Developing of Indonesian colored cotton varieties to support sustainable traditional woven fabric industry

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**Abstract.** There are four color groups of cotton fiber, namely white, brown, green and blue. The most cultivated colored-cottons are brown and green cotton fiber. The program for assembling colored-cotton varieties, especially brown color in Indonesia began in 2006. Crossing activities used three Indonesian National Cotton superior varieties, namely Kanesia 7, Kanesia 8 and Kanesia 9 as female founder and three cotton accessions with brown fiber cotton characters 73814, Multiple Dominant and RLBL as male founder. From crosses followed by selection based on desired character, tests of selected lines and multi-location tests of expected lines, we obtained 3 brown-cotton-fiber varieties with 3 color gradations: Bronesia 1 (light brown), Bronesia 2 (light brown), and Bronesia 3 (dark brown). The potential production of the three varieties are 909 kg, 859 kg, 1,010 kg fiber/ha, respectively. The quality of Bronesian cotton fiber is generally lower compared to the new superior varieties of white fiber cotton (Kanesia 16-Kanesia 23) for fiber length and strength. Cotton fibers of Bronesian varieties are classified as short fibers (23.2-25.7 mm), so that manual and conventional spinning techniques will produce yarn suitable for traditional weaving, especially for woven fabrics with brown based colors.

1. Introduction

The use colored cotton fibers has been done in Mexico since 3400-2300 BC, Peru in 3100, Egypt in 2250 BC, and in China in 1200 AD [1]. Colored cotton is commonly found in diploid cotton (*Gossypium arboreum* and *G. herbaceum*) with pink, red, blue, green, and black colors, and is widely developed in Asia, especially India, China and mainland Russia [2]. The history of its development is thought to be earlier than that of allotetraploid cotton (*G. hirsutum* and *G. barbadense*), which is widely developed today. There are four color groups of cotton fibers, namely white, brown, green and blue [3], but the most widely cultivated are brown and green fiber colors. The colors of brown, gray and reddish-brown fibers are caused by the tannin content and phenolic compounds in lumen vacuoles. While the green fiber is caused by the presence of caffeine and cinnamic acid in the waxy layer and cellulose layer that surrounds the cotton fiber [4].

Brown fiber is more common than other color fibers and is more stable than green fibers [5]. Colored cotton varieties have lower fiber quality (strength, length, micronaire) than that most white fiber cotton. Cotton varieties with colored fibers have relatively low fiber content, which ranges from 19-33% [4], and colored cotton fiber productivity only ranges from 50-70% [6]. Therefore, even though the price of fiber is
expensive, the colored cotton has not been optimized for commercial textile production [7]. Among colored cotton fibers, brown fibers are more commonly cultivated and its colors are more stable than green fibers [5].

Cotton fiber production in the cotton development areas, which are far from the active ginery, for example in East Nusa Tenggara (NTT) and West Nusa Tenggara (NTB), is directed to support the traditional weaving industry. Traditional woven cloths that exist in many parts of Indonesia are a prosperity of Indonesian culture that must be preserved and if possible are appointed to be recognized as one of the national and international heritages (world heritage). The use of natural color cotton fibers is expected to support the traditional small and medium weaving industry. The use of color fibers in the traditional weaving industry will provide benefits, because colored cotton fibers have a high color resistance during repeated washing and do not fade easily when exposed to ultraviolet light [8]. In terms of plant breeding, cotton fiber accessions have resistance to important diseases and have a high tolerance to salinity [9]. Colored cotton are also resistant to pests and drought, resulting in the use of lower amount of pesticides and more adaptive on dry or semi-arid lands or would be directed toward organic agriculture [10].

Indonesian Sweetener and Fiber Crops Research Institute (Balittas) manages three accessions of brown cotton, namely KI 42 (73814, originating from Greece), KI 124 (Multiple Dominant), and KI 502 (RLBL, originally from Australia). These three accessions have been used as male founders in the crossing program which aimed to assemble varieties of brown fibrous cotton based on Kanesia 7, Kanesia 8, and Kanesia 9 as female founders. This paper aims to inform the stages of assembling Indonesian brown cotton fibers and the first cotton fiber varieties released in Indonesia. This paper discusses the steps in assembling of Indonesian colored cotton until releasing varieties of national colored cotton with brown fiber character.

2. Assembly of Colored Cotton Varieties
Assembling varieties of brown-colored cotton plants is carried out through several stages, namely crossing of the founders, selection of F1 as the results of crossing, selection up to F6 of selected lines, potential yield testing of selected lines, and multilocation trials of promising lines.

The crossing was carried out by involving six founders of the cotton germplasm collection in Balittas in 2006. The parents consisted of female founders using three national Indonesian cotton varieties (Kanesia), namely Kanesia 7, Kanesia 8, and Kanesia 9); and male founders from three selected accessions introduced from Greece, the United States and Australia namely KI 42 (accession 73814), KI 124 (Multiple dominant accession), and KI 502 (RLBL accession - Red Leaf Brown Lint), respectively.

