MONITORING THE GROWTH OF COTTON GROWN IN LOW DENSITY IN THE HUMID/SUBHUMID TROPICS

Y. Crozat
CIRAD-CA
Montpellier, France
P. Kasemsap
Kasetsart University
Bangkok, Thailand

Abstract

Plant structure components related to variation in yield between 25 thai cotton fields grown at low plant density were investigated in the cotton growing area of Chaibadan District, Lopburi Province, Thailand during 1994 and 1995. Despite a low contribution of P1 bolls to yield and a high number of sympodia, survival of P1 fruits of the first-ten fruiting nodes together with the change in Height to Node Ratio (HNR) provided a meaningful appraisal of the origin of yield variation between farm plots. The relevance of these criteria was validated with data from an additional 75 plots surveyed in 1993. Standards for predicting yield and adjusting crop management decisions to actual plant structure were generated.

Introduction

User-friendly techniques for monitoring changes in cotton growth have been successfully developed for adjusting crop management to plant structure in the American cotton-belt (Hake et al., 1994, Bourland et al., 1994, Klein et al., 1994 and Kirby and Hake, 1994). However cultivars and plant structures in the USA differ much from those found in humid and sub-humid tropical conditions such as in Thailand. In Thailand, field-grown cotton plants display exuberant growth and fruiting as a result of a long growing season (130-150 days) and a low plant population (< 30.000 plants.ha^{-1}). The aim of this study was to assess the relevance of plant monitoring techniques for such conditions. It was assumed that for being considered as a relevant technique, plant structure components recorded during the monitoring should fairly explain yield variation between farm plots.

Identification of key components of plant structure

Methods

In the cotton growing area of Chaibadan District (14.7 lat., 101 long.), Lopburi Province (Thailand), 20 and 15 farm plots (2.000 m² to 9.000 m²) were chosen in 1994 and 1995, respectively . All plots were planted with the cultivar Srisamrong 60. After emergence, a monitoring area of 4 rows by 10m long representative of the average plant stand was selected in each plot. Crop management was left to farmers decisions. Plant population averaged 1.9 plants.m^{-2} (± 0.4) in 1994 and 2.3 plants.m^{-2} (± 0.6) in 1995. Changes in plant structure and insects population were monitored at weekly intervals on the same 30 plants (6 groups of 5 consecutive plants/row). The Technique of plant monitoring was adapted from the recommendations of Kirby and Hake (1994). Seed-cotton was harvested by hand (4- 8 picking according to plots) over the whole observation area (4 rows * 10 m). The number of bolls harvested as well as dry-weight of seed-cotton, were measured after each picking. At final picking, 10 out of the 30 monitored plants were pulled-out. All fruiting sites of these plants were inspected in order to provide a comprehensive mapping of the yield structure.

Results

Over both years, averaged seed-cotton production was 2.36 t. ha^{-1}, but large variation existed between plots. Yield ranged from 1.5 to 3.4 t. ha^{-1} in 1994 and from 1.1 to 3.5 t. ha^{-1} in 1995. Variation in boll number was the major determinant of seed-cotton yield (Fig. 1). Conversely the average boll-size which varied little between plots and years, was poorly correlated with the yield ($r^2 < 0.12$). Mainstem-bolls. m^{-2} removed at least 80% of the variation in total boll observed each year (Fig.2). It indicated that bolls on vegetative branches were not a substantial source of differentiation in boll production, although their average contributions to total boll number were 15% and 26% in 1994 and 1995 respectively. Little variation between plots in their contribution explain this result. In addition bolls found on vegetatives per unit area increased linearly with bolls on mainstem (r = 0.74). High contribution of vegetative branches to boll production is a common feature of cotton crop grown at low plant population (Constable 1986, Munro1987). Furthermore, bolls in first position (P1) on mainstem sympodia contributed for less than 30% to total boll production (29% in 1994 and 19.5% in 1995). However, P1-bolls.m^{-2} removed at least 79% of the variation in mainstem-bolls. m^{-2}(r^2=0.79 in 1994 and r^2= 0.82 in 1995). It suggested that P1 bolls could be a fair indicator of yield variation between farmers plots. Thus, in both years, the retention rate of P1 fruits located on the first-ten sympodia along the mainstem was a relevant criteria for analyzing boll production (Fig. 3). *Helicoverpa armigera* infestation from squaring to 10 days after anthesis of the first-ten P1 fruits was the major cause of abscission (Crozat et al., 1995). In plots with low (or no) *H. armigera* infestation (< 3 larvae. 20 pl.-1) boll production increased with the change in Height to Node Ratio (HNR) between node 10 to 20 (Fig. 4). This is in agreement with Kirby and Hake (1994), who reported that change in HNR after node 10 is related to plant growth rate and photosynthesis capacity which in return determine the boll carrying capacity of the stand.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1730-1733 (1998)
National Cotton Council, Memphis TN

