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Research Article/Araştırma Makalesi

The effect of post-sowing potassium fertilizer application on the yield and some fiber technological properties of cotton (*Gossypium hirsutum* L.)

Ekimden sonra uygulanan potasyum gübresinin pamuğun (Gossypium hirsutum L.) verim ve bazı lif teknolojik özelliklerine etkisi

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ABSTRACT

This study was conducted to determine the effects of different post-sowing potassium fertilizer doses on cotton (*Gossypium hirsutum* L.) yield and fiber properties in Haliliye district of Şanlıurfa province in 2020-2021. The experiments were arranged in a randomized split-plot design with three replications. The Fiona cotton variety was used as plant material, and six-row plots were sown (row spacing: 75 cm, plant spacing: 5-6 cm). Main plots were defined by post-sowing days (30, 40, 50 days), while subplots consisted of potassium doses (control, 10, 20, 30 kg da^{-1}). Results showed that seed cotton yield ranged between 396 and 520 kg da^{-1}, with the highest yield achieved with 50 days post-sowing and 30 kg da^{-1} KCl application (520 kg da^{-1}). Plant height varied from 77.95 to 85.41 cm in 2020 and from 81.13 to 87.63 cm in 2021. The highest boll weight (6.97 g) was recorded in 2021 with 50 days post-sowing and 30 kg da^{-1} KCl application. The number of fruiting branches and bolls per plant varied across years, with the highest boll count observed with 40 days post-sowing and 20 kg da^{-1} KCl application. Fiber uniformity index ranged between 82.23% and 85.40%, while short fiber content varied from 6.70% to 11.70%. As a result, potassium fertilizer doses were found to be effective in increasing cotton yield and fiber quality; in particular, the application of 30 kg da^{-1} KCl on the 50th day gave the best results.

Keywords: Cotton, Fertilization, Fiber properties, Potassium, Yield

ÖZ

Bu çalışma, ekim sonrası farklı potasyum gübresi dozlarının pamuk (*Gossypium hirsutum* L.) verimi ve lif özelliklerine etkisini belirlemek amacıyla 2020-2021 yıllarında Şanlıurfa İli Haliliye İlçesi'nde yürütülmüştür. Denemeler, tesadüf bloklarında bölünmüş parseller deneme desenine göre üç tekerrürlü olarak gerçekleştirilmiştir. Fiona pamuk çeşidi kullanılarak 6 sıralı parsellerde (sıra arası 75 cm, sıra üzeri 5-6 cm) ekim yapılmıştır. Ana parsellerde ekim sonrası gün sayısı (30, 40, 50 gün), alt parsellerde ise potasyum dozları (kontrol, 10, 20, 30 kg da^{-1}) değerlendirilmiştir. Sonuçlar, kütlü pamuk veriminin 396-520 kg da^{-1} arasında değiştiğini ve en yüksek verimin 50. gün 30 kg da^{-1} KCl uygulamasıyla elde edildiğini göstermiştir (520 kg da^{-1}). Bitki boyu 2020'de 77.95-85.41 cm, 2021'de 81.13-87.63 cm arasında değişmiştir. En yüksek koza ağırlığı (6.97 g), 50. gün 30 kg da^{-1} KCl uygulamasında 2021 yılında kaydedilmiştir. Meyve dalı ve koza sayıları yıllara göre değişim göstermiş, en yüksek koza sayısı 40. gün 20 kg da^{-1} uygulamasında belirlenmiştir. Lif özellikleri açısından üniformite indeksi %82.23-%85.40 arasında, kısa lif oranı ise %6.70-%11.70 arasında değişmiştir. Sonuç olarak, potasyum gübresi dozları pamuk verimi ve lif kalitesini artırmakta etkili bulunmuş; özellikle 50. gün 30 kg da^{-1} KCl uygulaması en iyi sonuçları vermiştir.

Anahtar Kelimeler: Pamuk, Gübreleme, Lif özelikleri, Potasyum, Verim

Introduction

Clothing, an indispensable aspect of life, continues to underscore the growing importance of cotton fibers in meeting protection and covering needs. Cotton stands as the most significant fiber crop in the world. As the most valuable raw material in the global textile industry, cotton can only be cultivated in a limited number of countries due to its specific climatic requirements. Supplying raw materials to approximately fifty industrial sectors, cotton is not only an industrial crop but also a strategic product of great significance. Factors such as its natural composition, high moisture absorption capacity, ability to retain its properties even after multiple washes, greater durability compared to other fibers, low static electricity conductivity, excellent air permeability due to its high porosity, hygienic characteristics, and the inability of synthetic fibers to replicate its natural qualities all contribute to the increasing importance of cotton (Usta, 2003).