Selection of F1 - F6 crosses population began in 2007 to 2012 in Karangploso Experimental Station, Malang (112°37'53″ EL dan 7°52'27″ SE, altitude 515 m asl). Selections were carried out under conditions without insecticide sprays for pest control. Selection criteria include the level of damage to plants due to the cotton leafhopper *Amrasca biguttula* and cotton bollworm *Helicoverpa armigera*, the number of bolls were more than 15 bolls/plants with a selection pressure of 15%. The selection results up to F6 obtained 19 lines (Table 1) that are ready to be tested for their potential yield.

The next step after obtaining 19 lines was testing for F7 lines for their potential yield. This was conducted in 2013 at the Pasirian Experimental Station, Lumajang (113° 07' 08" EL dan 8° 2' 14" SE, 110 m asl). In this activity 19 selected lines were used in a trial arranged in Randomized Block Design with 2 replicates. Power test results of brown fiber cotton were carried out using a comparator of Kanesia 10 varieties. Test of potential yield of these lines was done in plots which were were not subject to pest control. From this test we obtained 6 lines of promising lines which in the next stage was carried out in multi-location test.
Table 1. Promising cotton lines with drought tolerant trait and high production potency

| No  | Lines    | Crossing combination                  | Color of the fiber |
|-----|----------|---------------------------------------|--------------------|
| 1   | 97013/6  | ALA-73-2M X ACALA 1517-BR-2           | White              |
| 2   | 97023/8  | PUSA 1 X DP 5690                      | White              |
| 3   | 03001/9  | DPX 7062-7077 X MYSORE VIJAYA         | White              |
| 4   | 03002/12 | DPX 7062-5288 X MYSORE VIJAYA         | White              |
| 5   | 03006/1  | DP 5415 X MYSORE VIJAYA               | White              |
| 6   | 03008/7  | NUCOTN 35 B X MYSORE VIJAYA           | White              |
| 7   | 03008/24 | NUCOTN 35 B X MYSORE VIJAYA           | White              |
| 8   | 03008/25 | NUCOTN 35 B X MYSORE VIJAYA           | White              |
| 9   | 03009/3  | CAMBODIA X MYSORE VIJAYA              | White              |
| 10  | 03012/17 | DPX 7062-7244 X LAXMI                 | White              |
| 11  | 03014/12 | DPX 7062-1883 X LAXMI                 | White              |
| 12  | 03017/13 | NUCOTN 35 B X LAXMI                   | White              |
| 13  | 03017/15 | NUCOTN 35 B X LAXMI                   | White              |
| 14  | 06063/5  | KANESIA 8 X 73814                     | Dark brown         |
| 15  | 06062/3  | KANESIA 7 X RLBL (Red Leaf Brown Lint)| Light brown        |
| 16  | 06066/2  | KANESIA 8 X RLBL (Red Leaf Brown Lint)| Light brown        |
| 17  | 06066   | KANESIA 8 X RLBL (Red Leaf Brown Lint)| Light brown        |
| 18  | 06067/3  | KANESIA 9 X 73814                     | Dark brown         |
| 19  | 06063/3  | KANESIA 8 X 73814                     | Dark brown         |

Multilocation test activities were carried out in three locations, namely the Asembagus Experimental Station, Situbondo, Pasirian Experimental Station, Lumajang, and Sumberejo Experimental Station, Bojonegoro (111°09' EL; 7°37' SE; 16 m asl) in 2014-2016. The multilocation test involved 6 promising lines of the 2013 results, arranged in a randomized block design with 3 replicates. This test consisted 2 test units, namely without pest control (without seed treatment and other pest control) and with pest control (seed treatment and pest control). The three test sites are rainfed lands. The rainfall conditions in Asembagus ranged between 254 mm - 538 mm, in Pasirian varying between 260 mm - 1263 mm and in Sumberejo varying 276 mm - 428 mm.

The results of the multilocation test obtained 3 superior lines that were proposed to be released as new high yielding varieties of drought tolerant and brown fibrous cotton, namely lines 06062/3, 06066/2, and 06063/3. In 2018, the three superior lines were released as new high yielding varieties of brown colored cotton, namely Bronesia 1 originating from line 06062/3, Bronesia 2 originating from line 06066/2, and Bronesia 3 originating from line 06063/3.

