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Improving Cotton Fiber Quality Through Strategic Sowing: Implications for Phosphorus Management from Experiments in Chato District, Tanzania

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ABSTRACT
This study was conducted in Msilale Village, Chato District in Tanzania, to evaluate the influence of sowing dates and phosphorus levels on cotton fiber quality. The study was established according to a factorial trial, with varying sowing dates (25th November 2022, 15th December 2022 and 4th January 2023) and phosphorus levels (control, 20 kg P ha^{-1}, 40 kg P ha^{-1}, 60 kg P ha^{-1}). Results revealed that early planting had a statistically significant ($p < .001$) effect on fiber cotton quality, including spinning coefficient index, fiber length, fiber strength, uniformity index, short fiber content, and grade/color. Early sowing dates (25th November 2022 and 15th December 2022) consistently produced superior fiber quality, including spinning coefficient index (156.5 and 148.4), moisture content of the fiber (7.8% and 7.7%), micronaire (3.5 µg/inch), upper half mean length (1.2 cm), uniformity index (84.6% and 84.2%) and shorter fiber (6.8% and 7.0%) relative to late sowing (4th January 2023). Conversely, phosphorus levels did not significantly ($p > .05$) impact these parameters within the tested range. This research underscores the critical role of selecting appropriate sowing dates for cotton cultivation to achieve better fiber quality.

摘要
本研究在坦桑尼亚查托区Msilale村进行，以评估播种日期和磷水平对棉花纤维质量的影响.　该研究是根据析因试验建立的，具有不同的播种日期（2022年11月25日、2022年12月15日和2023年1月4日）和磷水平（对照组，20 kg Pha-1、40 kg Pha-2、60 kg Pha-3）. 结果表明，早期种植对纤维棉质量有统计学意义（p<0.001），包括纺纱系数指数、纤维长度、纤维强度、均匀性指数、短纤维含量和等级/颜色. 早播日期（2022年11月25日和2022年12月15日）始终产生优异的纤维质量，包括纺纱系数指数（156.5和148.4）、纤维含水量（7.8%和7.7%）、马克隆值（3.5 µg/英寸）、上半平均长度（1.2厘米）、均匀性指数（84.6%和84.2%）和较短的纤维（6.8%和7.0%）. 相反，在试验范围内，磷水平对这些参数没有显著影响（p > .05）. 这项研究强调了为棉花种植选择合适的播种日期以获得更好的纤维质量的关键作用.

KEYWORDS
Crop management strategies; fibre value attributes; improved livelihoods; soil fertility; sustainable agricultural systems; Tanzania

关键词
作物管理战略; 纤维价值属性; 改善生计; 土壤肥力; 可持续农业系统; 坦桑尼亚

Introduction

Cotton (*Gossypium hirsutum* L.) fiber qualities are crucial in determining the value and utility of cotton in various industries, particularly in textile production. Textile industries gave more importance to cotton fiber as fiber value count depends on fiber yield and quality (Darawsheh et al. 2022). Cotton fiber qualities can be influenced by a variety of factors, both intrinsic to the cotton plant itself

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and external environmental factors. These factors include cotton variety (cultivar) as different cotton cultivars have varying fiber properties (Ishaq et al. 2022). Cotton plants are bred for specific qualities such as fiber length, strength, and color (Mauget, Ulloa, and Dever 2019). The choice of cultivar can significantly impact the final fiber quality (Karavina et al. 2012). Environmental factors such as temperature, rainfall, humidity, and sunlight can affect cotton fiber development (Darawsheh et al. 2022; Mudassir et al. 2022). Ideal weather conditions can lead to longer, stronger fibers, while adverse conditions may result in shorter and weaker fibers. The soil's composition, fertility, and nutrient content can impact the growth and quality of cotton fibers (Hulugalle, Nehl, and Weaver 2004; Johnson et al. 2002; Khalil et al. 2015). Nutrient deficiencies or imbalances can affect fiber development (Sun et al. 2023). The agronomic practices such soil preparation, planting date, planting density, weed control, pest and disease management, harvest timing, harvesting methods, ginning, cover crops and crop rotation, integrated farming practices, pest scouting and monitoring post-harvest residue in cotton production require a combination of knowledge, experience, and careful management to optimize crop yield and fiber quality while minimizing environmental impact (Li et al. 2020).

