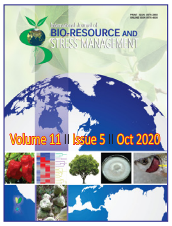

Article AR2151d
DOI: HTTPS://DOI.ORG/10.23910/1.2020.2151d

International Journal of Bio-resource and Stress Management

October 2020

Crossref

Print ISSN 0976-3988
Online ISSN 0976-4038

IJBSM 2020, 11(5):451-455

Research Article
Natural Resource Management

The Environment and Textile Industry-Friendly Hirsute Cotton Variety, Indica

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Open Access

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Citation: Sundaramurthy and Saxena, 2020. The Environment and Textile Industry- Friendly Hirsute Cotton Variety, Indica. International Journal of Bio-resource and Stress Management 2020, 11(5), 451-455. HTTPS://DOI.ORG/10.23910/1.2020.2151d.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Funding: The research was conducted with the kind and supports from Institute. No fund from out sidewas entertained. My personal fund was utilized in the early stages of development of Indica andfor conducting the field trials in the village farms in nearby my village.

Conflict of interests: The authors have declared that no conflict of interest exists.

Acknowledgement: Author(s) acknowledge the supports from institutes involved. The lab work was done in our Institute.It is suitably acknowledged

Abstract

A short statured variety Indica with open type of canopy that matured in 130 days yielded 2246 kg of seed cotton ha^{-1} with better quality of fibres than the other popular varieties MCU5, MCU5 VT and Surabhi which recorded 6.50 to 12.15% lesser yield in the village farms with lower quality of fibres than Indica. The bleached fibres of variety Indica were brighter white in colour with lower tinge of yellowness than the other varieties. Upon dyeing with a blue and a red reactive dye to 0.5% shade, the uptake of dyes by Indica was more than the other varieties and it left lesser dye in the dye bath irrespective of the dye. The variety MCU 5VT recorded the lowest dye uptake and left more dye residue in the dye bath as compared to the other varieties. The dyed fibres of Indica were darkest in colour with better colour strength than the other varieties which may save some dye costs for the textile industries since a darker colour can be produced with lesser amount of dye. Since Indica left least residual dye, dye effluent from this variety will cause lesser damage to the environment and soil. It may also help the Textile industries to spend less on treatment of dye effluent as lesser quantity of residual dye is likely to be present in it. Use of this cotton variety may thus reduce the overall dyeing costs and make the garments made out of the fibres of this variety to cost less than the other popular cotton varieties.

Keywords: Hirsute cotton, short stature, open canopy, fibre dyeing

1. Introduction

Cotton is one of the principal crops belonging to the genus *Gossypium* interlinked with culture, civilization, economy and livelihood of mankind. Among the known fifty species of *Gossypium* (Wendel et al., 2009), only four of them, *G. arboreum*, *G. herbaceum*, *G. hirsutum* and *G. barbadense* are being cultivated in 2.5% of the world's arable land in 70 countries producing annually 110 million bales of cotton (Shahbandeh, 2019). A large number of high yielding varieties and hybrids of cotton have been developed in the different countries in recent decades to meet the increasing demand of the growing population of mankind. But their cultivation is interlinked with several eco-social problems (Beaudry, 2020) due to their bushy nature of canopy with indeterminate growth habits and indiscriminate use of chemicals (Sundaramurthy, 2002). The non-bushy determinate, short statured early maturing cotton varieties (Sundaramurthy, 2003) and hybrids (Sundaramurthy, 1996) with high degree of photosynthesis, efficient utilization of increasing CO_2 in the environment, water and nutrients with easy penetrability of applied