According to the data from the International Cotton Advisory Committee (ICAC) for the years 2016-2021, cotton cultivation worldwide during this six-year period covered an average area of 33.128 million hectares, with an annual average production of 25.57 million tons of cotton fiber. The United States ranked as the world's largest exporter, with an average annual export volume of 3.35 million tons, while China was the largest importer, with an annual average import volume of 1.87 million tons. Turkey, on the other hand, imported an annual average of 0.99 million tons of cotton during this period. In the 2020-2021 production season, the global cotton cultivation area was recorded at 32.1 million hectares. India had the largest cotton cultivation area, followed by the United States and China. Although Turkey ranked ninth globally in terms of cotton cultivation area, it held third place in productivity, following Australia and China. In Turkey, 814,000 tons of cotton fiber were produced on 477.8 thousand hectares during the 2019/2020 production season, but this figure declined to 656,000 tons on 359.2 thousand hectares in the 2020/2021 season (ICAC, 2022).

According to the Turkish Statistical Institute (TÜİK), in 2019, 55% of the cotton produced in Turkey was grown in the Southeastern Anatolia Region, 22% in the Aegean Region, 22% in the Çukurova region, and 1% in the Antalya region. Cotton is not only an agriculturally significant crop at both national and international levels due to its economic and strategic importance but also an indispensable raw material for the sustainability of the textile industry. Ensuring the continued success of Turkey's clothing sector, which plays a crucial role in the nation's economy and development, depends on increasing the production of cotton fiber, often referred to as "white gold." In the 2020 cotton production season, cotton was cultivated on 224,000 hectares in Şanlıurfa, compared to 232,000 hectares in 2019. These figures indicate that Şanlıurfa accounts for approximately 45% of Turkey's cotton production and 75% of the Southeastern Anatolia Region's output (TÜİK, 2020). To increase yield per unit area, it is essential to implement practices such as selecting high-quality seeds suitable for the region, optimal irrigation, proper fertilization, and pesticide application methods that do not disrupt the natural balance or harm predators, all executed at the right time and with maximum efficiency. Among these practices, fertilization holds a particularly critical role as it enhances the effectiveness of other agricultural inputs and is one of the most significant factors in improving both the yield and quality of agricultural production.

In large-scale field agriculture conducted in Turkey, fertilization typically focuses on the essential nutrients nitrogen and phosphorus, while applications of other nutrients, particularly potassium, remain quite limited. However, according to the "Law of the Minimum," also known as "Liebig's Law," which is critical for plant productivity, the deficient nutrient acts as a limiting factor for growth, and its uptake by the plant is of vital importance. Cotton is known as a crop that consumes large amounts of potassium, making potassium one of the most crucial plant nutrients for its cultivation. Potassium plays a critical role in both increasing yield and improving fiber quality. Addressing potassium deficiencies has emerged as a strategic necessity for ensuring sustainability in cotton production and enhancing the sector's competitive edge.

In cotton plants, potassium is one of the most important nutrients influencing fruit quality. Its primary functions include its role in protein synthesis and photosynthesis, as well as facilitating the transport of sugars from leaves to fruits. Effective potassium application maintains leaf activity throughout fruit development, increases soluble matter content (more sugars) in the fruit at harvest, and reflects positively on yield. It has been observed that approximately 60-66% of the total potassium taken up by the plant is found in the fruit. Potassium also has beneficial effects on plants exposed to environmental stress factors and significantly reduces the adverse impacts of diseases and pests (Ramazanoglu, 2024). Various studies have reported that potassium applications substantially increase yield in cotton (Çağlayan and Demoğlu, 2005).

Potassium deficiency can negatively impact numerous physiological activities in plants, such as reduced yield, poor growth, decreased enzyme activation, impaired water relations, and lower resistance to stress (Wang et al., 2012; Hu et al., 2016, 2017; Qi et al.). For instance, Adeli and Varco (2014) found that applying potassium doses of 0, 68, 136, and 204 kg/ha either as band applications alongside rows or broadcast over the field on non-acidic silty soils in Mississippi resulted in a linear increase in cotton yield. The same study reported fiber yields ranging between 1142 kg/ha and 1449 kg/ha, with the highest fiber yield achieved through the broadcast application of 13.6 kg da^{-1} potassium. Similarly, a study conducted in China's Hebei region demonstrated that different potassium doses (0, 45, 90, 180 kg/ha) and six different application timings had significant effects on fiber yield.

In terms of fiber yield, potassium applications made particularly before planting and during the squaring stage resulted in a 5% to 8% increase compared to the control group (Yang et al., 2017). Another study conducted in the same region found no significant difference in yield between potassium sources (K_2SO_4 or KCl), but application timings led to variations in yield ranging from 23% to 103% (Yang et al., 2016). Additionally, polymer-coated potassium chloride was reported to enhance potassium release during the flowering and boll formation stages, significantly improving the number of bolls and seed cotton yield.

In large-scale agricultural production in Turkey, nitrogen and phosphorus, which are essential nutrients, are widely applied, whereas potassium fertilization is often neglected. However, potassium is as important as nitrogen for cotton. Soil analysis results indicate that the potassium levels in the experimental field, ranging from 98 to 108 kg da^{-1}, classify these soils as high in potassium content. Nevertheless, the ability of plants to utilize soil potassium depends on factors such as genetic makeup, soil characteristics, temperature, and humidity.