3. Production and Quality Potency of Bronesian Cotton Varieties

The productivity of cotton Bronesian varieties at three test sites without pest control is presented in Table 2. The cotton seed productivity of the varieties was generally lower than that of Kanesia 10. Fiber content and quality of the varieties that consist of length, fineness, strength, elongation, and uniformity of the fibers are presented in Table 3. Based on the fiber content of each variety, the productivity of Bronesias varieties and its comparative varieties (Kanesia 10) is presented in Table 4. In general, the fiber quality of brown colored cotton varieties was lower than that of Kanesia 10.
Table 2. Potential of seed cotton production of Bronesian varieties in the three test locations.

| Location  | Seed Cotton Productivity (kg/ha) |
|-----------|----------------------------------|
|           | Bronesia 1 | Bronesia 2 | Bronesia 3 | Kanesia 10 |
| Asembagus | 2.047      | 1.939      | 1.796      | 1.808      |
| Pasirian  | 2.199      | 2.004      | 1.856      | 2.338      |
| Sumberejo | 1.671      | 1.572      | 1.538      | 1.853      |

Source: Balittas (2018)

Table 3. Fiber Quality of Bronesian Varieties

| Variety    | Fiber Quality  | Fiber Content (%) |
|------------|----------------|-------------------|
|            | Length (mm)    | Fineness (mic)    | Strength (g/tex) | Elasticity (%) | Uniformity (%) |
| Bronesia 1 | 23.96          | 5.70              | 22.4            | 6.9           | 84.7           |
| Bronesia 2 | 25.74          | 4.00              | 23.7            | 5.9           | 84.9           |
| Bronesia 3 | 23.20          | 4.10              | 21.2            | 8.8           | 83.6           |
| Kanesia 10 | 28.28          | 4.60              | 27.0            | 8.1           | 88.7           |

Source: Balittas (2018)

Table 4. Fiber Productivity of Bronesian Varieties and Kanesia 10

| Location  | Fiber Productivity (kg/ha) |
|-----------|----------------------------|
|           | Bronesia 1 | Bronesia 2 | Bronesia 3 | Kanesia 10 |
| Asembagus | 687.8      | 669.0      | 594.5      | 739.5      |
| Pasirian  | 738.9      | 691.4      | 614.3      | 956.2      |
| Sumberejo | 561.5      | 542.3      | 509.1      | 757.9      |

Source: Balittas (2018)

Fiber length is the average length of the fiber staple based on length-weight data. The staple lengths of Bronesia 1 and Bronesia 3 were classified as medium length fibers, while Bronesia 2 was medium-long fibers, and Kanesia 10 varieties was long fibers. The fiber length of Bronesian varieties were relatively longer that those of colored cotton fibers originally from Greece, Turkey, Brazil, Bulgaria and the US are classified as short fibers [12]. Cotton fibers of Bronesian varieties which are classified as short fibers (23.2-25.7 mm), so that manual and conventional spinning techniques will produce yarn suitable for traditional weaving, especially for woven fabrics with brown based colors.

Cotton grading is done depending on their physical characteristics such as length, strength, fineness, maturity, trash content. Data on fiber fineness measurements show that the Bronesian varieties reached 5.70, 4.00 and 4.10 micronaire, respectively. However, Bronesia 1 has a level of refinement that does not belong to the range of refinement level desired by the textile industry which ranges from 3.5-4.9 micronaire. Based on the classification of Cotton [13], the strength of Bronesian varieties are relatively low, but the uniformity of fiber lengths is classified as high or medium according to [14].
4. Brown-colored Cotton Fiber

Fibers of Bronesian varieties showed three brown color degradation. Observation of brown-colored cotton fiber used two colored-cotton fiber comparison tools namely Munsell Color Charts for Plant Tissues and Royal Horticultural Society (RHS) Color Charts. The Bronesia 1 has a medium brown color with Munsell color charts: group 7.5 YR and value 7/6, while the RHS value is included in the Grayed Orange Group 165C. Bronesia 2 has a light brown color with Munsell color charts: 6.0 YR group and 7/6 value, while the RHS values are included in the Grayed Orange Group 165D. Bronesia 3 has a dark brown color with Munsell color charts: group 5.0 YR and value 6/10, while the RHS value is included in the Grayed Orange Group 164A. Figure 1 shows the color of cotton fibers from all three Bronesian varieties. The color of the cotton fibers is different from the results of the study [15] that the color of the fibers of 14 cotton fiber genotypes is included in the yellow-orange color group with an RHS value between 158 A - 168 D.

![Figure 1](image.png)

**Figure 1.** Color of Bronesian cotton fiber: A. Bronesia 1-medium brown; B. Bronesia 2-light brown; C. Bronesia 3-dark brown.

5. Conclusion

Bronesian colored-cotton varieties, namely Bronesia 1, Bronesia 2 and Bronesia 3, are the first colored-cotton varieties released in Indonesia. The cultivation of Bronesian varieties could be applied as low input cultivation, without spraying insecticides, and has the opportunity to be developed into organic cotton cultivation. Utilization of brown cotton fiber which is more environmentally friendly can be used to support traditional woven fabric industries.

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