Integrated Pest Management against Chinese Rose Beetles for Cacao

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Hawaii represents a special niche for cacao (*Theobroma cacao*) production as the highest latitude in the world where cacao is grown commercially. Cacao fermentation here develops a unique chocolate flavor, producing high value cacao estimated at 2 to 4 times greater price than the other cacao traded in the world (Smith et al., 2009). Hawaii cacao faces less disease pressure compared to other parts of the world, and we also have endemic pollinators (O'Doherty and Zoll, 2012) allowing for high cacao yields.

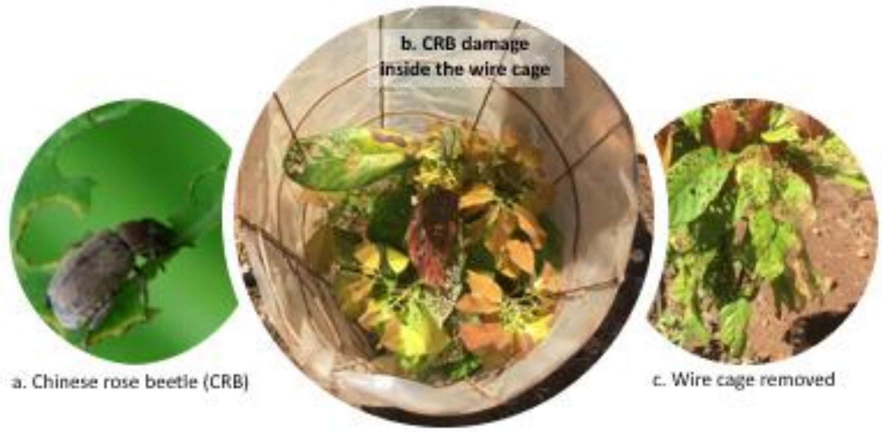
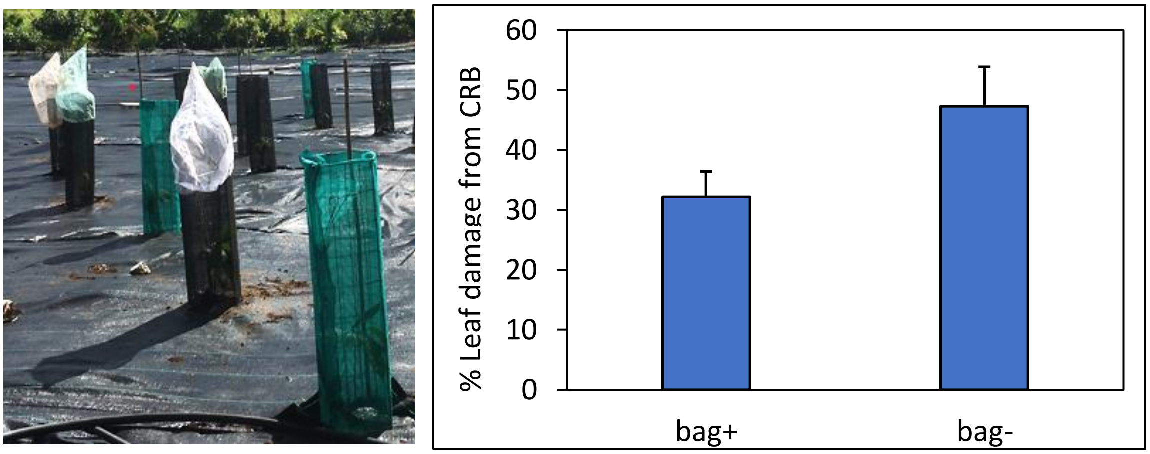


Fig. 1. a) A Chinese rose beetle (CRB) feeding on a cacao leaf; b) despite installation of wire cage, some CRB can still enter the wire cage and cause severe leaf damage on cacao seedlings; c) small cacao tree outgrown the wire cage or when wire cage is removed continued to suffer from the CRB damage.