Various studies have found that potassium fertilization in cotton enhances seed cotton yield, the number and weight of bolls, fiber length, fiber fineness, and uniformity. Generally, yield and its components improve as potassium doses increase (Pervez et al., 2004; Khalifa et al., 2012; Zia-ul Hassan et al., 2014; Bumguardner, 2018). Additionally, it has been noted that potassium application as a foliar fertilizer boosts seed cotton yield and fiber quality, though soil applications are also necessary to meet the plant's potassium requirements.

This study was conducted in the Şanlıurfa region during 2020 and 2021 to determine the effects of timing and doses of potassium fertilization on yield, quality, and certain yield components in cotton.

Material and Method

Material

The study was conducted during the 2020 and 2021 cotton growing seasons in Haliliye District, Şanlıurfa Province. The plant material used in the study was the Fiona cotton variety (*Gossypium hirsutum* L.), one of the standard varieties of the region. Fiona is known for its high yield potential, medium-to-long growing season, short fruiting branches, and cluster structure, making it suitable for dense planting and mechanical harvesting.

It has a ginning outturn of 44–46%, medium-sized bolls, and strong boll opening characteristics. Approximately 12,000 seeds are found in 1 kilogram, and its high fiber quality makes it a preferred choice in the textile industry (agro.basf.com.tr/tr).

The study was conducted in the Harran Plain, characterized by red-brown soils with low organic matter content. The soils in this region are derived from alluvial parent material, have a flat to nearly flat slope, and exhibit a clayey structure with high lime content. Organic matter content decreases from surface to deeper layers, ranging from 0.9% to 0.3%. The cation exchange capacity increases in the lower layers due to the high clay content (Dinç et al., 1986; Öztürkmen et al., 2021). Soil samples taken from a depth of 0–20 cm in the experimental area were analyzed at the GAP Agricultural Research Institute (GAP TAEM) Soil Analysis Laboratory. According to these analyses, the experimental field was classified as having a clay-loam texture, with silt content ranging from 22% to 33% and sand content from 20.8% to 26.6%. The soil pH was measured as 7.76 in 2020 and 7.50 in 2021. Potassium content was found to range between 98.8 and 109.8 kg da^{-1}, classifying these soils as potassium.

The experimental area experiences a continental climate characterized by hot and dry summers and cold winters. Between April and November, the average temperatures ranged from 11.4°C to 33.4°C in 2020 and from 12.6°C to 34.0°C in 2021, with the long-term average recorded as 12.8°C to 33.1°C. Total precipitation varied between 0 mm and 81.1 mm in 2020, and between 0 mm and 49.2 mm in 2021. The average relative humidity was recorded as 40.8%–62.9% in 2020 and 31.3%–66.5% in 2021. The average temperature across Turkey in 2020 and 2021 was 14.9°C, which is 1–1.4°C above the 1981–2010 average. In this context, 2020 was recorded as the third warmest year since 1971, while 2021 was the fourth warmest (MGM, 2022).

The experimental field was deeply plowed in the fall of 2019 and cultivated in April 2020. A trifluralin-based herbicide was applied to prepare the field for sowing. After harvesting, the field was plowed again in November 2020, and the same procedures were repeated for the 2021 growing season. Sowing was performed with a six-row pneumatic cotton seeder on April 25, 2020, and April 29, 2021. The study was designed with potassium application timings (30th, 40th, and 50th days after planting) assigned to main plots, and potassium doses (0 kg da^{-1} as control, 10, 20, and 30 kg da^{-1}) assigned to subplots. Each plot consisted of six rows, with a row spacing of 75 cm and an intra-row spacing of 5.4 cm, and measured 12 meters in length. This arrangement resulted in a total area of 54 m^2 per plot.

Using these methods, the study aimed to determine the effects of potassium applications on cotton yield, the number and weight of bolls, ginning outturn, fiber quality, and other yield components. During the research period, maintenance, pest control, irrigation, and harvesting operations were carried out meticulously. In both experimental years, after achieving a uniform plant population in the plots, hand hoeing was performed twice for weed control once at the end of May and again in the first week of June. Subsequently, tractor hoeing was conducted twice in conjunction with top-dressing fertilization.

Method

Agricultural Pest Control

Table 1. Agricultural pest control measures applied in the experimental area

Pest	Application
Thrips (Aphis gossypii)	In both years, an insecticide containing Dimethoate (40%) was applied at a dose of 100 cc da^{-1}.
Red Spider Mite (Tetranychus urticae Koch)	In July, Nissoril (Hekythiozox) was applied at a dose of 100 cc da^{-1}.
Leafhopper (Empoasca spp.) and Whitefly (Bemisia tabaci Genn.)	In August, a mixture of Hekplan (Acetamiprid, 20 g da^{-1}) and Sumigold (Esfenvalerate, 60 cc/da) was applied.
Helicoverpa (Helicoverpa armigera Hübner)	At the end of August, Hekplan (Acetamiprid, 20 g da^{-1}) and Dursban-4 (Chlorpyrifos, 200 cc da^{-1}) were applied.
Aphid (Aphis gossypii)	In 2020, Movento (Spirotetramat, 100 cc da^{-1}) and Transform (Sulfoxaflor, 15 g da^{-1}) were applied for control.

