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Productivity and fibre attributes of absorbent Asiatic cotton (*Gossypium arboreum*) cultivars in rainfed central India

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ABSTRACT

Asiatic cotton (*Gossypium arboreum* L.) cultivars, possessing short staple length, superior water holding capacity and high micronaire values are considered fit for manufacturing absorbent cotton. Such cultivars are cultivated in north and northeast India. Field studies were conducted at the experimental farm of the ICAR-Central Institute for Cotton Research, Nagpur, from 2013–14 to 2015–16, to evaluate productivity and fibre properties of Asiatic cotton cultivars from north (race *bengalense*) and northeast (race *cernuum*) India vis-à-vis the cultivars of central and south India (race *indicum*). In 2013, RG8 produced the highest seed cotton yield (1759 kg/ha), but did not differ from Phule Dhanwantary (1599 kg/ha) and BG-II hybrid H6 (1518 kg/ha). Averaged over 2014–15 and 2015–16, AKA8, CNA418, CNA375, CNA423, Phule Dhanwantary and MDLABB (1489 to 1989 kg/ha) gave significantly higher seed cotton yield than BGII hybrid Mallika (953 kg/ha). In general, cultivars from north and northeast India produced less seed cotton yield than those from central and south India. Out of the 13 cultivars, Assam Comilla and Phule Dhanwantary met the Indian Pharmacopoeia standards (fibre length ~20 mm, micronaire >6.5, absorbency and sinking time <10 sec and ash content <0.5%). Cultivation costs were lower for the Asiatic cotton (₹49420 per ha) than the BGII hybrid (₹62895 per ha). Thus, cultivation of Asiatic absorbent cotton, such as Phule Dhanwantary, could be an alternative option for the rainfed cotton farmers of central India.

Keywords: Ash content, *Bt* cotton, *Gossypium hirsutum*, Micronaire, Semi-arid tropics

Absorbent cotton has high water-holding capacity (Raja *et al*. 2016) and is mainly used for medical purposes (Gayal *et al*. 2012). According to the Indian Pharmacopeia (IP), the major parameters for absorbent cotton are short fibres (<20 mm), high micronaire (>6.5), low sulphated ash (<0.5%), short absorbency and sinking time (<10 sec) and high water holding capacity (>23 g/g of cotton). Cotton cultivars belonging to the Asiatic cotton (*Gossypium arboreum* L.) have high micronaire (mic), fluid absorbency and low ash content and are ideal for preparing absorbent cotton (Nachane *et al*. 2004). However, not all Asiatic cotton cultivars are equally suited for the purpose (Nachane *et al*. 2004). Asiatic cotton cultivars belonging to race *bengalense*, suited for preparing absorbent cotton, are cultivated only in north India (Meena *et al*. 2016). Landraces of the *G. arboreum* race *cernuum* referred to as the Assam Comilla cottons are cultivated on a limited scale, in northeast India (Venugopalan *et al*. 2016). Asiatic cotton cultivars were cultivated on 17% of India's cotton area in 2002 and raw material for absorbent cotton was available easily. *Bt* cotton introduced to India in 2002 soon replaced Asiatic cotton cultivars (Blaise *et al*. 2014) resulting in shortage of the short staple cotton. Presently, more than 95% cotton acreage in India is occupied by the long lint Upland (*G. hirsutum*) *Bt* cotton hybrids.

Because of short supply of raw material required for absorbent cotton, surgical cotton manufacturers use comber-noil, a byproduct of the yarn spinning industry (Sawhney *et al*. 2011). Because of the innate tolerance to insect pests, diseases, drought and salinity, Asiatic cotton cultivars do not need synthetic agro-chemicals and pesticides, and are grown almost without any chemical inputs. Thus, cultivation of Asiatic cotton cultivars is not only inexpensive but also eco-friendly. Cultivation of Asiatic cotton in central India would facilitate easy access to raw material for the local absorbent cotton industry. Presently, very little is known about productivity potential and the economics of the absorbent cotton cultivars in central India. In the present study, field studies have been conducted to identify high yielding cultivars possessing short fibre length with high micronaire and low ash content, and to determine the

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profitability of Asiatic cotton cultivars vis-à-vis the *Bt* cotton hybrids.

