Advances in Agriculture and Biology (2018) 1(1): 15-22
RESEARCH PAPER

Effect of sowing time, advanced genotype, and potassium application on seed cotton yield in relay cropping with wheat

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Received: 11 January 2018
Accepted: 9 April 2018

Key Message: This study highlights the critical impact of sowing time, advanced genotypes, and potassium application on seed cotton yield in relay cropping with wheat. Early sowing proved essential for optimal agro-resource utilization, maximizing cotton productivity and economic benefits in Pakistan.

Abstract

This research study was conducted at Central Cotton Research Institute Multan during 2016 to evaluate the effect of sowing dates on seed cotton yield of different Bt cultivars. Experimental design was split plot. Sowing dates were kept in main block and genotypes in sub plot with four replications. The plot size was 30 × 20 ft. An experiment was conducted at central cotton research institute Multan during 2016 to evaluate the effect of sowing dates on seed cotton yield of different conventional cultivars. Experimental design was split plot. Sowing dates were kept in main block and genotypes in sub plot with three repeats. The findings indicate that the height of cotton plants, the number of nodes, and the quantity of buds decreased when planting was delayed. In contrast, earlier sowing resulted in a higher yield compared to later sowing. This outcome is likely attributed to the more effective utilization of agro-resources. Therefore, it is advisable to engage in early sowing of cotton in the primary (conventional) zone of Pakistan for optimal harvesting of agro-environmental factors and enhanced economic benefits for the farming community, aligning with practices in other cotton-producing nations. Among genotypes Cyto-122 gave maximum plant height, number of nodes and number of buds as compared to the other genotypes Cyto-124, CIM-620 and FH-942.

Keywords: Agro-resources, Productivity, Relay cropping, Seed cotton yield, Sowing time

Citation: Iqbal, J., Shah, S. F. H., & Ahmad, I. (2018). Effect of sowing time, advanced genotype, and potassium application on seed cotton yield in relay cropping with wheat. *Advances in Agriculture and Biology, 1*(1), 15-22.

Introduction

Cotton plays a significant role in the economies of many countries as a major cash crop (Ali et al., 2012). It serves as an integral component of daily life, being the world's foremost natural textile fiber and the fifth-largest oilseeds crop, addressing approximately 40% of the global textile demand (APTMA, 2012; Zia et al., 2018a, 2018b) and accounting for 3.3% of edible oil (FAS, 2014). Pakistan stands at 4th largest global producer of cotton, ranking third in consumption, and is a leading exporter of yarn during the year 2012 (ICAC, 2012), achieving a production of 12.8 million bales from a cultivation area spanning 2.8 million hectares (Economic Survey of Pakistan, 2014). The cotton industry significantly contributes to Pakistan's economy. However, despite its economic importance, the per-hectare yield in Pakistan remains comparatively low when juxtaposed with other cotton-producing nations worldwide. In Pakistan, low seed cotton production per unit area is attributed to a lack of awareness about essential agronomic practices such as selecting the right variety, choosing the appropriate planting time, and maintaining optimal plant density. These factors are considered crucial for improving yield performance. Sowing time plays a central role in determining the yield of cotton. Unlike rice and wheat, the cotton plant exhibits a limited range of ecological adaptability and is significantly influenced by climatic conditions and sowing dates. The sowing time has a direct impact on seed cotton yield, given that early maturing cultivars initiate flowering and boll formation much earlier than their late-maturing counterparts. Achieving optimal dry matter accumulation before flowering, coupled with substantial dry matter accumulation after flowering, has been identified as crucial for increasing seed cotton yield (Chen et al., 2001). For growers aiming to optimize both yield and quality, selecting the right sowing time is a paramount agronomic consideration. Delayed sowing, however, poses a risk by reducing the overall season length and subsequently diminishing the yield potential. Therefore, the judicious choice of sowing time is imperative for cotton cultivation, ensuring favorable conditions for the crop's growth and development.

It is widely recognized that the optimum sowing time for regions will be different. While it is not possible to collect data and produce sowing time responses for all regions concurrently, we can use the data collected from most sowing time trials to help improve our understanding of the cotton crop's response to temperature (Khan et al., 1980). In a study conducted by Khan et al. (1981) in Faisalabad and Sargodha districts, the impact of different sowing periods on seed cotton yield was investigated. The findings indicated that cotton sown between the 15th and 30th of April resulted in the highest per-acre yield compared to late sowings. Additionally, Khan et al. (1981) observed that the seed cotton yield of various varieties is influenced by seasonal variations. The researchers concluded that, considering the prevailing conditions in Dera Ghazi Khan, the optimal planting period for cotton is during the second fortnight of May.

