2). This additional space reduced inter-plant competition and created a more favourable micro-environment, which promoted enhanced leaf initiation, expansion, and canopy development. Similar findings were reported by Kim *et al.* (1987) where wider spacing of 105 cm × 42 cm significantly enhanced leaf area, leaf area per plant, and weight per unit leaf compared to a closer spacing of 105 cm × 35 cm. These observations clearly indicate that reduced inter-plant competition under wider spacing supports better individual leaf development and biomass accumulation. Likewise, Razak *et al.* (1989) reported that closer spacing of 40 cm increased plant height, whereas wider spacing of 80 cm promoted leaf expansion and thicker lamina, which are desirable traits for quality improvement.

Among the various spacing 90 cm × 60 cm proved most effective, consistently producing the higher green leaf yield and cured leaf yield. This spacing maintained a favourable plant population (18,518 plants ha^{-1}) that balanced inter-plant competition and resource availability, resulting in vigorous vegetative growth, larger leaf area and better canopy development ultimately enhancing photosynthetic efficiency and assimilate production. In contrast, 90 cm × 45 cm spacing (24,691 plants ha^{-1}) recorded lower green leaf yield cured leaf yield 3.6 per cent and 1.5 per cent due to excessive competition restricting lateral spread and leaf expansion. Wider spacing at 90 cm × 75 cm (14,518 plants ha^{-1}) and 75 cm × 75 cm (17,777 plants ha^{-1}) promoted better individual plant growth but resulted in 8.6 per cent, 10.5 per cent and 18.2 per cent, 18.8 per cent lower green and cured leaf yield respectively, due to reduced plant population and cumulative photosynthetic surface. Although growth parameters were comparable between 90 cm × 60 cm and 90 cm × 75 cm yield differences were primarily attributed to plant density. These results align with the findings of Thakur and Modgal (1983) confirming that moderately wider spacings within the optimum range favour superior green and cured leaf yield.

Application of 150 per cent RDF recorded the higher green leaf and cured leaf yield which corresponded to increased yield of 11.4 and 10.9 per cent over the 100 per cent RDF. The increased yield under higher fertilizer application may be attributed to enhanced nutrient availability, greater leaf area expansion, higher photosynthetic efficiency and improved partitioning of assimilates towards economically important plant parts. The superior performance of 150 per cent RDF was mainly due to higher values of growth attributing characters such as increased cumulative number of harvested leaves per plant, higher leaf area per plant, higher leaf weight and thickness, which together contributed to higher green leaf and cured leaf yield. Similarly, 125 per cent RDF also resulted in significantly higher yield over 100 per cent RDF but was comparatively lower than 150 per cent RDF. These findings are in close agreement with the earlier report of Reddy *et al.* (2008). Who observed that the application of additional fertilizer doses increased cured leaf yield in FCV tobacco. This was attributed to greater nutrient uptake, enhanced photosynthate production, and improved translocation of assimilates to the leaves.

Effect of spacing and fertilizer levels on nutrient uptake on FCV tobacco var. FCS-4

Plant spacing significantly influenced nutrient uptake of FCV tobacco. The wider spacing of 90 cm × 60 cm recorded the higher uptake of nitrogen (48.3 kg ha^{-1}), phosphorus (11.2 kg ha^{-1}) and potassium (93.6 kg ha^{-1}) with increases of 31.6 per cent, 36.5 per cent and 21.7 per cent over 75 cm × 75 cm spacing respectively. Wider spacing reduced inter-plant competition for soil nutrients, moisture, and light, thereby favouring vigorous root development and efficient nutrient assimilation. Enhanced P uptake at wider spacing improved root development, energy transfer and crop maturity (Patil *et al.*, 2015) which contributed to uniform leaf ripening and better burning quality critical traits for superior cured leaves. Adequate K supply supported carbohydrate metabolism, assimilate translocation (Tandon, 2013).

