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A Comparative field assessment of Bt and non-Bt cotton varieties in Swaziland

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Abstract

The field performance of Bt cotton hybrids was evaluated in open field trials for growth and yield from November 2016 to June 2017. Under rainfed conditions in both locations, the two Bt cotton hybrids (JKCH 1947 Bt and JKCH 1050 Bt) exhibited significantly different cotton yield compared to the control variety, Alba Plus QM 301 NBt. The lowest cotton yield was observed in inbred, JKC 724 NBt. The highest cotton yield was recorded for JKCH 1947 Bt (3070.0 $kgha^{-1}$) compared to JKC 724 NBt (1173.0 $kgha^{-1}$) at Lowveld Experimental Station. JKCH 1050 Bt recorded 1817.0 $kgha^{-1}$ with JKC 724 NBt having lowest 821.0 $kgha^{-1}$ under Malkerns Research Station soil and climatic conditions. Moreover, the same trend was observed for the higher number of bolls where in both locations JKCH 1050 Bt recorded higher number of bolls followed by JKCH 1947 Bt compared to Alba Plus QM 301 NBt and JKC 724 NBt. Results showed that Bt cotton cultivation had significant average agronomic and yield traits. The study proved the potential adaptation of Indian Bt cotton strains and giving increased cotton yield under two different locations in the Kingdom of Swaziland.

Keywords: Rainfed Conditions; Bt Cotton; Cotton Yield; Swaziland

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1. Introduction

Cotton (*Gossypium hirsutum*) is an important cash crop in the Southern African Development Community (SADC) region (Gwarazimba, 2009). The management of dry land cotton production is a challenge accompanied by a high-risk enterprise given the uncertainty of rainfall during the growing season and high pest infestations. Africa has been at the centre of the biotechnology debate, where opposition by various public environmental groups has largely succeeded in delaying the introduction of agricultural biotechnology products (Cohen and Paarlberg, 2002; Paarlberg, 2008).

Bt cotton has drawn more attention because of genetic modification using modern biotechnology, such as new insect-resistant and herbicide-tolerant cotton varieties and is proving more productive than traditional cotton varieties. Bt cotton is a variety of cotton genetically modified to contain a gene (cry1Ac) of *Bacillus thuringiensis* (Bt), which is foreign to its genome and is a naturally occurring soil bacterium used to control Lepidopteran insects because of a toxin it produces (Maharana et al., 2011). In June 2014, the Eswatini Environment Authority (SEA) through its Biosafety Unit authorized the commercial planting of Bt cotton in Swaziland to Eswatini Cotton Board. This was a significant milestone for Swaziland, marking the first demonstration plots of Bt cotton in the country in six locations. Current research on Bt cotton in developed countries has revealed that this transgenic crop provides key means for enhancing yields and boosting profits (Hofs et al., 2006). Genetically engineered crops that produce insecticidal proteins from the bacterium *Bacillus thuringiensis* (Bt) have been planted globally on a cumulative total of over 732 million hectares since 1996 (James, 2015). Evidence shows that countries such as United States of America, Australia, China, Mexico, Argentina, South Africa, and India, which have allowed the cultivation of Bt cotton at a commercial level, have gained in terms of reduced pesticide use, costs and obtained higher yields (Bennett et al*.,* 2006: Qaim et al*.,* 2006). Studies by Huang et al. (2003): Qaim and Zilberman, (2003) stated that Bt cotton adoption reduces pesticide sprays and increases seed cost and yields.

In the Republic of South Africa, small-scale farmers in Makhathini Flats in KwaZulu Natal have been allowed by their government to plant genetically modified Bt cotton since 1997–1998 (Bennet et al., 2003). A study conducted in 2001 showed that when these farmers switched from conventional to Bt cotton they observed less insect damage, sprayed fewer insecticides, and enjoyed an average net income gain of $50 per hectare per season (James, 2002). In an effort to overcome bollworm pest damage in cotton, India approved Bt-transgenic cotton for commercial cultivation in 2002. So far, five Bt genes through six events such as, Cry1Ac through MON 531 (Monsanto), truncated Cry1Ac through Event-1 (JK Agri Genetics Ltd.) and a variety Bikaneri Nerma (UAS Dharwad and ICAR); Cry1Ac + Cry2Ab through MON15985(Monsanto); Cry1Ab + Cry1Ac, GFM Cry1A (Nath Seeds Ltd.); and cry1C through event 9124 (Metahelix), have been approved, and based on these six events a total of 809 cotton hybrids are under commercial cultivation in India (Gujar and Dhillon, 2011). India cultivated a record 11.6 million hectares of Bt cotton planted by 7.7 million small farmers with an adoption rate of 95%, up from 11.0 million hectares in 2013 (James, 2014). Notably, the increase from 50,000 hectares of Bt cotton in 2002 (when Bt cotton was first commercialized) to 11.6 million hectares in 2015, represents an unprecedented 230-fold increase in thirteen years.