Cotton thrives as a warm-season crop, and its progress and fiber maturation are intricately tied to a range of environmental factors, including temperature, daylight duration, and soil conditions (Johnson et al. 2002; Sharry 2021). The quality of the fiber may deteriorate when poor cultural practices and challenging climatic conditions are prevalent (Yeates, Constable, and McCumstie 2010; Iqbal et al. 2020). Sowing date is a major factor which play important role in maximum production and better quality cotton as it can significantly affect cotton fiber quality, as they play a crucial role in determining the growth and development of cotton plants (Abbas and Ahmad 2018). Early sowing may result in longer daylight exposure during the critical flowering and boll-setting stages, which can positively impact fiber quality (staple length, lint fineness, and strength) by promoting better fruiting and fiber (Godfrey et al. 2023; Ullah et al. 2019). Previous studies have consistently emphasized the indispensable roles of cellulose and sucrose in shaping fiber quality, a relationship modulated by sowing dates (Zhao et al. 2012). Proper timing of sowing can help minimize pest and disease pressure, leading to healthier plants and better fiber quality (Karavina et al. 2012; Singh, Singh, and D Mishra 2020). Sowing dates should align with the availability of soil moisture. Adequate soil moisture during critical growth stages is essential for fiber development (Wu et al. 2023). To optimize cotton fiber quality, it is crucial to consider local climate conditions, soil types, and pest pressures when selecting sowing dates (Zhang et al. 2024). Proper timing and management practices can help achieve the desired fiber quality characteristics, such as length, strength, and fineness, which are crucial for the cotton industry (Mauget, Ulloa, and Dever 2019).

Phosphorus stands as one of the three crucial nutrient elements required for the growth and progress of cotton (Sun et al. 2022). This nutrient plays a pivotal role in stimulating the budding and flowering during the middle growth stage and further aids in enhancing the maturity and weight of cotton bolls in the late growth phase. These effects have a direct impact on the final lint yield and fiber quality of cotton (Mauget, Ulloa, and Dever 2019). Alarming statistics reveal that approximately 5.7×10^9 hectares of land globally suffer from a deficiency in available phosphorus significantly affecting agricultural production (Xu et al. 2020). The vital biological role of phosphorus is met with a formidable challenge in tropical soils, where its presence is a mere 0.1% across 5.7 billion hectares of land (Granada et al. 2018). Furthermore, phosphorus, a critical element, is predominantly obtained from finite resources such as phosphate-rich rock, and the alarming fact remains that 83% of these global reserves have been exhausted (Magallon-Servín et al. 2019; Sun et al. 2023). Plants depend on phosphorus for the synthesis of critical biomolecules, such as ATP, nucleic acids, and proteins, essential for their survival and growth (Heuer et al. 2017). Phosphorus can affect cotton fiber quality in several ways, both positively and negatively, depending on the specific context and application (Sun et al. 2023). Adequate phosphorus levels can contribute to longer and stronger cotton fibers while deficiency can contribute to reduced fiber length (Sun et al. 2023). Longer fibers are generally preferred in the textile industry, as they can be spun into finer and more durable threads. It can also increase cotton yield by promoting the development of more cotton bolls. A higher yield can lead to more fiber production, potentially improving overall fiber (dos Santos et al. 2023). Phosphorus can enhance the cotton plant's resistance to pests and diseases, indirectly improving fiber quality by reducing damage caused by these factors (Bertrand et al. 2021). Adequate phosphorus levels in the soil can lead to better plant growth, which can indirectly affect cotton fiber quality by producing more and healthier cotton bolls (Iqbal et al. 2020).

In conjunction with persistent drought conditions and scarce rainfall, the deficiency of available phosphorus in the soil poses a significant challenge in cotton cultivation regions (X. Wang et al. 2010). In the face of this challenge, the necessity for regular phosphate fertilizer applications remains imperative to sustain cotton yields and fiber quality. Consequently, the imperative for achieving both high yield and cotton quality necessitates the application of recommended amounts of phosphorus-based fertilizers. As the demand for higher cotton fiber quality escalates, it becomes paramount for cotton plants to receive a consistent phosphorus supply throughout their entire growth cycle. This is crucial not only to secure optimal lint yield but also to ensure superior fiber quality, a point underscored by Chen et al. (2020). Therefore, the overall objective of the present study is to assess the influence of sowing dates and phosphorus levels on cotton fiber quality, with a focus on optimizing fiber quality through strategic sowing timing and providing practical insights for cotton growers.

