

Annex 2. Key Scientific findings of the SRA

1. SLCMV spread and incidence in Vietnam and Cambodia

For virus diagnostics leaf sample collection was conducted in tandem with survey activities, covering a total of 419 fields and 6,480 plants (15 fields per district, 16 plant samples per field) (**Table 1 and Figure 1**). We extracted total DNA from all of the samples using a modified CTAB method, and ran PCR-based diagnostics detecting the *AC1* gene of SLCMV.

In the 2016 planting season we found nine SLCMV-infected fields, which were restricted to Ratanakiri and Stung Treng provinces of Eastern Cambodia, while no infection was detected from any other sites (**Figure 2**). In the Ratanakiri province, where the disease had been reported in 2015, the virus occurrence was 13.3%, whereas in Stung Treng province, next to Ratanakiri, seven fields (46.6%) were infected, and four of those fields had within-field SLCMV incidences higher than 40%. The most distant infected field was approximately 70 km away from the first reporting site of 2015, indicating that the virus had already spread at least this distance by the 2016 cropping season.

Table 1. Locations of SLCMD and seed system survey sites in Vietnam and Cambodia.

| Vietnam | | Cambodia | |
|------------|-------------|------------------|-----------------|
| Province | District | Province | District |
| Gia Lai | Chu Prong | Oddar Meancheay | Anlong Veaeng |
| Dak Lak | Madruk | Banteay Meanchey | Malai |
| Dak Lak | Eaklak | Pailin | Sala Krau |
| Dak Nong | Dak G' long | Pailin | Pailin |
| Binh Tuan | Bac Binh | Battambang | Kamrieng |
| Dong Nai | Long Tham | Battambang | Phnum Proek |
| Son La | Thuan Chau | Battambang | Rattanak mondul |
| Kon Tum | Sa Thay | Pursat | Kravanh |
| Yen Bai | Van Yen | Ratanakiri | Koun Mom |
| Gia Lai | Krong Pa | Steung Treng | Steung Treng |
| Phu Yen | Song Hin | Kratie | Snoul |
| Tay Ninh | Chau Thanh | Tbong Khmun | Dambae |
| Binh Thuan | Ham Tan | Tbong Khmun | Memot |
| Tay Ninh | Tan Bien | Svay rieng | Romeas Haek |
| Tay Ninh | Tan Chau | Kampong Thom | Sandan |
| | | Kampong Thom | Baray |

Figure 1. Location of survey sites in Vietnam and Cambodia. Black symbols indicate the locations of sampling sites of the national survey. Green symbols on the inset maps indicate the locations of the 4 subnational surveys (clockwise from bottom left: Battambang, Ratanakiri, Dak Lak, Tay Ninh). The inset scale bar applies to all inset maps.