Article History
RECEIVED in 04th September 2020 RECEIVED in revised form 20th October 2020 ACCEPTED in final form 29th October 2020

insecticides onto all parts of the plant canopy, with high productivity is the need of the hour under the global warming situation (Sundaramurthy, 2017) as the global warming will increase the use of garments and bedding made out of cotton. It would also be more amenable to mechanical picking which is desirable in view of the shortage and high cost of labour in cotton farming. The developed short statured hirsute cotton variety Indica with open type of canopy that utilizes less chemicals and matures in a short period giving better yield with good quality fibres would be much needed in the current global warming scenario. Dyeing is a vital process in cotton industry as it improves the aesthetics of finished textile goods. The history of dyeing is almost as old as human civilisation (Saxena and Raja, 2014). Today mostly synthetic reactive dyes are being used for dyeing cotton goods on account of their brilliant shades and good fastness properties (Raja et al., 2020). As these dyes are costly and also difficult to biodegrade, dyeing performance of the fibres of this new cotton variety Indica with other popular varieties was studied and their possible impact on the environment and textile industry are presented in this communication.

2. Materials and Methods

2.1. Development of variety and collection of fibres

The variety Indica was developed by hybridizing two short statured hirsute strains (Sundaramurthy, 2003). The F1 seeds from a single boll were used for raising the progenies. Pedigree method was employed for further selection of progenies with high single plant yield with the desired quality of fibres. On stabilization they were tested for four years (2015 to 2018 crop season) in the village farms on one acre plots following the recommended agronomy (Sundaramurthy, 2019). The hirsute varieties MCU5, MCU5VT and Surabhi that were popularly grown in the villages were used for comparisons. The raw cotton fibres collected at random from the village farms were used for studying their dyeing behaviour in the present study.

2.2. Scouring and bleaching

A mild preparatory process consisting of single step scouring and bleaching was followed to remove non-cellulosic impurities and to make the fibres absorbent and ready for dyeing. 12 g samples of each variety were treated in two replications with process liquor at 120°C temperature for 1 hour in Infracolour IR beaker dyeing machine (R.B. Electronics, Mumbai). The process liquor consisted of 1 gpl sodium hydroxide, 1 gpl hydrogen peroxide (50%), 0.5 gpl sodium silicate and 0.5 gpl wetting agent Ultravon WA in water. Material to liquor ratio was 1:15. After completion of the treatment, samples were cooled and first washed with hot and then with running tap water. These were then dipped in 0.1% acetic acid solution for 10 mins to remove traces of alkali, rinsed again with tap water till neutral and air-dried.

2.3. Dyeing

Bleached, air dried samples were dyed with two reactive dyes Novacron Dark Blue S-GL and Novacron Ruby S-3B (Huntsman Chemicals) using exhaust method. Dyeing was carried out to 0.5% shade (on weight of fibre) and material to liquor ratio of 1:20 was used. Two replicates weighing 5 g each of bleached cotton fibres of each variety was used for dyeing. Similar dyeing procedure was used for both the dyes. Fibre samples were introduced into the dye liquor kept in separate stainless steel beakers in the IR beaker dyeing machine at room temperature (30°C) and dyeing machine was run at this temperature for 15 mins. Then 40 gpl Glauber's salt (sodium sulphate) was added to each beaker and temperature was raised to 60°C. Dyeing continued at this temperature for 30 mins, 10 gpl sodium carbonate was then added to the dyebath for fixing the dye and dyeing further continued for 20mins. The bath was then allowed to cool, dyed fibre samples were removed, washed with water, soaped with Ultravon WA at 70°C for 15 min, washed again with tap water and air-dried. The exhausted and original dyebaths from two replicates were appropriately diluted for absorbance measurements to calculate dyebath exhaustion.