Validation step

The relevance of key plant structure components identified previously was tested with another set of data from on-farm trials and agronomic surveys carried-out in 1993 at Lopburi and Kanchanaburi Provinces (Castella, 1996). In total there were 75 plots for which plant mapping at harvest, yield components and seed-cotton yield were available. As shown in Table 1, a large range in plant structure was explored. Seed-cotton yield varied from 0.1 to 3.8 $t.ha^{-1}$. It was the consequence of various pest management programs (such as no control and maximum control) together with planting dates (early June to mid-August) which were tested in the network of plots (Castella et al., 1997). Seed-cotton yield was well correlated with boll-number whose variation was explained to a large extent by the variation in mainstem-bolls (Table 2). The relationship observed between retention rate of the first-ten P1 fruits and boll number confirmed the determinant role of fruit survival and early boll setting on final yield. Like in 1994 and 1995, fruit abscission was mainly caused by *H. armigeria* damage and in a lesser extent by jassid (*Amrasca biguttula biguttula* Ishida) infestation through a reduction in the photosynthesis capacity (Castella et al., 1997). As a result, with the exception of dammage-free plots, their was a weak relationship between boll production and plant growth rate estimated by the change in internode length because abscission caused by bollworms probably masked physiological shedding caused by growth limitation.

These results confirmed that plant growth and yield build-up can be monitored through the change in plant height and nodes of the mainstem coupled with a record of the production and survival of P1 fruits only, despite their low contribution to boll production. It can be assumed that the survival pattern of P1 fruits is a practical appraisal of the survival of other fruits positions of same age-cohort. Two observations support this assumption : (i) in a cohort of iso-born fruits, although P1 fruits survive better than fruits from other positions (Kerby and Buxton, 1981; Constable, 1991, Crozat et al. 1997a) their changes in survival with time were found to follow similar trends (Crozat et al. 1997b); (ii) fruit abscission caused by *H.armigera* (which is a major cause of abscission in our conditions) has been reported to be fruit-age dependent rather than position dependent (Wilson and Guitierrez, 1980).

Generation of standards for crop management

Overall data (110 plots), a typology of cotton fruiting structure based on the survival of P1 fruits located on the first-ten sympodia provided a rather accurate classification of seed-cotton yield observed (Table 3). It indicates that high yield is achieved when P1-fruit retention of the first-half fruiting nodes is high ($70%). In case of poor retention rate of the five-first nodes (<50%) , compensation on upper nodes may exist but in a limited extent since maximum yield never surpassed 2$t.ha^{-1}$. Such a typology provide a framework for predicting potential yield according to the actual fruit retention rate of the crop. On-farm trials are presently undertaken for testing the economic performance of a cessation in bollworms control when the difference between gross product of actual yield (estimated by the number of green bolls. m^{-2} with a diameter > 5 cm) and that of potential yield (Table 3) approaches two times the cost of insecticide spraying.

High yielding plots (>3$t.ha^{-1}$ in our conditions) displayed a similar change in HNR with mainstem nodes appearance (Fig. 5). As proposed by Kirby and Hake (1994) this relationship may be used as a standard curve (an ideal change in plant structure) for assessing if a crop has a proper size for its physiological age. A crop with a change in HNR lower than the standard curve, especially between node 10 and 20, is likely to experience a growth limitation which will limit its boll carrying capacity. According to Figure 1, a carrying capacity of a minimum of 60 $bolls.m^{-2}$ should be targeted for achieving a final yield of at least 3 $t.ha^{-1}$. Change in HNR is also a key criteria for making decisions concerning the application of growth regulators such as Mepiquate Chloride (Constable, 1994). In our conditions, application of Mepiquate Chloride on SSR60 cultivar was found effective when the change in internode length surpasses 6 cm/node durring the week prior application (Fig.6).