Irrigation

In both experimental years, flood irrigation was applied in April before sowing to ensure adequate moisture for germination. The irrigation process was carried out using the furrow method, with a total of ten irrigations performed. The first irrigation was applied 30 days after sowing, along with top-dressing fertilization. Subsequent irrigations were conducted on June 22, July 2, July 12, July 22, August 2, August 11, August 21, September 3, and September 15. This systematic irrigation schedule was meticulously followed to ensure optimal plant development.

Harvest

In both years, approximately 15 days after the final irrigation, 60 ml da^{-1} of Bayer Finish Drop (ethephon + cyclanilide) defoliant and boll opener was applied. Depending on weather conditions, manual harvesting was performed 10–12 days later. To account for edge effects, 1 meter from the start and end of each plot was excluded, and the middle 10-meter-long 2 rows (15 m^2) were harvested by hand.

Determination of Yield and Fiber Characteristics

The yield and fiber characteristics obtained in the study were evaluated according to the methods suggested by Şenel (1980). Yield components measured included seed cotton yield (kg da^{-1}), plant height (cm), the number of fruiting branches (units/plant), the number of bolls (units/plant), boll weight (g), seed cotton weight per boll (g), 100-seed weight (g), and ginning outturn (%). Technological fiber characteristics such as fiber length, fiber fineness, fiber strength, uniformity, short fiber index, and brightness were analyzed using the HVI 900-A device at the Rubenis Textile Company Laboratory. These methods provided detailed results on cotton yield and fiber quality.

Data Analysis

The measurements, weights, and fiber analysis results obtained from the research were analyzed using the SPSS statistical package, following the randomized block design. Grouping was performed using Tukey's test. The homogeneity of the error variances across years was tested, and the years were combined for a unified evaluation of the results.

Results and Discussion

*Seed Cotton Yield (*kg da^{-1}*)*

The number of days after sowing (DAS), potassium doses, and the interaction between potassium application doses and DAS were statistically significant at the $p \leq 0.01$ level (Table 2). The seed cotton yield was determined as 416.36 kg da^{-1} in 2020 and 401.41 kg da^{-1} in 2021. It was found that potassium applications on the

30th, 40th, and 50th days after sowing had statistically significant effects on seed cotton yield, with average yield values ranging between 385.37 kg da^{-1} and 437.41 kg da^{-1}. When the average yield values for 2020, 2021, and the two-year average were analyzed, the highest seed cotton yield was observed in the 30th-day application. Specifically, in 2020, the yields for the 30th, 40th, and 50th-day applications were 458.00, 407.73, and 383.35 kg da^{-1}, respectively. Similarly, in 2021, the yields were 416.82, 400.01, and 387.40 kg da^{-1}. The two-year average also followed a similar trend, with the highest yield recorded in the 30th-day application at 458.00 kg da^{-1}, followed by the 40th-day and 50th-day potassium applications.

Potassium doses also had a statistically significant effect on seed cotton yield. Yields varied between 376.25 kg da^{-1} and 459.52 kg da^{-1} depending on potassium dose. Based on the two-year average, the highest seed cotton yield was obtained with a 20 kg da^{-1} potassium application, a trend that was also evident when the years were evaluated individually. The 20 kg da^{-1} potassium dose was followed by the control, 10 kg da^{-1}, and 30 kg da^{-1} potassium applications. These results highlight the critical role of an optimal potassium dose in improving seed cotton yield. When interactions between the number of days after sowing (DAS) and potassium doses were analyzed, seed cotton yields ranged from 357.15 kg da^{-1} to 496.97 kg da^{-1}. The highest yield, 496.97 kg da^{-1}, was obtained from the interaction between the 30th-day application and 20 kg da^{-1} potassium dose (DAS30 × K20). Similarly, this interaction produced the highest seed cotton yield in both experimental years. However, a decrease in seed cotton yield was observed as the potassium application was delayed. These findings demonstrate that early potassium applications have a positive impact on yield, underscoring the importance of timely nutrient management.

The findings of this study are fully or partially consistent with the results of studies by Akhtar et al. (2003); Pervez et al. (2004); Çağlayan and Demoğlu (2005); Khalifa et al. (2012); Adeli (2014); Ziaul Hassan et al. (2014); Shahzad et al. (2019); Hussain et al. (2021); Wang et al. (2012); Phipps et al. (2007); Mozaffari (2018); Yang et al. (2017); Kusi (2019); and Bumgardner et al. (2024). However, the finding by Bumgardner (2018), which reported that potassium fertilization had no effect on cotton yield, does not align with our study. This discrepancy may be attributed to differences in the ecological conditions under which the experiments were conducted, the genotypic characteristics of the cotton seeds used, or variations in cultural practices applied during the trials.