The gist of the entire study was on improvement of cotton yield and fiber quality through sowing dates manipulation and phosphorus application in Chato District of Tanzania. Therefore, the objectives were multifaceted, spanning an exploration of agronomic, socioeconomic, and policy implications for sustainable cotton production on small landholdings – led to the publication of Tlatlaa et al. (2023a), which presents findings from a systematic review, illuminating previously uncharted territories crucial for the sustainability of the cotton farming sector. Additionally, the research investigated the impacts of varying sowing dates and phosphorus levels on cotton growth and yield, with a particular emphasis on soil analysis and implications – disseminated in a publication of Tlatlaa et al. (2023b), providing significant insights into optimizing agricultural practices to enhance cotton productivity. Another aspect of the study focused on enhancing cotton fiber quality through strategic sowing practices, with a specific emphasis on phosphorus management – presented in this manuscript of the Journal of Natural Fibers, providing crucial quality parameters of cotton fiber pivotal for the textile industry. Lastly, the study aimed to optimize economic returns in cotton production, particularly examining the implications of sowing dates and phosphorus application – following the completion of the review process, the research outcomes have been endorsed for publication in the Frontiers in Plant Science journal, expected to provide practical insights for stakeholders in the cotton industry, facilitating informed decision-making processes to maximize economic benefits.

Materials and methods

Description of the study area

Field experiments were carried out in the picturesque Msilale village, nestled within Chato District, Tanzania, positioned between latitudes 02° 15' and 03° 15' S, and longitudes 31° and 32° E The elevation of this area varies between 1135 meters and 1141 meters above mean sea level (Tlatlaa, Tryphone, and Nassary 2023a). It experiences a bimodal rainfall pattern, with short rains occurring from September to December, and the long rainy season spanning from February to May. The average annual rainfall registers at 850 mm, and temperatures range from 24°C to 30°C (Msigwa 2019).

We started our experiment by collecting soil samples from Chato-Msilale and Muungano-Kahumo at a depth of 0–30 cm. The analysis showed Chato-Msilale soil is slightly acidic, making it suitable for cotton. On the other hand, Muungano-Kahumo has high organic matter and available phosphorus, promising better cotton growth. The choice of Chato-Msilale site was based on consideration of soil

Table 1. Factors and treatments used in the experiment and their combinations.

			Phosphorus levels and Treatment Combinations			
1. Sowing dates	Code used	Dates	P0	P1	P2	P3
25th November 2022	D1	**D1**	D1P0	D1P1	D1P2	D1P3
15th December 2022	D2	**D2**	D2P0	D2P1	D2P2	D2P3
4th January 2023	D3	**D3**	D3P0	D3P1	D3P2	D3P3
2. Phosphorus treatments/rates (kg ha^{-1})	Code used					
0	P0					
20	P1					
40	P2					
60	P3					

conditions, focusing on addressing available phosphorus limitations (Tlatlaa, Tryphone, and Nassary 2023a).

Research framework and intervention strategies

The research was established as randomized blocks design in a factorial trial with three replications. The main plots were dedicated to planting times, with phosphorus levels assigned to the sub-main plots. Two factors (i.e., sowing dates and phosphorus levels) were considered at various levels as detailed in Table 1. Each treatment (sowing dates × phosphorus levels) was replicated three times for each sowing date, resulting in a total of 36 experimental plots.

Diammonium phosphate (DAP, 46% P_2O_5) was applied to supply phosphorus during seed sowing. Nitrogen deficiency was addressed 21 days after sowing based on routine soil characterization, with an equivalent of 70 kg N ha^{-1} applied to all plots from urea (46% N), following recommendations by Savoy and Joines (2009). Two seeds of the cotton variety UKM-08 were sown per hole, with interrow spacing of 0.6 m and 0.3 m for the intrarow. The chosen variety is well-suited for the region and commonly used by local farmers. Each plot measured 2.4 m × 2.7 m (6.48 m^2) with 5 rows and 10 holes per row, totaling 100 plants per experimental plot (equivalent to 154,321 plants per hectare). Plots within a replicate were spaced 0.5 m apart, and replicates were spaced 1 m apart.

