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Sustainable cotton production through fertigation scheduling: A growth stage-based approach

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Abstract

Cotton cultivation in black soil regions faces challenges in optimizing nutrient use efficiency and maintaining soil health. This study was conducted to develop a fertigation schedule based on the crop growth nutrition curve for cotton to enhance sustainability. The suggested cultural practices are implemented and interventions comprised varying levels of recommended dose of fertilizers (RDF) through fertigation. Nutrients were supplied in stages: seedling stage (10 % NPK), vegetative stage (20 % NPK), square formation (30 % NPK), 50% flowering (20 % NPK) and boll formation and development stages (10 % NPK). The treatments included absolute control (T1) and various combinations of N, P and K at 75 %, 100 % and 125 % RDF levels (T2 to T8). Among all treatments, T8 (125 % potassium along with 100 % nitrogen and phosphorus), achieved the highest cotton yield. This suggests that increasing potassium levels through fertigation significantly enhances both crop productivity and soil health in black soils. These findings facilitate advancement of more effective fertigation methodologies that balance nutrient application with soil biological health, offering practical implications for sustainable cotton farming.

Keywords

cotton; fertigation; nutrition curve; scheduling; yield

Introduction

Cotton (*Gossypium* spp.) is a significant cash crop worldwide, contributing substantially to the global textile industry and the livelihoods of millions of farmers. It accounts for approximately 2-3 % of global agricultural trade and plays a crucial role in the economies of major cotton-producing countries, making it a key driver of global GDP. In India, cotton cultivation spans diverse agro-climatic zones, with black soil regions being a major contributor to the country's production. However, achieving optimal productivity in these soils is challenging due to issues related to nutrient availability and soil health degradation. Around 60 % of fiber to Indian textiles is from cotton. Its production generates income for over 250 million individuals globally and supports approximately 7 % of workforce in developing nations (1).

Fertigation, a technique that combines irrigation and fertilization, has emerged as an effective strategy to enhance nutrient use efficiency and crop productivity. By delivering nutrients directly to the root zone, fertigation ensures precise nutrient application and minimizes losses. The concept of fertigation scheduling based on the crop growth nutrition curve aligns nutrient supply with the specific demands of the crop during various growth phases. This method enhances nutrient absorption while also mitigating environmental issues such as groundwater contamination from leaching and greenhouse gas emissions from excessive fertilizer use.

Despite having the largest area under cotton cultivation globally, India's productivity (487 kg/ha) is significantly lower than the world average (775 kg/ha). Longer duration cultivars require multiple pickings, increasing labor requirements and costs. Cotton cultivation demands substantial water resources, approximately 10000 L to yield 1kg of cotton. Approximately 67 percent of cotton in India gets produced in rain-fed regions, making production vulnerable to monsoon fluctuations.

To address these challenges, this study focuses on drip fertigation, a method that combines water-saving technology with targeted fertilizer application. This approach has the potential to induce drought tolerance and sustain cotton lint yield. The research was conducted to develop optimal fertigation schedule for cotton, utilizing the Crop Growth Nutrition Curve, with an emphasis on sustainable cotton production.

The main purpose of this investigation is to produce fertigation schedule for cotton based on the crop growth nutrition curve, to assess the impacts of diverse fertigation procedures on cotton growth, yield, soil health and to assess changes in microbial biomass and enzyme activities under varying fertigation levels. The outcomes of this research have the potential to advance sustainable fertigation practices, ensuring high productivity while maintaining long-term soil health in cotton-growing regions.

Materials and Methods

Location of the experimental site

The field experiment was executed at Eastern Block Farm, Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore, India. The region resides in the western agro-climatic zone of Tamil Nadu, with coordinates 11°N latitude and 77°E longitude, at elevation of 426.7m above mean sea level.

Climate and weather

The experimental site in Coimbatore is located within Western agro-climatic zone of Tamil Nadu. This region has a tropical semi-arid climate. The winter cropping period recorded total rainfall of 342.0 mm and 285.5 mm, along with mean solar radiation of 322.5 cal/cm^2/day and 347.7 cal/cm^2/day. The average maximum and lowest temperatures observed throughout winter season are 31.2 °C along with 20.9 °C, while those for summer season are 32.6 °C and 22.5 °C, correspondingly.