Table 2. Variance Analysis Results, Mean Values, Tukey-HSD Test Groups, and Coefficient of Variation (% C.V.) for Seed Cotton Yield and Plant Height in 2020, 2021, and Combined Years

Source of Variation	**Seed Cotton Yield (kg da^{-1})**			**Plant Height (cm)**		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
DAS	**	**	**	ns	*	*
K	**	**	**	ns	ns	ns
DAS × K	**	**	**	ns	ns	*
Year (Y)	-	-	**	-	-	**
Y × DAS	-	-	**	-	-	ns
Y × K	-	-	**	-	-	ns
Y × DAS × K	-	-	**	-	-	ns
Years (Y)	416,36 a	401,41 b		98,71 a	86,19 b	
Days After Sowing (DAS)						
DAS 30	458,0 a	416,8a	437,4 a	99,3	88,2 a	93,7 a
DAS 40	407,7 b	400,0b	403,9 b	99,2	87,0 ab	93,1 ab
DAS 50	383,4 c	387,4c	385,4 c	97,6	83,4 b	90,5 b
Potasyum Dose (K)						
K_0 (Control)	415,4 b	409,8b	412,6 b	99,2	85,2	92,2
K_{10} (10 kg da^{-1})	386,5 d	366,1d	376,3 d	100,3	85,9	93,1
K_{20} (20 kg da^{-1})	466,8 a	452,6a	459,5 a	97,7	85,5	91,6
K_{30} (30 kg da^{-1})	397,2 c	377,2c	387,2 c	97,6	88,2	92,9
Interactions (DAS × K)						
DAS 30 × K_0	481,7 b	461,1a	471,4 b	93,6	86,1	89,9 ab
DAS 30 × K_{10}	416,2 c	356,7e	386,4 de	106,5	88,5	97,5 a
DAS 30 × K_{20}	523,7 a	472,3a	498,0 a	101,7	87,0	94,3 ab
DAS 30 × K_{30}	410,5 cd	377,2 cd	393,9 d	95,3	91,2	93,2 ab
DAS 40 × K_0	371,2 fg	388,2c	379,7 e	104,3	85,5	94,9 ab
DAS 40 × K_{10}	394,2cde	376,2cd	385,2 de	101,8	87,8	94,8 ab
DAS 40 × K_{20}	485,6 b	453,6a	469,6 b	93,8	85,3	89,5 ab
DAS 40 × K_{30}	379,9 ef	382,0cd	381,0 de	97,0	89,2	93,1 ab
DAS 50 × K_0	393,1 def	380,1cd	386,6 de	99,8	83,9	91,9 ab
DAS 50 × K_{10}	349,0 g	365,3de	357,2 f	92,6	81,3	86,9 b
DAS 50 × K_{20}	390,2 def	431,9 b	411,0 c	97,8	84,3	91,0 ab
DAS 50 × K_{30}	401,1cde	372,4cde	386,7 de	100,4	84,1	92,3 ab
%CV	12,35	10,02		6,59	4,50	

DAS: days after sowing

Plant Height (cm)

In 2020, none of the treatments had a statistically significant effect on plant height. However, in 2021, the number of days after sowing (DAS) had a significant effect at the p ≤ 0.05 level, while other variations were found to be insignificant (Table 2). In the combined analysis of both years, DAS and DAS × K dose interactions were determined to be significant. The average plant height was measured as 98.71 cm in 2020 and 86.19 cm in 2021. Applications on the 30th, 40th, and 50th days after sowing did not have a statistically significant effect on plant height in the first year, but in the second year, they were significant at the p ≤ 0.15 level. The average plant height values ranged from 90.53 cm to 93.74 cm, with the highest combined years' average (93.74 cm) recorded in the 30th-day application.

Potassium application doses did not have a statistically significant effect on plant height, which ranged from 92.21 cm to 93.08 cm. When DAS and potassium dose interactions were analyzed, plant height values ranged from 81.33 cm to 106.53 cm, with the highest values recorded in the first year for the DAS30 × K10 and DAS30 × K0 interactions (104.26 cm). The findings regarding the effects of potassium applied at different doses and growth stages on plant height are consistent with studies by Hussain et al. (2021); Wang et al. (2012); Qi et al. (2019); and Bumguardner (2018, 2024). No studies in the literature contradict our results regarding plant height.

Number of fruiting branches (number plant^{-1})

The number of days after sowing (DAS) and potassium doses had statistically significant effects on the number of fruiting branches in 2020, 2021, and the combined years' average (Table 3). The average number of fruiting branches per plant was 11.30 in 2020 and 10.18 in 2021. Applications on the 30th, 40th, and 50th days after sowing significantly influenced the number of fruiting branches, which ranged between 10.40 and 11.20 number plant^{-1}. The highest combined years' average (11.20 number plant^{-1}) was obtained from the 30th-day application. In 2020, the number of fruiting branches per plant was 11.85, 11.23, and 10.82 for the 30th, 40th, and 50th-day applications, respectively. In 2021, these values were 10.50, 10.01, and 9.98 number plant^{-1}, respectively. Delayed applications resulted in a decrease in the number of fruiting branches.

Potassium application doses also had a statistically significant effect on the number of fruiting branches, with values ranging from 10.99 to 11.90 number plant^{-1} in 2020 and 9.56 to 10.81 number plant^{-1} in 2021. The combined years' average showed values between 10.28 and 11.36 number plant^{-1}, with the highest value obtained from the 20 kg da^{-1} potassium dose. When DAS and potassium dose interactions were analyzed, the number of fruiting branches ranged from 9.47 to 12.64 units/plant. In both years, the highest value was obtained from the DAS30 × K20 interaction. A decrease in the number of fruiting branches was observed with delayed applications. The results for the number of fruiting branches obtained in this study align with the findings of Wang et al. (2012), Ziaul Hassan et al. (2014), Yang et al. (2016), Hu et al. (2017), Qi et al. (2019).