However, some pests are considered a key stumbling block for cacao production here. **Chinese rose beetle** (CRB, *Adoretus sinicus*) feeding (Fig. 1a) can cause **aggregate defoliation** and is destructive to young cacao seedlings often leading to seedling death or delay in crop maturity. Cacao seedlings are also known to be very sensitive to wind damage. Wire-cages had been used to protect the seedlings from wind damage and are now shown to protect the seedlings from CRB. Sugano demonstrated that UV-protected clear plastic seedling cages resulted in plants two times taller than uncaged seedlings, and outperformed cages with black weed mat (Sugano et al., 2019). Some challenges of wire cage to protect cacao seedlings include high labor and material cost ($10/cage per grower, Kevin Chan), or insect escape i.e. CRB enters the wire cages from the top opening or the bottom opening if not tightly sealed to the ground. CRB can still cause damage within the cage (Fig. 1b). Moreover, once a cacao tree outgrown the cage, or the cage needs to be removed, CRB will continue to cause foliage damage though it will not cause mortality (Fig. 1c). Kirk et al. (2021) developed a proof of concept of living cage to protect cacao seedlings from wind damage and CRB concurrently with less labor and material cost using insect nettings or cover crops as living mulch surrounding each seedlings.

Organza netting as floating cage: We explored other approaches using a **floating cage** made from organza cloth loosely tied to the wire cage surrounding a cacao seedling. We refer to this as a floating cage as the cage can be adjusted as the cacao grows taller. First, we integrated wire cages with organza insect nettings (Fig 2a) to prevent insects from entering from the top of the wire cage. We found this approach further reduced 32% of CRB damage on cacao leaf foliage compared to wire cage alone (Fig. 2b) as it blocked the top entrance of CRB.



(a) (b)

Fig. 2 a) Adding organza netting on top of the wire cage, b) further reduce leaf damage from Chinese rose beetles (CRB) by 32% on cacao seedlings (n=15).

Floating cage and Night light with red bowl traps: Unfortunately, cacao seedlings continue to be damaged severely by CRB once wire cages were removed, another field trial was conducted to examine if small cacao tree could be protected from CRB using organza netting as a floating cage (Fig. 3a). Percentage of cacao leaves with CRB damage holes was compared among branches with organza net (N) on half side of a tree, no net (NN) on the other side of a tree, or no net on the entire tree as the control (C). In addition, we also added a solar powered night light inserted into a red bowl (Mintra 600 ml-home snack bowl), using a uniseal (¾" black pipe-to-tank uniseal) after drilling a ¾" hole (Fig. 3b, c). The red bowl was filled with soapy water one week before data collection. Thus, this was a 3×2 factorial designed experiment with 6 replications. Numbers of leaves with and without CRB damage were recorded 1 week after setting up, and repeated twice.

(a) (b) (c)

Fig. 3. Comparing % of cacao leaves with Chinese rose beetles (CRB) damage holes on branches of cacao with a) organza cloth netting as a floating cage on one side of a young cacao tree (N), b) no net (NN) on the other side of a cacao tree, vs c) no net on the entire tree as the control (C). These netting treatments were repeated with night light (L) and without night light (NL) with a red bowl filled with soapy water.

Surprisingly, lowest CRB damage was detected from branches not covered by netting (NN) on trees with half the site covered with netting (N). Branches in NN actually had similar % CRB damage holes as the untreated control (C) trees. It is possible that the organza netting was loosely tied to the branches that allowed CRB to get in, and CRB might have preferred to feed on cacao leaves inside the netting at night due to less wind disturbance. Once they were inside this netting, CRBs were trapped inside the floating cage, this resulted in approximately 50% less damage on the NN branches compared to other treatments (Fig. 4a). Perhaps future research can investigate setting organza nettings on only small branches of cacao tree to sacrifice as CRB trap for better health of the tree.