MATERIALS AND METHODS

Field studies were conducted at the experimental farm of the ICAR-Central Institute for Cotton Research, Nagpur (21°9'N and 17°7'E) from 2013–14 to 2015–16 without irrigation. Soil at the experimental site is classified as fine, smectitic, hyperthermic, Typic Haplusterts. Soil had slightly alkaline *p*H (8.1) with low organic C (3.9 to 4.1 g/kg). It was low in 0.5 M sodium bicarbonate extractable P (5.7 to 6 mg/kg). Ammonium acetate (1 M) exchangeable K content was high (278 to 334 mg/kg).

Eight Asiatic cotton cultivars were evaluated vis-à-vis the transgenic Bollgard-II® (BG-II) hybrid (H6) in 2013–14. The Asiatic cotton cultivars from the north zone were LD327, LD491, RG8, HD123; from the central zone were Phule Dhanwantary, CNA375 and AKA8; and Assam Comilla from the northeast India belonging to the race *cernuum*. Seeds of Assam Comilla (IC412229) were obtained from the Germplasm Unit of ICAR-CICR, while those of other cultivars were obtained from the State Agricultural Universities. In 2014–15 and 2015–16, 13 Asiatic cotton cultivars (RG8, RG540, HD123, HD432, CISA-17-93, CISA-6-295 : north Indian cultivars; Phule Dhanwantary, CNA375, CNA418, CNA423, MDLABB and AKA8 : cultivars belonging to central and south India; and Assam Comilla from northeast India) were evaluated and compared with the BGII hybrid (Mallika). The experiment was conducted in a randomized block design with each variety having three replicates. Asiatic cotton cultivars LD327, LD491 were not included in 2014–16 seasons because these cultivars were de-notified for cultivation due to low yield levels.

The crop was sown with the onset of rains (22 June 2013, 18 June 2014 and 20 June 2015). In 2014, germination was poor because of low rainfall received after sowing. Therefore, the crop was re-sown on 11 July 2014 and gap filling was done on 21 July 2014 to maintain the plant stand. A spacing of 0.60 m between rows and 0.10 m between plants was maintained for the absorbent cotton cultivars while the BGII hybrid was sown at the recommended spacing of 0.90 m × 0.60 m for rainfed conditions. Entire P and K was applied as basal dose at the rate of 13 kg P and 25 kg K per ha for the Asiatic cotton cultivars and 25 kg P and 37 kg K per ha for the BGII hybrid. Nitrogen was applied through urea in three equal splits, half at the time of thinning and the remaining in two equal splits 45 days after sowing and 70–75 days after sowing, coinciding with the square and boll formation stages, respectively. The fertilizer-N dose was 90 kg/ha for the BGII hybrids and 60 kg/ha for the cultivars. Recommended plant protection measures were adopted, whenever insect pests exceeded economic threshold levels.

Seed cotton was harvested from each net plot of three 6 m long rows. The seed cotton was ginned and the fibre was bulked. Composite sample was analysed for fibre length and micronaire (mic) using High Volume Instrument.

Cultivars found suitable were used to prepare absorbent cotton by employing the CIRCOT single stage chemical process (Raja *et al*. 2016) in 2013–14. However, in 2014–15 and 2015–16, lint samples from all the Asiatic cotton cultivars were used to prepare absorbent cotton in order to elucidate whether differences exist between the short and long fibre length. Absorbent cotton samples, thus prepared, were evaluated for absorbency and other parameters (Raja *et al*. 2016).

Data on seed cotton yield was statistically analyzed following procedures outlined in Gomez and Gomez (1984). Data for the seed cotton yield and the fibre properties of 2014–15 and 2015–16 were combined over years and treatment differences were separated using the least significant difference (LSD) at the 5% level of probability.