Choosing the appropriate cultivar is a crucial aspect of crop management in any cropping system. This is particularly significant when compared to considerations such as plant spacing and sowing date in cotton production. Some varieties have more yielding character regardless of other parameters (Ali et al., 2009). Cotton stands out as a primary agricultural product, with its chief output being the fiber or lint. The quality of this fiber encompasses key attributes such as length, strength, fineness, maturity, and uniformity, with spinning capacity serving as a pivotal indicator of overall quality. Noteworthy advancements, particularly in fiber length and spinning capacity, have been achieved (Akhter et al., 2002). Widely recognized as a leading global fiber and cash crop, cotton is cultivated on a commercial scale for both agricultural and industrial purposes across more than fifty countries in tropical and temperate regions. While its primary cultivation is geared towards fiber production, cotton offers multiple valuable uses. Notably, its seeds contain 30% starch, 25% crude oil, and 16.2% protein (Heuze et al., 2015). This versatile crop plays a vital role in the economic landscape of countries, contributing significantly to GDP due to its high-quality fiber. Despite its ancient cultivation history, the widespread adoption of cotton was catalyzed by the invention of the cotton gin, which dramatically lowered production costs. Today, cotton remains the most widely utilized natural fiber in clothing (Ansari et al., 1991). In Pakistan, cotton takes center stage as the main industrial crop, covering 15 percent of the country's arable land (Economic Survey of Pakistan, 2015). The cotton sector, coupled with the textile and apparel industry, collectively constitutes 11 percent of the country's GDP (Economic Survey of Pakistan, 2015). This emphasizes the deep economic significance of the cotton industry in Pakistan.

Wheat stands out as the primary food grain in Pakistan, serving as the staple diet for the population and holding a central position in agricultural policies (Khan et al., 2016; Anser et al., 2018). It plays a substantial role in the economy, contributing 12.5 percent to the value added in agriculture and 3.1 percent to the GDP (Economic Survey of Pakistan, 2015). In 2013-14, the wheat cultivation area expanded to 9039 thousand hectares, marking a 4.4 percent increase from the previous year's 8660 thousand hectares. Relay cropping is a modified form of double cropping, involving planting the second crop into the first before harvest, rather than waiting until after harvest as in traditional double-cropping (Akanvou et al., 2002). This approach allows both crops to share a portion of the growing season, maximizing solar radiation and heat. Late plantation of cotton significantly contributes to low yields, primarily stemming from the delayed harvesting of wheat crops. The delayed sowing of cotton is particularly susceptible to various pests, including whiteflies, jassids, mealy bugs, thrips, boll worms, and CLCV. The vulnerability arises as the tender stages of the crop coincide with the peak infestation of these pests, resulting in reduced yields. Additionally, the infestation of insect pests on the cotton crop further hampers the timely sowing of wheat.

The sowing time plays a key role in determining cotton yield, with the plant's ecological adaptability being significantly influenced by climatic conditions and sowing dates. This factor has a linear impact on seed cotton yield, as early maturing cultivars initiate flowering and boll formation earlier than their late counterparts (Ansari et al., 1991). Optimal dry matter accumulation before flowering and substantial dry matter accumulation after flowering contribute to increased seed cotton yield. Selecting the right sowing time is a critical agronomic consideration for growers aiming to optimize both yield and quality in cotton crops (Arain et al., 2001). Striking the right balance is challenging, as sowing too early exposes the crop to cold weather-related issues, while sowing too late reduces the season length and subsequently the yield. Timing the sowing when conditions are warmer mitigates risks associated with poor establishment and allows for more vigorous crop growth, offering a practical approach to achieving optimal yields. It is widely recognized that the optimum sowing time for regions will be different. While it is not possible to collect data and produce sowing time responses for all regions concurrently, we can use the data collected from most sowing time trials to help improve our understanding of the cotton crop's response to temperature. Some varieties have more yielding character regardless of other parameters.

