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Short-season cotton (*Gossypium hirsutum*) may be a suitable response to late planting in sub-Saharan regions

Tuong-Vi Cao[a,*], Palaï Oumarou[b], Gérard Gawrysiak[a], Célestin Klassou[b], Bernard Hau[a]

[a] CIRAD, Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Avenue Agropolis, TA B-102/02, 34398 Montpellier Cedex 5, France
[b] IRAD, Institut de Recherche Agricole pour le Développement, BP 33, Maroua, Cameroon

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ABSTRACT

In Cameroon, seed cotton yields have not increased over the last 20 years because of the shortening of the rainy season and the worsening socioeconomic context. Farmers consequently often delay planting their crops. The main objective of this study was to investigate whether local indeterminate long-season cottons, grown at the recommended density, were more consistent with the farmers' current constraints than determinate short-season cultivars from Latin America that could be sown more densely. We carried out a 3-year three-location survey in northern Cameroon, which included two planting dates (recommended and delayed) and two planting densities (recommended and high). We show that these three factors acted independently. Late planting had a highly negative impact on most traits at both plant and plot scale by delaying flowering, reducing seed cotton yield and fibre quality. Dense sowing mainly had an impact on individual plant traits by reducing boll retention and elongating main-stem internodes. Local cultivars have already evolved favourably (enhanced earliness, yield performance, harvest index, ginning out-turn, and fibre maturity) and could be improved further by crossing with highly determinate cottons. However, such a strategy requires further investigation to ensure that a more determinate growth pattern would not have a negative impact on the adaptive response of the traditional cotton plant to other adverse conditions.

1. Introduction

Because cotton (*Gossypium hirsutum* L.) is the main cash crop in most of the sub-humid region of West Africa, improved cultivars and cropping systems are needed to encourage economic development. Cotton adaptation and productivity in sub-Saharan Africa is an important issue for African cotton producing countries, particularly in the current context of global climate change and unfavourable regional socioeconomic conditions (Pichot et al., 2006). Cotton faces the same difficulties as other crops grown in the area (InterAcademy Council, 2004; FAO, 2006; Lane and Jarvis, 2007).

Cotton has a particular growth pattern. During part of its cycle, vegetative growth occurs concurrently with the development of fruits or 'bolls'. This results in competition for the allocation of photosynthates to benefit fruiting and vegetative growth, with a higher priority of the former over the latter. When the demand for assimilates of growing bolls balance or exceed the carbohydrates supply at the plant scale, the vegetative growth will temporarily stops until the end of boll ripening. This phenomenon can be referred to as "physiological cut-out", defined by Oosterhuis et al. (2008), which is to be distinguished from another form of cut-out that can also occur in adverse weather conditions, the "premature cut-out". Cut-out enhances the versatility of cotton (Oosterhuis and Jernstedt, 1999). When boll development is stalled by stress, the plant switches to channelling photosynthates in favour of vegetative development. New bolls may then develop to replace the ones that have been shed. The cut-out is more or less pronounced depending on the cultivars, i.e., the determinism of the plant growth.

In French-speaking Africa, the 'indeterminate' type widely prevails (Sekloka, 2006). This type features high growth vigour, abundant flowering, high physiological shedding, and gradual boll formation. The cut-out is not clearly defined because at this point, the first bolls have mostly already ripened and the vegetative phase may begin again. An indeterminate growth pattern enables cotton plants to respond appropriately to adverse conditions (pest infestation and irregular rainfall). This is of interest for farmers who grow cotton in extensive rainfed cropping systems, which are common throughout Africa (Crétenet, 2006). On the other hand, the 'determinate' short-season type features early flowering, grouped fruiting, lower physiological shedding, as well as clearly defined cut-out, which may last several weeks. This ideotype is common in mechanized cropping systems in the Americas, for instance.

Like in all French-speaking Africa, seed cotton yields in Cameroon increased regularly until the mid-1980s, peaking at around 1200 kg ha^{-1} (Deveze and Halley des Fontaines, 2005) with

* Corresponding author. Tel.: +33 4 67 61 58 00x54 60; fax: +33 4 67 61 55 00.
E-mail address: tuong-vi.cao@cirad.fr (T.-V. Cao).