RESULTS AND DISCUSSION

Seed cotton yield: Seed cotton yield, averaged over cultivars, was affected by season with significantly lower yield in 2014–15 (746 kg/ha) than in 2015–16 (1809 kg/ha). In the rainfed areas of central India, cotton is grown as a rainy season crop, wherein, seed cotton yield is primarily dependent on the rainfall received during the crop growing period (Blaise *et al*. 2006). Low seed cotton yield in 2014–15 was due to re-sowing late in the season in July because of poor germination owing to a prolonged dry spell immediately after the first rain showers in June. Furthermore, rainfall during the season was less than normal with only 26 rainy days.

Among cultivars, seed cotton yield in 2013–14, was least with Assam Comilla followed by LD327, LD491 and HD123 (Table 1) which was significantly lesser than the other Asiatic cotton cultivars. Cultivar RG8, a north Indian cultivar, had the highest seed cotton yield followed by Phule Dhanwantary, BGII hybrid H6, AKA8 and CNA375. Averaged over seasons in 2014–15 and 2015–16, in general, all the central zone Asiatic cotton cultivars had significantly greater seed cotton yield than those from north and northeast (Table 2). Seed cotton yield of the Assam Comilla was the least and significantly lesser than the other cultivars. Yield levels of all the north Indian cultivars, viz. RG8, RG540, HD123, HD432, CISA-17-93, CISA-6-295, were not significantly different and were similar to the yields obtained with the popular BGII hybrid Mallika. The north Indian cultivars were significantly inferior to the cultivars from central and south India, except RG540 which yielded equivalent to those of MDLABB, Phule Dhanwantary and CNA423. Seed cotton yield of AKA8 was the highest, and was statistically similar to CNA375 and CNA418 and significantly superior to CNA423, Phule Dhanwantary and MDLABB. Expectedly, cultivar differences were significant because the cultivars belonged to different races of *G. arboreum*, viz. *indicum, bengalense* and *cernuum*. Among the Asiatic cotton cultivars, the lowest seed cotton yield was obtained with the Assam Comilla (race *cernuum*) from northeast in all the years of the study. Venugopalan

Table 1 Seed cotton yield and fibre properties of Asiatic cotton cultivars in 2013–14

	Seed cotton yield (kg/ha)	Fibre length (mm)	Micronaire (ug/inch)	Ash (%)	Absorbency (sec)	Sinking time (sec)	Water holding capacity (g/g of cotton)
LD327	797	20.2	6.1	0.26	1.0	1.5	24.5
LD491	830	20.6	6.0	0.32	1.1	1.5	24.2
RG8	1759	20.5	6.1	0.28	1.1	1.7	25.7
HD123	1035	20.1	5.8	0.30	1.1	1.5	25.2
Phule Dhanwantary	1599	20.4	6.9	0.34	1.4	2.0	28.0
CNA375	1277	26.0	4.8	na	na	na	na
Assam Comilla	428	18.2	7.9	0.30	1.2	1.3	25.6
AKA8	1286	25.4	4.4	na	na	na	na
H6 BGII	1518	30.1	3.4	na	na	na	na
LSD (0.05)	729	3.5	0.3				

na, not analyzed.

et al. (2016) observed these cultivars to be shy bearing. Furthermore, these take longer to fruit (>210 days) as compared to the cultivars of central India belonging to the race *indicum*. Similarly, most of the north Indian cultivars, race *bengalense*, (LD327, LD491, RG-540, HD123, HD432, CISA-6-295, and CISA-17-93) also mature between 180–210 days. Therefore, seed cotton yield of the north Indian cultivars when planted in the rainfed tracts of central India gets adversely affected because the monsoon rains cease by mid-September.

Low yields are seen in BGII hybrid compared to some of the Asiatic cotton cultivars because BGII hybrids are more susceptible to moisture stress than the Asiatic cotton cultivars. Blaise *et al*. (2006) reported high yield with the Asiatic cottons compared to the Upland cotton.

