Yield analysis and adaptation for Bacillus thuringiensis (Bt) and non-Bacillus thuringiensis (Bt) Cotton varieties in the kingdom of Eswatini

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Abstract— Cotton in Eswatini contributes 2.1% of the country’s Gross Domestic Product owing to low cotton yield due to high pest pressure. Eswatini farmers grow Alba QM 301 a conventional non Bt variety which is affected by bollworm. Cotton is no longer profitable and farmers are quitting the industry, yet it is the only source of livelihood in drought prone areas of Eswatini. Countries like India and South Africa have replaced conventional cotton with high yielding Bt or genetically modified cotton. The study analyses yield and adaptation of Bt cotton under rain fed condition. Bt cotton hybrid was evaluated under field condition for adaptation and yield performance in 2016 and 2017 season. Two Bt cotton varieties JKCH 1947 Bt and JKCH 1050 Bt were tested against the local variety Alba Plus QM 301 and JKC 724 both Non Bt (NBt). JKCH 1947 recorded significantly higher seed cotton yield per ha of 3070 kg/ha on the first year. It was closely followed by JKCH 1050 with a yield of 2955 kg/ha. The number of boll per plant was also significant higher compared the control. Alba Plus QM 301 and JKC 724 both Non Bt (NBt) recorded the lower yields of 2066 and 821 kg/ha respectively, under the same condition with less number of bolls per plant. Similar observations were recorded on the second year, JKCH 1947 and JKCH 1050 recording 1765 kg/ha and 1865 kg/ha respectively. A similar trend was observed on the number of bolls per plant, higher number of bolls were recorded in JKCH 1050 Bt followed by JKCH 1947 Bt. Alba Plus QM 301 NBt and JKC 724 NBt recorded fewer boll in both years. All varieties showed good adaptability to local environment with good plant stand.

Keywords— Bt cotton, rain fed conditions, seed cotton.

I. INTRODUCTION

This paper is about introducing genetically modified cotton in the Kingdom of Eswatini. Discussions in the paper are guided by management processes of introducing a new product or new technology in a market. In the Kingdom of Eswatini, agriculture plays a major role in the economy; it’s a major source of food, and also employs more than 60% of the country’s population (ISAAA, 2014; Thomson, 2012). Eswatini’s agriculture is mainly dependent on sugar cane, cotton and forestry. Cotton is the second biggest cash crop after sugarcane in Eswatini. It is an important cash crop for most Swazis who live on drought prone areas and smallholder farmers who are reliant on the crop for their livelihood (Central Bank of Swaziland, 2013). Eswatini farmers are still entirely reliant on conventional hybrid cotton seeds. Hybrid cotton seeds have long been used in the industry as the sole means for cotton production.

Genetically modified cotton is a variety of cotton that has been modified through a biotechnological process in order to achieve a higher yield. Bollworm resistant, Bacillus Thuringiensis (BT) cotton is the most popular genetically modified cotton seed used throughout the world. Genetically modified cotton was first introduced in the early 1990s and has since been adopted by major cotton producing countries such as the USA, India, China and South Africa (James, 2011). The genetically modified cotton seeds are engineered via a biotechnological process to reproduce the soil bacterium Bacillus Thuringiensis in a crystal form in order to exterminate certain types of insects and pests which damage the cotton crop and reduce farmer’s yields (Craig et al., 2008). The new genetically modified seed has outstripped its traditional hybrid counterparts in terms of yield (Brookes & Barfoot, 2013).

In Eswatini, the cotton industry is currently facing a decline in production and this has affected the textile industries which relied on Eswatini cotton as their main source of inputs. Most textile industries have closed due to the shortage of cotton. The few textile factories that are operational survive through importing cotton supplement locally depressed supplies for the daily operations. The government of Eswatini has to revive the cotton industry by introducing a new product in the market. The purpose of this paper is to analyse yield and adaptability of genetically modified cotton in Eswatini. The paper will compare two Bt cotton varieties against the locally grown conventional cotton variety by evaluating the agronomic characteristics of the varieties under condition of the in the Kingdom of Eswatini.

The cotton industry in Eswatini is currently facing many challenges. The country’s largest cotton ginnery which is under the stewardship of the Swaziland Cotton Board.
II. MATERIALS AND METHODS

Field experiment was conducted at two years on the same site in Eswatini during 2016 and 2017 planting season. The trials focused on agronomic and yield performance of two Bt cotton hybrids (JKCH 1947 Bt and JKCH 1050 Bt), inbred (JKC 724 Non Bt) developed and owned by JK Agri Genetics Limited and the control was a locally grow conventional variety (Alba Plus QM 301 Non Bt). The Lowveld Experimental Station (LES) 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 of 450 mm. The soils are M-series, which are sandy loam, well drained and fertile (Murdoch, 1968). The experiment 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 variety per replication for the characters viz., 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 (%), 50 bolls dry weight (g), ginning out turn (%) and cotton yield (Kg/Ha). Out of all the bolls per plant, fifty bolls were randomly selected and weighed using a digital balance. Thereafter, the seed 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 scale from kg/plot to kg/ha for each cotton strain and replication. Field management was done general agriculture practice in the cotton industry of Eswatini. 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.