Nitrogen, phosphorus and potassium uptake by the crop increased significantly with higher fertilizer levels. The highest uptake was observed at 150% RDF, recording 48.1, 12.4 and 93.6 kg ha^{-1} of N, P_20_5 and K_20 respectively, representing increases of 31.0 per cent, 82.3 per cent and 19.7 per cent over 100% RDF. The increase can be due to nitrogen's key role in chlorophyll synthesis, enzymatic activity, and biomass production. Phosphorus-enhanced root proliferation and energy transfer process, which improved nutrient absorption efficiency. The pronounced response reflects the low mobility of phosphorus in soil, making higher fertilizer applications more effective in its uptake. Potassium's role in enzyme activation, stomatal regulation, and photosynthate translocation, which supported greater biomass accumulation and nutrient use efficiency. Previous studies (Krishna *et al.*, 2016).

Effect of spacing and fertilizer levels on chemical quality parameters on FCS-4 var. of FCV tobacco

There was no significant variation in leaf chemistry at four spacing and three different levels of fertilizers (Table 3). But, all the leaf quality constituents *viz*., nicotine, reducing sugar chloride, total nitrogen and potassium were within the acceptable limits. It may be mainly because of no over accumulation of available nutrients in the soil with the tried doses, paving way for normal content of nutrients. There was a gradual increase of nicotine, potassium, nitrogen with increase nitrogen level in both 'X' and 'L' position leaves. It is the interplay of the nitrogen and carbohydrate metabolism as influenced by management that predetermines the quality and chemical composition of cured leaf tobacco. Nitrate reductase is an important substrate inducible enzyme, whose activity is affected by the nitrate-nitrogen concentration of leaves and therefore the amount of nitrogen available in the soil. There is a very good negative relationship between its activity and the accumulation of starch in the leaves (Flower, 1999). An increase in nitrogen level decreased the sugars and increased the nicotine potassium and total nitrogen. Lower levels of sugars are associated with higher levels of nitrogen. Krishna *et al.* (2016). These results are also in agreement with the findings of Krishnamurthy *et al*. (2009). The chloride content of the leaf did not vary significantly due to NPK and was within the desirable limit in all the treatments.

Table 1: Growth and yield of of FCV tobacco var. FCS-4 as influenced by spacing and fertilizer levels

Treatment	Plant height (cm) 45DAP	Leaf area per plant (dm^2 $plant^{-1}$) 30 DAP	Leaf area (cm^2) of X position leaves	Leaf area (cm^2) of L position leaves	Green leaf yield (kg ha^{-1})	Cured leaf yield (kg ha^{-1})
Spacing (S)						
S_1	46.4	28.5	878.7	745.2	10499	1328
S_2	43.4	29.8	888.2	753.7	10889	1348
S_3	38.3	30.2	893.4	757.1	10030	1102
S_4	30.3	18.4	871.7	738.7	9749	1094
S.Em±	0.82	1.3	5.5	4.2	262.3	22.5
C.D at 5 %	2.4	3.7	16.2	12.2	769.5	65.9
Fertilizer level (F)						
F_1	38.4	25.0	869.4	742.9	9771	1163
F_2	39.3	26.1	872.2	745.0	10218	1201
F_3	41.1	29.0	907.4	758.2	10886	1290
S.Em±	0.7	1.1	4.8	3.6	227.2	19.4
C.D at 5 %	2.1	3.2	14.0	10.6	666.4	57.1
Interaction (S × F)						
S_1F_1	45.3	31.8	869.6	742.0	10093	1260
S_1F_2	46.7	29.3	872.4	746.7	10254	1299
S_1F_3	47.2	28.3	894.1	747.0	11150	1426
S_2F_1	42.3	24.6	876.5	748.0	10051	1295
S_2F_2	43.3	28.4	876.3	750.5	10823	1308
S_2F_3	44.7	32.5	927.3	770.8	11793	1441
S_3F_1	37.3	28.3	866.3	745.0	9641	1076
S_3F_2	38.3	28.8	870.0	748.1	10026	1112
S_3F_3	39.1	33.2	928.3	778.2	10423	1119
S_4F_1	28.7	15.4	865.0	735.6	9299	1020
S_4F_2	29.0	18.0	870.3	738.7	9770	1086
S_4F_3	33.3	21.9	879.7	741.8	10178	1174
S.Em±	1.43	2.2	9.6	7.2	454.46	38.96
C.D at 5 %	NS	NS	NS	NS	NS	NS