Fibre length and micronaire: In 2013–14, all the Asiatic cotton cultivars had fibre length >20 mm, except the Assam Comilla (Table 1). The Asiatic cotton cultivars of north and central India except, AKA8 and CNA375 had fibre length of 20.1–20.6 mm. A similar trend was observed for the micronaire values as well. The Assam Comilla cotton had the coarsest cotton compared to the other Asiatic cotton cultivars. Among the other Asiatic cotton cultivars, cultivar Phule Dhanwantary had high micronaire values, significantly greater than LD327, LD491, RG8 and HD123. The latter group did not differ significantly. The BGII hybrid H6 had the longest fibre and the least mic values and was significantly different from the rest of the cultivars.

Averaged over seasons, only two cultivars had fibre length <20 mm, viz. the Assam Comilla and Phule

Table 2 Seed cotton yield, fibre length, microniare and absorbency properties of the Asiatic cotton cultivars evaluated in 2014–16

Cultivar	Seed cotton yield (kg/ha)	Fibre length (mm)	Micronaire (ug/inch)	Ash (%)	Absorbency (sec)	Sinking time (sec)	Water holding capacity (g/g of cotton)	Water soluble substance (%)
RG8	1150	22.0	6.2	0.49	1.4	2.3	28.1	0.41
RG540	1299	23.0	5.5	0.56	1.5	2.2	27.6	0.40
HD123	1180	21.2	6.1	0.51	1.5	2.2	28.0	0.37
HD432	858	22.5	5.3	0.50	1.6	2.6	27.9	0.39
CISA-17-93	949	23.1	5.8	0.48	1.6	2.2	26.8	0.38
CISA-6-295	904	24.7	5.0	0.42	1.8	3.2	27.9	0.42
Phule Dhanwantary	1568	19.9	6.6	0.42	1.2	2.1	27.8	0.41
CNA375	1739	25.6	5.1	0.45	1.6	2.7	27.3	0.39
CNA418	1769	26.8	4.9	0.44	2.1	3.0	28.0	0.37
CNA423	1593	28.0	4.9	0.34	1.6	2.5	26.1	0.42
AKA8	1989	26.2	4.8	0.43	1.9	2.8	27.2	0.38
MDLABB	1489	21.5	6.2	0.53	1.5	2.9	26.5	0.41
Assam Comilla	444	18.9	6.9	0.32	1.2	1.9	26.8	0.32
Mallika BGII	953	29.4	3.5	na	na	na	na	na
LSD (0.05)	371	1.1	0.3	0.20	0.3	NS	NS	NS

na, not analyzed.

Dhanwantary (Table 2). Seven cotton cultivars (RG8, RG540, HD123, HD432, CISA-17-93, CISA-6-295 and MDLABB) had fibre length more than 20 mm and less than 25 mm. However, these cultivars were coarse with >5 mic values. Phule Dhanwantary had mic values similar to the Assam Comilla and MDLABB. Cultivars RG8, RG540, CISA-17-93 had similar mic values and were significantly greater than HD432 and CISA-6-295. Cultivars, CNA375, CNA418, CNA423 and AKA8 had fibre length >25 mm and were less coarse than the Asiatic cotton cultivars with mic values of 5.2–6.9. The BGII hybrid Mallika had the longest fibre and the lowest mic values and was significantly different compared to the Asiatic cotton cultivars. All the Asiatic cotton cultivars had short fibre length and high micronaire values compared to the *Bt* cotton hybrid. *Bt* cotton hybrids belong to the long-staple category with fine fibres.