Experimental site and soil characteristics

The experimental site features sandy clay loam soil, classified as part of the Periyanaickenpalayam series and taxonomically identified as Vertic Ustropepts according to USDA classification. The composite soil sample obtained before conduct of experiment was analysed for diverse physicochemical properties. The pH was 8.35, exhibiting low soluble salts (EC = 0.68), medium available phosphorus (16 kg/ha), low available nitrogen (205 kg/ha) and high available potassium (372 kg/ha).

Crop, variety and season

Cotton variety CO17 was chosen for study which is short duration genotype which possesses zero monopodia with short sympodial length and synchronized boll maturity.

Experimental design

The research was structured employing RBD (randomized block design) with 3 replications. Eight treatments were evaluated, including an absolute control (no fertilization) and varying levels of potassium (K), phosphorus (P) and nitrogen (N), applied through fertigation.

Treatment details

T1	Absolute control (no NPK)
T2	Drip Fertigation with 100 % RDF (Recommended Dose of Fertilizer)
T3	Drip Fertigation with 75 % N + 100 % P and K of RDF
T4	Drip Fertigation with 125 % N + 100 % P and K of RDF
T5	Drip Fertigation with 75 % P + 100 % N and K of RDF
T6	Drip Fertigation with 125 % P + 100 % N and K of RDF
T7	Drip Fertigation with 75 % K + 100 % N and P of RDF
T8	Drip Fertigation with 125 % K + 100 % N and P of RDF

Fertilizer application schedule

Based on the treatment recommendation, a fertilizer solution had been formulated by dissolving appropriate quantity of each fertilizer in water and subsequently pumped into the irrigation system via a venturi assembly for easy delivery through emitters.

Seedling Stage	10 % of the total NPK
Vegetative Stage	20 % of the total NPK
Square Formation	30 % of the total NPK
50 % Flowering Stage	20 % of the total NPK
Boll Formation and Development Stage	10 % of the total NPK

Irrigation water management

An irrigation was first applied at the time of seeding and then on the third day after seeding initial establishment irrigation. Drip irrigations were applied to cotton at crucial growth phases, which include the seedling, vegetative, square formation, 50 % blooming, boll formation and boll development stages, in accordance with the treatment schedule. The experimental plots received successive irrigations on a 7-day interval schedule, depending on the soil and weather conditions.

Biometric observations

At 30, 60, 90 and 120 DAS as well as during harvest, observations were made about growth characteristics like dry matter production, dry matter accumulation, plant height and partitioning. Days to 50 % blooming and boll bursting were noted during the reproductive stages and physiological parameters such as relative growth rate, crop growth rate, as well as crop growth intervals (30-60, 60-90, 90-120 and 120-harvest), were noted. At various horizontal and vertical depth intervals, water studies such as total water use, water use efficiency and percentage soil moisture were estimated during the cropping period and soil nutrient dynamics studies were also estimated. Root studies, yield and yield attributes, quality attributes and efficiency indices were computed at the time of harvest.

Soil and plant sampling

Soil samples have been obtained prior to sowing, at various phases and at the conclusion of the experiment from each treatment plot at a depth of 0 to 15 cm. Plant samples are then collected at key growth stages for analysis of nutrient uptake.

Data analysis

The data obtained from the experiment underwent statistical analysis by ANOVA (analysis of variance). The LSD (least significant difference) test has been utilized for comparing treatment means at a significance level of 0.05.

Results and Discussion

The biometric observations of cotton planted were significantly influenced by drip fertigation scheduling with different levels of NPK fertilizers (75 % RDF, 100 % RDF and 125 % RDF NPK) in split ratios during the peak growth phases (seedling stage, vegetative stage, squaring stage, 50 % flowering stage, boll formation and boll development stages).

