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RESEARCH ARTICLE

Impact of organic and inorganic nutrient management on yield, nutrient uptake and fibre quality of coloured cotton (Vaidehi 1)

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Abstract

Cotton is one of the most widely grown and important fibre crops in the world, serving as the backbone of the textile industry. However, Conventional white cotton has several environmental drawbacks, including high water comsumption, reliance on synthetic chemicals and the need for dyes, which lead to soil degradation, water pollution and health risks for farmers. In contrast, organic coloured cotton offers a sustainable alternative by producing colourful fibres naturally without synthetic dyes. It also enhances soil fertility, conserves water and reduces chemical inputs, benefiting both the environment and farming communities. Therefore, field experiments were conducted at the Central farm, Agricultural College and Research Institute, TNAU, Madurai, Tamil Nadu during Kharif 2023 and Summer 2024 to evaluate a comparative assessment of organic and inorganic nutrient management practices on yield, nutrient uptake and quality parameters of coloured cotton. The experiment was laid out in a randomized block design with nine treatments of nitrogen (N) on an equivalent basis, using different organic manures, compared with inorganic fertilizers and replicated thrice. A significant increase in yield and nutrient uptake of coloured cotton was recorded with 100% NPK applied through site-specific recommendations (T1), which was on par with 100% NPK through blanket recommendations (T2). Organic treatments that incorporated cover crops and green manure, along with vermicompost, poultry manure and FYM, also showed comparable results to inorganic treatments. However, no significant differences were observed in the quality parameters across the various nutrient management practices.

Keywords

coloured cotton; fibre quality; nitrogen equivalent; nutrient uptake; yield

Introduction

Cotton (*Gossypium* spp.), often termed "White Gold" and often called "the King of Fibres," holds a significant position among cash crops both nationally and internationally (1, 2). It is indigenous to arid and semi-arid regions of the tropics and subtropics (3). Cotton contributes to 80% of global natural fibre production (4) and accounts for approximately 1.5% of the Gross Domestic Product (GDP) and 7.1% of agricultural value addition (5, 6). It provides livelihoods for around 5.8 million farmers and supports approximately 50 million people through its production, processing and trade activities (7).

Globally, cotton is cultivated in an area of 30.65 m ha with an annual production of 41.60 Mt and productivity of 1360 kg ha^{-1}. India ranks first in cotton cultivation with a contribution of around 41.43% of global area. In India, cotton occupies an area of 12.70 m ha with an annual production of 10.95 million tonnes and accounts for around 26.32% of the total global cotton production (8). However, in terms of productivity (seed cotton), national figures are low (860 kg ha^{-1} of seed cotton and 441 kg ha^{-1} of lint cotton), compared to China (3760 kg ha^{-1}) and the USA (1270 kg ha^{-1}) (8). In Tamil Nadu, cotton is cultivated on about 0.09 m ha, with an annual production of 0.19 million bales. The states's productivity stands at 710 kg ha^{-1} of seed cotton and 364 kg ha^{-1} of lint cotton (9).

Cotton is a dual-purpose crop grown for both fibre and oil (10). Cottonseed contains 20- 25% protein and oil, with its oil widely used in the edible oil industry. Cottonseed oil contains 26% palmitic (16:0), 2% stearic (18:0), 15% oleic (18:1) and 55% linoleic (18:2) acids (11). Globally, it is the third most produced oil after rapeseed and soybean, used in food and animal feed (12).

Globally, organic cotton is grown in an area of 0.62 m ha (certified land) and 0.29 m ha (in- conversion land) with an annual production of 0.34 million tonnes (certified land) and 0.34 million tonnes (in- conversion land). It is grown in 21 countries worldwide, with 97% of global organic cotton production coming from eight countries: India (38%), Turkey (24%), China (10%), Kyrgyzstan (9%) Tanzania (6%), Kazakhstan (4%), Tajikistan (4%) and the US (2%). The remaining 13 organic cotton-producing countries account for 3% (13). The current energy crisis and rising prices of N, P_2O_5 and K_2O fertilizers have made chemical fertilizers costly and increasingly unavailable for crop production. While high-input technologies have improved yield and labour efficiency in modern agriculture, concerns are growing about their negative impacts on soil productivity and environmental quality. Significantly, cotton cultivation accounts for more than 55% of agrochemical usage in India (14).

