Strip Cropping: A Potential IPM Tool for Reducing Whitefly, *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) Infestations in Cassava

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Abstract

Insect pests and diseases are a major limiting factor to cassava production in Africa. The cassava mosaic virus disease (CMVD), caused by cassava mosaic geminiviruses (CMGs) (*Geminiviridae*: *Begomovirus*) and transmitted by whitefly, *Bemisia tabaci* Gennadius, threatens the production of the crop in Africa, causing an estimated annual yield loss of over 1.5 billion US dollars. A 6-month field experiments were conducted to explore the potential of using strip cropping to reduce whitefly infestations in cassava, *Manihot esculenta* Crantz (Euphorbiaceae). Five rows each of cassava, *Jatropha* and cotton were grown around a 10-row (1 m row width) × 25 m cassava plots in a randomized complete block design. At weekly intervals, the levels of whiteflies infestations (number of eggs, nymphs and adults) per plot were determined. A significantly lower numbers of immature (egg and nymph) and adult *Bemisia tabaci* were found in cassava plots surrounded on all sides by five rows of both cotton and *Jatropha curcas*, clearly demonstrating the potential of strip cropping as a management option for the suppression of *Bemisia tabaci* populations.

Introduction

Cassava (*Manihot esculenta* Crantz) is an essential part of the diet for more than half a billion people in Africa, Latin America and Asia (FAO, 2000). However, its production is constrained by the cassava mosaic virus disease (CMVD), a viral disease causing economic yield losses (Calvert & Thresh, 2002). The disease is caused by Begomoviruses (Geminiviridae: Geminivirus Subgroup III), transmitted by the whitefly, *Bemisia tabaci* Genn (Legg *et al.*, 2001; Fargette *et al.*, 2006). The viruses are spread through infested stem cuttings, which is the usual mode of cassava propagation. CMVD, which is characterized by a mosaic pattern of chlorotic areas on the leaves and stunting of plant during severe infestations, has a higher incidence in all the ecozones of Ghana (Wydra & Verdier, 2002). Unfortunately, majority of farmers in Ghana have very little or no understanding of causes of plant diseases, and, as a result, do little or nothing to control the diseases. Surprisingly, most cassava farmers believe some of the disease signs of the crop are common features of the plant (Moses *et al.*, 2005).

The primary control measures for CMVD to date have focused on phytosanitation and planting of disease-resistant cultivars. Thresh & Cooter (2005) reported that research effort has been very inadequate in relation to the enormous importance of cassava in Africa and to the enormity of the CMD problem. Nevertheless, several approaches to controlling this disease have been considered but have not been fully evaluated to examine their efficacy in various agroecosystems. There is also a general lack of educational information available to growers as to the understanding of crop cultivars, disease severity, and management practices (Thresh & Cooter, 2005). Cultural methods of control using varietal mixtures, intercrops or other cropping practices have been relegated to the background, and there is a need for additional research before they can be deployed effectively (Thresh & Cooter, 2005).

Manipulating the habitat has been shown to enhance biological control of crop pests in agroecosystems (Thomas *et al.*, 1991; Alderweireldt, 1994). Strip intercropping, growing two or more crops concurrently in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically (Vandermeer, 1989), can be adopted for various purposes, such as habitat diversification in agro-ecosystems for the benefit of insect predators (Tonhasca, 1993), attracting pests away from the target crop(s) and adding valuable biodiversity to the agro-ecosystem. Thus, strip crops are plant stands that are set up to attract, divert, intercept, and, or retain targeted insects or the pathogens they vector so as to reduce damage to the main crop (Shelton & Badenes-Perez, 2005). A classic example of habitat manipulation is the interplanting of strips of alfalfa among larger blocks of cotton (Stern, 1991). The alfalfa strips was an effective trap crop in this system as they were more attractive to *Lygus* spp. and spider mites than the blocks of cotton. This study was designed to explore the potential of using strips of *Jatropha curcus* L. and cotton, *Gossypium hirsutum* L., in reducing whitefly infestations in cassava.

Materials and methods

Study location

The study was conducted at the Ghana Atomic Energy Commission's Biotechnology and Nuclear Agriculture Research Institute farm in Accra, Ghana. The study site was located about 20 km north of Accra (05° 40' N and 0° 13' E), with an elevation of 76 m above sea level. Ghana is situated in West Africa, just above the Equator.