2.3. Dyebath exhaustion

Absorbance values of the original and exhausted dyebaths after appropriate dilution were recorded in the UV- visible spectrophotometer (Analytik Jena) at the wavelength of the maximum absorption (λ_{max}) of the respective dyes. Percent dyebath exhaustion for each dye was then calculated by using the following formula-

Percent dyebath exhaustion= A_o-A_{exh}/A_o×100

Where A_o is the absorbance of the original dye bath and A_{exh} is the absorbance of exhausted dyebath

2.4. Evaluation of colour characteristics of bleached and dyed samples

Dried bleached samples were opened in a Shirley fibre opener and their percentage reflectance was measured in a reflectance spectrophotometer (Spectrascan 5100, Premier Colorscan, Mumbai) which was then used to calculate the whiteness index (CIE) and colour coordinates by colour matching software. Dyed samples were also similarly opened up and evaluated for reflectance characteristics which were used to calculate colour coordinates and K/S (colour strength) values using the Kubelka- Munk equation:

$K/S=(1-R)^2/2R$

Where K is the Absorption Coefficient, S is the Scattering Coefficient and R is the reflectance.

3. Results and Discussion

The short statured hirsute cotton variety, Indica (Figure 1) with open canopy, growing to a maximum height of 120-130 cm with short internodes and 16-18 boll bearing sympodial

Figure 1: The structure of the variety Indica in the farmer's field

branches matured in 130 days. It recorded a mean yield of 2246 kg ha^{-1} in Farmers' fields in the villages with 4-5 applications of insecticides.The mean fibre length of Indica was 34.27 mm with the strength of 23.02 g tex^{-1} and had a high degree of polymerization of 3926, While the other varieties MCU 5, MCU 5VT and Surabhi recorded (Sundaramurthy, 2019). A mean yield of 2020, 2100 and 1973 kg ha^{-1} respectively with comparatively lesser length ranging from 23.50 to 33.40 mm and strength varying from 22.10 to 24.02 g tex^{-1} with degree of polymerization ranging from 2490 to 3360 which was 14.42 to 36.58% lower than Indica (Table 1).

Although the nature has provided coloured cotton (Sundaramurthy et al., 1994) along with white cotton they are with short and weak fibres mostly of brown colour with poor yields hence are difficult to process in the mill and unable to meet the demand of the growing population and fast changing fashion. Hence the fibres of white cotton are being dyed with the organic and inorganic chemicals to improve the aesthetics of the fabric made out of them to meet the demands of the mankind. As dyeing is carried out in aqueous medium, it is necessary to first make the fibre hydrophilic and white so that it can absorb dyes and good colouration is produced. The properties of the scoured and bleached fibres of different hirsute varieties showed that the fibres of cotton variety Indica were whiter as these recorded the highest whiteness index of 72.05 and lightness (L^*) value of 94.10 than the other varieties (Table 2). The lighter colour and maximum whiteness of fibres of Indica is likely to confer darker colour to the fabrics than other hirsute varieties. The fibres of MCU-5 were next in whiteness to Indica with whiteness index of 68.45 while the variety MCU-5 VT a reselection made from MCU5 for Verticillium wilt tolerance though had same degree of lightness (L^*) of 93.15 was found to have the lowest whiteness index of 66.10 due to slight tinges of yellowness as seen from its b^* value and this might be due to changes in the gene profile as compared to MCU5. The fibres of variety Surabhi followed Indica in lightness value but again due to the presence of a tinge of yellowness as evident from a slightly higher positive value of b^*, its whiteness index was lowered to 67.60 (Table 2) and this might be due to structural differences of the fibres. All varieties however had satisfactory whiteness and were free of colour as seen from the very low values of both a^* and b^* and hence were suitable for dyeing.

Table 1: Mean productivity of cotton and quality of fibre of the different hirsute varieties grown in the farms of different villages in Tamilnadu

	Indica	MCU 5	MCU5 VT	Surabhi	Mean	SEm±
Yield of seed cotton (kg ha^{-1})	2246	2020	2100	1973	2084	59.80
2.5% Span Length (mm)	34.27	33.40	33.50	23.50	31.16	2.56
Strength (g tex^{-1})	23.02	24.40	22.10	22.70	23.05	0.49
Micronaire (ug $Inch^{-1}$)	3.83	3.60	3.70	3.60	3.70	0.05
Degree of polymerisation	3926	3229	3360	2490	2946.40	286.33
Cuprammonium Fluidity at 20 deg, C Poise	0.88	1.01	2.79	2.39	1.77	0.37