Table 3. Variance Analysis Results, Mean Values, Tukey-HSD Test Groups, and Coefficient of Variation (% C.V.) for Number of Fruiting Branches and Number of Bolls in 2020, 2021, and Combined Years

Source of Variation	**Number of Fruiting Branches**			**Number of Bolls**		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
DAS	**	*	**	**	**	**
K	*	**	**	**	**	**
DAS × K	ns	ns	ns	ns	ns	ns
Year (Y)	-	-	**	-	-	**
Y × DAS	-	-	ns	-	-	ns
Y × K	-	-	ns	-	-	**
Y × DAS × K	-	-	ns	-	-	ns
Yıllar (Y)	11,30 a	10,18 b		14,63 a	14,03 b	
Interactions (DAS × K)						
DAS 30	11,85 a	10,50	11,20 a	15,29 a	14,61 a	14,96 a
DAS 40	11,23 b	10,01	10,62 b	14,39 b	14,16 b	14,27 b
DAS 50	10,82 b	9,98	10,40 b	14,21 b	13,32 c	13,76 b
Potasyum Dose (K)						
K_0 (Control)	11,10 b	10,10 ab	10,60 b	14,84 a	14,18 b	14,51 b
K_{10} (10 kg da^{-1})	10,99 b	9,56 b	10,28 b	13,93 b	13,02 c	13,48 c
K_{20} (20 kg da^{-1})	11,90 a	10,81 a	11,36 a	15,22 a	15,21 a	15,22 a
K_{30} (30 kg da^{-1})	11,21 ab	10,26 ab	10,74 b	14,53 ab	13,70 b	14,12 b
Interactions (DAS × K)						
$DAS_{30} \times K_0$	11,86 ab	10,47	11,17	15,47	14,62	15,05
$DAS_{30} \times K_{10}$	11,37 ab	9,73	10,55	14,95	14,00	14,48
$DAS_{30} \times K_{20}$	12,64 a	11,20	11,92	15,76	15,62	15,69
$DAS_{30} \times K_{30}$	11,51 ab	10,82	11,17	14,99	14,21	14,60
$DAS_{40} \times K_0$	10,57 b	10,04	10,31	14,84	14,11	14,47
$DAS_{40} \times K_{10}$	11,06 ab	9,49	10,28	13,22	13,08	13,15
$DAS_{40} \times K_{20}$	11,80 ab	10,60	11,20	15,02	15,49	14,21
$DAS_{40} \times K_{30}$	11,48 ab	9,91	10,70	14,47	13,95	15,25
$DAS_{50} \times K_0$	10,85 b	9,78	10,32	14,20	13,81	14,00
$DAS_{50} \times K_{10}$	10,53 b	9,47	10,00	13,62	11,97	12,80
$DAS_{50} \times K_{20}$	11,27 ab	10,64	10,96	14,88	14,53	14,70
$DAS_{50} \times K_{30}$	10,64 b	10,04	10,34	14,12	12,95	13,54
%CV	6,70	6,83		6,13	7,50	

Number of Bolls (number plant^{-1})

The number of days after sowing (DAS) and potassium doses had statistically significant effects on the number of bolls per plant in 2020, 2021, and the combined years' average (Table 3). The average number of bolls per plant was 14.63 in 2020 and 14.03 in 2021. Applications on the 30th, 40th, and 50th days after sowing significantly influenced the number of bolls, with averages ranging between 13.76 and 14.96 units/plant. The highest combined years' average was obtained from the 30th-day application. Specifically, the number of bolls per plant was 15.29, 14.39, and 14.21 *units plant^{-1}* for the 30th, 40th, and 50th-day applications, respectively, in 2020, and 14.61, 14.16, and 13.32 *units plant^{-1}* in 2021. The highest number of bolls was recorded for the 30th-day application, followed by the 40th and 50th-day applications. A decrease in the number of bolls was observed with delayed application timings.

Potassium doses also had a statistically significant effect on the number of bolls. In 2020, the number of bolls ranged from 13.93 to 15.22 *units plant^{-1}*, while in 2021, it ranged from 13.02 to 15.21 *units plant^{-1}*. Combined years' averages varied between 13.48 and 15.22 *units plant^{-1}*, with the highest value (15.22 *units plant^{-1}*) obtained from the 20 kg da^{-1} potassium dose. When DAS and potassium dose interactions were analyzed, the number of bolls ranged from 11.97 to 15.76 *units plant^{-1}*. In both years, the highest values were obtained from the DAS30 × K20 interaction, while delayed applications resulted in a reduction in the number of bolls per plant. The results obtained for the number of bolls per plant in this study are in full or partial agreement with those reported by Faircloth et al. (2004), Pervez et al. (2004), Khalifa et al. (2012), Zia-ul Hassan et al. (2014), Yang et al. (2017), Bumguardner (2018), and Echera et al. (2020).