Experimental design

Strips of cotton hybrid (Sarcot 5), cassava (Tuaka) and *Jatropha* were grown around 8 m × 25 m Tuaka cassava plots. The experimental treatments were in a r randomized complete block design (RCBD), replicated three times (Fig. 1). Each strip crop treatment consisted of five rows each of cassava (control), *Jatropha* or cotton on all sides of a 10-row (1 m row width) × 25 m cassava plot, hereinafter referred to as CCAS, CJAT, and CCOT as main treatments, respectively. Plots were separated by 4 m of fallow land (alley) and the intervals between adjacent plots were 1.5 m. Neither irrigation nor pesticides were used during these experiments. The predominant weeds encountered were *Chromolaena odorata, Panicum maximum, Tridax procumbens, Euphorbia heterophylla, Sida acuta, Sporobolus pyramidlis, Saccharum spontaneum, Glucaenia* spp.*, Azadirachta indica, Pennisetum spp.* and *Taraxacum officinale.* Weeds were cleared by hoeing three times during the course of the study and the interval between weeding was approximately 2 months.

Fig. 1. Experimental units in a randomized complete block with three replications

Whitefly sampling: visual observation

Visual sampling of whiteflies began 6 weeks after planting (WAP) (27 Jul 2007) in both cassava main plots and in adjacent strips, and continued weekly, until the 28th Dec 2007. For each main cassava plot and strip plots, 10 plants were randomly selected and whitefly numbers counted. Sampling was conducted by randomly selecting the first plant in the plot and then sampling the 20th plant along the sampling trajectory. A modified Otim-Nape *et al.* (1994) method was used to determine the numbers of whiteflies on the first five most expanded apical leaves of each selected plant.

Arthropod sampling: trap catches

Yellow sticky traps were deployed to monitor relative abundance of whiteflies in cassava main plots influenced by surrounding strip crops (Ekbom & Xu, 1990). Wooden boards with dimensions of 20 cm × 13 cm were made from ¼ inch plywood. The edges of the boards were covered with masking tape to minimize water seepage into the board during rain events. The boards were painted with yellow oil paint and mounted on 1 m wooden stakes. The board surfaces were coated with a commercially available jelly adhesive (Tanglefoot Company, Grand Rapids, MI) to form whitefly sticky traps. Five yellow sticky traps were placed randomly on each of the nine experimental units (cassava plots surrounded by a strip crop, namely CCAS, CJAT, and CCOT × 3 replications), with a total of 45 traps in the entire study field.

The stakes of the traps were driven into the soil close to the plants that were to be monitored. Traps were placed such that the sticky side faces the plants but is out of direct sunlight. Trap catches were recorded weekly throughout the 6-month study period, after which the boards were cleaned to remove insects and debris using soapy water. The adhesive glue was then reapplied to maintain the sticky surface. Ten plants each from the strip crops and main cassava plots were sampled weekly by direct/visual method for 23 weeks from 27 Jul (6WAP) to 28 Dec 2007.

Statistical analysis

Number of whitefly (*Bemisia tabaci*) adults, eggs and nymphs, found on the first five fully expanded leaves per plant and sticky trap counts for each treatment by sampling date, were analyzed using linear mixed model techniques (SAS Institute, 2003). The linear mixed model (LLM) correctly models correlated errors which the general linear model (GLM) does not. Additionally, LLM is a further generalization of GLM to better support analysis of continuous dependant for random effects, repeated measures and, thus, provides one with the flexibility of modelling not only the means of a data, but their variances and covariance's as well.

Strip crops were the treatments and the fixed factors were the bigger cassava plots, method, strip crop and weekly counts, whilst the random factors were replications interacting between method, strip crop, weekly counts and, finally, residual error. The numbers of whiteflies were accumulated by date to produce a better test of the treatments for each replication, treatment and method. For each method of sampling, data were analyzed as a randomized block design with three blocks and three treatments.