In an effort to try and revive the cotton industry in the Kingdom of Swaziland, it is essential to conduct agronomic field trials of Bt cotton and test its adaptability under Swaziland soil and climatic conditions. Therefore, an Indian company, JK Agri-Genetics Limited provided two hybrids carrying a Bt source from India (Cry 1Ac). The two Bt cotton hybrids were approved for cultivation by the national authority in India and have a proven safety and efficacy in insect pest control for more than ten years. This study aimed to evaluate agronomic, yield potential and fibre properties of two Bt cotton hybrids, JKCH 1947 Bt and JKCH 1050 Bt with popular control variety Alba Plus QM 301 NBt and an inbred JKC 724 NBt in two locations in Swaziland.

2. Materials and methods

Field trials were conducted at two sites being Lowveld Experimental Station (LES), Big Bend and Malkerns Research Station (MRS) in Swaziland during 2016/17 summer planting season. The trials focused on agronomic, yield performance and fibre properties of two Bt cotton hybrids (JKCH 1947 Bt and JKCH 1050 Bt), inbred (JKC 724 NBt) developed and owned by JK Agri Genetics Limited, India along with control variety (Alba Plus QM 301 NBt). The Lowveld Experimental Station (LES), Big Bend is located in the Lowveld region (26° 57.95S, 31° 31.52E; 89m asl), with mean temperatures ranging between 26.4 to 30.5°C and annual rainfall average of 450 mm. The soils are M-series, which are sandy loam, well drained and fertile (Murdoch, 1968). The Malkerns Research Station is located in the Middleveld of Swaziland 26°33' S, longitude 31°10' E; 750m asl with an average mean temperature of 18°C and an annual mean rainfall of 800 mm respectively. The soil type is M-set soil series; dark loam to sandy loam (Murdoch, 1968). The trials used a randomized complete block design (RCBD) with six replications. Gross plot size of experiment was 4 rows of 6 metres length planted at an inter-row spacing of 90 cm and 25 cm between plants. Whereas, the net plot constituted of 2 middle rows with each row having 20 plants thus a total of 40 plants for the net plot.

Observations were recorded on six randomly selected plants from each hybrid/variety per replication for the characters viz., plant height (cm), number of lateral branches, number of lateral branches (≥ 4 bolls), days to 50% flowering, number of damaged bolls, number of bolls/plant, damaged bolls (%), 50 bolls dry weight (g), ginning out turn (%) and cotton yield (kgha^{-1}). Out of all the bolls per plant, fifty bolls were randomly selected and weighed using an A&D EP Series KA Version, Japan electronic balance. Thereafter, the cotton yield per plot was estimated after picking the cotton from the whole plot and adding the weight of the collected bolls. The values were up scaled from kgplot^{-1} to kgha^{-1} for each cotton hybrid/variety and replication. Field trials management was done following the guidelines on the farmer's handbook (Buckham and Lukhele, 1991). Multiple foliar sprays were applied on control variety, Alba Plus QM 301 NBt and inbred, JKC 724 NBt to manage cotton bollworm infestation. No foliar sprays were applied on Bt cotton hybrids. Fibre quality characteristics based on micronaire, uniformity (%), fiber strength (g/tex), stab length (mm), stab length, trash count and maturity were computed for all the cotton hybrids/varieties in both locations.

2.1. Trial management as per Bio-safety protocols

The trials were conducted at specified sites and were restricted to public access. The Swaziland Cotton Board was the only organisation issued seed import permit of the Bt cotton hybrids in the country. This was done to make sure that the movement and access to the Bt cotton seeds remained within a single institution. Upon completion of the field trials in both sites, the remaining crop residues were uprooted burnt in the presence of National Biosafety Officer from the Swaziland Environmental Authority, Biosafety Unit.