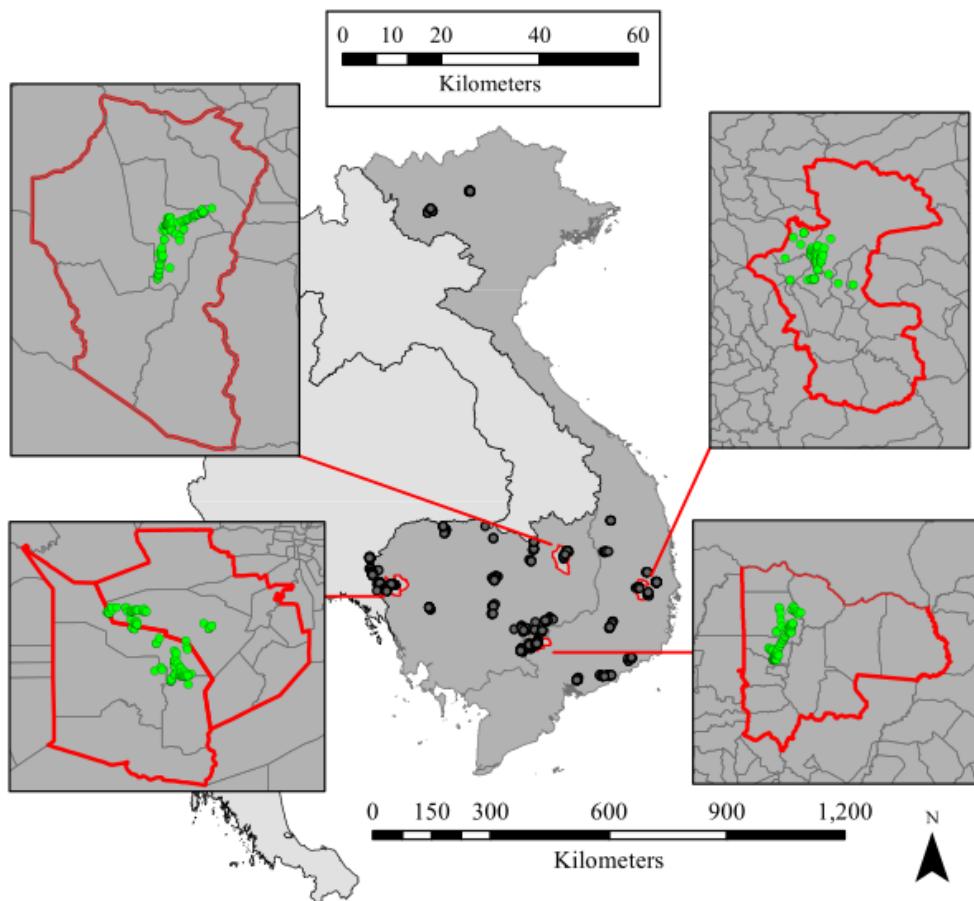
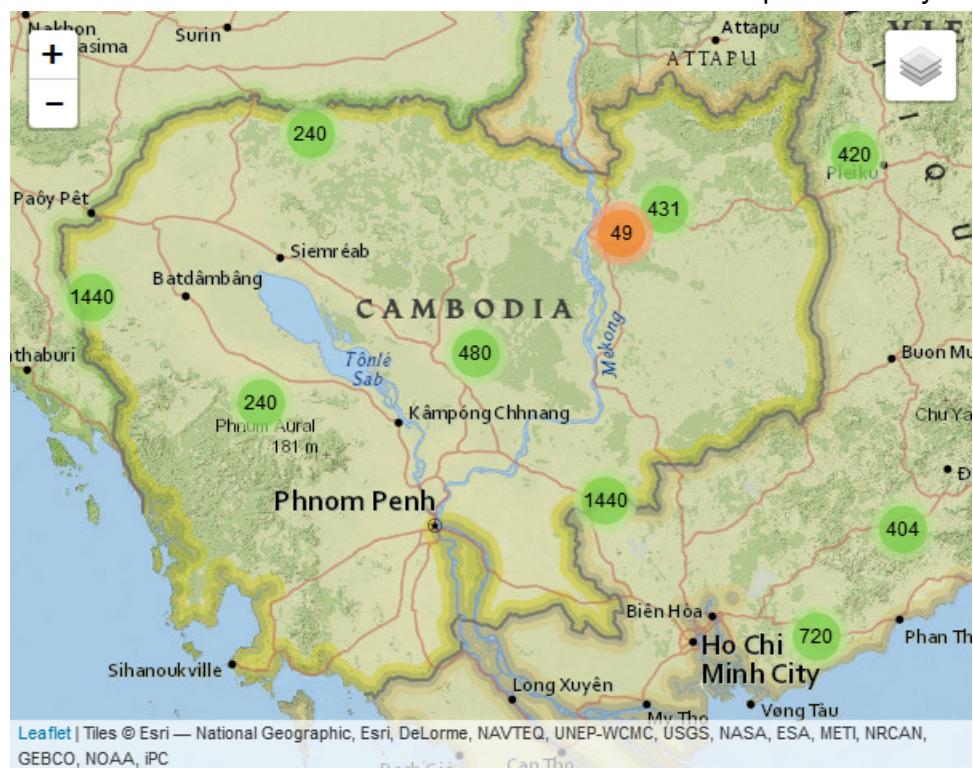


Figure 2. Distribution of clustered SLCMV-infected (orange) and non-infected (green) plants in Southern Vietnam and Cambodia. Numbers indicate the number of plants surveyed.



From the surveillance in Cambodia, we found plants showing SLCMD symptoms both systemically and non-systemically (limited to upper leaves) in one field, indicating that the virus infected plant showing mosaic only on upper leaves might have been a result of insect vectoring. We also found SLCMV-infected plants exhibiting typical symptoms of cassava witches' broom disease, suggesting the occurrence of multiple diseases in one plant. Interestingly, from Ratanakiri and Stung treng provinces, over 25% of SLCMV-infected cassava plants did not show typical visual symptoms of SLCMD. Non-symptomatic infection has not been reported commonly in other cassava mosaic diseases, and this finding raises the possibility that, unlike African cassava mosaic virus, SLCMD may be able to spread asymptotically on Southeast Asian varieties.