Potassium is very important for the growth and development of the cotton plant. It is very necessary for the enzymatic activity in the cotton plant and plays a role in reducing of the wilting disease. The application of potassium is also help in translocation of the carbohydrates, photosynthesis, water relation and resistance against the pest and disease (Brar & Tiwari, 2004). The potassium also helps in increasing the boll weight, boll number, and lint quality (Pettigrew, 2002). The deficiency of the potassium also effect on the physiological disorder, retarded in plant growth and development (Wang et al., 2013). It also affects the cotton yield and fiber quality. The potassium deficiency causes the reduction in the photosynthesis because of the reduction in leaf area .Severe deficiency of potassium in cotton can lead to limited yield through decreased leaf area expansion and CO_2 assimilation capacity and low productivity associated with fiber quality (Hafsi et al., 2014). A pronounced potassium deficiency during active fiber growth significantly reduces the turgid pressure of cotton fibers, leading to decreased cell elongation and shorter fibers at maturity (Asif et al., 2018). This deficiency is more prevalent in cotton crops compared to other agronomic plants. Common symptoms include yellowish-white mottling of leaves evolving into numerous brown specks at the leaf tips, margins, and between veins (Marschner, 1995). As the deficiency progresses, the leaf tips and margins curl downward, resulting in a rust-colored, fragile leaf that drops prematurely, halting boll development and yielding dwarfed and immature fruit. The presence of small bolls is a distinctive indicator of potassium deficiency in cotton (Weir et al., 1986; Maples et al., 1988). This study was conducted to determine the optimum sowing time of different advanced genotypes for their productivity.

Materials and Methods

Experiment 1: Cotton as relay crop - cotton sowing in standing wheat

Experimental site

The study took place at the Central Cotton Research Institute in Multan, Pakistan, located at 30°12' N latitude and 71°28' E longitude, at an elevation of 123 meters above sea level, in the year 2016. The experimental site experienced a very hot climate with relatively low humidity during April-May, along with a steady increase in temperature from March to July. The soil at the experimental site was characterized as low fertility silt loam, with a pH of 8.2, organic matter content of 0.42%, and an electrical conductivity (EC) of 3.83 dSm^{-1}.

Experimental design

Four cotton genotypes, namely Cyto-124, CIM-620, FH-942, and Cyto-122, were evaluated in this study. Five different sowing dates were tested, commencing from the 15th of April to the 15th of June at fortnightly intervals. The experimental design employed was a split-plot design, with the sowing dates designated as the main blocks and the genotypes as subplots. Each combination of sowing date and genotype was replicated three times, resulting in a net plot size of 30×20 feet.

Field preparation and sowing

Bed furrows were prepared after land preparation in dry conditions, followed by bed shaping and the application of Dual Gold (S-Metolachlor 960 EC) at a rate of 800 ml per acre. Sowing was carried out by dibbling at a seed rate of 24 kg ha^{-1}, with a plant-to-plant distance of 22.5 cm. Irrigation was applied immediately after sowing. Subsequently, the furrows were irrigated again 72 hours after dibbling to ensure successful seed germination and emergence. Additional irrigation was provided after one week to address any gaps where seeds had not germinated. Phosphorus was applied at a rate of 58 kg ha^{-1} during seed bed preparation, while nitrogen was applied at a rate of 150 kg ha^{-1} in three split doses, corresponding to seed bed preparation, flowering, and boll formation.

Crop management

Throughout the crop season, the cotton crop was protected from insect pest attacks through regular application of recommended pesticides, following the guidelines provided by the Punjab Agriculture Department. All other agronomic practices, such as weeding and nutrient management, were consistently applied in a uniform manner in the field.

Harvest and data collection

At maturity, plants were picked from a 1 m² area within each experimental plot. Data pertaining to various growth and yield parameters, including the number of bolls and boll weight, were collected and recorded.

Sowing schedule

The sowing schedule for the experiment was as follows:

D1: 15th April 2016
D2: 1st May 2016
D3: 15th May 2016
D4: 1st June 2016
D5: 15th June 2016

Experiment 2: Effect of time of sowing on productivity of advanced genotypes

Experimental site

The experiment was conducted at the Central Cotton Research Institute in Multan, situated in a semi-arid region characterized by four distinct climatic seasons, including mild winters and hot summers.

Soil analysis

Soil samples were collected at depths of 0-6 inches and 6-12 inches. Analytical results revealed that the soil had an alkaline pH of 8.4 and was free from excessive salt content. It exhibited low organic matter content (0.52%), while the available phosphorous content was measured at 8.2 mg kg^{-1}, and potassium content was at a medium level, with 155 mg kg^{-1}.