The Indian government, in collaboration with the industry, is promoting the cultivation of coloured cotton, supported by ongoing research efforts. Recent advancement in coloured cotton research have demonstarted that its productivity, staple length and fibre strength can be improved to match the textile standards of white cotton. Coloured cotton cultivation is currently limited to small areas in Dharwad (Karnataka), Coimbatore (Tamil Nadu), Vidarbha (Maharashtra) and Guntur (Andhra Pradesh), with an estimated total cultivation area of around 200 acres and a production of approximately 330 quintals (15). Naturally coloured cotton reduces the environmental pollution from artificial dyes and minimizes health risks to farmers and communities. Since the dyeing process is not needed, it lowers fabric production costs. However, naturally coloured cotton has shorter fibres and is less profitable than white cotton. If coloured cotton is priced higher than white cotton, it could offset the lower production costs of the fabric (16, 17).

The rising costs and reliance on non-renewable energy for chemical fertilizers and pesticides, along with their overuse, have degraded soil health and environmental quality (18). This has sparked increased interest in organic cotton as a sustainable alternative. Effective nutrient management through organic inputs such as farmyard manure, vermicompost, poultry manure, cover crops, green manures and biofertilizers can help to maintain soil health by enhancing organic matter, microbial activity and soil properties (18).

Nitrogen stands as the predominant nutrient extracted by cotton, exerts a key impact on growth period, maturity time, productivity and fibre quality (19). In addition to this nitrogen can increase chlorophyll content, carotenoid content, electron transport rate, free amino acids, soluble proteins, specific leaf nitrogen and stomatal conductance. These factors are closely correlated with the fibre quality of cotton. (20, 21). Organic coloured cotton provides a sustainable alternative amid rising fertilizer costs and environmental concerns. Using organic inputs like farmyard manure, vermicompost and cover crops for nitrogen management improves soil health, yield and fibre quality. Although coloured cotton has shorter fibres and lower profitability than white cotton, ongoing research including this study, aims to optimize the nitrogen use to enhance its production and economic viability. This research supports the sustainable cultivation of organic coloured cotton while addressing environmental and economic challenges.

Materials and Methods

Experimental site

Field experiments were conducted at the Central Farm, Agricultural College and Research Institute, TNAU, Madurai, Tamil Nadu during Kharif 2023 and Summer 2024. The experimental site is located in the Southern Agroclimatic Zone of Tamil Nadu at 9°54' N latitude, 78°54' E longitude and an elevation of 147 m above mean sea level. The soil of the experimental field was sandy clay loam in texture with pH range of 8.2 to 8.12, EC was 0.18 and 0.20 dS m^{-1}. Before the experiment, the nutrient status of the soil was low in available nitrogen (268.8 and 235.2 kg ha^{-1}, respectively), medium in available phosphorus (268.8 and 235.2 kg ha^{-1}, respectively) and high in available potassium (360.7 and 331.1 kg ha^{-1}, respectively) and high in soil organic carbon (0.78% and 0.85%, respectively). Post-harvest soil nutrients were analyzed using standard methods, including alkaline permanganate for nitrogen (22), Olsen colorimetry for phosphorus (23), neutral ammonium acetate for potassium (24) and Chromic acid wet digestion for organic carbon (25).

Experimental design and treatments

The field experiments were laid out in a Randomized Block Design (RBD) with three replications. Treatment details are shown in Table 1. The nitrogen content of organic manures was analyzed before application and their quantities are mentioned in Table 2. The physico-chemical properties of FYM, vermicompost and poultry manure are in Table 3.

Table 1. Treatment details

	Treatments
T1:	100% NPK (Blanket recommendation of inorganic nutrients)
T2:	100% NPK (Based on site specific recommendation)
T3:	Cover crop + 75% N through Farm yard manure (N equivalent)
T4:	Cover crop + 75% N through Vermicompost (N equivalent)
T5:	Cover crop + 75% N through Poultry manure (N equivalent)
T6:	Green manure + 75% N through Farm yard manure (N equivalent)
T7:	Green manure + 75% N through Vermicompost (N equivalent)
T8:	Green manure + 75% N through Poultry manure (N equivalent)
T9:	Complete organic package (Cover crop + Organic manure + Biofertilizers + Bio agents + Foliar spray)

*100% NPK (Blanket recommendation of inorganic nutrients) - (80: 40: 40 NPK kg ha^{-1})

100% NPK (Based on site specific recommendation) - (100: 40: 30 NPK kg ha^{-1})

Cover crop - Cowpea; Green manure - Sunhemp; Organic manure - Vermicompost; Biofertilizers - *Azospirillum* and Phosphobacteria Bio agents - *Pseudomonas flurescens* and *Trichoderma viride*;Foliar spray - Pink pigmented facultative methylotrophs