Data collected throughout 23 weeks of sampling were analyzed as repeated measures factor. Normality of errors was tested with the Shapiro & Wilk (1965) test. Sphericity was assessed with Mauchly's (1940) test. Data was log-transformed before analysis. When treatment and week interacted, the simple main effect of treatment at each week with an error term specific to the contrast were tested (Kirk, 1995), and if this test was significant, pairwise comparisons among treatments for each week of sampling was accomplished with protected least significant difference (LSD**)**. When treatment and week did not interact, the main effect of treatment was tested; if this was significant, pairwise comparisons among treatments were made with protected LSD. Separate error terms were used if sphericity was violated.

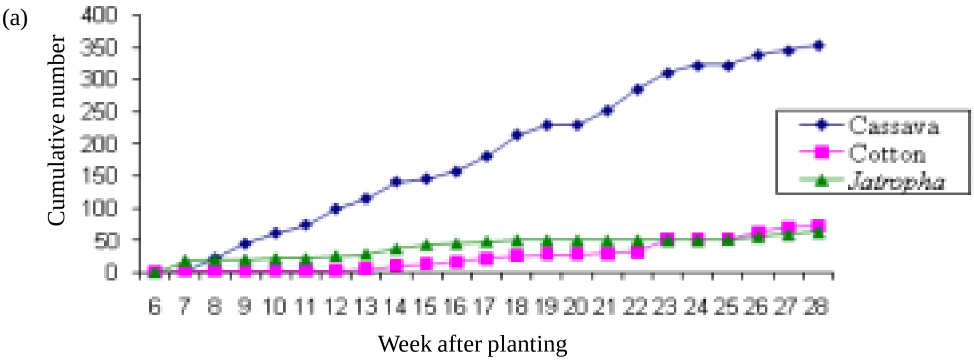
Results and discussion

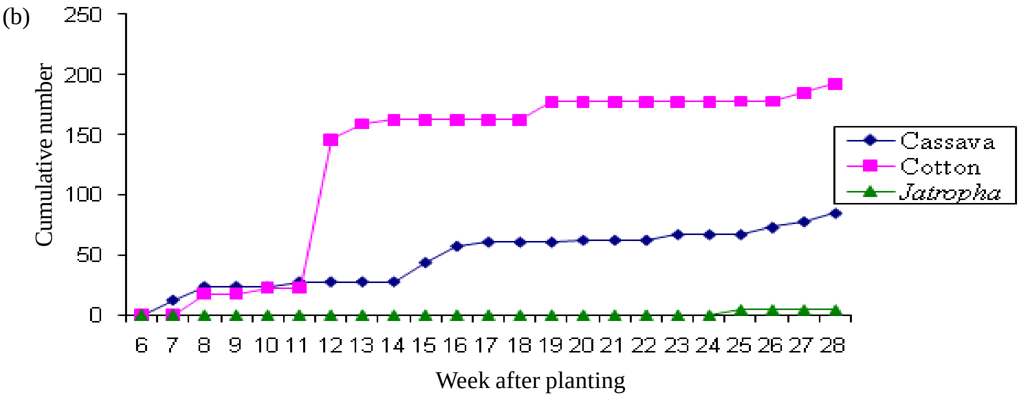
Visual cumulative weekly egg counts

The trends of cumulative whitefly eggs oviposited in the main cassava plots (CCAS, CCOT and CJAT) and in the strip crops are shown in Fig. 2ab, respectively. Cumulative weekly eggs counts in CCAS started increasing earlier compared with those for CCOT and CJAT. This increase continued throughout the 23 weeks of monitoring {27 Jul (6WAP) to 28 Dec 2007 (28WAP)}. Total number of eggs oviposited in CCAS surpassed those in CCOT and CJAT from 9 to 28 weeks. Statistical analysis of these differences showed that CCAS had significantly higher number of eggs (353.30 ± 144.30, *P* = 0.0466). However, similar numbers of eggs were oviposited in both CCOT and CJAT. Among the strip crops, higher numbers of eggs were found in cotton than cassava and *J. curcas* from 12 to 28 WAP. *J. curcas* strip had the lowest number of eggs (62.70 ± 29.80, *P* = 0.9267).