2.2. Statistical analysis

All agronomic, yield and fibre properties data were expressed as means. Agronomic and yield traits data from the cotton varieties were pooled and analysed using one way ANOVA. Analysis of variance was performed by using the ANOVA procedure of the SAS 9.3 (SAS Institute, Cary NC). Significant differences between varieties agronomic and yield traits means were determined by Fischer's Least Significant Difference Test at the level of $p \leq 0.05$.

3. Results

3.1. Lowveld Experiment Station (LES), Big Bend

Early flowering was observed in cotton hybrids JKCH 1947 Bt (85.0 days) and JKCH 1050 Bt (86.0 days) compared to the control variety, Alba Plus QM 301 NBt (106 days). Damaged cotton bolls were prominent in Alba Plus QM 301 NBt (35.6%) compared to minimum damaged bolls in JKCH 1947 Bt and JKCH 1050 Bt almost (6.6%) each (Table 1). Industrially acceptable ginning out turn percentage (GOT%) ranged between 43.1% observed in JKCH 1947 Bt to 44.7% in Alba Plus QM 301 NBt except JKC 724 NBt with 41.0%. Under rainfed conditions, among four hybrids/varieties tested, JKCH 1947 Bt (3070.0 $kgha^{-1}$) and JKCH 1050 Bt (2955.0 $kgha^{-1}$) produced significantly superior cotton yield compared to control variety Alba Plus QM 301 NBt (2066.0 $kgha^{-1}$). The lowest yielding variety was inbred JKC 724 NBt (1173.0 $kgha^{-1}$). Bigger boll size was observed in JKCH 1947 Bt (311.5 g/50 bolls) followed by JKCH 1050 Bt (294.7 g/50bolls) and Alba Plus QM 301 NBt (283.3 g/50 bolls (Table 2).

Table 1. Agronomic traits of Bt and Non-Bt cotton at Lowveld Experiment Station, Big Bend soil and climatic conditions

Cotton Variety/Hybrid	Plant Height (cm)	No. of Lateral Branches	No. of lateral Branches (≥ 4 bolls)	Days to 50% Flowering	No. of Damaged Bolls	No. of bolls/plant	Damaged Bolls (%)
Alba Plus QM 301 NBt	83.4a[1]	9.5a	2.5b	107.0a	20.5a	58.8b	35.6
JKC 724 NBt	48.1b	7.7b	3.0ab	111.0a	16.2a	56.2b	29.0
JKCH 1947 Bt	87.7a	9.4a	3.8ab	85.0b	6.7b	92.0a	7.6
JKCH 1050 Bt	78.0a	9.8a	4.2a	86.0b	6.1b	90.2a	6.6

[1] *Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test*

Table 2. Yield and yield components of Bt and Non-Bt cotton at Lowveld Experiment Station, Big Bend, soil and climatic conditions

Cotton Variety/Hybrid	50 Bolls Dry Weight (g)	Ginning Out Turn (%)	Cotton Yield (kgha^{-1})
Alba Plus QM 301 NBt	283.3a[1]	44.7a	2066.0b
JKC 724 NBt	207.2b	40.8c	1173.0b
JKCH 1947 Bt	311.5a	43.1b	3070.0a
JKCH 1050 Bt	294.7a	43.3b	2955.0a

[1] Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test

3.2. Malkerns research station

Significantly higher number of bolls were recorded in JKCH 1050 Bt (67.2) followed by JKCH 1947 Bt (65.5) compared to Alba Plus QM 301 NBt (41.0). Considerably shorter number of days to 50% flowering were observed in hybrids JKCH 1947 Bt (102.0 days) and JKCH 1050 Bt (106.0 days) compared to Alba Plus QM 301 NBt (159.0 days). Control entry Alba Plus QM 301 NBt exhibited 2.4% boll damage higher compared to minimum boll damage in JKCH 1947 Bt (0.5%) and JKCH 1050 Bt (0.7%) (Table 3). Industrially acceptable ginning out turn (GOT%) was observed in JKCH 1050 Bt (47.3%), JKCH 1947 Bt (46.3%) and control variety, Alba Plus QM 301 NBt (45.7%). JKC 724 NBt exhibited a low GOT% (44.0 %). Based on the weight of 50 balls per hybrid/variety, JKCH 1947 Bt (226.8 g/50 bolls) had bigger boll weight followed by Alba Plus QM 301 NBt (220.3 g/50 bolls) and JKCH 1050 Bt (218.8 g/50 bolls). Significant differences were observed among four cotton hybrids/varieties trials at Malkerns Research Station in cotton yield with JKCH 1050 Bt (1817.0 Kg/ha) and JKCH 1947 Bt (1765.0 kgha^{-1}) compared to control variety Alba Plus QM 301 NBt (1337.0 kgha^{-1}).The lowest yield was observed in inbred JKC 724 NBt (821.0 kgha^{-1}) (Table 4).