Experimental design

The experiment employed a randomized complete block design (RCBD). The selected cotton variety, Bt. CIM 616, was sown

at a rate of 24 kg ha^{-1} with a spacing of 22 cm between plants (P×P) and 75 cm between rows (R×R). Four distinct treatments were applied as follows:
T1 - Sole crop (Fallow land): Variety Bt. CIM 616 was sown as a sole crop on fallow land during the third year of the study.

T2 - Cotton sowing in standing wheat (Row to row distance 75 cm): Cotton was sown in standing wheat, with a row-to-row distance of 75 cm.
T3 - Cotton sowing in standing wheat (Row to row distance 150 cm): Similar to T2, cotton was sown in standing wheat, but with a wider row-to-row distance of 150 cm.
T4 - Cotton planting after wheat harvesting (Conventional method): Cotton was planted following the wheat harvest, with sowing occurring during the 1st week of May.

Cultivation

To facilitate the transition from wheat to cotton cultivation in treatments T2 and T3, plowing was conducted when the wheat reached maturity using a cultivator. Subsequently, dibbling was performed manually.

Data collection

The experiment focused on collecting data related to plant structure, yield and its components, incidence of Cotton Leaf Curl Virus (CLCV) on a fortnightly basis up to 150 days after planting, and various fiber characteristics.

Experiment 3: Effect of potassium application on relay cropping with wheat

The study aimed to explore the impact of potassium application strategies on the Bt Cyto-301 cotton variety at the Central Cotton Research Institute. The experimental design employed a Randomized Complete Block Design (RCBD). Cotton was sown with row-to-row spacing set at 75 cm, and plot-to-plot distance was maintained at 22 cm. There were five treatment groups:
T1 (Control)
T2 (100 kg ha^{-1} applied in full at sowing time)
T3 (100 kg ha^{-1} with two splits - half at sowing and half at 45 days DAP)
T4 (200 kg ha^{-1} applied in full at sowing time)
T5 (200 kg ha^{-1} with four splits - 1/4 at sowing time, 1/4 at 30 days DAP, 1/4 at 45 days DAP, and 1/4 at 60 days DAP).
The seedbed preparation involved cultivating wheat, followed by the use of a rotavator to incorporate the remaining wheat crop residues. Cotton seeds were sown manually using a dibbling method, with a seeding rate of 24 kg ha^{-1}.

The layout of the experimental plots was as follows:

R1: Potassium sulphate (K_2SO_4) (2%) - 45 ft × 20 ft
R2: Potassium sulphate (K_2SO_4) (2%) - 45 ft × 20 ft
R3: 200 (No spray) - 3 ft
R4: 200 (No spray) - 10 ft

Each treatment plot was spaced at 3 ft or 10 ft intervals as specified above. Control plots were interspersed as appropriate to facilitate comparison.

Results

Cotton sowing in standing wheat: Cotton as relay crop

The results from Table 1 demonstrate that early planting in wheat affects the plant structure and fruiting points of Cotton cultivar Bt CIM-616 under various treatments. In treatment T1, where cotton was grown as the sole crop on fallow land with early planting, the cotton plants reached a height of 36.40 cm with 16.20 nodes, although bolls per square meter data was not provided. In treatment T2, cotton was sown within standing wheat at a row-to-row distance of 75 cm, also with early planting. This resulted in taller cotton plants, averaging 76.60 cm in height and having 23.60 nodes, accompanied by a notable 24.8 bolls per square meter. In treatment T3, the cotton was similarly sown in standing wheat, but with a wider row-to-row distance of 150 cm. The cotton plants reached an average height of 67.70 cm, had 19.50 nodes, and produced 19 bolls per square meter. In treatment T4 involved planting cotton after wheat harvesting, still with early planting, but the cotton plants remained relatively short at 18.80 cm in height, had 14.10 nodes, and yielded 1.6 bolls per square meter.