The Change in the number of Nodes Above White Flower (NAWF) in high yielding plots was 9 at first flower and decreased steadily at the rate of 0.15 node. day^{-1} (6.7 $days.node^{-1}$) after first flower (Fig. 7). According to Oosterhuis et al., (1993), the decrease in NAWF coincides with the decline in canopy photosynthesis and provides an indication whether the developing bolls or the upper canopy vegetative growth is the predominant sink. NAWF = 5, is generally considered as a critical value below which new fruits produced are likely to abscise in large number (Hake et al., 1994, Bourland et al., 1994, Klein et al., 1994 and Kirby and Hake, 1994). A low NAWF in comparison with the standard pattern indicates an insufficient vegetative growth in comparison with fruit requirement, leading to an early stop of fruiting. Contrastly, high NAWF indicates excessive vegetative growth (often due to fruit loss by insects), low boll setting and a delay in crop harvest. In our conditions, NAWF may be used also for making decision about the cessation of jassid control. According to preliminary results (Renou, personal communication) When NAWF = 3, insecticide spraying against jassids is likely to be cost ineffective.

Summary

As expected, large variation in seed-cotton yield existed between farmers' fields. This variation was related to the variation in boll number. Despite a complex plant fruiting structure, the production and survival of P1 fruits only, together with the change in node number and height of the mainstem were meaningful appraisal of the origins and causes of the difference in boll number. As a consequence, these simple plant monitoring techniques provide decision-making tools for adjusting crop management according to actual yield potential.

Acknowledgments

The authors thank Miss Chuensumon Sriwongklang, Nuntana Hunyon and Mr. Sutat Poonoi for their technical assistance. This research work was partly supported by the Ministry of Foreign Affairs of the Government of France.

References

Bourland F. M., N. P. Tugwell, D. M. Oosterhuis, and M. J. Cochran, 1994. Cotton plant monitoring : the Arkansas system (an overview). In Cotton Physiology Seminar,1994 Beltwide Cotton Conferences, 1280 - 1281.

Castella J.C., 1995. Stratégies de lutte contre les insectes ravageurs dans les systèmes de culture cotonniers en Thaïlande: logiques actuelles et propositions pour une gestion durable. Ph.D disertation, INAPG, Paris, France, 288p.

Castella J.C., Vié K., and S. Savary. 1997. Path coefficient analysis to assess yield losses due to a multiple pest complex in cotton. *Journal of plant protection* in the tropics (in press).

Constable G.A. 1986. Growth and light receipt by mainstem cotton leaves in relation to plant density in the field. *Agric. For. Meteorol*. 37: 279-292.

Constable G.A. 1991. Mapping the production and survival of fruit on field-grown cotton. *Agron.J.* 83:374-378.

Constable, G.A., 1994. Predicting Pix yield responses. Paper presented at the World Cotton Research Conference 1. Brisbane, Australia Feb. 14 - 17, 1994.

Crozat Y., Judais V., Kasemsap P., and A. Saimaneerat. 1995. “Agrophysiology of cotton: progress report II”, DORAS Project, Kasetsart University, Bangkok, Thailand, 94p.

Crozat Y., Judais V., and P. Kasemsap. 1997a. Survival of cotton fruiting forms after a temporary light reduction as affected by fruit age and plant structure. *In* “1997 Beltwide Cotton Conf., Physiology conference, 1432-1435.

Crozat Y., Judais V., Samaneerat A., and P. Kasemsap. 1997b. Development and survival of cotton fruit in relation to plant structure. (submitted to the Kasetsart Journal).

Hake K., Stichler C., and J.C. Banks. 1994. Cotton monitoring in practice: Southwest approach. Proc. 1994 Belt. Cott. Conf., Cotton Physiology Conference, 184-185.

Kirby T.A.., and D.R.Buxton. 1981. Competition between adjacent fruiting forms in cotton. *Agron. J.* 73:730-735.