Box 1. Key messages for 2016 distribution, spread, and incidence of SLCMD

1. At the time of the study, **no SLCMD-infected fields were detected in Vietnam²**, indicating that border control and prevention of stake imports into the country could be a possible control measure;
2. At the time of the study, **SLCMD had spread at least 70 km from the initial point of detection**. The geographical distribution of the detected disease in Cambodia was relatively limited, suggesting that eradication of infection hotspots was still a viable route to extinguish the disease.
3. At least one quarter of the plants infected didn't show clear symptoms of SLCMV, indicating that **spread through movement of asymptomatic, healthy looking plants and stakes is likely**. This finding aggravates the situation, and limits options for control through simple roughing or positive selection at the farm-level.

3.1.2 Seed systems and anthropogenic spread

The results of the 2-country survey showed that seed flows were heterogeneous, and depended greatly on contextual factors. Farmers in Vietnam (N=206) always used stakes produced in their own country, and more frequently acquired rather than provided stakes: 234 versus 104 transactions registered, respectively. In Vietnam, the most important sources of stakes acquisition, in order of importance, were: (i) own seed stocks, (ii) acquaintances within the community, and (iii) agroinput dealers. The most important sinks for provision in Vietnam were: (i) acquaintances within the community, (ii) agroinput dealers, and (iii) traders. Conversely, in Cambodia the import of seed from neighboring countries was relatively common, with stake acquisitions registered from Thailand, Vietnam, and in a single instance, Laos. Stakes from Vietnam in particular were transported deep into Cambodia, covering larger distances than would normally be predicted for bulky, vegetatively propagated seed. This is largely due to the nature of the Cambodian cassava value chain, which involves long transport routes for root products; an existing channel that is easily exploited to effectuate stake transport. Farmers in Cambodia also tended to be involved in more acquisition transactions than provisions. This is important as it demonstrates Cambodia's status as a sink rather than a source of seeds. This reality, due in part to environmental conditions (many areas of Cambodia experience a 3-month dry season, pushing the limits of storage for viable cassava stakes), means that Cambodia is at increased risk of phytosanitary contamination than its more self-sufficient neighbors. In Cambodia, the most common sources of stakes acquisition, in order of importance, were: (i) own seed stocks, (ii) acquaintances within the community, and (iii) traders. The most important sinks for provision in Cambodia were: (i) acquaintances within the community, and (ii) community collection points. The prevalence of traders in Vietnamese

systems contrasts with the high level of interaction with community collection points in Cambodia. Figure 3 also shows variability for exchange methods.

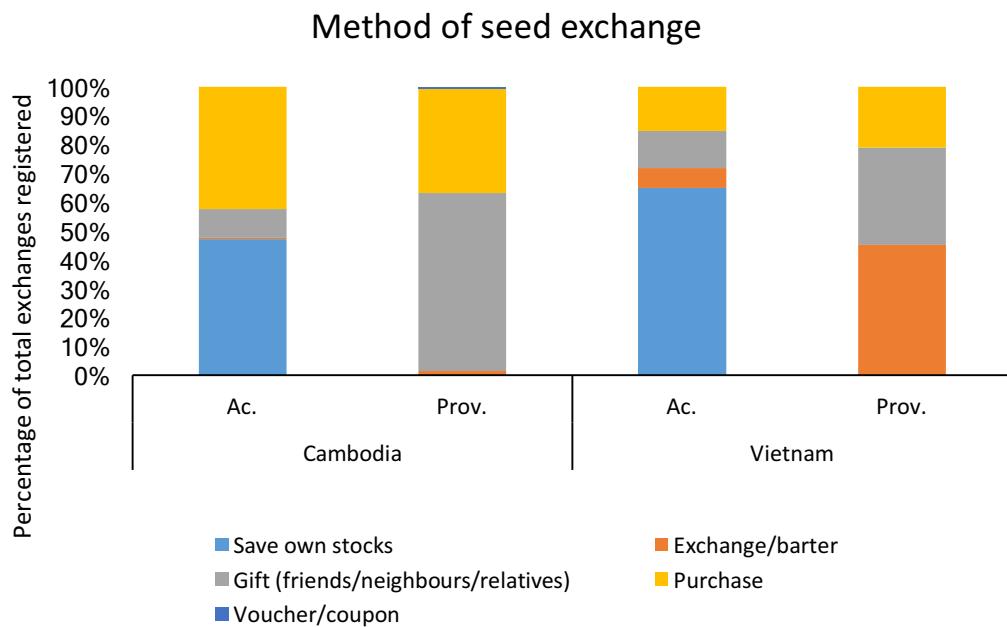


Figure 3. 100% stacked chart of stake exchange methods from the National surveys. 'Ac.' indicates seed acquisition, 'Prov.' indicates seed provision to others.