Note: S_1: 90 cm × 45 cm, S_2: 90 cm × 60 cm, S_3: 90 cm × 75 cm S_4 :75 cm × 75 cm
F_1:100 % RDF, F_2:125 % RDF, F_3:150 % RDF.
DAP: days after planting, RDF: recommended dose of fertilizer, NS: Non significant

Table 2: Nutrient uptake of FCV tobacco var. FCS-4 as influenced by spacing and fertilizer levels

	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
Treatment	**Leaf**	**Stem**	**Total**	**Leaf**	**Stem**	**Total**	**Leaf**	**Stem**	**Total**
Spacing (S)									
S_1	32.5	12.6	45.1	6.4	11.5	10.2	61.6	26.3	87.9
S_2	33.5	14.9	48.3	6.6	13.0	11.2	62.6	31.0	93.6
S_3	26.8	11.5	38.4	5.0	10.1	8.4	50.9	24.0	74.8
S_4	26.1	10.5	36.7	4.9	9.9	8.2	50.4	23.3	73.6
S.Em±	0.6	0.2	0.5	0.2	0.6	0.2	1.0	0.2	1.0
C.D at 5 %	1.6	0.5	1.5	0.5	1.9	0.5	3.1	0.6	2.9
Fertilizer level (F)									
F_1	26.5	10.2	36.7	4.4	6.6	6.8	52.7	22.9	75.6
F_2	29.3	12.2	41.6	5.5	11.3	9.3	55.5	25.9	81.4
F_3	33.4	14.7	48.1	7.2	15.5	12.4	60.9	29.6	90.5
S.Em±	0.5	0.1	0.5	0.1	0.6	0.1	0.9	0.2	0.9
C.D at 5 %	1.4	0.4	1.3	0.4	1.6	0.4	2.7	0.5	2.5
Interaction (S × F)									
S_1F_1	29.0	10.7	39.7	4.8	7.5	7.3	57.3	23.2	80.5
S_1F_2	31.4	12.3	43.7	6.2	11.6	10.1	60.0	25.9	85.9
S_1F_3	37.1	14.8	51.9	8.1	15.5	13.3	67.5	29.8	97.3
S_2F_1	29.5	12.1	41.5	5.1	6.3	7.9	58.8	27.5	86.3
S_2F_2	32.5	14.8	47.3	6.5	14.1	11.1	60.6	30.8	91.4
S_2F_3	38.5	17.7	56.2	8.3	18.7	14.5	68.5	34.6	103.1
S_3F_1	24.4	9.5	33.9	4.0	6.2	6.1	48.7	20.9	69.6
S_3F_2	27.3	11.2	38.4	4.8	9.4	7.9	51.3	23.2	74.5
S_3F_3	28.8	14.0	42.7	6.2	14.7	11.1	52.6	27.8	80.4
S_4F_1	23.0	8.5	31.5	3.6	6.2	5.7	45.9	19.9	65.8
S_4F_2	26.0	10.7	36.9	4.7	10.2	8.1	50.0	23.8	73.8
S_4F_3	29.3	12.5	41.8	6.3	13.3	10.8	55.2	26.2	81.4
S.Em±	1.0	0.3	0.9	0.3	1.1	0.3	1.8	0.3	1.7
C.D at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: RDF: recommended dose of fertilizer, NS: Non significant
S_1: 90 cm × 45 cm, S_2: 90 cm × 60 cm, S_3: 90 cm × 75 cm S_4 :75 cm × 75 cm
F_1:100 % RDF, F_2:125 % RDF, F_3:150 % RDF.