Table 2. Quantities of organic manures - RDF: (80: 40: 40 NPK kg ha^{-1})

Manures	N content (%)	Quantity (kg ha^{-1})	
		100% N	75% N
FYM	0.39	20513	15385
Vermicompost	1.85	4324	3243
Poultry manure	2.55	3137	2325

Table 3. Physico-chemical properties of FYM, vermicompost and poultry manure

Particulars	Farm yard manure	Vermicompost	Poultry manure
pH	6.9	6.7	7.4
EC (dSm^{-1})	0.2	0.5	1.3
N (%)	0.39	1.85	2.55
P (%)	0.25	0.7	0.96
K (%)	0.45	0.85	1.48
Organic carbon (%)	14.40	12.60	23.20
Organic matter	24.82	21.72	39.99

Crop management practices

The field was prepared to a fine tilth and Vaidehi 1 (dark brown) coloured cotton was used as the seed material. Cowpea (Pusa 152) was used as a cover crop and sunhemp (ADT 1) was used as green manure. These were incorporated 45 days after flowering (DAS) at their 50% flowering stage. Cotton seeds were dibbled at 3 cm, at rate of 6 kg ha^{-1}, spaced 90 x 45 cm apart. Fertilizers were applied at 80:40:40 kg NPK ha^{-1}, with full NPK from inorganic sources and 75% nitrogen from organic sources (FYM, vermicompost and poultry manure) before sowing. Biofertilizers Azospirillum and Phosphobacteria (2 kg ha^{-1}) and bio-control agents *Trichoderma viride* and *Pseudomonas fluorescens* (2.5 kg ha^{-1}) were applied basally. A foliar spray of Pink Pigmented Facultative Methylotrophs (PPFM) (1%) was applied @ 5 liters per hectare during flowering and boll development.

Seed cotton yield

Seed cotton yield was recorded from each net plot area at regular 10-day intervals between pickings. The picked seed cotton was shade dried for 4 hours and weighed. The total yield was computed and recorded as kg ha^{-1}.

Quality parameters

Sample preparation

Seed cotton was randomly picked from each plot in all replications and manually cleaned to remove debris and insect damage. Approximately 100 g of lint was collected, cleaned, ginned, packed, labeled and submitted for fibre quality testing.

Ginning out turn (GOT)

This is the ratio of weight of lint to the weight of seed cotton and expressed as percentage. It was calculated by the following formula (26).

$$\text{Ginning out turn} = \frac{\text{Lint weight (g)}}{\text{Seed cotton weight (g)}} \times 100 \quad \text{(Eqn 1)}$$

Lint index

The lint obtained from ginning 200 seed cotton was weighed and expressed in grams. The lint index was calculated by using the following formula (26).

$$\text{Lint index} = \frac{\text{Lint weight (g)}}{\text{Number of seeds}} \times 100 \quad \text{(Eqn 2)}$$

Seed index

The weight of 200 seeds randomly collected from each plot, their average weight was recorded in grams after ginning. The seed index was calculated using the formula previously suggested (26).

$$\text{Seed index} = \frac{\text{Seed weight (g)}}{\text{Number of seeds}} \times 100 \quad \text{(Eqn 3)}$$

Fibre quality parameters

Various conventional instruments were integrated into a compact system using advanced optics, machinery and electronics. Cotton samples were tested for fibre quality parameters including 2.5% staple length, 50% staple length, uniformity ratio, mean length, upper half mean length, uniformity index, fibre strength, micronaire, fibre elongation and short fibre index. These analyses were analyzed using a standard High-Volume Instrument (Uster HVI 1000 model) in ICC mode, by the method adopted from ASTM D-5867 (27, 28) at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore.

Nutrient uptake

Collection and preparation of plant sample

The treatment wise plant samples were collected randomly from each net plot. The collected samples were first dried in the shade after that in oven at 60 ± 5°C grounded in Willey mill and sieved through 20 mm mesh screen and stored in labeled container for further analysis. The powdered plant samples were used for estimation of total nitrogen (29), phosphorus (29) and potassium (29) by adopting the standard procedure.