Visual cumulative nymphs

There were three nymphal activity peaks on cassava (18, 22 and 28 WAP) for CCAS, CCOT and CJAT (Fig. 3a). Statistically, similar whitefly nymphs were observed in CCOT (162.00 ± 25.40) and CJAT (120.30 ± 37.60). However, it was only in 18 WAP that this peak was significant in all treatments. Nymphal density counts in CCAS were significantly higher (275.00 ± 59.50, *P* = 0.0437) compared to those of CCOT and CJAT. With regard to strip crops (Fig. 3b), *J. curcas* as a strip crop supported significantly lower nymphal population (7.30 ± 7.30, *P* = 0.0492) compared with cotton and cassava, which had 222.70 ± 93.30 and 108.00 ± 2.60, respectively.





(a)

Fig. 2. Visual cumulative weekly whitefly (*Bemisia tabaci*) egg counts in (a) cassava and (b) strip crops. GAEC, Accra, Ghana (Jul 27–Dec. 2007).

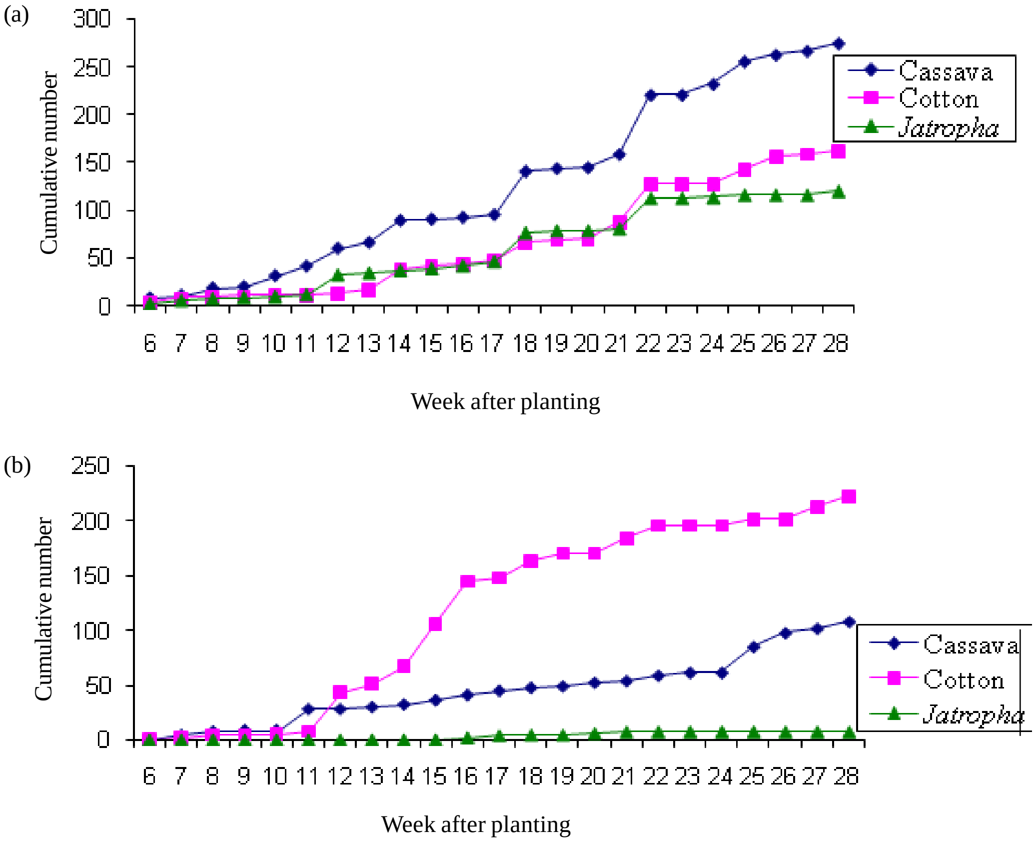


Fig. 3. Visual cumulative weekly whitefly (*Bemisia tabaci*) nymphs on (a) cassava and (b) strip crops. GAEC, Accra, Ghana (Jul 27–Dec 2007).

Visual cumulative adults

The effect of strip crop on adults was significantly different (P = 0.0184). Adult whitefly numbers in CCAS and CCOT were similar (P = 0.0699); however, there were significantly fewer adult whiteflies in CJAT than CCOT (P = 0.0604), and significantly fewer whiteflies in CJAT than CCAS (P = 0.0072) at P = 0.05 level (Fig. 4a). Type of strip crop had a significant effect on the number of whitefly adults (P = 0.0028). Strip cropped cassava (Fig. 4b) had a significantly higher (P = 0.0197) adult counts than that of cotton (441.70 ± 52.50 and 259.70 ± 11.30, respectively). *J. curcas* had the lowest abundance of adult whiteflies (35.00 ± 3.10, P = 0.0097).