In periods of drought with uneven rainfall, frequent irrigation was implemented, accompanied by the use of mulching materials to enhance soil water-holding capacity in the study area. A local weather station had been established two months before the experiment to collect data on rainfall and temperature before, during, and after the experimentation period. However, the relevant data covers the months from November 2022 to June 2023, with harvesting taking place in May and June 2023.

Data collection

During the data collection phase, 30 representative plants were randomly selected in each plot and marked with colored strings. The growth-related data focused on plant height (cm). In contrast, the data pertaining to yield parameters included the number of bolls per cotton plant, individual boll weight, ginning turnout, and lint yield.

Post-harvesting, cotton fiber samples were stored in separate containers and submited to the Tanzania Agricultural Research Institute (TARI), Ukiriguru Centre Laboratory in Mwanza for ginning. The lint samples were conveyed to another laboratory in the Shinyanga region of Tanzania for a thorough analysis of fiber quality, utilizing the High Volume Instrument (HVI 1000) fiber analyzer. The analysis included staple length, fiber length, fiber strength, micronaire (fineness), elongation, spinning coefficient index, trash area, trash count, uniformity index, and color/grade. These variables measuring fiber quality in cotton are well elaborated by Azzouz et al. (2008), as compiled in Table 2.

Table 2. A general overview of how some of the cotton fiber quality properties might relate.

Fibre quality indicator	Explanation
Spinning coefficient index	The spinning coefficient index reflects the spinning performance of fibers. It may be influenced by factors such as fiber length, strength, and uniformity. It is an indicator that includes the specific integral properties of cotton, such as the micronaire, length, uniformity, tensile strength, light reflection coefficient (Rd), and yellowing rate (+ b) of the cotton fiber
Moisture content	Moisture content can impact the physical properties of fibers, including their weight and flexibility. It may influence measurements like micronaire and fiber strength
Micronaire	It is a measure of fiber fineness and maturity. It may be related to the spinning performance and can influence the quality of the yarn produced
Upper half mean length	It is a measure of the average length of the longer fibers in a sample. It can impact yarn strength and overall textile quality
Uniformity index	The uniformity index measures the consistency of fiber length. Fibres with higher uniformity are generally desirable for textile processing
Shorter fiber	The presence of shorter fibers in a sample can affect the overall quality of the yarn and may be related to properties like uniformity and spinning performance
Fibre strength	Fiber strength is a critical property influencing yarn and fabric strength. It is often a key factor in determining the suitability of fibers for various applications
Yellowness	Yellowness is a color-related property. It might be influenced by factors such as fiber maturity, processing conditions, and exposure to environmental factors
Trash count and trash area	These properties measure the presence of impurities in the fiber. Higher trash count or trash area can negatively impact processing efficiency and yarn quality

Statistical data analysis

For the statistical analysis, the data underwent a two-way analysis of variance (ANOVA), where the sowing dates and phosphorus levels constituted the main fixed effects (two factors), and replicate blocks were considered as a random factor. The comparison of significant treatment means was performed using standard errors of differences of means (s.e.d.) with a 5% threshold, employing Tukey's post-hoc multiple comparisons.

Results

Effects of sowing dates and phosphorus on quality statistical parameters

The analysis of variance results of the main effects of sowing dates and phosphorus levels and their interactions on fiber quality parameters of cotton are presented in Table 3. With quality parameters, sowing dates have a significant effect on spinning coefficient index ($p < .001$), fiber strength ($p < .001$), fiber length ($p < .001$), uniformity index ($p < .001$), short fiber ($p = 0.006$), and grade/color ($p = .002$), but they did not significantly ($p > .05$) affect the moisture content of the fiber, maturation, trash count, trash area, and micronaire. Conversely, phosphorus levels have no significant ($p > .05$) effect on fiber

Table 3. Analysis of variance (ANOVA) for the effects of sowing dates, phosphorus levels and their interaction on fiber quality parameters.