Uptake of nutrients

Total nitrogen, phosphorus and potassium were estimated at 150 DAS using the Microkjeldahl digestion (diacid) method for nitrogen (29), the vanado-molybdo phosphoric acid (Triple acid) using spectrophotometer method for phosphorus (measured at 470 nm) (29) and flame photometry for potassium (29). The uptake of different nutrients at different stages was computed by the following formula given below and expressed in kg ha^{-1}.

$$\text{Uptake of nutrients} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{100} \quad \text{(Eqn 4)}$$

Statistical analysis

The data for all observed traits were subjected to analysis of variance (ANOVA) using R software (version 4.2.1) within the R Studio for Windows. Mean comparisons were carried out using Fisher's Least Significant Difference (LSD) test at a 5% level of significance to determine significant differences. Mean values with no significant differences were marked as 'NS' (30).

Results

Seed Cotton Yield

The seed cotton yield was significantly influenced by different nutrient management practices on coloured cotton (Fig. 1 and 2). Inorganic treatments, including 100% NPK based on site-specific (100:40:30 kg ha^{-1}) (T2) and blanket (80:40:40 kg ha^{-1}) (T1) recommendations, achieved the highest seed cotton yields of 2223 and 2198 kg ha^{-1} in Kharif 2023 and 2199 and 2166 kg ha^{-1} in Summer 2024, respectively. This was followed by the complete organic package (1843 and 1944 kg ha^{-1}), cover crop with vermicompost (1826 and 1913 kg ha^{-1}) and cover crop with poultry manure (1778 and 1878 kg ha^{-1}) and all other organic treatments during the same seasons. These two inorganic treatments were comparable and positively affected seed cotton yield, significantly outperforming organic nutrient management sources.

Nutrient uptake

Nutrient uptake in coloured cotton was significantly influenced by various nutrient management strategies (Fig. 3 and 4). The application of 100% NPK based on site-specific recommendations (100:40:30 kg ha^{-1}) (T2) recorded the highest uptake of N (144.15 and 141.44 kg ha^{-1}), P (37.18 and 35.45 kg ha^{-1}) and K (59.44 and 55.27 kg ha^{-1}) during Kharif 2023 and Summer 2024, respectively. This performance was comparable to the 100% NPK blanket application (80:40:40 kg ha^{-1}) (T1), which registered uptake of N (142.13 and 139.19 kg ha^{-1}), P (36.24 and 34.94 kg ha^{-1}) and K (58.85 and 54.95 kg ha^{-1}) during Kharif 2023 and Summer 2024, respectively. Both inorganic treatments exhibited similar effects, significantly outperforming all organic nutrient management treatments during the both seasons.

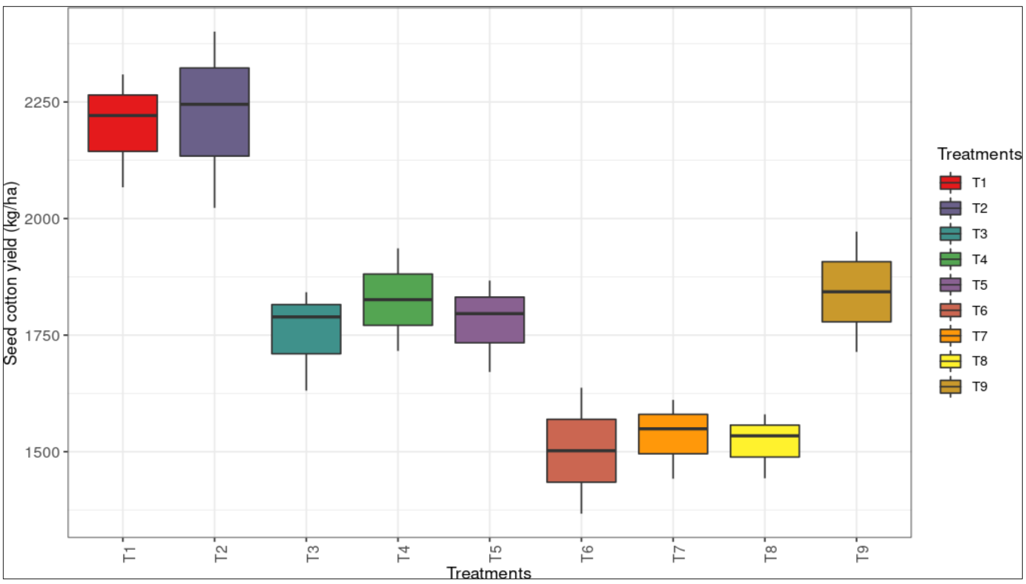

Fig. 1. Impact of different nutrient management practices on seed cotton yield (kg ha^{-1}) of coloured cotton (Kharif 2024).