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Table 1
Experimental design at three test sites representative of the cotton-growing area in Cameroon (2003, 2004, 2005).

Site	Djalingo	Makébi	Kodek
Department	Bénoué	Mayo-Kani	Diamaré
Province	Nord	Extrême-Nord	Extrême-Nord
Site closest city	Garoua	Kaélé	Maroua
Latitude	9°18′N	10°06′N	10°35′N
Longitude	13°24′E	14°27′E	14°19′E
Annual rainfall (mm)			
2003	971 mm	912 mm	836 mm
2004	885 mm	628 mm	543 mm
2005	708 mm	734 mm	695 mm

Date of first and last rain > 1 mm

Year	First	Last	First	Last	First	Last
2003	02 June	23 October	02 June	23 October	03 June	13 October
2004	01 June	24 October	03 June	19 October	01 June	23 September
2005	05 June	23 October	04 May	19 October	01 July	05 October

Plant density

Recommanded	62 500 (0.8 m × 0.4 m)	100 000 (0.8 m × 0.25 m)	100 000 (0.8 m × 0.25 m)
High density	167 000 (0.6 m × 0.2 m)	167 000 (0.6 m × 0.2 m)	167 000 (0.6 m × 0.2 m)

Planting date

Year	Early	Late	Early	Late	Early	Late
2003	19 June	14 July	07 June	14 July	14 June	08 July
2004	08 June	14 July	08 June	15 July	09 June	13 July
2005	13 June	07 July	10 June	07 July	08 June	06 July

Preplanting cultivation	2003: no tillage; plots were seeded in drilled holes 2004: planting after animal or tractor drawn tillage 2005: planting after animal or tractor drawn tillage		
Thinning	Two plants per hole at the 3- or 4-true leafs stage for all sites		
Organic fertilization before planting	None	5 tons ha^{-1} manure	None
Chemical fertilization after thinning	Early planting: 200 kg ha^{-1} 15–20–15 Late planting: 100 kg ha^{-1} 15–20–15 45 days after planting: 50 kg ha^{-1} urea	Early planting: 200 kg ha^{-1} 22–10–15 Late planting: 100 kg ha^{-1} 22–10–15 45 days after planting: None	Early planting: 200 kg ha^{-1} 22–10–15 Late planting: 100 kg ha^{-1} 22–10–15 45 days after planting: None
Pest and weed management	Maximum weed control for all sites Weekly pesticide treatments for all sites		

recent cultivars producing 30–45% more than older cultivars as estimated by Lançon et al. (1990). However, in the last 20 years yields have levelled off, which could be explained by climatic and biotic factors, especially the shortening of the rainy season and the development of pest resistance to pesticides. Deveze and Halley des Fontaines (2005) also identified unfavourable socioeconomic factors, including the drop in the purchase price of cotton, and farmers' land-use strategies (as farmers are not encouraged to sustainably improve the land because of the absence of land property rights), and the lack of training and extension for young farmers and new farmers. As a result, increasing numbers of farmers are adopting cropping practices that are unsuitable for cotton: reducing fertilizer, cultivating infertile plots, and planting late.

This prompted us to address the question of the mismatch between current recommendations and real cropping constraints, which include a wide range of yield potentials and cropping practices, including late planting. Sekloka et al. (2008) proposed using short-season cultivars with low vegetative growth adapted to both late planting and high plant density.

In order to validate Sekloka's proposal under the conditions that prevail in Cameroon, we conducted a 3-year study at three sites in northern Cameroon representative of the Cameroonian cotton-growing area. The objective was to evaluate the potential of short-season cottons, (1) in comparison with currently used local cultivars, (2) with recommended planting and late planting, as well as (3) with recommended spacing and high plant density. We considered most traits of interest to breeders (including fibre quality) to better account for the high compensatory capacity of the cotton plant.

2. Materials and methods

2.1. Experimental design

The trials were carried out over a 3-year period in northern Cameroon at three test sites representative of the Cameroonian cotton-growing area. The rain distribution in this tropical region is typically mono-modal with rainfall lasting for 4–5 months from May–June to September–October, with local differences between sites due to either their latitude or altitude. Rainfall data (Table 1) conform to the classification of Bella-Medjo (2008): annual precipitation of 970–1430 mm at Djalingo in the southern area and