The zoom-in surveys allowed for a much higher level of resolution in terms of actors, mechanisms and sub-national dynamics. A comparison of seed networks in 2016 in Ratanakiri (expansion site in Cambodia) and Tay Ninh (established site in Vietnam) makes this very clear (Figures 4 and 5). In Ratanakiri, most exchanges were farmer-to-farmer, with traders mostly involved in seed acquisition. The 100 interviews conducted in Ratanakiri identified only a single trader in the community. Conversely, in Tay Ninh, a highly commercial production area, over 30 trader-mediated transactions were recorded, with dozens of traders in the area. Seed networks here are active and seed provision through trade networks have a large national and cross-border character. In other words, the Ratanakiri network is more inwards centered, while the Tay Ninh network reaches widely beyond the district's borders. In a sense, this is a positive finding for the possible spread of SLCMD infected materials from Ratanakiri, which does not seem to be a major source of stake export, reducing the risk of spread compared to the situation in Tay Ninh. Farmers in Tay Ninh were integrated into a highly organized trader network, with an exchange system unique in this study. Farmers indicated receiving stakes from a trader on a yearly basis, an exchange founded on the expectation that the farmer would respond in-kind by selling their next year's crop (both roots and stakes) to the same trader. These were not formal agreements, but rather informal contracts founded on sociocultural expectations from both parties. In both countries a number of inter-provincial trades were identified, with the major difference being that in Vietnam these were strictly trader-mediated transactions. Trader-mediated exchange also led to more instances in Vietnam in which the geographical origin of the stakes was unknown to the farmer.