Kirby T.A. , and K. Hake, 1994. Monitoring cotton's growth. *In* "Cotton Production", edited by T. Kerby, K. Hake and S. Hake, University of California, ANR publications, Chap.15.

Klein C. D. , D. M. Oosterhuis, F. M. Bourland, M. J. Cochran, and N. P. Tugwell. 1994. Practical on-farm experience utilizing the Arkansas system of crop monitoring. "Cotton Physiology Conference", 1994 Beltwide Cotton Conferences, 1288-1290.

Munro J.M. 1987. Cotton. John Whiley and sons. 436p.

Oosterhuis D.M., Bourland F.M., and N.P. Tugwell. 1993. Physiological basis for the node-above-white-flower cotton monitoring system. Proc. 1993 Belt. Cott. Conf., Cotton Ohysiology Conference, 1181-1183.

Wilson L.T., and A.P. Gutierrez. 1990. Fruit predation submodel: Heliothis larvae feeding upon cotton fruiting structures. *Hilgardia*, 48 (2), 24-36.

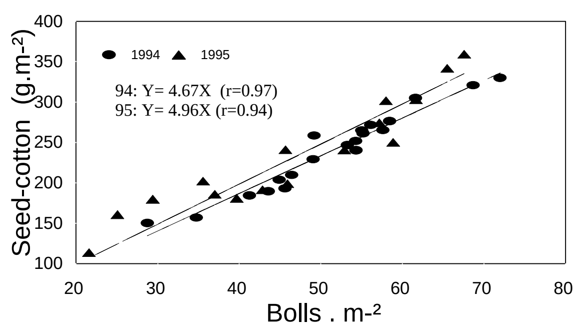

Figure. 1: Seed-cotton yield (in g.m^{-2})recorded in farmers’plots according to the number of bolls harvested.m^{-2}.

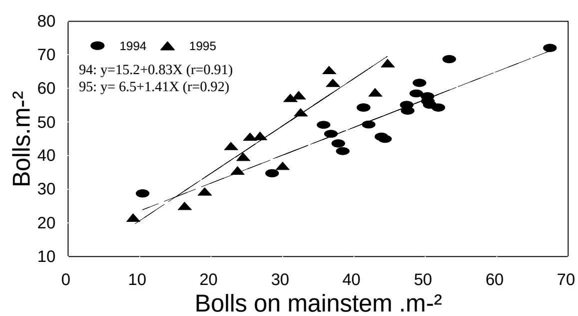

Figure 2: Relationship between the total number of bolls.m^{-2} and the number of bolls located on the mainstem (.m^{-2})

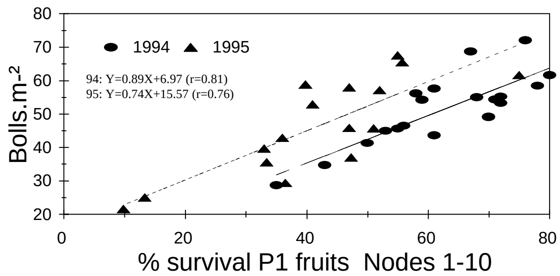

Figure 3: Relationship between the number of bolls.m^{-2} and the survival rate of P1 fruiting sites of the first-ten fruiting sympodia.

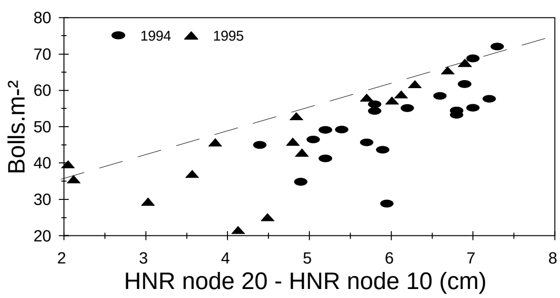

Figure .4: Boll production (Bolls.m^{-2}) according to the change in internode length (Height to Node Ratio) between mainstem-node 10 and 20.

Table 1: Range in plant structure and yield recorded at harvest in the 75 plots used for the validation step.