Sticky trap counts

The effect of strip crop on whitefly abundance was significant (P = 0.0334). The number of adult whiteflies caught by the sticky traps rose slowly from 6 WAP and did not show signs of levelling off in all treatments (Fig. 5). Sticky traps placed in CCAS caught greater number of adults

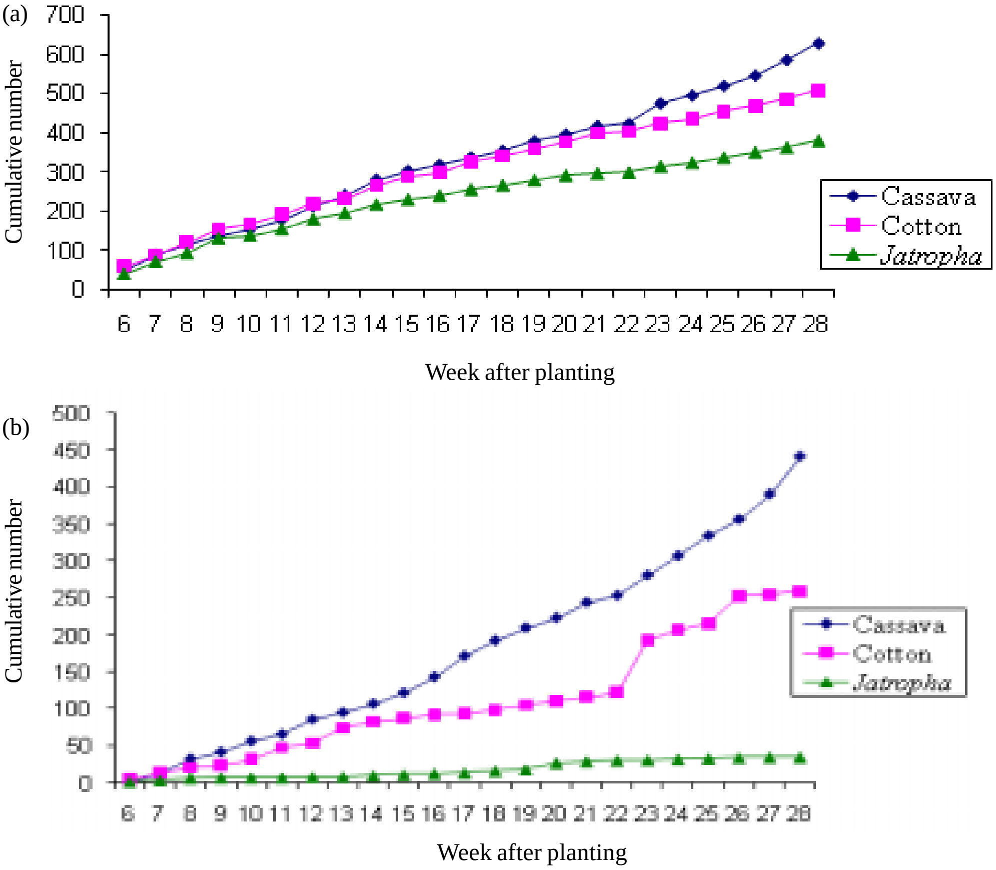


Fig. 4. Mean visual cumulative weekly whitefly (*Bemisia tabaci*) adults in (a) cassava and (b) strip crops. GAEC, Accra, Ghana (Jul 27–Dec 2007)

(1159.33 ± 162.87) compared to that in CCOT (1153.00 ± 162.87), but this difference was not significant (*P* = 0.1278). However, significantly fewer numbers of whitefly adults (622.00 ± 162.87) were recorded in CJAT than both CCAS (*P* = 0.0135) and CCOT (*P* = 0.0824).

insecticidal or inhibitory properties (Tewari & Shukla, 1982).