Effect of fertigation on plant height

Plant height increased gradually until the maximum height was reached as the plants approached maturity and reached the harvest phases. The maximum plant height was measured with fertigation of 125 % K with 100 % N & P at 30, 60, 90 and 120 DAS (days after sowing) as well as harvest stage during winter and summer seasons. The maximum plant height was recorded with 41.5, 77.2, 106.5, 124.3, 146.3cm at 30, 60, 90 and 120 DAS (days after sowing) and harvest stage, respectively (Table 1). This might be due to an increased supply of potassium with split doses which in turn resulted in higher production of Indole Acetic Acid (IAA) which subsequently stimulated cell elongation process and increased plant height. These outcomes conformed with findings of (2).

Effect of fertigation on dry matter production

Drip fertigation with 125 % K with 100 % N & P, produced greater DMP of 500, 2051, 4541, 9059, 9351 kg ha^{-1} (Table 2). The incremental effect on dry matter production is mainly due to the supply of K which contributes proper functioning of the photosynthetic unit within plant system as it is responsible for fixing carbon dioxide fixation rates as well as chlorophyll concentration (3).

Effect of fertigation on Leaf Area Index (LAI) and Crop Growth Rate (CGR)

The fertigation of 125 % percent K alongside 100 % N & P recorded highest LAI and CGR at the seedling stage, vegetative stage, squaring, boll formation and boll development stages, respectively (Fig. 1, 2). The incremental effect on CGR and LAI may be attributed to higher chlorophyll content in leaf tissue, which enhances water and nutrient use efficiency. This, in turn, improves metabolic activities, promoting cell division and elongation. These findings are consistent with the previous research (4).

Effect of fertigation on root Attributes

Root characteristics, including root volume, root length and root dry weight, were significantly influenced by fertigation scheduling. The variation in fertilizer quantities applied in split ratios during peak growth stages played a key role in these effects. The application of 125 % potassium alongside 100 % nitrogen and phosphorus resulted in elevated

Table 1. Effect of fertigation on plant height

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	HARVEST
T1	26.5	43.2	76.6	96.3	125.1
T2	34.4	63.7	88.2	108.6	136.1
T3	31.5	48.2	81.6	101.3	130.1
T4	37.2	67.7	91.2	111.2	138.5
T5	32.3	58.2	87.7	106.3	133.1
T6	38.8	71.4	94.4	118.6	142.3
T7	29.3	54.8	83.8	104.5	131.2
T8	41.5	77.2	106.5	124.3	146.3
SEd	1.99	3.59	5.10	6.23	7.62
CD (p=0.05)	4.28	7.71	10.95	13.37	16.25

Table 2. Effect of fertigation on dry matter production

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	HARVEST
T1	370	1256	2320	6025	7120
T2	395	1616	3642	7960	8248
T3	316	1530	3061	7010	7320
T4	422	1638	3890	8245	8333
T5	382	1588	3418	7451	7538
T6	440	1680	4049	8526	8751
T7	348	1567	3120	7337	7446
T8	500	2051	4541	9059	9351
SEd	23	93	208	446	463
CD (p=0.05)	50	199	445	956	993

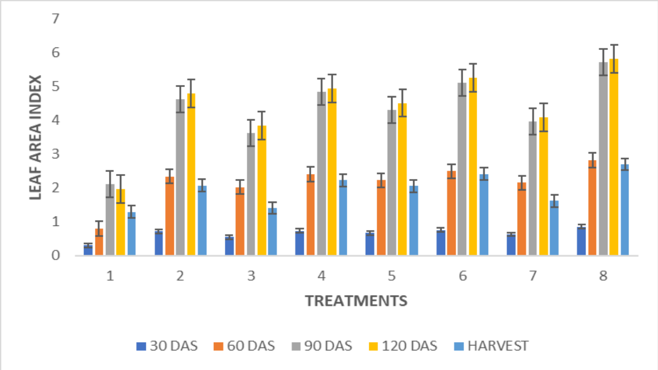

Fig. 1. Effect of fertigation on leaf area index.