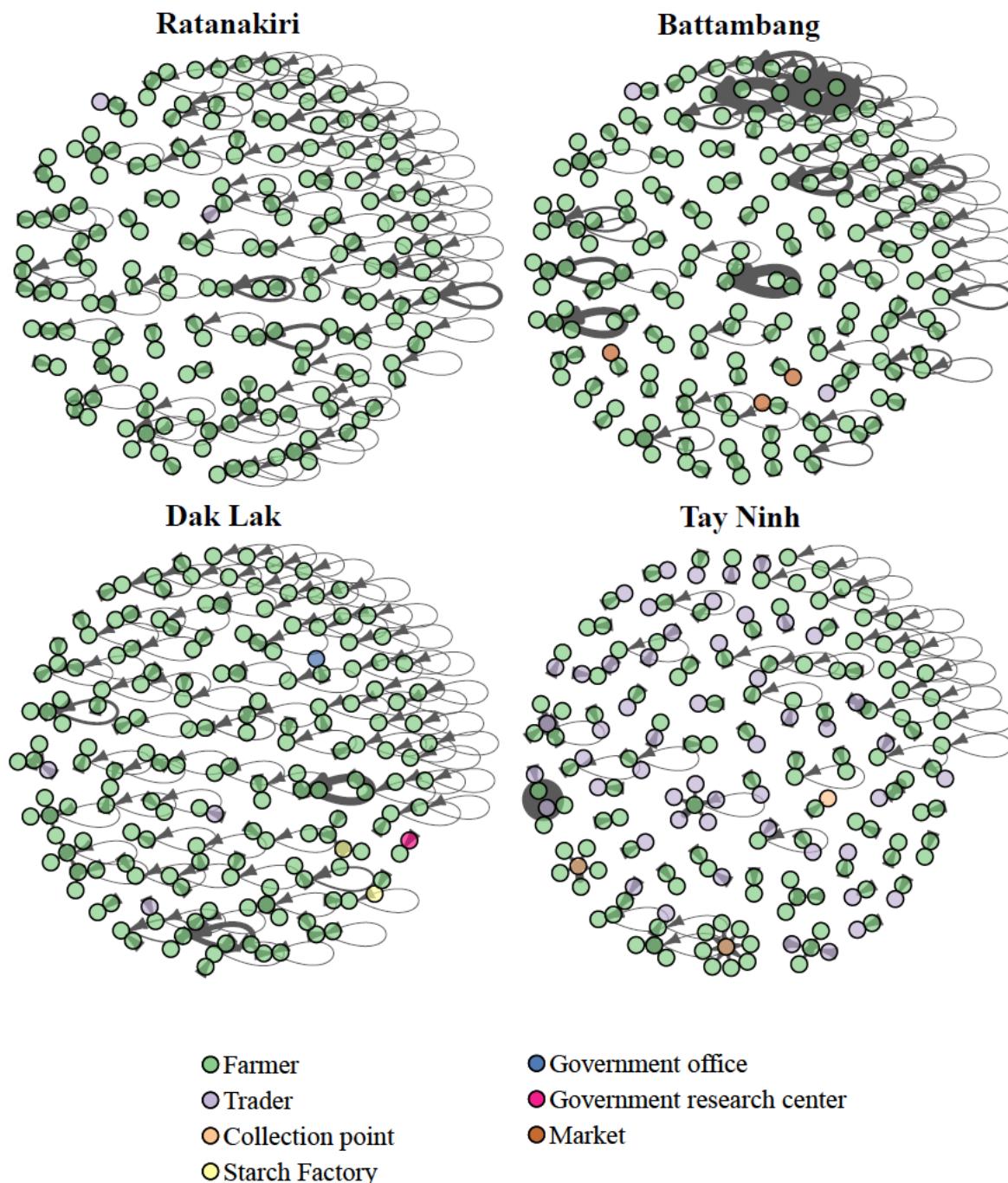


Figure 4. Network representations of stake provisioning in 4 ‘zoom-in’ sites of Cambodia and Vietnam in 2016. Arrows indicate directionality of exchange, while line weight indicates relative volume. Node color denotes type of actor involved in exchange (see legend). Self-loops indicate provision from the farmer’s own stocks from the previous year.

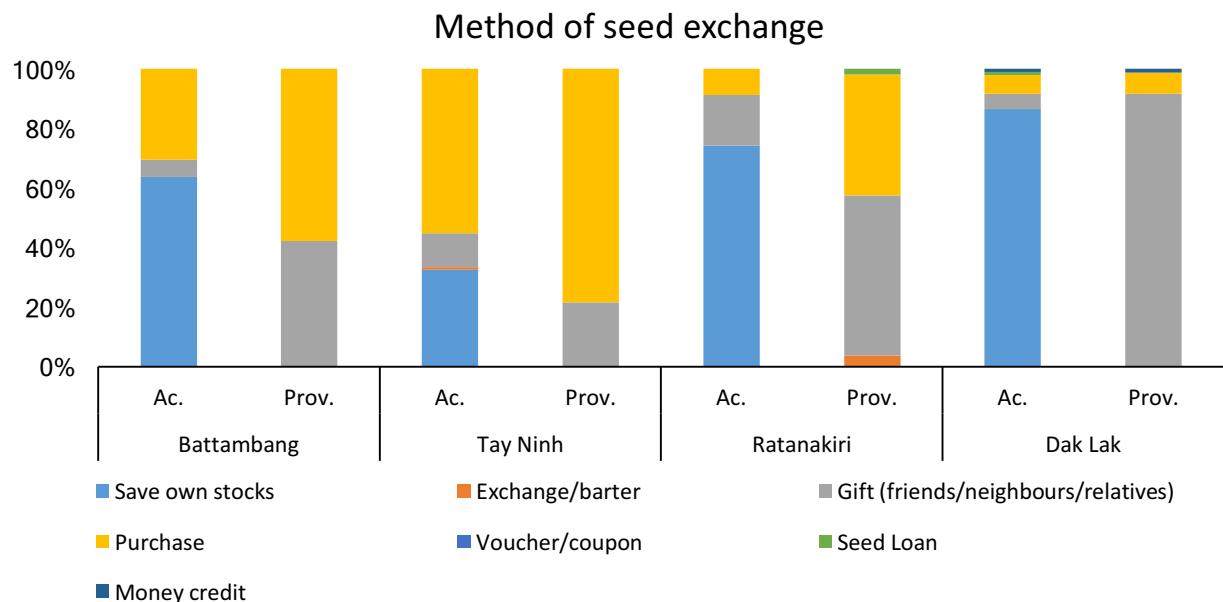


Figure 5. 100% stacked chart of methods of seed exchange in zoom-in surveys. ‘Ac.’ indicates seed acquisition, ‘Prov.’ indicates seed provision to others.