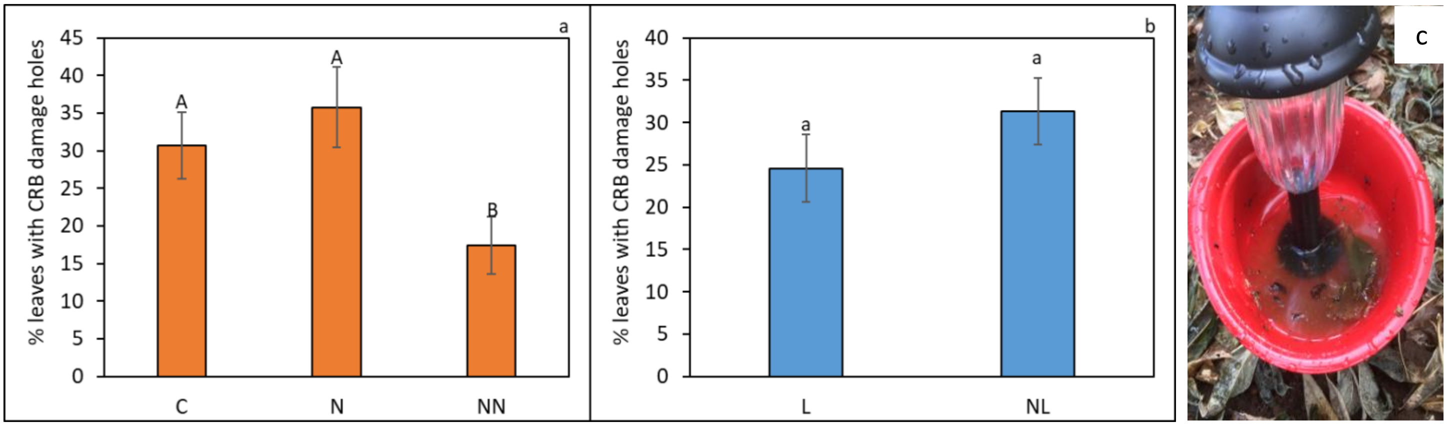


Fig. 4. Percent of cacao leaves with Chinese rose beetles (CRB) damage holes affected by a) netting (N), no netting (NN) or untreated control (C), and b) night light (L) vs no night light (NL) traps. Means (n=18 for insect netting treatments; n=27 for night light treatments) followed by the same letter in each graph were not significantly different based on Waller-Duncan *k*-ratio (*k*=100) *t*-test or analysis of variance. c) Solar night light captured CRB in soapy water.

Solar night lights with red bowl trap only slightly reduced CRB leaf damage without significant difference (Fig. 4b). Thus, there is no need to set up many red bowl night light traps, but this could be sporadically integrated into the overall cacao IPM plan in the area of an orchard with more frequent visits of CRB. Future research could look into other bowl color that might be more attractive to CRB.

Green illumination at night: Larger-scale cacao growers are concerned about the high cost of insect cage ($10/plant) and labor cost to manage floating cage especially under windy conditions. Another promising pesticide-free method for CRB management is nighttime illumination through a portable solar-based light-emitting diode spotlight to reduce CRB populations (McQuate and Jameson, 2011). McQuate determined that 4 nights of nighttime light illumination with 4.0 lux suppressed >75% more beetle damage. Two prototypes of night light illumination were built using solar-powered flood light (Lysed, 50W, 12V) wrapped or not wrapped with green cellophane wrapping paper and turned on daily at sunset for 2 hours and observed for 5 weeks. Research is underway to compare CRB leaf damage on green light vs regular LED flood light illuminated cacao plants (Fig. 5).