Boll Seed Cotton Weight (g)

The number of days after sowing (DAS), potassium doses, and DAS × K interactions had no statistically significant effect on boll seed cotton weight in 2020, 2021, or the combined years' average (Table 5). The average boll seed cotton weight was 5.48 g in 2020 and 4.83 g in 2021. Applications on the 30th, 40th, and 50th days after sowing did not significantly influence boll seed cotton weight in either study year. The average weight ranged from 5.44 g to 5.50 g in 2020 and from 4.76 g to 4.88 g in 2021. Similarly, potassium doses had no statistically significant effect on boll seed cotton weight, which ranged from 5.39 g to 5.57 g in 2020 and from 4.77 g to 4.88 g in 2021. The DAS × K interactions also showed no significant differences.

The findings on boll seed cotton weight in this study align with the first-year results of Sawan et al. (2006) and Faircloth et al. (2004), but they contradict the second-year findings. Furthermore, they do not align with the results reported by Pervez et al. (2004), Khalifa et al. (2012), Zia-ul Hassan et al. (2014), and Yang et al. (2016). These discrepancies may stem from variations in ecological conditions of the experimental regions, genetic differences in the cotton varieties used, or differences in cultural practices applied during the trials.

100-Seed Weight (g)

In 2020, none of the treatments had a statistically significant effect on 100-seed weight, whereas in 2021, the number of days after sowing (DAS) had a significant effect at the $p \leq 0.05$ level. The 100-seed weight was recorded as 8.73 g in 2020 and 8.85 g in 2021 (Table 5). Applications on the 30th, 40th, and 50th days after sowing did not significantly affect 100-seed weight in 2020, but they were significant at the $p \leq 0.05$ level in 2021. The average 100-seed weight ranged from 8.66 g to 8.78 g in 2020 and from 8.61 g to 9.10 g in 2021, with the highest value (9.10 g) obtained from the 30th-day application. This was followed by the 40th and 50th-day applications.

Potassium doses did not have a statistically significant effect on 100-seed weight. Analysis of DAS × K interactions revealed that 100-seed weight values ranged between 8.36 g and 9.43 g, but these differences were not statistically significant. The findings of this study are consistent with those reported by Krisnan et al. (2007). However, they do not align with the results of Sawan et al. (2006), Pervez et al. (2004), and Görmüş & Kanat (1998). These discrepancies may be attributed to differences in ecological conditions of the experimental regions, genetic variations in the cotton varieties used, or diversity in cultural practices applied during the experiments.

Table 5. Variance Analysis Results, Mean Values, Tukey-HSD Test Groups, and Coefficient of Variation (% C.V.) for Boll Seed Cotton Weight and 100-Seed Weight in 2020, 2021, and Combined Years

Source of Variation	**Boll Seed Cotton Weight (g)**			**100-Seed Weight (g)**		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
DAS	ö.d.	ö.d.	ns	ns	*	ns
K	ns	ns	ns	ns	ns	ns
DAS × K	ns	ns	ns	ns	ns	ns
Year (Y)	-	-	**	-	-	ns
Y × DAS	-	-	ns	-	-	ns
Y × K	-	-	ns	-	-	ns
Y × DAS × K	-	-	ns	-	-	ns
Yıllar (Y)	5,48 a	4,83 b		8,73	8,85	
Days After Sowing (DAS)						
DAS 30	5,49	4,84	5,16	8,78	9,10 a	8,94
DAS 40	5,44	4,88	5,16	8,66	8,61 b	8,64
DAS 50	5,50	4,76	5,13	8,75	8,84 ab	8,79
Potasyum Dose (K)						
K_0 (Control)	5,39	4,83	5,11	8,71	9,07	8,89
K_{10} (10 kg da^{-1})	5,48	4,88	5,18	8,92	8,66	8,79
K_{20} (20 kg da^{-1})	5,48	4,82	5,15	8,58	8,74	8,66
K_{30} (30 kg da^{-1})	5,57	4,77	5,17	8,71	8,92	8,82
Interactions (DAS × K)						
$DAS_{30} \times K_0$	5,49	4,90	5,20	8,70	9,43	9,06
$DAS_{30} \times K_{10}$	5,34	4,84	5,09	8,96	8,89	8,93
$DAS_{30} \times K_{20}$	5,36	4,70	5,03	8,36	8,82	8,59
$DAS_{30} \times K_{30}$	5,76	4,91	5,33	9,11	9,26	9,19
$DAS_{40} \times K_0$	5,30	4,82	5,06	8,62	8,62	8,62
$DAS_{40} \times K_{10}$	5,41	4,96	5,19	8,97	8,61	8,79
$DAS_{40} \times K_{20}$	5,42	4,92	5,17	8,62	8,49	8,56
$DAS_{40} \times K_{30}$	5,64	4,81	5,23	8,43	8,73	8,58
$DAS_{50} \times K_0$	5,36	4,76	5,06	8,82	9,16	8,99
$DAS_{50} \times K_{10}$	5,67	4,85	5,26	8,82	8,48	8,65
$DAS_{50} \times K_{20}$	5,67	4,83	5,25	8,75	8,92	8,84
$DAS_{50} \times K_{30}$	5,30	4,60	4,95	8,61	8,77	8,69
%CV	4,34	5,00		5,31	4,87	