Source of variation		SCI	Mst	Mic	UHML	Str	(+b)	UI	SF	TrCnt	TrAr
	d.f.	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*	*F pr.*
Replication	2										
Dates	2	<0.001	0.267	0.288	<0.001	<0.001	0.002	<0.001	0.006	0.781	0.467
Phosphorus	3	0.678	0.585	0.571	0.859	0.759	0.657	0.515	0.479	0.074	0.054
Dates × Phosphorus	6	0.27	0.125	0.845	0.024	0.473	0.9	0.042	0.565	0.183	0.23
Residual	22										
Total	35										

Key: SCI = Spinning Coefficient Index; Mst = Moisture content; Mic = Micronaire; Mat = maturation; UHML = Upper Half Mean Length; Str =Fiber strength; (+b) = Fibre colour (yellowness); UI = Uniformity Index; SF= Short Fibre; TrCnt = Trash count; TrAr = Trash area; *d.f. = degrees of freedom, F pr. = test-F probability.*

quality parameters. However, it is noteworthy that the interaction between sowing dates and phosphorus levels exhibited a discernible, albeit moderate, effect on fiber length ($p = .024$) and uniformity index ($p = .0042$)

Effects of sowing dates and phosphorus on mean fibre quality parameters

The data presented in Table 4 offers a comprehensive view of how fiber quality parameters in cotton are influenced by sowing dates and phosphorus levels. When evaluated the impact of sowing dates (25th November 2022, 15th December 2022, and 4th January 2023) on these parameters, notable differences emerge across various aspects of fiber quality. For most of the parameters, such as spinning coefficient index, fiber length, uniformity index, short fiber content, fiber strength, and trash area, there exists a significant disparity among the sowing dates. Specifically, sowing date 25th November 2022 consistently yields superior values compared to 15th December 2022 and 4th January 2023. The spinning coefficient index, for instance, tells a compelling story, displaying a pronounced significance ($p < .001$) with its pinnacle achieved in plots sown on the 25th November 2022. Similarly, when we scrutinize fiber length, a significant ($p < .001$) divergence is evident in plots sown on the 25th November 2022. Fiber strength, too, exhibits a remarkable variance among the three sowing dates, displaying significant differences ($p < .001$) with the highest values observed in plots sown on the 25th November 2022. Furthermore, the analysis of grade/color (yellowness) discloses another significant ($p < .001$) distinction across the sowing dates. The highest grade fibers, though exclusive to plots sown on the 15th December 2022, show a poor grade in terms of color. Additionally, there is a significant difference in short fiber content, with a highly significant ($p = .006$) difference discernible among the sowing dates. Early sowing dates (25th November 2022 and 15th December 2022) present commendably low short fiber percentages, in stark contrast to 4th January 2023, where notably higher short fiber content is observed. The uniformity index of the fibers also demonstrates a notable dependency on sowing dates, with the highest values recorded for plots sown on the 25th November 2022 and 15th December 2022, respectively. However, it is important to note that micronaire, elongation, moisture content, trash area, and trash count exhibited no statistically significant ($p > .05$) differences across different sowing dates. Conversely, when considering the impact of phosphorus levels, the results reveal an absence of any discernible ($p > .05$) influence on the variables under examination. The sowing date factor exerts a substantial impact on several key parameters, with early sowing (25th November 2022) generally outperforming middle and

Table 4. Mean fiber quality parameters of cotton as affected by sowing dates and phosphorus levels.

Factors	Treatments	SCI	Mst	Mic	UHML	UI	SF	Str	(+b)	TrCnt	TrAr
			(%)	(µg/inch)	(cm)	(%)	(%)	(MPa)		(g^{-1})	(%)
Sowing dates	25th November 2022	156.5^{a}	7.8^{a}	3.5^{a}	1.2^{a}	84.6^{a}	6.8^{b}	30.0^{a}	8.5^{b}	8.2^{a}	0.09^{a}
	15th December 2022	148.4^{a}	7.7^{a}	3.5^{a}	1.2^{a}	84.2^{a}	7.0^{b}	28.0^{b}	8.4^{b}	8.0^{a}	0.09^{a}
	4th January 2023	133.8^{b}	7.9^{a}	3.3^{a}	1.1^{b}	82.6^{b}	7.6^{a}	26.6^{b}	8.9^{a}	6.8^{a}	0.10^{a}
	L.S.D. $_{(0.05)}$	7.7	0.3	0.3	0.03	0.8	0.5	1.4	0.3	2.4	0.03
	p-value	<0.001	0.267	0.288	<0.001	<0.001	0.006	<0.001	0.002	0.467	0.781
Phosphorus levels (kg ha^{-1})	0	146.3^{a}	7.7^{a}	3.3^{a}	1.1^{a}	83.5^{a}	7.3^{a}	28.3^{a}	8.5^{a}	9.3^{a}	0.12^{a}
	20	148.9^{a}	7.8^{a}	3.4^{a}	1.1^{a}	84.1^{a}	6.9^{a}	28.4^{a}	8.7^{a}	9.3^{a}	0.08^{a}
	40	146.1^{a}	7.9^{a}	3.5^{a}	1.1^{a}	83.7^{a}	7.3^{a}	28.3^{a}	8.7^{a}	9.3^{a}	0.01^{a}
	60	143.6^{a}	7.9^{a}	3.5^{a}	1.1^{a}	83.8^{a}	7.1^{a}	27.7^{a}	8.6^{a}	9.3^{a}	0.07^{a}
	L.S.D. $_{(0.05)}$	8.9	0.4	0.4	0.03	0.9	0.6	1. 6	0.4	2.8	0.04
	p-value	0.678	0.585	0.571	0.859	0.515	0.479	0.759	0.657	0.054	0.074