The production landscapes of the sites interviewed very much indicated a ‘cassava countryside’. Overall 94-100% of respondents indicated that their production field was adjacent to at least one other cassava field, and despite low cassava prices in 2016, between 81 and 95% of respondents indicated that they would continue to grow cassava the next season. These findings suggest a context suitable for whitefly-mediated transmission of the virus. In 3 of 4 in-depth survey sites a majority of respondents indicated losses of viable stakes during storage, with losses averaging 28% of stored seed. The percentage of respondents buying new stakes in 2016 varied from 7 and 14 percent in the expansion sites (Dak Lak and Ratanakiri) to 30 and 63 percent in the established sites (Battambang and Tay Ninh; Figure 6). In the same year, respondents also reported paying higher prices for stakes in the established sites than in the newer ones. These results demonstrate that despite the prevalence of self-provisioning of stakes, a significant amount of respondents source stakes from outside their farm, and suggest the potential for clean seed schemes to make possible impacts in local seed networks.

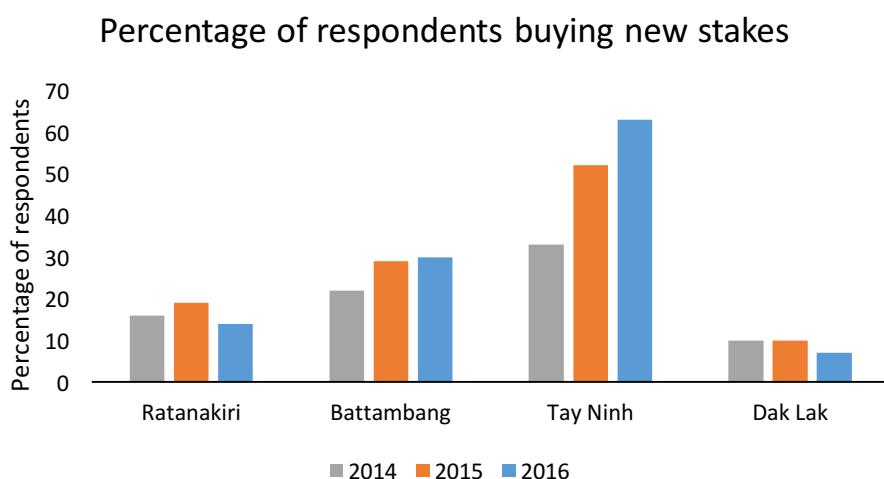


Figure 6. Percentage of respondents reporting buying stakes in the last 3 production seasons.

Box 2. Key messages as far as the 2016 cassava seed networks and likely anthropogenic spread of SLCMD are concerned

1. At the time of the study, farmers in Cambodia were found to purchase stakes from Vietnam, Thailand, and Laos. **Cross-border trade of seed penetrates deep into Cambodia**, even though self-saved seed and acquaintances within the community were more important sources of stake acquisition for Cambodian farmers.
2. Subregional district-level seed networks are highly distinct between districts. Seed networks in Ratanakiri, the province where SLCMD was first reported, are largely farmer-to-farmer based with seed acquisition flows staying within the province. Therefore **the risk of intensive anthropogenic spread of SLCMD from Ratanakiri to other provinces is relatively low**.
3. **Traders are key actors in stake provisioning beyond the community level.** Future studies on the informal seed sector should specifically target traders to better understand their networks so that lessons can be drawn on possible linkages to upgraded or clean seed interventions.
4. **Farmers already pay significant amounts of money, with regular frequency, to replenish their seed stocks.** This finding has important implications for potential phytosanitary or varietal interventions deploying through existing seed networks.

3.1.3 Whitefly biotyping

A total of 150 whitefly samples of different life stages of *Bemisia tabaci* whiteflies were collected and subjected to PCR-based genotyping and comparison with a global biotype base. Results show that 149 out of 150 samples belonged to the biotype AsiaII1 (**Table 2**). Only one sample belonged to the AsiaII6 biotype. This result is an important first step towards further intelligence concerning the insect-mediated spread of SLCMD. One biotype is predominant, but more research remains to be done on its ability to spread SLCMD, and the population dynamics of the insect in relation to the phenology of the cassava crop and the nature of its surrounding landscape.