Ginning Outturn (%)

In 2020, none of the treatments had a significant effect on ginning outturn, while in 2021, the number of days after sowing (DAS) showed a statistically significant effect at the $p \leq 0.01$ level. Potassium applications and DAS × K interactions were significant at the $p \leq 0.05$ level (Table 6). The ginning outturn was recorded as 44.25% in 2020 and 43.76% in 2021. Applications on the 30th, 40th, and 50th days after sowing had no significant effect on ginning outturn in 2020 but were significant at the $p \leq 0.01$ level in 2021. The average ginning outturn ranged from 43.88% to 44.60% in 2020 and from 43.03% to 44.20% in 2021. The highest ginning outturn values were obtained from the DAS50 (44.20%) and DAS40 (44.06%) applications.

Potassium doses did not have a statistically significant effect on ginning outturn in 2020, but they showed a significant impact in 2021. In 2020, ginning outturn values ranged from 43.88% to 44.47%, while in 2021, they ranged from 43.45% to 44.22%, with the highest value (44.22%) obtained from the 30 kg da^{-1} K application. Analysis of DAS × K interactions revealed that ginning outturn ranged from 42.43% to 45.31%, but these differences were not statistically significant. The results on ginning outturn from this study are consistent with the findings of Phipps et al. (2007) and Yang et al. (2016a). However, they do not align with the results reported by Read et al. (2006), Faircloth et al. (2004), and Pervez et al. (2004). These discrepancies may be attributed to differences in ecological factors of the experimental regions, genetic characteristics of the cotton varieties used, or variations in cultural practices applied.

Table 6. Variance Analysis Results, Mean Values, Tukey-HSD Test Groups, and Coefficient of Variation (% C.V.) for Ginning Outturn in 2020, 2021, and Combined Years

Source of Variation	Ginning Outturn (%)			Interactions (DAS × K)			
				Sources of variation	2020	2021	Mean
	2020	**2021**	**Mean**	$DAS_{30} \times K_{0}$	44,09	42,86 cd	43,47
DAS	ns	**	ö.d.	$DAS_{30} \times K_{10}$	44,53	42,43 d	43,48
K	ns	*	ö.d.	$DAS_{30} \times K_{20}$	44,11	43,51 abcd	43,81
DAS × K	ns	*	ö.d.	$DAS_{30} \times K_{30}$	42,80	43,31 bcd	43,06
Year (Y)	-	-	ö.d.	$DAS_{40} \times K_{0}$	44,49	44,55 ab	44,52
Y × DAS	-	-	ö.d.	$DAS_{40} \times K_{10}$	43,90	43,56 abcd	43,73
Y × K	-	-	ö.d.	$DAS_{40} \times K_{20}$	43,68	43,53 abcd	43,61
Y × DAS × K	-	-	ö.d.	$DAS_{40} \times K_{30}$	44,99	44,59 ab	44,79
Years (Y)	44,25	43,76		$DAS_{50} \times K_{0}$	44,84	43,68 abcd	44,26
Days After Sowing (DAS)							
DAS 30	43,88	43,03 b	43,46	$DAS_{50} \times K_{20}$	45,03	43,97 abc	44,50
DAS 40	44,26	44,06 a	44,16	$DAS_{50} \times K_{30}$	45,31	44,77 a	45,04
DAS 50	44,60	44,20 a	44,40	**%CV**	4,14	1,79	
Potasyum Dose (K)							
K_0 (Control)	44,47	43,70 ab	44,08				
K_{10} (10 kg da^{-1})	43,88	43,45 b	43,67				
K_{20} (20 kg da^{-1})	44,27	43,67 ab	43,97				
K_{30} (30 kg da^{-1})	44,37	44,22 a	44,29				

Conclusion

This study has revealed the effects of different potassium fertilizer doses on cotton (*Gossypium hirsutum* L.). The findings indicate that potassium applications on the 30th, 40th, and 50th days after sowing statistically influenced yield parameters such as seed cotton yield, plant height, number of fruiting branches, and number of bolls. Moreover, fiber technological properties such as uniformity and short fiber content varied depending on potassium doses. The highest seed cotton yield and ginning outturn were achieved with 30 kg da^{-1} potassium applied on the 50th day. However, some parameters, such as boll seed cotton weight and 100-seed weight, were found to be statistically unaffected by certain treatments, highlighting the complex effects of varying application timings and doses on plant growth and quality.

Based on the results, potassium applications of 20–30 kg da^{-1} on the 30th and 50th days after sowing are recommended to improve yield and quality in cotton production. However, the findings also suggest that the effects of potassium applications can vary under different ecological conditions and among cotton varieties with genetic differences. Therefore, the development of specific fertilization programs based on soil and plant analyses for each region is essential. Such practices will not only support sustainable agriculture but also enhance the economic value of cotton production.

Declarations

Conflict of Interest: The authors declare that there is no conflict of interest between them.

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