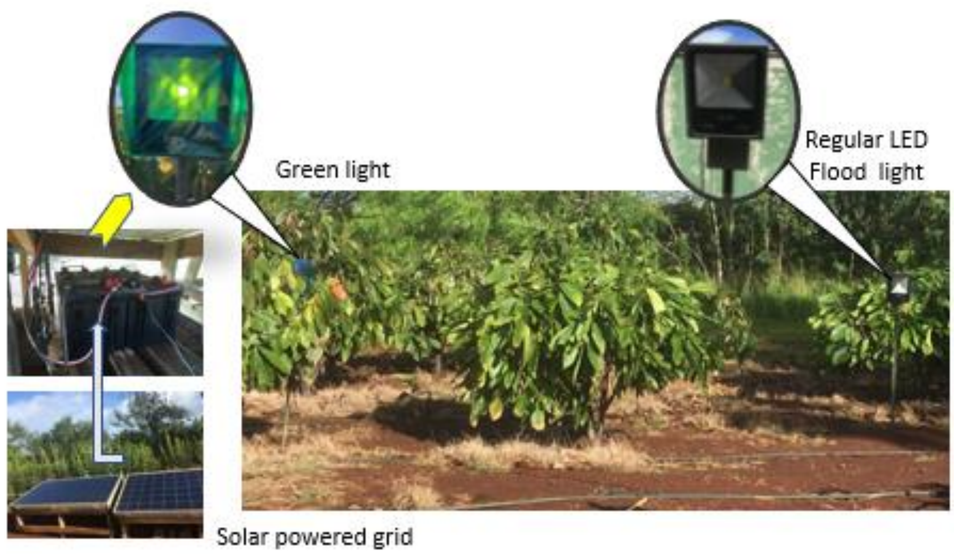


Fig. 5. Solar-powered flood light wrapped with green cellophane wrapping paper shining on small cacao trees no longer fit in wire cage.

Fun Facts about behavior of Chinese Rose Beetles

Adult CRBs are nocturnal, feeding at night on leaves of a wide range of crops (e.g. cacao, longan, rose, taro, wax apple etc.) and weeds (castor bean plant, maile pilau, etc). However, CRB grubs stay in the soil or under leaf litter and do not cause harm to plants (Mau and Kessing, 1991). During the day, adult CRB stay in the soil or underneath leaf litter and only emerge from the ground about 30 min after sunset and fly towards their host plants (Tsutsumi et al., 1993). Therefore, when using solar-based lighting to deter CRB flying towards cacao, the nightlight needs to be switched on within the first 30 minutes of nighttime. Although the efficacy of nightlight to repel CRB varies by the light intensity, and the light intensity of the solar-powered light declines over night (due to the battery being drained), CRB beetles seek their host plants during a short period of flight activity after dusk. It is during the host searching time that the illumination plays its deterrent role (McQuate and Jameson, 2011). Based on the studies by McQuate and Jameson (2011), light intensity of 2.5 lux was sufficient to suppress >50%, and 4.0 lux was sufficient to suppress >75% of CRB visits on cacao seedlings over 4 nights of continuous illumination. They also suggested that the cost of illumination can be minimized by setting a timer to illuminate only during time of plant searching of CRB (1-2 hours after sunset). Thus, there is no need to turn on the light for the entire night. They reported a continued drop-off in beetle numbers on cacao if the cycle of nighttime illumination continues. Nighttime illumination does not cause any beetle mortality, but CRB adults will avoid feeding on plants that are illuminated at night. The beetles will move to feed on alternative host plants that are not illuminated. McQuate further noted that once beetles choose an alternative feeding host, they may continue to feed there, even if nighttime illumination of the plant to be protected is terminated. While more research is needed to determine the efficacy of nightlights with different light source or wavelength, it is known that the visual system of beetles is sensitive to green spectra. Thus, it might be interesting to study the effects of green vs regular nightlights as CRB deterrents.

Summary

Current approaches practiced by most cacao growers in Hawaii by building or recycling wire cages (from another orchard after cacao had established) are durable and successful in protecting cacao plants from CRB but aggregate defoliation of CRB can still be damaging after cage removal. This article provides alternative options (floating cage, night light illumination soon after sunset) to further protect plants from CRB especially in areas where the population densities are too high and when cacao plants outgrown the wire cages. Night light intensity of > 2 flux about 30 min after sunset can significantly deter CRB adults' emergence from the soil and flight to host plants.

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Acknowledgement: This project is supported by HDOA SCBG FY2020 Project 4, CTAHR Hatch, Multistate (NE2140) and Plan of Work (HAW9048-H, 9034-R and POW 16-964).