Byrne & Draeger (1989) reported that first instars of *B. tabaci* failed to survive on mature lettuce, and they suggested that nutrition-related plant quality might be the most important factor affecting survival rather than the inability of young nymphs to reach the phloem tissue. Elucidation of the precibarial and cibarial chemosensilla of *B. tabaci* by Hunter *et al.* (1996) indicates that *B. tabaci* may be able to evaluate plant sap before ingesting it. Significantly, higher densities of *B. tabaci* (eggs, nymphs and adults) were found in strip planted cotton compared with that of *J. curcas*. Additionally, significantly higher numbers of adults were observed in CCAS than in CJAT. This clearly demonstrates that cotton strip acted as a source and relayed whiteflies to adjacent cassava plots.

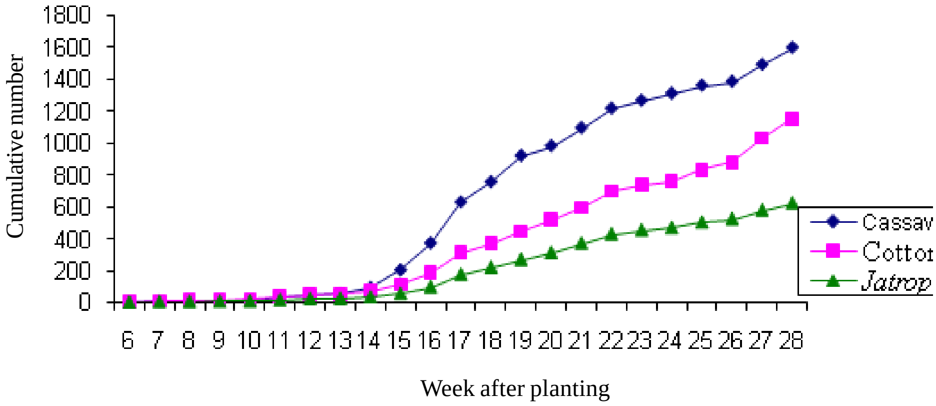


Fig. 5. Mean cumulative weekly whitefly (*Bemisia tabaci*) sticky trap catches. GAEC, Accra, Ghana (Jul 27–Dec 2007).

Discussion

A consistent lower cumulative number of *B. tabaci* was observed on strip planted *J. curcas* and adjacent cassava plant plots for all developmental stages. Therefore, *J. curcas* functioned more as a repellent than as a sink or source for *B. tabaci*. The dispersal and infestation of a crop by whiteflies depend on its acceptance for landing, feeding, oviposition and its suitability for nymphal development (Omondi *et al.*, 2005). Population reduction of whiteflies has been found associated with host plant quality and availability (Liu, 2000). Components of host plant quality (such as carbon, nitrogen, and defensive metabolites) (Awmack & Leather, 2002) of leaves of *J. curcas* either may have been unsuitable or may possess

While the reliability of yellow sticky traps in estimating population densities and within-field movement behaviour is debatable, (Horowitz, 1986), the number of *B. tabaci* detected by yellow sticky traps in the study provided a generally similar trend to what was observed in the visual sampling. Melamed-Madjar *et al.* (1982) showed a significant correlation between adults caught by yellow sticky traps and the numbers of larvae found in leaf samples in cotton field ($r = 0.91$, $P = 0.01$). Matsui (1992) showed a similar correlation in tomato grown in a greenhouse infested with *B. tabaci*.

Horowitz *et al.* (1984) and Horowitz (1986) showed a high correlation ($r = 0.99$, $P < 0.001$) between the number of adults caught by vacuum cleaner and those sampled by direct visual methods in tobacco field. Yellow sticky traps sampling seem, therefore, to reflect at least general population trends (Hirano *et al.*, 1993). This is confirmed by the results from this study, indicating that the yellow sticky traps are useful tool for estimating populations of whitefly.

Conclusion

A candidate strip crop plant among other qualities such as serving as cover crop or improving soil fertility should more importantly emit semiochemicals, some of which (allelochemicals) could act as attractant, repellent or toxins to targeted insects or the pathogens they vector. The potential of selected strip crops in managing whitefly (*Bemisia tabaci*) population clearly indicates that strip cropping can be a viable management strategy for the control of *Bemisia tabaci* populations in cassava production. Future studies, including investigations into the allelopathic and ovicidal properties in the leaf latex of *J. curcas*, and cassava yield comparison in this scenario, together may further knowledge and capacity to control CMVD.

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