3.3. Fiber properties

Tables 5 and 6 show the Fibre quality characteristics of the Bt and Non-Bt cotton at Lowveld Experiment Station and Malkerns Research Station. Micronaire values were higher in Lowveld experimental station compared to Malkerns Research Station. However, the trend of micronaire remained same. Uniformity ratio across the locations recorded more than 80.0% among the four cotton hybrids/varieties. Fiber strength was higher in Alba Plus QM 301 NBt (33.10 and 28.40 g/tex) in both locations. Fiber length also followed the same trend as Alba Plus QM 301 NBt had longer stab length compared to Bt cotton hybrids.

Table 3. Agronomic traits of Bt and Non-Bt cotton at Malkerns Research Station soil and climatic conditions

Cotton Variety/Hybrid	Plant Height (cm)	No. of Lateral Branches	No. of lateral Branches (≥ 4 bolls)	Days to 50% Flowering	No. of Damaged Bolls	No. of Bolls/Plant	Damaged Bolls (%)
Alba Plus QM 301 NBt	131.0a[1]	12.52a	2.56c	159.0b	1.0a	41.2b	2.4
JKC 724 NBt	89.0b	11.03a	2.36c	165.0a	1.2a	37.3b	2.7

JKCH 1947 Bt	148.0a	12.58a	3.67b	102.0c	0.3a	65.5a	0.5
JKCH 1050 Bt	131.0a	12.92a	5.39a	106.0c	0.5a	67.2a	0.7

[1] *Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test*

Table 4. Yield and yield components of Bt and Non-Bt cotton at Malkerns Research Station soil and climatic conditions

Cotton Variety/Hybrid	50 Bolls Dry Weight (g))	Ginning Out Turn %	Cotton Yield (kgha^{-1})
Alba Plus QM 301 NBt	220.3a[1]	45.7ab	1337.0b
JKC 724 NBt	172.2b	44.0b	821.0c
JKCH 1947 Bt	226.8a	46.3a	1765.0a
JKCH 1050 Bt	218.8a	47.3a	1817.0a

[1] *Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test*

Table 5. Fibre quality characteristics of the Bt and Non-Bt cotton at Lowveld Experiment Station, Big Bend soil and climatic conditions

Cotton Variety/Hybrid	Micronaire	Uniformity (%)	Fiber Strength (g/tex)	Stab Length (mm)	Trash Count	Maturity
Alba Plus QM 301 NBt	4.47ab[1]	84.53a	33.10a	29.16a	0.31a	0.83a
JKC 724 NBt	3.99b	83.02b	28.17b	27.31b	0.25ab	0.83a
JKCH 1947 Bt	4.44ab	85.10a	29.62b	27.99b	0.22ab	0.83a
JKCH 1050 Bt	4.60a	82.10b	27.53b	26.25c	0.15b	0.84a

[1] *Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test*

Table 6. Fibre quality characteristics of Bt and Non-Bt cotton at Malkerns Research Station soil and climatic conditions

Cotton Variety/Hybrid	Micronaire	Uniformity (%)	Fiber Strength (g/tex)	Stab Length (mm)	Trash Count	Maturity
Alba Plus QM 301 NBt	3.25a[1]	83.27a	28.40a	28.78a	0.18a	0.84a
JKC 724 NBt	2.72c	80.17b	22.58b	27.98a	0.33a	0.83b
JKCH 1947 Bt	2.98b	83.45a	26.82a	27.75a	0.29a	0.83b
JKCH 1050 Bt	2.72bc	82.13a	24.28b	26.28b	0.2a	0.83b