Key: SCI = Spinning Coefficient Index; Mst = moisture content of the fiber; Mic = Micronaire; UHML = Upper Half Mean Length; UI = Uniformity Index; SF = Shorter Fiber; Str = Fiber Strength; (+b) = Yellowness of the Fibre; TrCn = Trash Count; TrAr = Trash Area; L.S. D. (0.05) = Least Significant Difference (at 0.05 probability), D = sowing date; *p* = phosphorus.

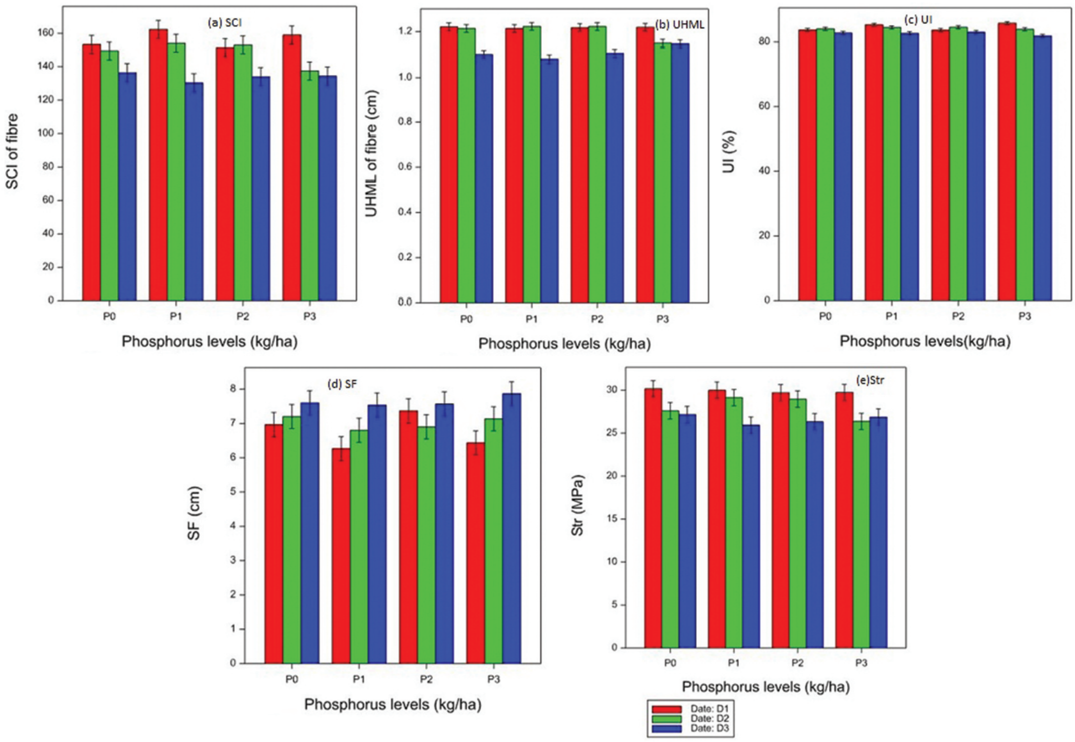

Figure 1. Interactive effects of sowing dates and phosphorus levels on (a) spinning coefficient index, (b) upper half mean length, (c) uniformity index, (d) short fibre, and (e) fibre strength.

late sowing dates (15th December 2022 and 4th January 2023). Although the interaction between sowing dates and phosphorus levels have no significant effect on the measured variables related to fiber quality the general trend is presented for some variables, including spinning coefficient index, upper half mean length, uniformity index, short fiber, and fiber strength (Figure 1).