Statistical Analysis

All data were expressed as mean with standard deviation. 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 software (version 9.3 for windows). Significant differences between varieties agronomic and yield traits means were determined by Fischer’s Least Significant Difference Test at the level of p<0.05.
III. RESULTS AND DISCUSSION

Table 1: Year 1 agronomic traits of Bt and Non-Bt cotton results

| 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             | 9.5a                    | 2.5b                               | 106.5a                | 20.5a                | 58.8b             | 35.6             |
| JKC 724 NBt           | 48.1b             | 7.7b                    | 3.0b                               | 110.5a                | 16.2a                | 56.2b             | 29.0             |
| JKCH 1947 Bt          | 87.7a             | 9.4a                    | 3.8ab                              | 84.8b                 | 6.7b                 | 92.0a             | 7.6              |
| JKCH 1050 Bt          | 78.0a             | 9.8a                    | 4.2a                               | 86.3b                 | 6.1b                 | 90.2a             | 6.6              |

1 Means with the same letters within the same columns are non-significant with Fischer’s Least Significant Differences (LSD) test

Table 2: Year 1 yield components of Bt and Non-Bt cotton results

| Cotton Variety/Hybrid | 50 Bolls Dry Weight (g) | Ginning Out Turn (%) | Cotton Yield (Kg/Ha) |
|-----------------------|-------------------------|----------------------|----------------------|
| Alba Plus QM 301 NBt  | 283.3a                  | 44.7a                | 2066b                |
| JKC 724 NBt           | 207.2b                  | 40.8c                | 1173b                |
| JKCH 1947 Bt          | 311.5a                  | 43.1b                | 3070a                |
| JKCH 1050 Bt          | 294.7a                  | 43.3b                | 2955a                |

1 Means with the same letters within the same columns are non-significant with Fischer’s Least Significant Differences (LSD) test

Table 3: Year 2 Agronomic traits of Bt and Non-Bt cotton results

| 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             | 12.52a                  | 2.56c                              | 158.6b                | 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                              | 101.5c                | 0.3a                 | 65.5a             | 0.5              |
| JKCH 1050 Bt          | 131.0a             | 12.92a                  | 5.39a                              | 106.1c                | 0.5a                 | 67.2a             | 0.7              |

1 Means with the same letters within the same columns are non-significant with Fischer’s Least Significant Differences (LSD) test

Table 4: Year 2 yield components of Bt and Non-Bt cotton results

| Cotton Variety/Hybrid | 50 Bolls Dry Weight (g) | Ginning Out Turn % | Cotton Yield (Kg/Ha) |
|-----------------------|-------------------------|--------------------|----------------------|
| Alba Plus QM 301 NBt  | 220.3a                  | 45.7ab             | 1337b                |
| JKC 724 NBt           | 172.2b                  | 44.0b              | 821c                 |
| JKCH 1947 Bt          | 226.8a                  | 46.3a              | 1765a                |
| JKCH 1050 Bt          | 218.8a                  | 47.3a              | 1817a                |

1 Means with the same letters within the same columns are non-significant with Fischer’s Least Significant Differences (LSD) test

Early flowering was observed in hybrids JKCH 1947 BT (85 days) and JKCH 1050 Bt (86 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 (7.0%) each.
This study analyzed the yield performance of two Bt cotton varieties in Eswatini over a period of 2 years based on rain fed conditions. Cultivation of hybrid Bt cotton did not only give a significantly higher yields but also realized significantly reduced insecticidal usage, hence giving security to farmers about the cotton yield. The study conducted over two year’s clearly depicted good adaptability of both Bt (JKCH1050 and 1947) cotton hybrids to Eswatini environment. The varieties were early maturing and high-yielding. Adoption of these Bt varieties can help empower Swazi cotton farmers to embrace and benefit from product of modern biotechnology. It is therefore concluded that the two Bt varieties (JKCH1050 and 1947) be released to farmers for commercial growing.

RECOMMENDATION
It is recommended that the kingdom of Eswatini commercialize the growing of Bacillus thuringiensis cotton to cotton growers.
It further recommended that further studies be conducted on the four region of Eswatini on the performance and adaptation of this technology.

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