Cotton bollworm economic injury levels based on crop model predictions: Another use of the Cotons® model

S. Nibouche[1, 2], J. Beyo[1], T. Brévault[1, 2], M. Crétenet[2], E. Gozé[2], E. Jallas[2], P. Martin[2] and A.A. Moussa[1]
[1] Annual Industrial Crops Program, IRAD, Maroua CAMEROON
[2] Annual Crops Department, CIRAD, Montpellier FRANCE
Correspondence author samuel.nibouche@cirad.fr

ABSTRACT

The Simbad model has been developed by the authors for modeling the demography and feeding behavior of the four main African species of cotton bollworms. Linked with the cotton crop simulation model Cotons®, CotonSimbad allows an assessment of yield loss due to a bollworm attack, given the size of the pest population, the species composition of the population, the date of the attack and the crop management sequence. The goal of the integrated model is to define rules allowing decision on a chemical spray according to the environment and the crop management. These decision rules have then to be tested at the on-farm level. This paper illustrates the use of CotonSimbad model to produce simple decision rules that can be tested in the field.

Introduction

Currently in sub-Saharan Africa, the control of cotton bollworms is mainly based on insecticide sprays following a fixed-date schedule. The need for rationalization of the use of pesticides requires an evolution toward integrated pest management (IPM). One of the main concepts of IPM is to use insecticides only when the pests are bound to have an actual economic impact on the crop. This approach is based on the use of Economic Injury Levels (EIL), which represent the limit of the size of a population beyond which the pest causes damages whose cost is greater than the cost of the control measure. Defining economic damage thresholds for cotton pests is a complex undertaking, since cotton growth is indeterminate and the plant can compensate for the loss of fruiting organs. A given population of insects can therefore cause varying yield losses, depending on whether or not the crop is able to compensate for the damage. The multiple interactions between the environment, the crop management sequence, plant growth and pest population dynamics make it difficult to establish damage thresholds using a conventional field experimental approach. The recent progress made on the COTONS® model for cotton development (Jallas *et al.*, 1999) has paved the way for a clearer understanding of the interactions between the crop and its environment.

The SIMBAD model (Nibouche *et al.*, 2002; and in press) was developed with a view on modeling the demography and feeding behavior of four species of cotton bollworms (*Helicoverpa armigera*, *Diparopsis watersi*, *Earias biplaga*) and for *Spodoptera littoralis* when it is acting as a boll feeder. Coupling the COTONS® and SIMBAD models allows an assessment of yield losses due to bollworm attacks, depending on parameters such as the size and species composition of the pest population, the date of the attack, crop management sequence, etc.

One of the challenges of the modeling approach to crop-pest interactions is to be able to translate the complexity of interactions into decision rules that can be used in the field. This point is of great significance when these decision-aid tools have to be used in developing countries, where the lack of means for extension services limits the complexity of the messages extended for smallholders. The aim of this paper is to illustrate the feasibility of generating simple decision rules using the integrated Cotons-Simbad model.

Experimental procedure

The example chosen refers to the situation of cotton pest management in Northern Cameroon. In this area, the main cotton pests are bollworms (*H. armigera*, *D. watersi*, *Earias* spp. and *S. littoralis*). Among these bollworms, *H. armigera* has developed resistance to pyrethroids in almost all parts of its distribution area, including West Africa (Vaissayre *et al.*, 1998). In Cameroon, resistance to pyrethroids is not yet well documented, but IRM (Insecticide Resistance Management) strategies are currently being tested and recommended in order to prevent such an evolution. The current IRM strategy is inspired from the window strategy (Forrester *et al.*, 1993; Ochou *et al.*, 1998). Pyrethroids are banned from the beginning of the cropping season and are replaced by endosulfan (Figure 1). A development of this strategy is currently being studied, which consists of using products alternative to pyrethroids in the last part of the season (mid-September to mid-October) when resistant *H. armigera* outbreaks could overcome the pyrethroid-based protection and could cause yield losses (Figure 1). The difficulty in this strategy is that the control of late season *H. armigera* outbreaks requires higher amounts of active ingredients than the amount used at the beginning of the cropping season (due to the higher pest population levels experienced). For example, endosulfan is used at 375 g ha^{-1} at the beginning of the cropping season and at 750 g ha^{-1} at the end of the season. The cost of a 750 g ha^{-1} endosulfan spray is high and such a spray should not be undertaken when the potential yield loss is not high enough. Our goal is to use the CotonSimbad model to define decision criteria to determine if the potential yield loss is high enough to deserve an endosulfan spray at the end of the cropping season.

