Autonomous Mobile Robot for Monitoring and Control of the Cotton Boll Weevil (*Anthonomus Grandis*)

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Abstract The cotton boll weevil is the key pest of Brazilian cotton: its management accounts for about 12% of production costs and, with yield losses, reaches roughly R$ 2470 ha^{-1} per season (≈ US$ 478 ha^{-1}). Because the immature stages develop protected inside the plant, insecticides reach only the adult, which entrenches calendar-based spraying; sparse manual scouting (as few as 0.1 points ha^{-1}) gives little resolution for localised decisions, and non-chemical control tactics, although effective, have not scaled for operational reasons. This paper presents an autonomous mobile robot (AMR) that integrates, on a single platform and across the season and off-season, computer-vision monitoring, mechanical control and localised chemical control, tracing each design decision to the pest's biology and the limits of current practice. A single-row prototype is under field validation in the 2025/26 season.

Keywords: agricultural robotics; integrated pest management; precision agriculture; computer vision; *Anthonomus grandis*

Introduction

The boll weevil (*Anthonomus grandis* Boheman) is the key pest of Brazilian cotton (Rolim et al. 2026). Its immature stages develop protected within the plant, sheltered from natural enemies and contact insecticides, and the pest completes several generations per season, which makes population growth rapid and control difficult (Coelho et al. 2026). Because only the adult is exposed, management relies on calendar-based broadcast spraying (Arruda et al. 2021): in intensive Brazilian production the pest accounts for about 12% of production costs and an average of 18 full-field insecticide applications per season, and combined control costs and yield losses reach roughly R$ 2470 ha^{-1} per season (≈ US$ 478 ha^{-1} at June 2026 rates; Miranda & Rodrigues 2016).

Growers already deploy intensive, well-organised management—frequent scouting, area-wide coordination, cultural control and a regulated sanitary break—so the constraint is not diligence but the available tools. Manual scouting samples as few as 0.1 points ha^{-1}, leaving most of the field unobserved and making localised intervention impractical at scale. Non-chemical control tactics with documented efficacy against the pest can substantially reduce insecticide reliance but have never scaled with manual labour. Agricultural robotics has matured across many field operations, and the enabling technologies for an insect-pest robot already exist in isolation—high-density visual crop monitoring, RTK-free row navigation (Sivakumar et al. 2021) and geostatistical pest mapping (Oliveira et al. 2022)—yet no reported system integrates them on a single ground platform dedicated to the boll weevil. Facing this gap, the authors propose such a platform, with each feature derived from a requirement set by the biology of the pest and the shortcomings of current practice.

Materials and methods

Every capability of the robot answers a requirement set by the pest. Development follows an iterative methodology (Boehm 1988): each subsystem is prototyped and validated in isolation—in simulation, laboratory and field—before integration, with maturity tracked by technology-readiness levels (TRL) and operationalised through the Modified Agile for Hardware Development framework, designed for the long cycles of hardware (Simpson & Sheth 2024); the software stack was built on ROS 2 (Fig. 1). The robot is organised in two subsystems: an autonomous mobile platform that carries locomotion, battery power and navigation on a frame raised above the canopy; and, mounted on it, a monitoring-and-control boom that positions the end-effectors of the perception and control modules. The platform covers an average plot of 200 ha per week with embedded, internet-independent processing, raising sampling density by orders of magnitude over the 0.1 points ha^{-1} of conventional scouting, follows crop rows without RTK and without crop damage.

Computer vision provides high-density monitoring of pest pressure: a convolutional neural network performs the detections, which feed a geostatistical model that fuses them with climatic and agronomic variables into a per-cell presence-probability map (Oliveira et al. 2022). Two complementary control strategies act on that map: a non-chemical mechanical-control module that suppresses the pest by acting directly on the crop, removing a key reinfestation source; and precision chemical control that applies insecticide at ultra-low volume only in the cells above a probability threshold, lowering total input and selection pressure for resistance relative to calendar spraying. Validation is carried out in a field experiment, in partnership with research institutions, that weekly tracks adult presence and crop condition under three management treatments—untreated control, chemical, and mechanical-plus-chemical—in a randomised block design over georeferenced cells, providing ground truth for the perception models.

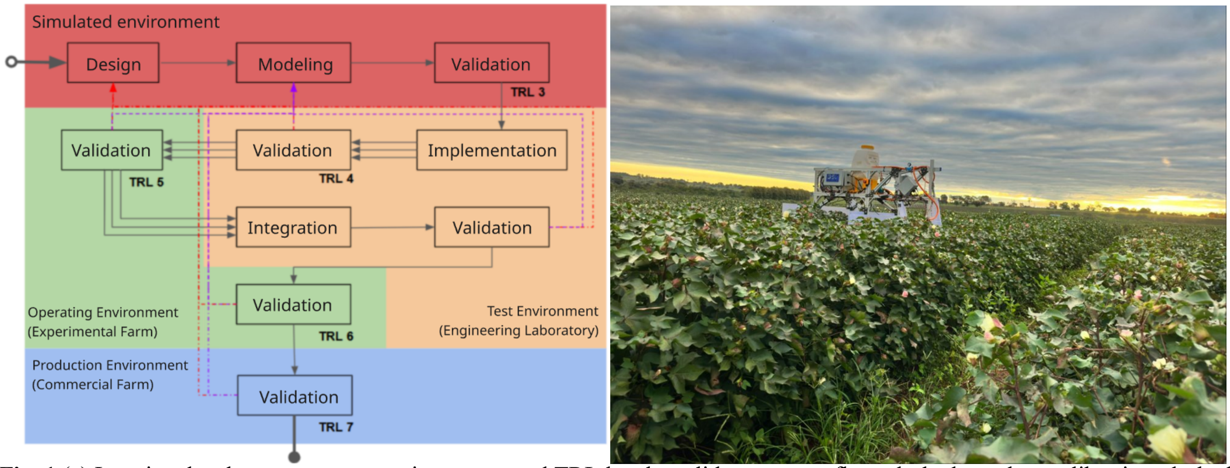

Fig. 1 (a) Iterative development across environments and TRL levels: solid = progress flow; dashed purple = calibration; dashed red = redesign; (b) Single-row prototype of the autonomous mobile robot under field validation

Results and discussion

Row-following navigation by line detection, via sensor fusion, added robustness to the trajectory—including in headland and turning manoeuvres—keeping the robot in the inter-row without crushing plants, even without an RTK-georeferenced map of the rows (Sivakumar et al. 2021). From the georeferenced detections the robot built a heat-map at a density of about one point per 3.6 m², with the weekly scout assessment as ground truth to benchmark detection and calibrate the vision models. The map drives localised chemical control, restricted to the zones with the highest probability of adult presence, while mechanical control is triggered directly on-board by the perception system. A single-row prototype implements this logic in the field (Fig. 2); efficacy and insecticide-saving indicators are being consolidated over the 2025/26 season.

Conclusions

Autonomous boll weevil management is technically and economically feasible. It combines localised chemical control with mechanical control of well-documented efficacy; the barrier to deploying such control at field scale has always been operational, and robotics removes it. By integrating on one platform capabilities that today exist only in isolation, traceable to the pest's biology, the AMR is a concrete step toward autonomous integrated pest management in large-scale cotton farms. Next steps include validation on a commercial plot and scale production in Mato Grosso to operate multiple robots.

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