Discussion

The effect of planting date on spinning coefficient index was highly significant in this study. Early sowing dates generally resulted in higher spinning coefficient index displaying a pronounced significance. Notably, the pinnacle of spinning coefficient index performance, a remarkable 156.5, was attained in plots sown on the 25th November 2022. The interplay between photosynthetic carbon fixation and cellulose synthesis is profoundly influenced by environmental factors, a dynamic relationship that significantly contributes to fiber wall thickening and, consequently, impacts fiber quality specifically spinning coefficient index The pivotal roles of cellulose and sucrose in shaping fiber quality have been underscored in previous research, with sowing dates shown to be a determinant in this regard (Darawsheh et al. 2022; Zhao et al. 2012). Upon analysis, the fiber length results unfolded a striking contrast with a highly significant divergence. For instance, an impressive 1.2 inches (55.9 mm) of length was documented for plots sown on 25th November and 15th December 2022, compared to 1.1 inch (27.9 mm) for the plots sown on 4th January 2023. This finding aligns with previous researchers who concluded that early planting resulted in the maximum staple length, while late planting yielded a slightly lower maximum staple length (Abbas and Ahmad 2018; Mauget, Ulloa, and Dever 2019).

The profound impact of planting dates on spinning coefficient index and fiber length underscores the intricate interplay between environmental factors and cotton fiber quality (Darawsheh et al. 2022; Thapliyal et al. 2023). Early sowing dates demonstrate a pronounced significance in yielding higher spinning coefficient index values (Sankaranarayanan, Prakash, and Rajendran 2020); with the highest performance observed in plots sown on November 25th, 2022 for the present study (Tlatlaa, Tryphone, and Nassary 2023a). This phenomenon is attributed to favorable environmental conditions during early growth stages, facilitating robust photosynthetic carbon fixation and cellulose synthesis, thereby contributing to fiber wall thickening and enhancing spinning coefficient index values (Khan et al. 2018; Y. Wang et al. 2009; Zou et al. 2022). Concurrently, the significant divergence in fiber length across planting dates highlights the correlation between early planting and longer staple lengths, indicative of optimal fiber development (Mauget, Ulloa, and Dever 2019; Mekonnen et al. 2023). This alignment with previous research emphasizes the critical role of early planting in maximizing fiber quality (Tlatlaa, Tryphone, and Nassary 2023a). Moreover, the pivotal roles of cellulose and sucrose present the biochemical underpinnings of these phenomena, with early planting regimes promoting enhanced carbohydrate accumulation and robust fiber development (Ma et al. 2014; Stein and Granot 2019).

Additionally, the present study unveils a remarkable variance in fiber strength among the three sowing dates. Specifically, the highest fiber strength, a noteworthy (29.9 g tex^{-1}), was achieved by plots sown on 25th November 2022, compared to the lowest value (28 and 26.6 g tex^{-1}) for the plots sown on 15th December 2022 and 4th January 2023, respectively. The results of the present study are in line with the research conducted by Awan et al. (2011) who reported higher fiber strength in early sown cotton as opposed to late sown cotton. Moreover, the analysis of grade/color (yellowness) disclosed yet another significant distinction across the sowing date. In this context, the highest grade fibers, scoring an impressive 8.4 were exclusively found in plots sown on 15th December 2022. These findings corroborate Abbas and Ahmad (2018) indicating that late sowing leads to increased lint yellowness. These results also highlight the contrasting results reported by Çopur, Polat, and Odabaşioğlu (2018) in Pakistan, who did not find any significant impact of sowing time on fiber yellowness. These disparities could be attributed to factors such as local climatic conditions, precise timing of the cropping season, soil properties, cotton cultivars, and soil amendments used in each study (Darawsheh et al. 2022; Hulugalle, Nehl, and Weaver 2004; Mauget, Ulloa, and Dever 2019). The study suggests significant implications regarding the timing of cotton sowing. It indicates that early sowing, particularly on 25th November 2022, results in higher fiber strength, while late sowing, as observed on 15th December 2022, produces cotton with better grade/color attributes, despite potentially increased yellowness. The alignment of these findings with previous research suggests that sowing time influences fiber quality. However, discrepancies with other studies, particularly Çopur, Polat, and Odabaşioğlu (2018), show the complex interplay of factors such as local climate, soil conditions, and cultivars.