Table 1 Influence of early planting in wheat on plant structure and fruiting points

Treatments	Plant height (cm)	No. of nodes	Bolls ($m^{2)}$
Cotton as sole (fallow land) early (T1)	36.40	16.20	
Cotton sowing in standing wheat (Row to row distance 75 cm (T2)	76.60	23.60	24.8
Cotton sowing in standing (Row to row distance 150 cm) T3	67.70	19.50	19
Cotton Planting after wheat harvesting (T4)	18.80	14.10	1.6

Influence of sowing time on plant structure in cotton genotypes

The results from Table 2 show the impact of sowing time and genotypes on plant structure. Plant height exhibited a decreasing trend as the sowing date was delayed, with crops sown on April 15th yielding the tallest plants (40.26 cm), while those sown on May 15th were the shortest (13.07 cm) in height. Among the genotypes, Cyto-122 displayed the greatest plant height (26.26 cm), followed closely by CIM-620 (25.17 cm), while FH-942 had the shortest plants (21.37 cm). The number of nodes on cotton plants also varied with sowing date and genotype, with the highest average of 14.40 nodes per plant observed in those sown on April 15th. Cyto-122 had the most nodes (9.73), followed by Cyto-124 (9.62), CIM-620 (9.55), and FH-942 (8.52). In terms of internodal distance between nodes, small differences were observed among sowing dates and genotypes, with distances ranging from approximately 2.44 cm to 2.99 cm. The number of buds per plant exhibited variability, with the highest average of 8.80 buds per plant in those sown on April 15th, and Cyto-122 having the most buds (3.35). Notably, no buds were observed in plants sown on May 1st. Hence, these results highlight the significant influence of sowing time on plant height, node count, and bud formation, favoring early sowing for better cotton production in terms of plant structure.

Table 2 Effect of sowing time and genotypes on plant structure

Sowing dates	Genotypes	Plant height (cm)	No. of nodes	Internodal-distance (cm)	No. of buds
April 15	Cyto-124	37.30	14	2.66	8.13
	CIM-620	38.46	13.2	2.91	6.53
	FH-942	32.26	12.06	2.56	6.60
	Cyto-122	40.26	14.40	2.79	8.80
May 1	Cyto-124	20.80	10.86	1.91	0
	CIM-620	23.46	10.46	2.24	0.53
	FH-942	21.46	10.06	2.13	0.46
	Cyto-122	25.46	10.40	2.44	1.26
May 15	Cyto-124	10.13333	4	2.53	
	CIM-620	13.6	5	2.72	
	FH-942	10.4	3.466667	2.99	
	Cyto-122	13.06667	4.4	2.96	

Effect of time of sowing on seed cotton yield of advanced genotypes

The data in Table 3 illustrates the impact of sowing date on various growth parameters, including plant height, nodes per plant, inter-nodal distance, and the number of buds. The results indicate a consistent decrease in plant height as the sowing date is delayed. Crops sown on March 1 exhibited the highest plant height at 76.43 cm, accompanied by 22.86 nodes, an inter-nodal distance of 3.34 cm, and 14.83 buds. In contrast, crops sown on March 15 showed slightly reduced values with a plant height of 69.45 cm, 22.00 nodes, an inter-nodal distance of 3.1 cm, and 13.73 buds. The trend continued with crops sown on April 1, which experienced further reductions in plant height (61.28 cm), nodes per plant (18.88), inter-nodal distance (3.2 cm), and the number of buds (12.95). Finally, the crops sown on April 15 demonstrated the most significant decrease, resulting in a plant height of 36.33 cm, 17.21 nodes, an inter-nodal distance of 2.1 cm, and 7.36 buds.

Table 3 Effect of time of sowing on seed cotton yield of advanced genotypes

Sowing date	Genotype	Plant height (cm)	Number of nodes	Inter nodal distance (cm)	Number of buds
1 March	CIM-632	79.40	23.55	3.3	15.15
	Cyto-301	75.05	22.45	3.3	16.20
	Cim-602	74.85	22.60	3.3	13.15
15 March	CIM-632	73.95	22.15	3.3	13.95
	Cyto-301	63.55	21.90	2.9	13.30
	Cim-602	70.85	21.95	3.2	13.95
1 April	CIM-632	53.15	17.75	2.9	11.45
	Cyto-301	66.60	19.50	3.4	15.75
	Cim-602	64.10	19.40	3.3	11.65
15 April	CIM-632	34.90	16.15	2.1	7.80
	Cyto-301	35.00	19.05	1.8	5.40
	Cim-602	39.10	16.45	2.3	8.90