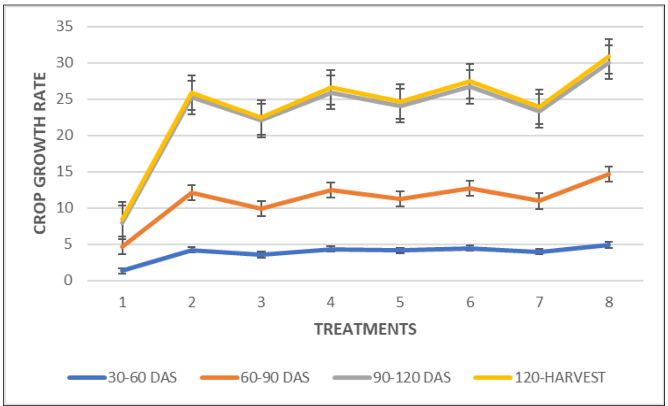

Fig. 1. Effect of fertigation on leaf area index.

measurements of root length, root dry weight and root volume (Table 3). Potassium shortage markedly impeded root elongation and lateral root development in cotton seedlings. A shortage of potassium (K), particularly below 120 -150 kg/ha, is likely to impede the formation of lateral root primordia, affecting root development and overall nutrient uptake. A notable decrease was seen in total root surface area, total root length and total root volume of both fine and coarse roots. The reductions exceeded 90 % for fine roots and approximated 50 % for coarse roots. The central roots were significantly less impacted by potassium deprivation (5). The suppression of root growth due to potassium deficiency likely stems from inadequate photosynthate supply, as potassium deficiency adversely impacts the photosynthetic rate and the translocation of photosynthate in cotton leaves. Comparable results were previously documented (6).

Effect of fertigation on yield and its attributes

The number of sympodial branches, number of fruiting points and bolls weight were enhanced with the fertigation of 125 % K with 100 % N & P. Boll setting percentage and individual boll weight were enhanced with the fertigation of 125 % K and 100 % N&P (Table 4). Enhanced potassium levels supplied to the crop recorded a greater number of sympodia per plant. This might be because enhanced potassium supply directly helps in maintenance of turgor and solute translocations within the plant which improved photosynthetic activity. These outcomes stood in close proximity to the conclusions of previous findings (7, 8) suggesting that higher a number of fruiting points and bolls per plant is due to higher concentration of potassium in leaf subtending cotton boll. Higher K is closely associated with mechanism of osmoregulation, maintenance of water status and reduced water loss from leaf surface for adaptation in drought-stressed conditions. Potassium needs in cotton are particularly pronounced from the first square through peak bloom. The results were in accordance with previous report (9). Potassium plays an important role in photosynthates assimilation and water balancing thus K fertilization improves boll setting at boll formation stage.

Effect of fertigation on nutrient uptake

The fertigation scheduling with different fertilizer levels in split ratio has significantly improved the NPK uptake at the peak growth stages viz., seedling, vegetative, squaring, 50 % flowering, boll formation and boll development stages. The fertigation of 125 % K & 100 % N and P registered maximum nutrient uptake at the respective growth stages (Fig. 3). This is because potassium plays a major role in better root vigour development. Potassium deficiency can hinder root elongation and development of lateral roots in plants thus adversely affecting the nutrient uptake capacity from soil.

Table 3. Effect of fertigation on root attributes

Treatments	Root length (cm)	Root volume (cc)	Root dry weight (g)
T1	22.0	61.8	8.4
T2	32.4	73.8	17.4
T3	27.0	66.8	13.4
T4	32.2	78.6	18.5
T5	29.3	71.0	16.8
T6	33.5	80.3	19.4
T7	28.4	68.2	14.2
T8	**36.3**	**84.4**	**21.2**
SEd	1.75	4.23	0.97
CD(p=0.05)	3.75	9.07	2.07