In addition, the present study provides a noteworthy disparity in short fiber content, with a highly significant difference discernible among the sowing date. Specifically, sowing dates 25th November 2022 and 15th December 2022 exhibited a commendably low shorter fiber percentage, at 6.8% and 7%, respectively, in contrast to 4th January 2023, where a notably higher shorter fiber, at 7.6% was observed. Furthermore, the uniformity index of the fiber exhibits a significant dependence on sowing dates, with the highest values, reaching 84.6% and 84.2%, being recorded for plots sown on 25th November 2022 and 15th December 2022, respectively. In stark contrast, plots sown on 4th January 2023, displayed a lower uniformity-index-ratio of 82.6%. These findings also concurs with prior study highlighted that early planting on yielded a higher uniformity-index-ratio (84.15%) compared to late planting which resulted in a slightly lower uniformity-index-ratio of 83.76% (Abbas and Ahmad 2018; X. Wang et al. 2014). Nevertheless, it is important to highlight that micronaire showed no statistically significant variances among various sowing dates. These findings are in line with previous similarly studies conducted elsewhere, which found that sowing dates did not exert a significant influence on fiber micronaire, elongation moisture content, trash area and trash count (Mauget, Ulloa, and Dever 2019). On the other hand, when considering the impact of phosphorus levels, the results reveal an absence of any discernible influence on the variables under examination. The phosphorus factor does not show significant differences among treatments for most parameters, suggesting that the different phosphorus treatments have similar effects on the measured variables.

In their study, Darawsheh et al. (2022) revealed significant variations in cotton fiber quality across different physiographic features, with environmental factors and seasonal changes playing pivotal roles. Despite these variations, there has been consistency in fiber quality parameters across diverse cultivation areas, suggesting that cotton cultivation maintains consistent fiber quality standards regardless of specific environmental conditions (Pettigrew 2001). Similarly, Thapliyal et al. (2023) shed light on the diverse properties of natural fibers, emphasizing the crucial roles played by core components like hemicellulose, cellulose, and lignin in determining fiber stiffness.

Conclusions and recommendations

Conclusions

This study finds out the critical factors influencing cotton fiber quality, namely sowing dates and phosphorus levels. The choice of sowing date significantly impacts cotton fiber quality parameters. Planting cotton seeds early, notably on 25th November 2022, consistently yielded superior fiber quality across a range of metrics including spinning coefficient index, fiber length, strength, uniformity index, short fiber content, and grade/color. This provides the importance of carefully selecting the planting date to optimize cotton fiber quality. Within the examined range of phosphorus levels, there was no significant effect observed on cotton fiber quality attributes. This suggests that adjustments to phosphorus levels within the tested range may not be necessary to enhance fiber quality.

Recommendations

Based on the conclusions obtained from the current study, aligning with parallel results detailing cotton growth and yield (specifically lint yield and gin turnout percentage) within the same experiment, it is advisable for cotton growers to consider initiating their crop sowing early in the season, particularly in late November. This strategic timing of cotton planting aims to maximize fiber quality. Given the observed limited impact of phosphorus levels on fiber quality within the tested range, farmers may not find it necessary to make substantial adjustments to phosphorus application rates solely for the purpose of enhancing fiber quality but through integration of nutrient management strategies. Nevertheless, it is crucial for farmers to conduct regular soil testing and nutrient management practices to ensure the overall health and yield of the crop.

The practical insights derived from this study hold particular significance for cotton growers in Tanzania, underscoring the pivotal role of sowing timing in achieving superior fiber quality. By embracing these recommendations, it is anticipated that farmers can actively strive toward optimizing their cotton cultivation practices, leading to improved yields and enhanced fiber quality.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Research highlights

- We assessed sowing timing of cotton and phosphorus (P) levels in Tanzania.
- Sowing dates significantly influenced cotton fiber quality parameters.
- Earlier sowing timing in the cropping season produced higher fiber quality.
- Phosphorus levels did not exhibit significant influence within the tested range.
- The interplay between sowing and P levels on fiber quality need more investigation.

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