Table 2: Properties of bleached fibres of different cotton varieties

Cotton variety	Whiteness index (CIE) (Mean)	Colour coordinates (CIELAB 1976)** (Mean)		
		L^*	a^*	b^*
MCU 5	68.45	93.15	-0.35	3.40
MCU 5VT	66.10	93.15	-0.50	3.90
Surabhi	67.60	93.75	-0.05	3.90
Indica	72.05	94.10	-0.35	3.05
Mean	68.55	93.53	0.31	3.56
SEm±	1.26	0.24	0.09	0.21

**L*: lightness axis from black (0) to white (100), b*: Blue/ yellow axis (-) blue to (+) yellow, a*: green/ red axis, (-) green to (+) red

The results of dyeing performance of fibres of different cotton varieties with Novacron blue and Novacron Ruby red dyes showed that the colour space of the fibres of different varieties dyed with the blue dye was less than the red one (Table 3) However the percent dye bath exhaustion of both dyes for all cotton varieties was above 80 which is quite good. Higher dye exhaustion results in higher uptake of dye by the fibre from the dye solution and leaves lesser residual dye in the dye bath. Among varieties studied, Indica had highest dye bath exhaustion of 82.4% for blue dye and 82.8% for red dye and left a lesser level of 17.60 and 17.20% residual blue and red dyes respectively in the dye bath which is lower as compared to other varieties (Table 3). The dyed fibres of Indica were darkest in colour at the similar 0.5% shade depth as compared to other varieties indicating that the fabric made out of such fibres will consume less quantity of dye and look darker in colour than the fabrics made from the fibres of other varieties. The varieties MCU 5 and Surabhi had almost samelevel of dye bath exhaustion for blue dye which means that they left almost same level of residual dye (19.00%) for this dye. But for red dye, dye bath exhaustion varied a little with Surabhi recording a little dyebath exhaustion of 82.45% next only to Indica. Dyebath exhaustion for MCU 5 was lower and it left 18.35% while Surabhi left only 17.55% of the red dye jn the dye bath. The variety MCU5 VT had the lowest dye bath exhaustion of 80.2% for the blue dye and 81.25% for the red dye and left 19.80 and 18.75% residue of blue and red dyes respectively in the dye bath and this variety is likely to cause more damage to the health of soils and environment due to higher dye discharge than the variety Indica if the effluents are not neutralized properly before letting out into the environment.

The colour strength of the dyed materials as measured by their K/S values at λ_{max} showed that Indica was best and was followed by Surabhi in case of blue dye and MCU-5 for the red dye. Interestingly, Surabhi showed lowest value of the colour strength for red dye while for blue dye it was same as that of MCU-5. The variety MCU5 VT had a K/S value of 1.70 for the blue and 1.86 for the red dye as against MCU5 which had lesser colour strength with K/S values of 1.60 and 1.79 for the blue and red dyes respectively. Interestingly, the variety MCU5 VT had 9.41% higher strength for red dye in spite of its lower dye bath exhaustion and L^* value (Table 3) and this might be due to the nature of the chemical molecules of red dye and their degree of affinity might be more towards the molecules of the fibres than the other dye. The fibres of variety Indica had a lowest L^* value of 58.60 and therefore as expected, the strength of colour of both dyes for this variety was highest as it recorded K/S values of 2.03 and 2.04 for blue and red dyes respectively and with lowest L^* values resulted in the darkest coloured fibres. This might be due to the presence of more specific surface area on the fibres and high micronaire as reported earlier (Crowle, 2017) as Indica had higher micronaire than other varieties (Table 1). As both colour strength and dye exhaustion were higher for this variety, it seems to have been caused by the structural differences in the fibres rather than the loose adherence of hydrolysed dye molecules on to the fibres which might have been the case if only dyebath exhaustion was higher.