Table 2. Results of whitefly biotype identification.

| Sample name | Species | Host | Location | side | stage of insect |
|-------------|---------|---------|---------------|-------|-----------------|
| ID 1 | Asiali1 | Cassava | Memot | F1-A | Adults |
| ID 2 | Asiali1 | Cassava | Memot | F4-A | Adults |
| ID 3 | Asiali1 | Cassava | Memot | F7-A | Adults |
| ID 4 | Asiali1 | Cassava | Memot | F10-A | Adults |
| ID 5 | Asiali1 | Cassava | Memot | F13-A | Adults |
| ID 6 | Asiali1 | Cassava | Samdan | F1-A | Adults |
| ID 7 | Asiali1 | Cassava | Samdan | F4-A | Adults |
| ID 8 | Asiali1 | Cassava | Samdan | F7-A | Adults |
| ID 9 | Asiali1 | Cassava | Samdan | F10-A | Adults |
| ID 10 | Asiali1 | Cassava | Samdan | F13-A | Adults |
| ID 11 | Asiali1 | Cassava | Thuan Chau | F5-A | Adults |
| ID 12 | Asiali1 | Cassava | Thuan Chau | F5-B | Pupa |
| ID 13 | Asiali1 | Cassava | Thuan Chau | F7-B | Pupa |
| ID 14 | Asiali1 | Cassava | Thuan Chau | F10-A | Adults |
| ID 15 | Asiali1 | Cassava | Thuan Chau | F10-B | Pupa |
| ID 16 | Asiali1 | Cassava | Thuan Chau | F13-A | Adults |
| ID 17 | Asiali1 | Cassava | Thuan Chau | F13-B | Pupa |
| ID 18 | Asiali1 | Cassava | Thuan Chau | F15-A | Adults |
| ID 19 | Asiali1 | Cassava | Thuan Chau | F15-B | Pupa |
| ID 20 | Asiali1 | Cassava | Long Thanh | F1-B | Adults |
| ID 21 | Asiali1 | Cassava | Long Thanh | F2-A | Adults |
| ID 22 | Asiali1 | Cassava | Long Thanh | F3-B | Adults |
| ID 23 | Asiali1 | Cassava | Long Thanh | F4-A | Adults |
| ID 24 | Asiali1 | Cassava | Long Thanh | F5-B | Adults |
| ID 25 | Asiali1 | Cassava | Bac Binh | F7-A | Adults |
| ID 26 | Asiali1 | Cassava | Bac Binh | F7-B | Adults |
| ID 27 | Asiali1 | Cassava | Bac Binh | F10-A | Adults |
| ID 28 | Asiali1 | Cassava | Bac Binh | F10-B | Adults |
| ID 29 | Asiali1 | Cassava | Bac Binh | F13-A | Adults |
| ID 30 | Asiali1 | Cassava | Bac Binh | F13-B | Adults |
| ID 31 | Asiali1 | Cassava | Dambae | F4-A | Adults |
| ID 32 | Asiali1 | Cassava | Dambae | F7-A | Adults |
| ID 33 | Asiali1 | Cassava | Romeas Haek | F4-A | Adults |
| ID 34 | Asiali1 | Cassava | Dambae | F13-A | Adults |
| ID 35 | Asiali1 | Cassava | Koun Mom | F7-A | Adults |
| ID 36 | Asiali1 | Cassava | Koun Mom | F10-A | Adults |
| ID 37 | Asiali1 | Cassava | Ham Thuan Nam | F4-B | Adults |
| ID 38 | Asiali1 | Cassava | Snoul | F1-A | Adults |
| ID 39 | Asiali1 | Cassava | Snoul | F13-A | Adults |
| ID 40 | Asiali1 | Cassava | Snoul | F10-A | Adults |
| ID 41 | Asiali1 | Cassava | Romeas Haek | F4-A | Adults |
| ID 42 | Asiali1 | Cassava | Romeas Haek | F4-B | Adults |
| ID 43 | Asiali1 | Cassava | Romeas Haek | F7-A | Adults |
| ID 44 | Asiali1 | Cassava | Romeas Haek | F10-A | Adults |
| ID 45 | Asiali1 | Cassava | Steung Treng | F1-A | Adults |
| ID 46 | Asiali1 | Cassava | Romeas Haek | F1-A | Adults |
| ID 47 | Asiali1 | Cassava | Steung Treng | F13-A | Adults |
| ID 48 | Asiali1 | Cassava | Baray | F1-A | Adults |
| ID 49 | Asiali1 | Cassava | Baray | F13-A | Adults |
| ID 50 | Asiali1 | Cassava | Baray | F7-A | Adults |
| ID 51 | Asiali1 | Cassava | Krong Pa | F1-A | Adults |
| ID 52 | Asiali1 | Cassava | Krong Pa | F4-A | Adults |
| ID 53 | Asiali1 | Cassava | Krong Pa | F7-A | Adults |
| ID 54 | Asiali1 | Cassava | Krong Pa | F10-A | Adults |
| ID 55 | Asiali1 | Cassava | Krong Pa | F13-A | Adults |
| ID 56 | Asiali1 | Cassava | Sa Thay | F1-A | Adults |
| ID 57 | Asiali1 | Cassava | Sa Thay | F4-A | Adults |
| ID 58 | Asiali1 | Cassava | Sa Thay | F7-B | Pupa |
| ID 59 | Asiali1 | Cassava | Sa Thay | F10-B | Adults |