Table 3: Effect of spacing and fertilizer levels on chemical constituents of nitrogen, potassium, nicotine, reducing sugar and chloride contents on X Position leaves in FCS-4 var. of FCV tobacco

Treatment	Leaf at X position				
	Nitrogen (%)	**Potassium (%)**	**Nicotine (%)**	**Reducing sugar (%)**	**Chloride (%)**
Spacing (S)					
S_1	1.46	1.96	0.92	16.16	0.43
S_2	1.46	1.83	1.06	16.15	0.42
S_3	1.51	1.93	0.92	16.20	0.41
S_4	1.53	1.96	0.90	16.24	0.43
S.Em±	0.05	0.09	0.05	64.74	0.02
C.D at 5 %	NS	NS	NS	NS	NS
Fertilizer level (F)					
F_1	1.51	2.03	1.02	16.03	0.45
F_2	1.46	1.87	0.90	15.87	0.40
F_3	1.51	1.87	0.93	16.66	0.41
S.Em±	0.05	0.08	0.04	0.32	0.02
C.D at 5 %	NS	NS	NS	NS	NS
Interaction (S × F)					
S_1F_1	1.44	2.13	0.93	16.4	0.48
S_1F_2	1.49	1.84	0.91	15.4	0.39
S_1F_3	1.45	1.92	0.91	16.7	0.41
S_2F_1	1.42	1.97	1.10	16.4	0.48

S_2F_2	1.51	1.80	0.98	15.2	0.38
S_2F_3	1.46	1.73	1.10	16.9	0.41
S_3F_1	1.58	1.98	0.99	16.0	0.39
S_3F_2	1.38	2.03	0.90	16.1	0.43
S_3F_3	1.57	1.79	0.88	16.5	0.41
S_4F_1	1.59	2.04	1.05	15.3	0.47
S_4F_2	1.47	1.81	0.81	16.8	0.42
S_4F_3	1.54	2.04	0.83	16.6	0.39
S.Em±	0.09	0.16	0.09	0.64	0.03
C.D at 5 %	NS	NS	NS	NS	NS

Table 4: Effect of spacing and fertilizer levels on chemical constituents of nitrogen, potassium, nicotine, reducing sugar and chloride contents on L Position leaves in FCS-4 var. of FCV tobacco

Treatment	Leaf at L position				
	Nitrogen (%)	Potassium (%)	Nicotine (%)	Reducing sugar (%)	Chloride (%)
Spacing (S)					
S_1	1.40	1.97	0.89	16.22	0.38
S_2	1.47	2.07	0.82	15.88	0.42
S_3	1.44	2.03	0.83	15.94	0.43
S_4	1.40	1.94	0.91	15.48	0.38
S.Em±	0.05	0.08	0.05	0.48	0.02
C.D at 5 %	NS	NS	NS	NS	NS
Fertilizer level (F)					
F_1	1.40	2.05	0.87	15.94	0.39
F_2	1.39	2.01	0.90	16.01	0.42
F_3	1.49	1.94	0.82	15.68	0.39
S.Em±	0.04	0.07	0.04	0.42	0.01
C.D at 5 %	0.12	0.21	NS	NS	NS
Interaction (S × F)					
S_1F_1	1.32	1.82	0.91	16.0	0.36
S_1F_2	1.37	2.11	0.80	16.7	0.41
S_1F_3	1.51	1.99	0.97	16.0	0.36
S_2F_1	1.43	2.28	0.79	16.3	0.40
S_2F_2	1.42	1.94	1.05	16.1	0.42
S_2F_3	1.57	1.98	0.63	15.2	0.43
S_3F_1	1.44	2.02	0.89	15.5	0.47
S_3F_2	1.44	2.25	0.84	15.9	0.45
S_3F_3	1.44	1.81	0.77	16.4	0.39
S_4F_1	1.41	2.07	0.90	16.0	0.35
S_4F_2	1.33	1.75	0.90	15.4	0.41
S_4F_3	1.46	1.99	0.93	15.1	0.38
S.Em±	0.08	0.14	0.09	0.83	0.03
C.D at 5 %	NS	NS	NS	NS	NS

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