Table 4. Effect of fertigation on yield and yield attributes

Treatments	Number of sympodia per plant	Number of fruiting points per plant	Number of bolls per plant	Boll setting percentage	Individual boll weight
T1	11.0	79.4	32.2	39.8	0.6
T2	14.5	85.4	38.0	44.1	2.8
T3	13.1	81.4	34.3	41.9	2.6
T4	14.0	88.7	39.6	44.1	3.0
T5	14.3	84.0	37.3	43.5	2.8
T6	15.1	92.1	41.1	44.3	3.1
T7	13.3	83.1	35.6	42.5	2.8
T8	**18.9**	**100.4**	**49.0**	**48.2**	**3.8**
SEd	0.83	4.97	2.23	2.45	0.16
CD(p=0.05)	1.77	10.67	4.78	5.66	0.34

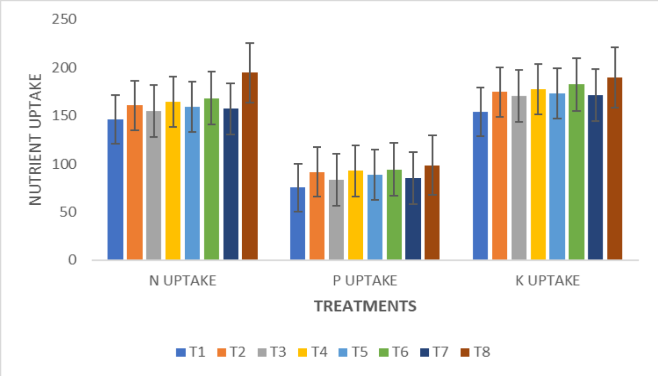

Fig. 3. Effect of fertigation on nutrient uptake.

These findings were in collaboration with (10).

Effect of fertigation on soil available nutrients

The fertigation schedule with varying NPK levels (75 %, 100 % and 125 %) in split ratios at peak growth stages (seedling, vegetative, squaring, 50% flowering. boll formation and boll development) had significant influence over the soil available nutrient at the respective growth stages (Fig. 4). Outcome of cotton may be limited by availability of nutrients in the soil, particularly if the supply fails to satisfy plant's needs. The yield enhancement was achieved by elevating the fertilization level from 100 % - 125 %. Increased level of fertilizer application increased the concentration of available nutrients in soil. There noticed a rise in soil available N, P & K at the successive growth stages *viz.,* seedling, vegetative, squaring, 50 % flowering, boll formation, boll development stages and a further decrease in nutrient concentration during post-harvest soil analysis. Greater nutrient uptake usually occurs during active growth stages, especially during reproductive development stages such as squaring, 50 % flowering, boll formation and boll development. Thereafter, a gradual decline in soil available N, P and K is noticed as the crop nears the harvest stage. Similar findings were previously reported (4). Hence under drip fertigation, higher N, P & K dynamics were noticed in top layers particularly in rhizospheric region where noticed the N, P and K nutrients in

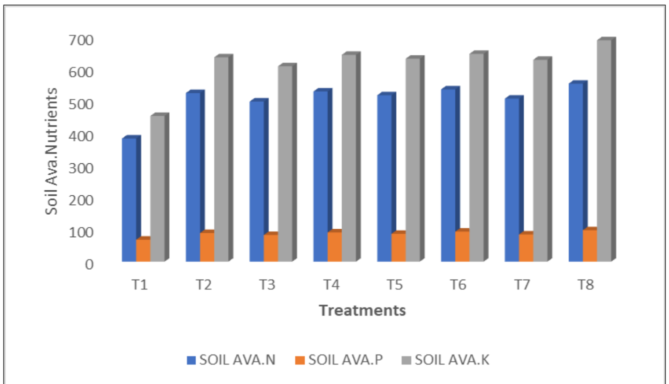

Fig. 4. Effect of fertigation on soil available nutrients.

most available form to plants thereby resulting in higher nutrient uptake. This is in accordance with the previous findings (11-14).

Conclusion

Cotton crop found to be more sensitive to potassium when compared to major field crops and often show symptoms of K deficiency. Therefore, a need for potassium increases dramatically at successive growth stages, especially at the reproductive development stages. Potassium has been established as the most crucial macronutrient for cotton, particularly for water relations, as it directly affects physiological processes and regulates plant developmental characteristics. In this study, the application of 125 % K (T8) resulted in the highest nutrient uptake, improved water-use efficiency and significantly enhanced boll development, ultimately leading to increased yield.