The cost of a 750 g.ha^{-1} endosulfan spray is equivalent to 40 kg.ha^{-1} of seed cotton (insecticide costs and seed cotton purchase price for the 2000 cropping season). Yield losses were evaluated by comparing the yield of clean seed cotton of an intact vs. an attacked crop with the same cropping sequence (date of emergence, density, fertilizer applications) and environment parameters (soil and climate). We used simulated outbreaks of 100000 1st instar *H. armigera* larvae ha^{-1}.

Where yield losses following such a high infestation level (highly improbable in the field) were lower than 40 kg ha^{-1} seed cotton, it was considered that an endosulfan spray could never be economically justified.

Four sets of simulations were carried out with pest outbreaks starting respectively on September 15th, September 22nd, October 1st and October 8th. Each set of simulations used the parameters listed in Table 1. The combination of these parameters allowed 792 simulations for each of the four sets of simulations.

The 33 years weather data were collected at Bobo-Dioulasso (Burkina Faso), with a mean rainfall of 811 mm (maximum=1116 mm, minimum=587 mm). They are similar to the sudano-sahelian climate encountered in the central part of the Cameroon cotton cropping area (Garoua area).

Results and Discussion

Complete exploration of the results of the simulations is not described here. Several output plant variables were tested as decision criterion: number of squares and green bolls per plant, number of nodes of the principal cotton plant stem (vegetative and fruiting nodes), number of nodes above white flower (NAWF), leaf area, height of plant. The mean number of green bolls appeared as the best decision criterion to decide if an endosulfan spray is justified or not. Illustrations are given in Figures 2 to 5.

With an *H. armigera* outbreak starting on September 15th the critical yield loss of 40 kg.ha^{-1} is almost never attained in crops having more than four green bolls per plant on September 15th (Figure 2). Below this limit of four green bolls, yield losses are highly variable, ranging from 0 to 308 kg ha^{-1}. None of the output plant variables gave a satisfactory explanation of this variability. With an outbreak starting on September 22nd, the relationship is similar (Figure 3). When the outbreak starts on October 1st, the same relationship is noticed but the frequency of yield losses higher than 40 kg ha^{-1} is low (Figure 4). With a pest infestation starting on October 8th, almost no yield losses are higher than the critical yield loss of 40 kg ha^{-1} (Figure 5).

These results suggest that the number of green bolls could be used as a decision criterion for the decision to carry out an endosulfan spray at the end of the cropping season: if the mean number of green bolls is higher than four, no endosulfan spray should be performed. Results of simulations also suggest that from October 8th endosulfan sprays should be systematically avoided.

Conclusion

These results illustrate the use of modeling of crop-pest interaction to produce operational decision-rules for pest management. More work is needed to calibrate the CotonSimbad model with currently extended varieties and to validate in the field the decision-rules elaborated from simulations.

References

- Forrester, N.W., Cahill, M., Bird, L.J. and Layland, J.K. (1993). Management of pyrethroid and endosulfan resistance in *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Australia. Bulletin of Entomological Research - Supplement Series, N°1.
- Jallas, E., Sequeira, R., Martin, P., Crétenet, M., Turner, S. and McKinion, J. (1999). Virtual Cotons, the firstborn of the next generation of simulation model. pp. 393-396. *In* Dugger, C.P. and D.A. Richter (eds) Proceedings of the 1999 Beltwide Cotton Production and Research Conferences, Orlando, January 3-7, 1999. National Cotton Council, Memphis, USA.
- Ochou, O.G., Martin, T. and Hala, N.F. (1998). Cotton insect pest problems and management strategies in Côte d'Ivoire, West Africa. *In* Gillham, F.M. (ed) Proceedings of the World Cotton Research Conference-2, Athens, September 6-12 1998, Volume 2. pp. 833-837. Cotton Research Institute, Thessaloniki, Greece.
- Nibouche, S., Beyo, J., Brévault, T., Crétenet, M., Gozé, E., Jallas, E., Martin, P. and Moussa, A.A. (2002). Cotons®-Simbad: a tool for establishing Cotton bollworm economic damage thresholds. pp 307-308. *In* Villalobos, F. J. and L. Testi (eds) VII Congress of the European Society for Agronomy, Cordoba, July 15-18, 2002. Junta de Andalucia, Sevilla, Spain.
- Nibouche, S., Martin, P., Cretenet, M., Jallas, E. and Turner, S. (2003). CotonSimbad system: modeling feeding behavior of cotton bollworms for evaluation of crop pest interactions. *In* Proceedings of the 2003 Beltwide Cotton Production and Research Conferences, Nashville, January 6-10, 2003. National Cotton Council, Memphis, USA.
- Vaissayre, M., Martin, T. and Vassal, J.M. (1998). Pyrethroid resistance in the bollworm *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in West Africa. *In* Gillham, F.M. (ed) Proceedings of the World Cotton Research Conference-2, Athens, September 6-12 1998, Volume 2. pp. 701-705 Cotton Research Institute, Thessaloniki, Greece.