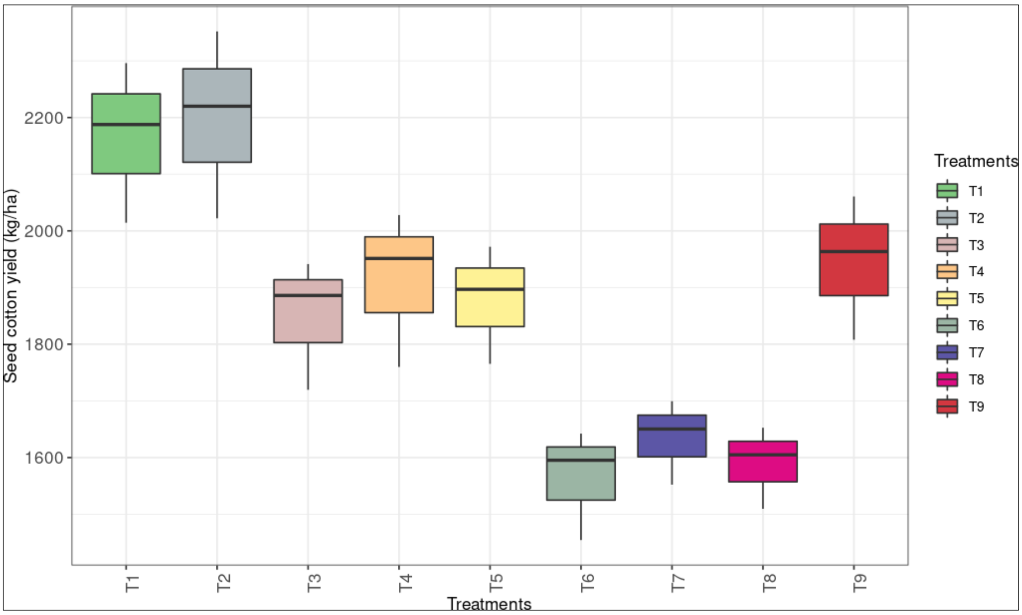

Fig. 2. Impact of different nutrient management practices on seed cotton yield (kg ha^{-1}) of coloured cotton (Summer 2024).

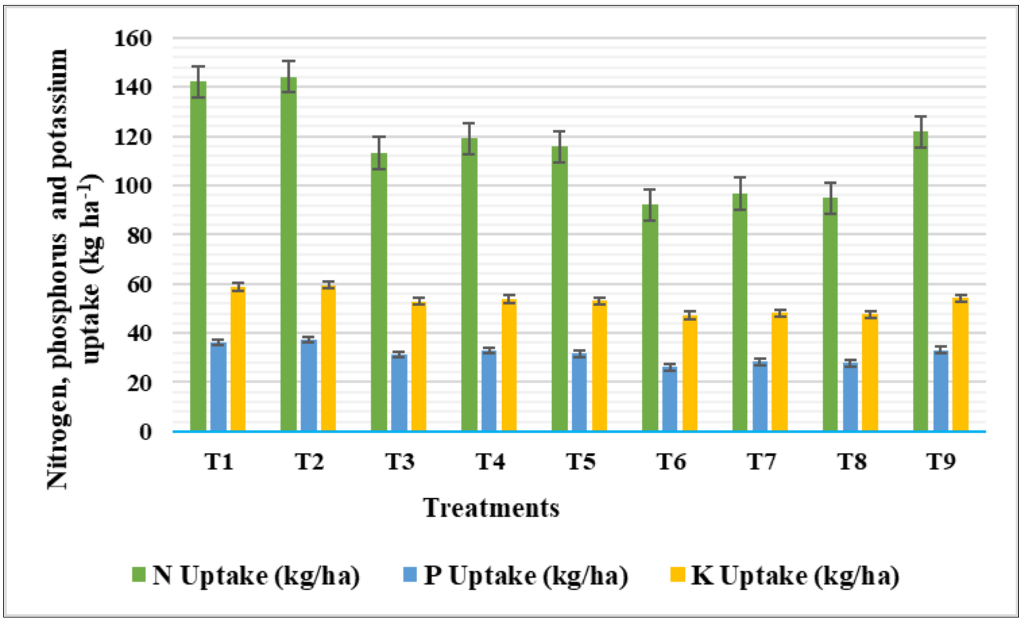

Fig. 3. Impact of different nutrient management practices on nutrient uptake (kg ha^{-1}) of coloured cotton (Kharif 2023).