Absorbent cotton properties: Absorbent cotton comes in direct contact with the wounded skin and therefore, needs to meet stringent IP standards (Gayal *et al*. 2012). Asiatic cotton cultivars were tested for absorbency (Tables 1 and 2) whereas the transgenic BGII hybrids were not tested because spinning and conversion to cloth is considered to be of better value addition. As per the IP standards, cultivars having fibre length less than 20 mm and micronaire values more than 6.0 can be considered by the absorbent cotton industry. Thus, six cultivars (LD327, LD491, RG8, HD123, Phule Dhanwantary and Assam Comilla) that met the IP standards were analyzed for absorbency during 2013–14 (Table 1). All these cultivars met the IP standards set for the absorbent cotton properties, viz. low ash content (<0.5%), high water holding capacity (>23 g/g of cotton), short sinking time (<10 sec) and quick absorbency (<10 sec). Except HD123, MDLABB and RG540, all Asiatic cotton cultivars had ash content ≤0.5% (Table 2). Sulphated ash represents the mineral constituents present in cotton fibre. However, the differences were not significant; except for the Assam Comilla that had significantly lower ash content than MDLABB and RG540. Other important properties include sinking time and water holding capacity such that the body fluids and exudates are readily absorbed at a faster rate. Differences among the cultivars were not significant with regard to absorbency, sinking time and water holding capacity. Meena *et al*. (2016) identified several cultivars, including HD123 and RG540, on the irrigated Inceptisols to have low ash and high absorbency. Globally, short-fibre mill waste called ‘comber-noil’ is used for preparing absorbent cotton due to its cost effectiveness (Sawhney *et al*. 2011). Domestically manufactured medical absorbent cotton mixed with wasted non-cotton chemical fibre, can cause harmful effects such as irritation, allergy and inflammation. Short staple Asiatic cotton is ideal for absorbent cotton preparation because of high micronaire values, high moisture holding capacity and less neps formation compared to comber-noil.

Cost of cultivation: The total cost of cultivation was computed, averaged over two seasons (2014–15 and 2015–16), for the BGII hybrid vis-à-vis the Asiatic cotton varieties (Table 3). The total cost of Asiatic cotton cultivation was 21.4% lower than the cultivation cost of BGII hybrid. The production costs of BGII hybrid was greater due to increased input use in terms of fertilizers, insecticide sprays and frequent weeding due to its wide spaced conditions. Although the BGII hybrid possesses Cry toxins offering protection against bollworms, it is susceptible to the sucking pests, viz. aphids (*Aphis gossypii*), leaf hoppers (*Amrasca biguttula biguttula*) and white flies (*Bemisia tabaci*). Therefore, early in the season multiple sprays had to be employed for the control of sucking pests. Furthermore, insecticide were sprayed to control pink bollworm in 2014–15 and 2015–16. Production costs in our study were nearly 9% less than what the farmers are spending on the cultivation of BGII since standard recommended agronomic practices were followed. Further, seed costs of the *Bt* cotton hybrids are higher than Asiatic cotton cultivars. Seed of the Asiatic cotton cultivars can be re-used over the next season while those of the BGII hybrids have to be bought every season. Although the gross return of the Asiatic cottons was not greater than that for the BGII hybrid, the net return was better for the Asiatic cotton cultivars. With regard to profitability, other studies, indicated *Bt* cotton cultivation in India to be profitable (Gandhi and Namboodiri 2009, Subramanian and Qaim 2010). However, our results indicate negative net return with the BGII hybrids. These differences stem from the fact that the wage rates increased nearly 2.2 folds, input costs of fertilisers and pesticides also increased (Reddy *et al*. 2018). In our studies, we compared the production costs of the Asiatic cotton cultivars with the BGII hybrids. Asiatic cotton cultivars possess innate resistance to sucking pests and consequently require less insecticides.

Our results indicate that the Asiatic cotton cultivars with short fibre length (~20 mm), low ash content and high yields, such as Phule Dhanwantary, are well suited for preparing absorbent cotton. Furthermore, because of the low cultivation costs and high profitability, growing absorbent cotton can

Table 3 Cost of cultivation, gross returns and net returns (₹/ha) of the Asiatic cotton vis-à-vis the BGII hybrid cotton

Component	Asiatic cotton	BGII hybrid
Land preparation	4347	4347
Seed	966	3367
Sowing	1043	1260
Fertilizer	6132	8400
Weeding	10136	15064
Plant protection	4739	8988
Cotton picking	7203	6615
Land rent, interest on working capital and miscellaneous charges	14854	14854
Total cost of production	49420	62895
Gross returns	52850	56231
Net returns	3430	-6664

Averaged over 2013–14 to 2015–16.

be considered as an option for the rainfed conditions of central India. However, there are critical challenges for growing Asiatic cotton, particularly, market and processing after harvest that need to be addressed.

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