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Authors' contributions

DR carried out the experiment, analyzed the data and wrote the draft manuscript. MB, ME, BS, VR and SM conceived, designed and coordinated the experiments and corrected the manuscript. All the authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The writers admitted no conflict of interest.

Ethical issues: None

Declaration of generative AI and AI -assisted technologies in the writing process

During the preparation of this work the authors used Chat GPT, Quillbot and Paperpal to improve language quality. After using this service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

References

1. India Cco. Ministry of Textiles Government of India. 2022.
2. Bharathi S, Sree Lakshmi B, Ratna Kumari S. Evaluation of compact cultures under high density planting system with different nutrient levels in rainfed vertisols. International Journal of Chemical Studies. 2018;6(5):3371-3.
3. Makhdum M, Pervez H, Ashraf M. Dry matter accumulation and partitioning in cotton (*Gossypium hirsutum* L.) as influenced by potassium fertilization. Biology and Fertility of Soils. 2007;43:295-301. https://doi.org/10.1007/s00374-006-0105-6
4. Harish J, Pawar D, Kal K, Hasure R, Dingre S. Nutrient availability in Bt. Cotton under drip fertigation. International Journal of Current Microbiology and Applied Science. 2018;7(4):3373-9. https://doi.org/10.20546/ijcmas.2018.704.381
5. Armengaud P, Breitling R, Amtmann A. The potassium-dependent transcriptome of Arabidopsis reveals a prominent role of jasmonic acid in nutrient signaling. Plant physiology. 2004;136 (1):2556-76. https://doi.org/10.1104/pp.104.046482
6. ZHANG Z-Y, Qing-Lian W, Zhao-Hu L, Liu-Sheng D, Xiao-Li T. Effects of potassium deficiency on root growth of cotton seedlings and its

physiological mechanisms. Acta Agronomica Sinica. 2009;35 (4):718-23. https://doi.org/10.1016/S1875-2780(08)60079-6

7. Bhalerao P, Gaikwad G, Imade S. Productivity and nutrient uptake of Bt-cotton (Gossypium hirsutum) as influenced by precision in application of irrigation and fertilizer. Indian Journal of Agronomy. 2011;56(2):150-3. https://doi.org/10.59797/ija.v56i2.4673

8. Kakade S, Bhale V, Deshmukh J, Wadatkar S. Growth, nutrient uptake and seed cotton yield as influenced by split application of nutrients through fertigation in Bt Cotton. International Journal of Current Microbiology and Applied Science. 2017;6(9):2982-90. https://doi.org/10.20546/ijcmas.2017.609.366

9. Dong H, Tang W, Li Z, Zhang D. On potassium deficiency in cotton –disorder, cause and tissue diagnosis. Agriculturae Conspectus Scientificus. 2004;69(2-3):77-85.

10. Rengel Z, Damon PM. Crops and genotypes differ in efficiency of potassium uptake and use. Physiologia Plantarum. 2008;133 (4):624-36. https://doi.org/10.1111/j.1399-3054.2008.01079.x

11. Hebbar S, Ramachandrappa B, Nanjappa H, Prabhakar M. Studies on NPK drip fertigation in field grown tomato (Lycopersicon esculentum Mill.). European Journal of Agronomy. 2004;21(1):117-27. https://doi.org/10.1016/S1161-0301(03)00091-1

12. Jayakumar M, Surendran U, Manickasundaram P. Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semi arid tropics. International Journal of Plant Production. 2014;8(3):375-90.

13. Baskar P, Jagannathan R. Resource use efficiency, productivity and profitability of Bt Cotton (interspecific) as influenced by crop geometry and drip fertigation. Indian Journal of Agricultural Research. 2021;55(3):323-8. https://doi.org/10.18805/IJARe.A-5485

14. Wang M, Zheng Q, Shen Q, Guo S. The critical role of potassium in plant stress response. International Journal of Molecular Sciences. 2013;14(4):7370-90. https://doi.org/10.3390/ijms14047370