[1] *Means with the same letters within the same columns are not significant with Fischer's Least Significant Differences (LSD) test*

4. Discussion

Agronomic performance of Bt cultivars may vary substantially from their non-Bt counterparts (Jenkins et al., 1997). Plant height plays an important role in determining the morphological frame work relating to plant type and canopy development in cotton. Hebbar et al. (2007) noted that plant height is one of the important characters of growth and yield of cotton and is influenced by both genetic and environmental factors. Further, they observed that plant height did not differ between Bt and non-Bt hybrids. In the field trial in Swaziland, JKC 724 NBt exhibited a considerably shorter plant height confirming contribution of genetic constitution of different varieties. The results are in conformity with those of Sharma and Sharma (1994), who found significant differences in plant height among different cotton cultivars.

Flowering is important to cotton production because pollinated flowers form cotton bolls. In addition to high-yielding ability, JKCH 1947 Bt and JKCH 1050 Bt matured early in both locations. The Bt cotton hybrids recorded significantly higher yield than non-Bt hybrids. The hybrids matured early and thus avoided unfavourable weather during later phases (Hofs et al., 2006). Early-maturity and high-yielding ability is double benefit to the rain fed farmers because earliness as a trait helps the cotton hybrids to escape from terminal moisture stress in the season and considered as very positive in cultivar development for rain fed areas.

Number of bolls per plant play a vital role in determining final yield of a cotton cultivar, which is influenced directly or indirectly by the growing conditions and its genetic ability to perform in the given environmental condition (Luqman et al., 2015). The statement by Luqman et al. (2015) clearly correspond to the observation of this study where in both locations, the Bt cotton cultivars expressed a higher mean number of bolls per plant compared to the local variety and the non-Bt hybrid in both locations. The results obtained from the field trials corroborated those of a trial by Sudha et al. (2011) in Govankoppa village, India. The two Bt hybrids JKCH 1947 Bt and JKCH 1050 Bt and the local Alba Plus QM 301NBt and the inbred JKC 724 NBt, across the two locations in Swaziland revealed the consistence superiority of the Bt genotypes. The two Bt-genotypes showed negligible damage due to bollworms in form of shedding or bolls damage while the local Alba Plus QM 301NBt and the inbred JKC 724 NBt suffered from significant damage in floral buds and bolls (Figure 1). This was directly reflected in the higher seed cotton yield of the Bt genotypes over the local variety.

Since yield is dependent on many component characters, such as boll weight, number of bolls per plant and harvest index and hence the study of interrelationship of these characters and their relationship with yield is essential. Bt cotton hybrids produced increased cotton yield over their non-Bt counterparts. In a study by Anonymous (2002), Bt cotton hybrids recorded more than 100% increased seed cotton yield over non-Bt and check hybrids.

On the other hand the data indicated that the two Bt genotypes had ginning out turn percent significantly higher than the local checks. Higher cotton yield in Bt cotton hybrids was due to high number of bolls observed in JKCH 1947 Bt and JKCH 1050 Bt and notably less damaged bolls. Alba Plus QM 301 NBt was protected using insecticides against bollworms but they were not applied to the Bt cotton hybrids. Despite no application of insecticides to Bt hybrids they showed higher boll retention and less damaged bolls indicating their resistance to bollworms. This indicated that the Bt cotton hybrids were resistant to bollworms and can recover the yield losses due to infestation of bollworms. Ginning out turn is primary industrial property; therefore, both Bt cotton hybrids had comparable lint percentage with local control variety.

Figure1. Cotton field trial at Malkerns Research Station showing visible differences between Bt and non-Bt cotton varieties

5. Conclusion

This preliminary study analyzed the performance of two Bt cotton hybrids in Swaziland based on comprehensive field trials data. Cultivation of hybrid Bt cotton not only gave significantly higher yields but also realized remarkably reduced insecticidal usage in crop cultivation giving greater security to the local cotton farmers about the surety of the cotton yield. Experiments conducted in both locations clearly depicted adaptability of both Bt cotton hybrids to Swaziland's soil and climatic conditions as they matured early and gave high yield. The adoption of these Bt varieties can help empower Swaziland cotton farmers with an already tested technology to help realize higher cotton yields in the country.

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