Plant structure	Mean	min-max
- plants.m^{-2}	1.7	1 - 2.7
- % bolls on vegetatives	36.6	3 - 65
- % bolls on P1	28.1	8 - 48
- fruit. nodes. mainstem $^{-1}$	18.4	10 - 24
- seed-cotton yield (t.ha^{-1})	0.8	0.1 - 3.8

Table 2:Relationships between plant structure components in the 75 plots used for the validation step (*linear regression, r²*)

Seed-cotton (g .m^{-2}) / Bolls.m^{-2}
(*Y = 3.99 X, r² = 0.94*)
Bolls.m^{-2} / Bolls mainstem.m^{-2}
(*Y = 0.92 + 1.21X, r² = 0.92*)
Bolls mainstem.m^{-2} / P1 Bolls.m^{-2}
(*Y=4.84 + 3.96X, r² = 0.73*)
Bolls.m^{-2} / % survival P1 fruits on nodes 1-10
(*Y = 11.5 + 0.63X, r² = 0.64*)
Bolls.m^{-2} / (HNR 90Days - HNR 60 Days)
(linear response of upper points as in Fig . 4)

Table 3: Yielding probability according to boll retention rates of the first-ten P1 fruiting sites (110 fields, SSR 60, 3 years)

% survival of P1 fruits		Probability to reach a yield higher than: (t/ha)					
nodes 1-5	nodes 6-10	0.5	1	1.5	2	2.5	3
H	H	1	1	1	1	1	0.8
H	M	1	1	1	0.9	0.75	0
H	L	1	1	0.4	0	0	0
M	H	1	1	1	0.75	0.5	0
M	M	1	1	0.7	0.5	0	0
M	L	1	0.7	0.4	0.1	0	0
L	H	1	1	0.3	0	0	0
L	M	1	1	0.2	0	0	0
L	L	0.8	0.2	0	0	0	0

H (High) : $70%, M (Medium) : $50% and < 70%
L(Low) : <50%

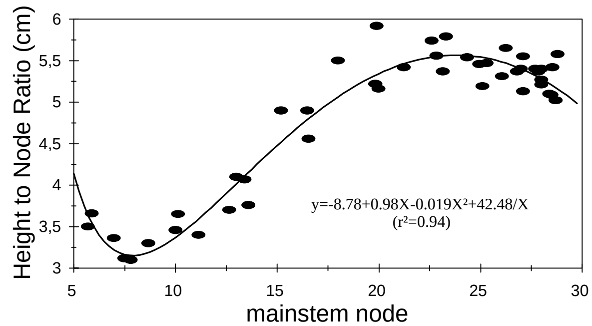

Figure 5: Change in the Height to Node Ratio with mainstem node appearance in high-yielding plots (> 3t.ha^{-1})

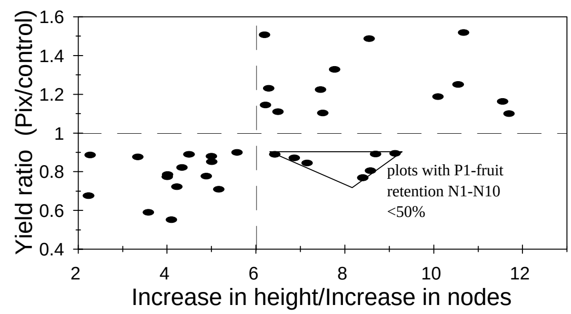

Figure 6: Yield response to Pix application in farmers plots according to the rate of internode increase during the week prior application (*only plots displaying a 10% increase/decrease were considered*).

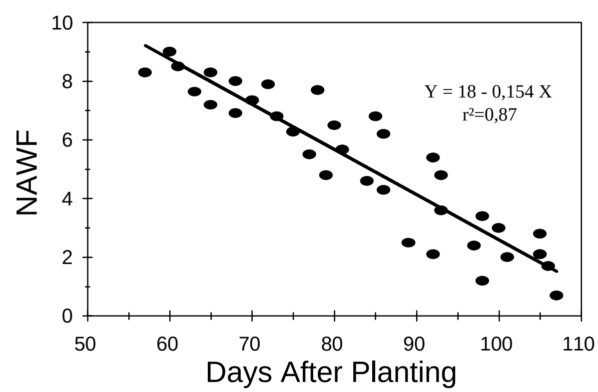

Figure 7: Decline in the number of Nodes Above White Flower (NAWF) recorded in high-yielding plots (> 3t.ha^{-1})