Table 3: Dyeing performance of cotton fibres of different varieties with Blue and Red dyes

Cotton variety	Dyebath exhaustion (%) (Mean)		Residual dye left in dyebath (%) (Mean)		K/S at λ_{max} (630 nm) (Mean)		Colour coordinates (CIELAB 1976)**					
							Blue dye (Mean)			Red dye (Mean)		
	Blue dye	Red dye	Blue dye	Red dye	Blue dye	Red dye	L^*	a^*	b^*	L^*	a^*	b^*
MCU 5	81.00	81.65	19.00	18.35	1.60	1.79	62.30	-10.50	-16.20	64.5	43.5	-10.30
MCU 5VT	80.20	81.25	19.80	18.75	1.70	1.86	59.50	-10,40	-16.60	63.0	43.0	-9.85
Surabhi	81.00	82.45	19.00	17.55	1.85	1.70	60.20	-10.40	-16.60	64.0	46.0	-10.50
Indica	82.40	82.80	17.60	17.20	2.04	2.03	58.6 0	-10.60	-17.00	62.0	43.0	-10.05
Mean	81.18	81.18	18.85	17.96	1.81	1.85	60.24	-10.50	-12.35	63.4	44.4	-10.16
SEm±	0.66	0.36	0.32	0.45	0.11	0.07	0.74	0.04	4.07	0.39	0.63	0.14

**L*: lightness axis from black (0) to white (100), b*: Blue/yellow axis (-) blue to (+) yellow, a*: green/ red axis, (-) green to (+) red

It is evident from the literature that any varieties or hybrids that are leaving less quantity of dyes in the dyebath after dyeing process can be considered to be environmentally friendly as the dyes are known to degrade environment (Hasanuzzaman, 2016) change the physico-chemical properties of soil (Ahmad et al., 2012), erode the fertility of soil (Malik, 2017), impair photosynthesis, inhibit plant growth, enter into the food chain and affect the health of living beings (Lellis et al., 2019) and may induce the chromosomal aberrations in crop plants (Lbeh and Umeham, 2018). It is evident from the present study that the fibres of variety Indica were whiter in colour upon bleaching and took up more dye upon dyeing thus left lesser residual dyes in the dye bath and caused lesser damage to the environment than other popular varieties. As the colour strength of this variety was more upon dyeing in comparison to other variety when dyeing with similar amount of dye which may also help the textile industries to invest less on the dyes for dyeing of the fabrics and neutralization processes of the effluents before these are let out into the environment and thereby reduce the cost of the garments.

The present study indicates the possibility of developing high yielding short statured cotton varieties and hybrids with the open canopy with quality fibres having high degree of polymerization of cellulose and capability to uptake more dyes and leave less dye in the dye bath after the dyeing processes which will meet the requirement of mankind with less disturbances to the health of the soils and environment including living beings under the global warming situation.

4. Conclusion

A short statured variety Indica matured in 130 days and yielded 2246 kg ha^{-1} of cotton with better quality fibres than the other varieties. The bleached fibres of Indica were whiter in colour with better colour strength upon dyeing than other varieties. The uptake of the dyes by Indica was higher and left least residual dye than others indicating its ability to cause lesser damage to the environment Since the dyed fibres of Indica were darkest in Colour, they would yield darker coloured fabrics with less consumption of dyes.

5. Acknowledgement

The assistance rendered by Mr. V. S. Senthil Kumar and Mrs. Anusuya Sundaramurthy for developing the variety in the home garden is acknowledged with thanks. Thanks are also due to Dr. P. G. Patil, Director and Mr. Ravi. R. Chhagani, Technical officer. ICAR- Central Institute for Research on Cotton Technology, Mumbai for their help and facilities provided for dyeing the fibres. The help provided by Dr. A.N. Desai, Director, Bombay Textile Research Association, Mumbai for testing the quality of fibres is acknowledged with thanks.The assistance rendered by Mrs D. Subhadra, Sugarcane Breeding Institute, Coimbatore, the farmers of the different villages, and the staffs of The South Indian Mill Owners Association, Coimbatore are gratefully acknowledged with thanks

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