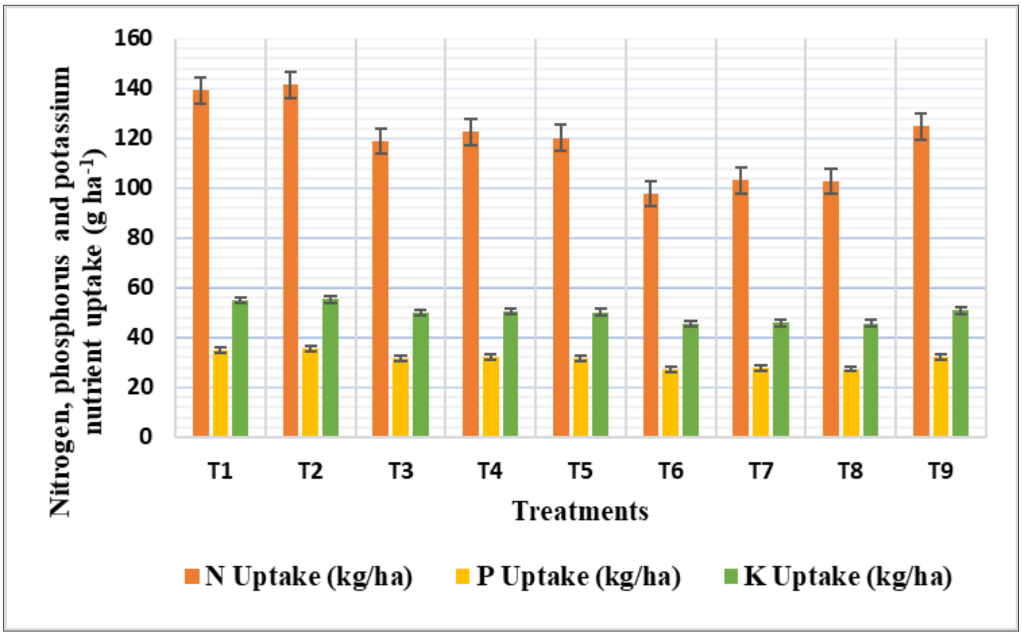

Fig. 4. Impact of different nutrient management practices on nutrient uptake (kg ha^{-1}) of coloured cotton (Summer 2024**)**.

Quality parameters

The quality parameters of coloured cotton showed no significant variation due to nutrient management practices (Tables 4-6). However, higher ginning outturn values were observed under 100% NPK (site-specific: 36.50 and 36.05%), blanket recommendations (36.0 and 35.5%), complete organic package (36.49 and 36.00%) and cover crop with vermicompost (36.47 and 35.99%) during Kharif 2023 and Summer 2024, respectively. A similar trend was observed in other fiber quality parameters including seed weight, lint weight, 2.5% staple length, 50% staple length, uniformity ratio, mean length, upper half mean length, uniformity index, fibre strength, micronaire, fibre elongation and short fibre index.

Discussion

Seed cotton yield

In the present study, higher seed cotton yield was achieved with inorganic fertilizers due to their rapid nutrient release, allowing the crop to immediately utilize nutrients for growth and yield. In contrast, organic manures provide a slower nutrient release, which initially results in lower yields but gradually improves soil health, nutrient cycling and long-term productivity. While inorganic fertilizers offer immediate benefits for crop growth, organic manures enhance soil structure and sustainability over time (31, 32).

Compared to site-specific and blanket 100% NPK applications, the use of recommended doses of nitrogen (RDN) through cover crops, green manure and organic manures resulted in lower yields. This is primarily due to the

Table 4. Impact of different nutrient management practices on fibre quality parameters of coloured cotton (Kharif 2023 and Summer 2024)

Treatments	Fibre quality parameters*					
	(Kharif, 2023)			***(Summer, 2024)***		
	GOT (%)	**SI**	**LI**	**GOT (%)**	**SI**	**LI**
T1	36.50	6.81	11.85	36.05	6.85	12.15
T2	36.58	6.84	11.86	36.11	6.89	12.19
T3	36.43	6.74	11.76	35.92	6.77	12.08
T4	36.47	6.78	11.81	35.99	6.81	12.11
T5	36.46	6.76	11.78	35.93	6.78	12.09
T6	36.32	6.68	11.71	35.84	6.72	12.03
T7	36.37	6.71	11.74	35.89	6.75	12.06
T8	36.35	6.7	11.73	35.87	6.74	12.05
T9	36.49	6.79	11.82	36.00	6.83	12.14
SEd	0.29	0.05	0.09	0.29	0.05	0.09
CD (p=0.05)	NS	NS	NS	NS	NS	NS