Table 1. *Model inputs used for the simulations.*

Parameters	Value
Date of emergence of seedlings	June, 17th July, 1st July, 15^{th}
Fertilization	None 200 kg/ha NPK at emergence + 50 kg/ha urea at 45 DAE
Sowing density	80 cm between rows, 20 cm between plants
Variety	IRMA 1243
Weather	33 years from 1950 to 1985
Soil texture	Sandy (50% sand, 20% clay) Clay (20% sand, 40% clay)
Soil fertility	Normal (102 kg.ha^{-1} nitrate, 11 kg.ha^{-1} ammonium, 0.3% organic matter in the 0-180 cm soil layer) Exhausted (half the amounts of nitrogen and organic matter of the “normal” soil)

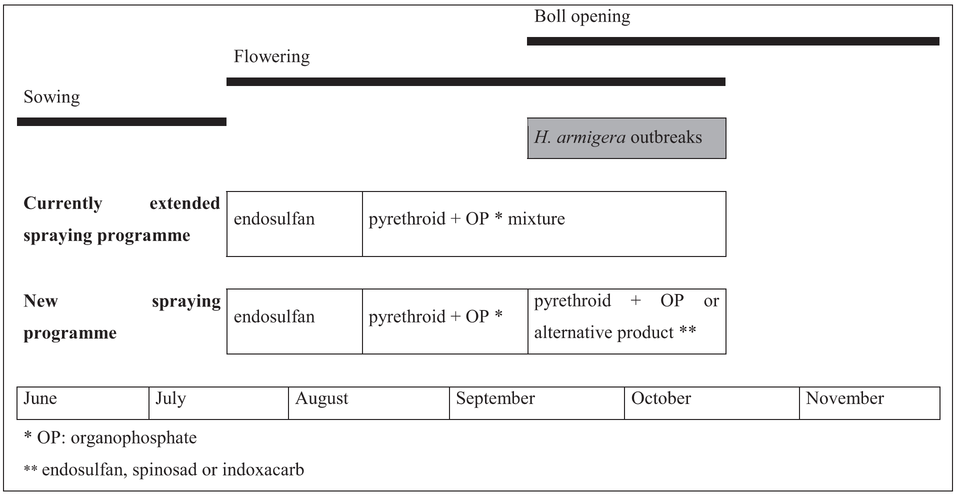

Figure 1. *Cotton crop phenology in Cameroon, schematic schedule of insecticide sprays and the main period of* H. armigera *outbreaks.*

Figure 2.
Relationship between the simulated number of green bolls on September 15th and the simulated yield loss caused by an outbreak of 100,000 larvae of H. *armigera per ha.*