Discussion

Cotton was sown in the standing wheat crop to increase the cotton production by early planting without sacrificing wheat crop and also to minimize cotton cultivation cost. Cotton as relay crop also increases farm income of small farmers by adopting modification in planting technique. Relay cropping technology for cotton emerges as a viable solution to address challenges faced in regions where cotton planting is delayed due to late maturity and the harvesting of wheat. This approach involves manually sowing cotton within the standing wheat crop. The wheat is allowed to mature and is subsequently harvested at the end of April or the first week of May, facilitating timely cotton sowing and offering the potential for additional benefits in cotton yield. To ensure the successful adoption of this technique, it is imperative for the agriculture department to provide comprehensive training and education to farmers on the nuances of relay cropping. A relay intercropping system, proposed as an alternative to both mono-cropped cotton and double-cropped cotton after wheat, entails planting wheat in the fall. This is done while leaving skip rows for wheel traffic, with cotton planting taking place in the spring while the wheat is still thriving. This period, often termed the relay intercropping period, typically occurs three to six weeks before the wheat harvest (Zhang et al., 2008a; 2008b). The practice of relay intercropping wheat and cotton has gained significant traction in China, covering an expansive 1,400,000 hectares. This system plays a crucial role in ensuring food security, fiber production, and augmenting farmer income (Zhang et al., 2007). However, it is essential to recognize that relay intercropping wheat and cotton presents several technical challenges, primarily arising from the limited use of pesticides and constrained traffic routes due to the presence of harvestable wheat (Hood et al., 1991). Early-season weed and insect management pose significant obstacles to the successful implementation of a wheat and cotton relay intercropping system. Hence, addressing these challenges through strategic planning and innovative solutions is paramount for the widespread and effective adoption of this promising agricultural technique.

One of the foremost considerations in agronomy is ensuring the optimal yield and quality of crops. In Pakistan, early planting offers the advantage of favorable environmental conditions prior to the onset of the monsoon and the occurrence of high temperatures during flowering and fruit development. Given that cotton is highly responsive to its surroundings, selecting an appropriate sowing time is crucial for growers to achieve optimal yield. Our findings align with the conclusions drawn by Yucel and Gormus (2002) who suggested that delayed planting makes cotton crops more susceptible to insects and adverse weather conditions, potentially leading to reduced yields. In contrast, early planting resulted in crops with more intact fruits leading to a higher number of bolls per unit area and a greater percentage of fiber maturity. While, late-planted crops tended to produce more vegetative dry matter with an elevated level of yellowness, an undesirable quality for the textile industry. These findings are consistent with the previous research studies (Pettigrew, 2002; Hassan et al., 2003; Ali et al., 2005). The increased yield associated with early sowing can likely be attributed to the advantageous utilization of soil and agro-environmental resources. Planting the crop a few days earlier allows growers to benefit from increased soil moisture, nutrients, and light due to a slight extension of the cotton crop's growing season. Our findings emphasize the critical role of sowing date in influencing the growth and development of advanced genotypes, with earlier sowing generally leading to more favorable outcomes in terms of plant height, nodes, inter-nodal distance, and bud production.

Our finding about increase in seed cotton yield in cotton relay cropping aligns with previous research findings (El-Hawary, 2009; EL-Zaher & Ali, 2012; Shah et al., 2016; Tariq et al., 2018). In contrast to our results, lower seed cotton yields have been reported in China when grown as a sole crop, attributed to insufficient light availability (Zhang et al., 2008). However, light availability was not a limiting factor in our study, and the presence of standing wheat provided protection to young cotton plants against hot winds. While relay cropping of cotton resulted in statistically similar yields, this technique also offers the added advantage of simultaneously cultivating wheat, providing an additional benefit compared to sole cotton cultivation.

Conclusion

The findings of this study highlight the critical role of sowing dates in shaping the plant structure, node development, and yield parameters of cotton. Early sowing particularly around mid-April emerged as a crucial factor contributing to taller plants, increased node count, and a higher number of buds, ultimately resulting in superior seed cotton yield. Furthermore, the study identified genotypic variations in response to sowing dates, with Cyto-122 exhibiting superior performance in terms of plant height, node development, and bud formation compared to other genotypes. This insight emphasizes the significance of selecting appropriate cotton genotypes tailored to specific sowing conditions for achieving optimal crop outcomes. Early planting within standing wheat, particularly at a row-to-row distance of 75 cm, resulted in taller plants with increased nodes and a higher number of bolls per square meter, reaffirming the positive correlation between early sowing and enhanced cotton productivity. The comparison of different potassium application strategies demonstrated varied effects on plant characteristics, emphasizing the need for tailored nutrient management practices to optimize cotton production.

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