*GOT - Ginning out turn/ LI - Lint index/ SI - Seed index

Table 5. Impact of different nutrient management practices on fibre quality parameters (2.5% SL, 50% SL, UR, ML, UHML and UI) of coloured cotton (Kharif 2023)

	Fibre quality parameters*						
Treatments	**2.5%SL (mm)**	**50% SL (mm)**	**UR**	**ML (mm)**	**UHML (mm)**	**UI**	**FS (g tex -1)**
T1	23.6	12.7	53.81	19.7	24.5	80.41	23.4
T2	23.7	12.8	54.01	19.9	24.6	80.89	23.5
T3	23.2	11.9	51.29	18.4	23.2	79.31	22.9
T4	23.4	12.4	52.99	19.0	23.8	79.83	23.1
T5	23.3	12.1	51.93	18.7	23.5	79.57	23.0
T6	22.8	11.5	50.44	17.4	22.2	78.38	22.5
T7	23.1	11.8	51.08	18.1	22.9	79.04	22.8
T8	22.9	11.6	50.66	17.7	22.5	78.67	22.7
T9	23.4	12.5	53.42	19.4	24.2	80.17	23.2
SEd	0.94	0.48	2.12	0.78	0.97	3.31	1.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

*SL - Staple length/ UR - Uniformity ratio/ ML - Mean length/ UHML - Upper half mean length/ UI - Uniformity index/ FS - Fibre strength

Table 6. Impact of different nutrient management practices on fibre quality parameters (2.5% SL, 50% SL, UR, ML, UHML and UI) of coloured cotton (Summer 2024)

Treatments	Fibre quality parameters*						
	2.5%SL (mm)	**50% SL (mm)**	**UR**	**ML (mm)**	**UHML (mm)**	**UI**	**FS (g tex -1)**
T1	23.6	12.8	54.24	19.5	24.3	80.25	23.6
T2	23.6	12.9	54.66	19.7	24.4	80.74	23.6
T3	23.2	12.2	52.59	18.5	23.6	78.39	23.2
T4	23.4	12.5	53.42	19.1	24.1	79.25	23.4
T5	23.3	12.3	52.79	18.7	23.8	78.57	23.3
T6	22.7	11.7	51.54	17.6	22.7	77.53	22.7
T7	23.0	12.0	52.17	18.2	23.3	78.11	23.0
T8	22.9	11.9	51.97	17.7	22.8	77.63	22.9
T9	23.5	12.6	53.62	19.4	24.3	79.84	23.5
SEd	0.93	0.49	2.25	0.77	0.98	3.28	0.93
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

*SL - Staple length/ UR - Uniformity ratio/ ML - Mean length/ UHML - Upper half mean length/ UI - Uniformity index/ FS - Fibre strength

Table 7. Impact of different nutrient management practices on fibre quality parameters (Micronaire, FE, SFI) of coloured cotton (Kharif 2023 and Summer 2024)

Treatments	Fibre quality parameters*					
	(Kharif, 2023)			*(Summer,* 2024)		
	Micronaire (µg inch-1)	FE (%)	SFI	Micronaire (µg inch-1)	FE (%)	SFI
T1	3.7	5.17	6.4	3.8	5.16	6.5
T2	3.7	5.10	6.3	3.7	5.12	6.4
T3	4.0	5.46	6.8	4.0	5.41	6.8
T4	3.9	5.30	6.5	3.9	5.28	6.6
T5	4.0	5.38	6.6	3.9	5.37	6.7
T6	4.3	5.67	7.1	4.3	5.63	7.1
T7	4.1	5.51	6.9	4.1	5.48	6.9
T8	4.2	5.59	7.0	4.2	5.56	7.0
T9	3.8	5.22	6.4	3.8	5.21	6.5
SEd	0.17	0.22	0.28	0.16	0.23	0.29
CD (p=0.05)	NS	NS	NS	NS	NS	NS

*FE - Fibre elongation/ SFI - Short fibre index

slow nutrient release from organic sources. Organic manures contain essential macro and micronutrients; however, their decomposition process is gradual, limiting the immediate availability of these nutrients to meet the cotton crop nitrogen, phosphorus and potassium (NPK) requirements, especially during the initial growth stages (33).

In the first season, yield reductions of 17.09% to 32.43% were observed under organic nutrient management (T3 to T9) compared to inorganic site-specific and blanket recommendations. By the second season, this reduction decreased to 11.56% to 28.84% as the yield gap narrowed. This improvement is likely attributed to the slow, continuous release of nutrients from organic manures over time (34, 35).