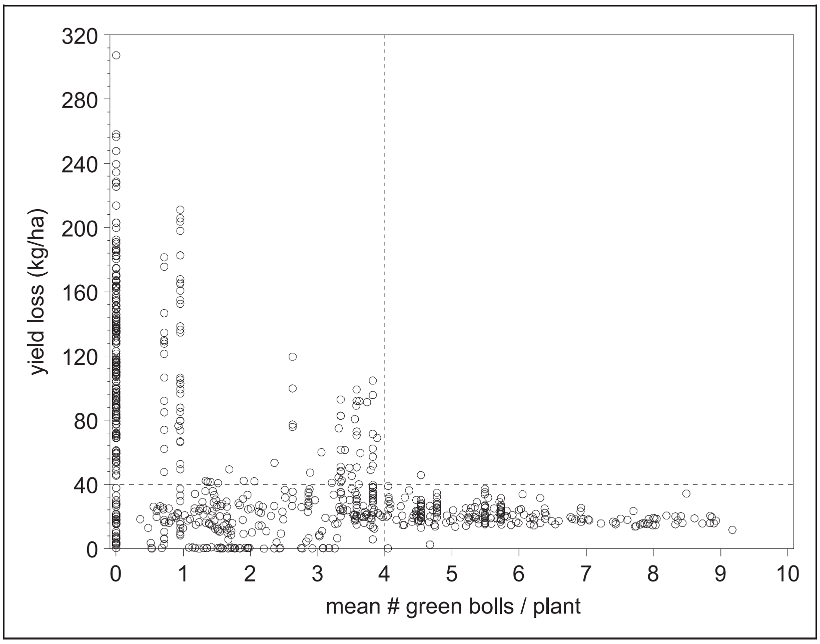

Figure 3.
Relationship between the simulated numbers of green bolls on September 22nd and the simulated yield loss caused by an outbreak of 100,000 larvae of H. *armigera per ha.*

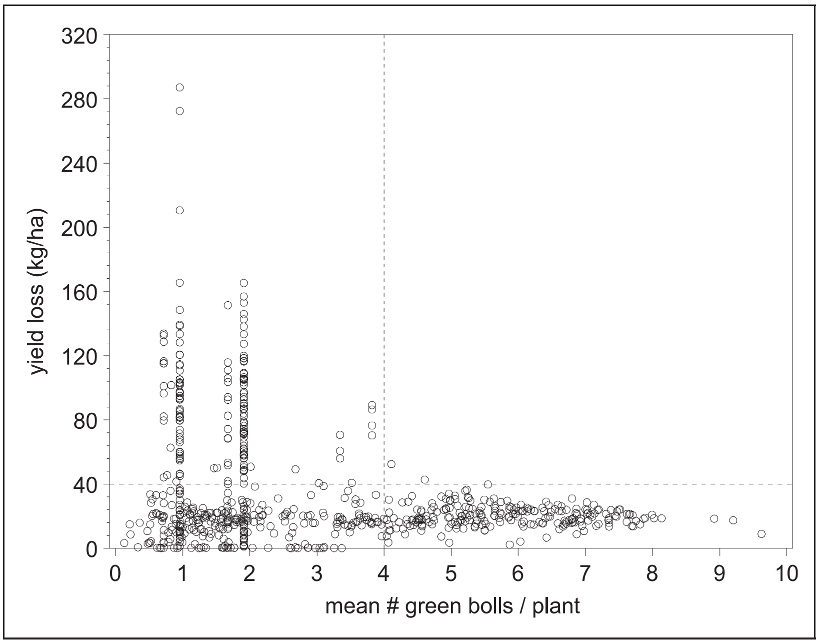

Figure 4.
Relationship between the simulated number of green bolls on October 1st and the simulated yield loss caused by an outbreak of 100,000 larvae of H. *armigera per ha.*

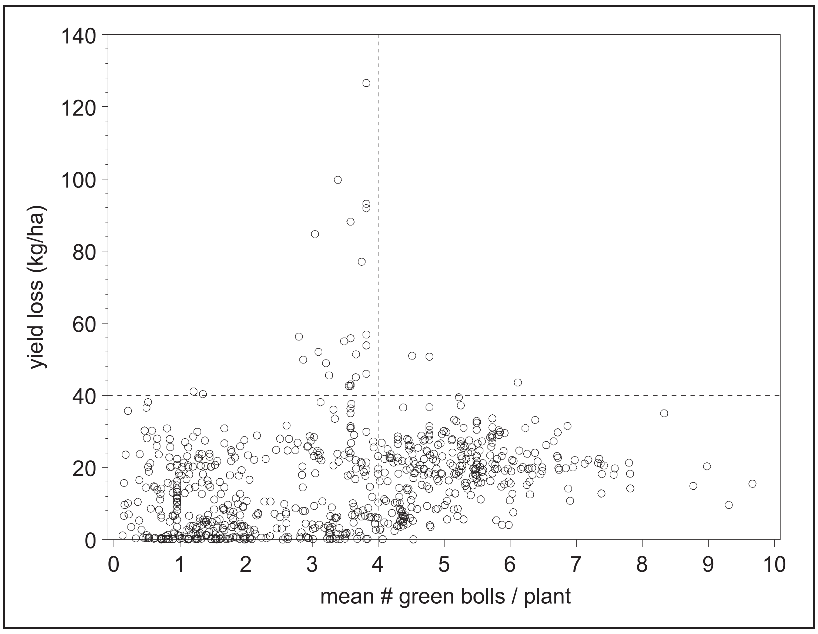

Figure 5. *Relationship between the simulated number of green bolls on October 8th and the simulated yield loss caused by an outbreak of 100,000 larvae of H. armigera per ha.*