Inorganic fertilizers, like 100% NPK provide rapid nutrient availability, ensuring quick uptake of essential nutrients for early cotton growth and higher initial yields making them effective for short-term yield maximization. Conversely, organic inputs such as cover crops, vermicompost, poultry manure and farm yard manure release nutrients gradually. This leads to lower initial yields, it improves soil structure, microbial activity, nutrient cycling, water retention, promoting long- term soil fertility and sustainable cotton production with progressively increasing yields over time. (36-39).

Nutrient uptake

Nutrient uptake in cotton was significantly influenced by diverse nutrient management practices. The application of inorganic nutrients, 100% NPK (both site-specific and blanket recommendations), enabled rapid absorption of N, P and K, optimizing nutrient use efficiency and supporting better boll development. Improved boll development was measured by recording increased boll weight, larger boll size (measured with a caliper) and a higher number of bolls per plant at maturity under optimal nutrient conditions (40-42). In contrast, organic management using cover crop and vermicompost provide slower, sustained nutrient release, improving soil microbial activity, nutrient cycling and long-term soil health (43, 18). While inorganic methods offer quicker nutrient uptake, organic practices improve soil structure, moisture retention and support sustainable cotton production with enhanced microbial activity (44-47). The improved uptake of nitrogen may be attributed to the mineralization of N from cover crops and its rapid decomposition following the incorporation of cover crops and green manure crops (48).

Quality parameters

Fibre quality along with lint yield, is vital for the acceptance of cotton technology. Key fibre quality parameters such as fibre length, strength, fineness and uniformity should be assessed alongside seed cotton yield for optimal results. For coloured cotton, factors such as colour fastness, shade consistency and fade resistance are critical for market success. Evaluating both conventional and coloured varieties based on these quality traits ensures a comprehensive approach that improves productivity while meeting industry standards. Increased productivity alone does not benefit growers, as fibre quality remains key to securing higher prices.

Most quality parameters in coloured cotton are primarily determined by genetic factors rather than management practices. The ginning out turn (GOT) in coloured cotton is primarily linked to the genetic characteristics of the specific variety. However, environmental variations can significantly impact these parameters. For instance, temperature fluctuations during boll development can affect fibre quality and quantity, leading to a reduced GOT. Similarly, water stress during critical growth stages can cause uneven boll maturation, decreasing the lint yield and consequently the GOT. Generally, the genetic traits of the varieties and species influence all quality parameters, resulting in infrequent improvements. This finding aligns with observations made previously (49, 32).

Improved soil moisture and nutrient availability in organic systems have been shown to produce cotton lint with longer and stronger fibres (50). While improved soil conditions availability may contribute to better fibre characteristics, genetic factors primarily govern fibre quality (51). Similarly, studies indicate that varying fertilizer levels do not significantly affect the fibre quality, further emphasizing the genetic control of cotton quality parameters (52-54). These findings align with the results reported earlier (35, 48).

Conclusion

Based on two seasons of field experiments, the study concluded that inorganic nutrient management, particularly 100% NPK applications based on site-specific (T2) and blanket recommendations (T1), significantly enhances seed cotton yield and nutrient uptake in coloured cotton compared to organic practices. Organic treatments, such as the complete organic package (T9) and cover crop with vermicompost (T4), resulted in slightly lower yields and nutrient uptake in the short term compared to inorganic treatments. However, both nutrient management strategies maintained acceptable fibre quality parameters. While inorganic nutrient management, particularly 100% NPK, boosts yield in the short term, it fails to address long-term sustainability issues, including soil health and environmental degradation. In contrast, organic nutrient management, complete organic package (T9) and cover crop with vermicompost (T4) enhances soil fertility, conserve water and reduces chemical inputs. Although organic practices initially yield slightly less, over time, they significantly improve eventually equaling inorganic yield and fibre quality. Thus, organic treatments (T9 and T4) are recommended for farmers as they ensure long-term sustainability, improve soil health and mitigate the environmental impacts.

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Authors' contributions

SS conducted the experiment, collected observations, and performed data analysis. RT provided guidance in formulating the research concept, methodology, supervision, facilitated the acquisition of research funds and approved the final version of the manuscript. GA played a key role in developing the research ideas, reviewing the manuscript and securing research grants. PJ provided guidance in soil and crop management aspects to conduct the research and helped in methodology, review and editing. GM contributed by imposing the experiment and provided guidance of entire research. ST conceptualized the study and participated in its design and coordination. RS provided guidance in resources and visualization. AB contributed by overall research work and summarized the weather and research data. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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