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|--------|---------|---------|---------------|-------|--------|
| ID 60 | Asiali1 | Cassava | Sa Thay | F7-A | Adults |
| ID 61 | Asiali1 | Cassava | Chu Prong | F1-A | Adults |
| ID 62 | Asiali1 | Cassava | Chu Prong | F1-B | Pupa |
| ID 63 | Asiali1 | Cassava | Chu Prong | F4-A | Adults |
| ID 64 | Asiali1 | Cassava | Chu Prong | F10-A | Adults |
| ID 65 | Asiali1 | Cassava | Chu Prong | F7-A | Adults |
| ID 66 | Asiali1 | Cassava | Sa Thay | F13-A | Adults |
| ID 67 | Asiali1 | Cassava | Dak G'long | F10-A | Adults |
| ID 68 | Asiali1 | Cassava | Dak G'long | F7-A | Adults |
| ID 69 | Asiali1 | Cassava | Dak G'long | F10-B | Pupa |
| ID 70 | Asiali1 | Cassava | Dak G'long | F13-A | Adults |
| ID 71 | Asiali1 | Cassava | Van Yen | F1-A | Adults |
| ID 72 | Asiali1 | Cassava | Sala Krau | F7-A | Adults |
| ID 73 | Asiali1 | Cassava | Sala Krau | F10-A | Adults |
| ID 74 | Asiali1 | Cassava | Sala Krau | F13-A | Adults |
| ID 75 | Asiali6 | Cassava | Malai | F1-A | Adults |
| ID 76 | Asiali1 | Cassava | Malai | F4-A | Adults |
| ID 77 | Asiali1 | Cassava | Malai | F13-A | Adults |
| ID 78 | Asiali1 | Cassava | Pailin | F1-A | Adults |
| ID 79 | Asiali1 | Cassava | Anlong Veaeng | F1-A | Adults |
| ID 80 | Asiali1 | Cassava | Anlong Veaeng | F4-A | Adults |
| ID 81 | Asiali1 | Cassava | Anlong Veaeng | F10-A | Adults |
| ID 82 | Asiali1 | Cassava | Bac Binh | F4-B | Adults |
| ID 83 | Asiali1 | Cassava | Kamrieng | F1-A | Adults |
| ID 84 | Asiali1 | Cassava | Tan Chau | F13-B | Adults |
| ID 85 | Asiali1 | Cassava | Kamrieng | F7-A | Adults |
| ID 86 | Asiali1 | Cassava | Kamrieng | F10-A | Adults |
| ID 87 | Asiali1 | Cassava | Kamrieng | F13-A | Adults |
| ID 88 | Asiali1 | Cassava | Kravanh | F1-A | Adults |
| ID 89 | Asiali1 | Cassava | Kravanh | F4-A | Adults |
| ID 90 | Asiali1 | Cassava | Kravanh | F7-A | Adults |
| ID 91 | Asiali1 | Cassava | Kravanh | F10-A | Adults |
| ID 92 | Asiali1 | Cassava | Baray | F10-A | Adults |
| ID 93 | Asiali1 | Cassava | Van Yen | F1-A | Pupa |
| ID 94 | Asiali1 | Cassava | Van Yen | F4-B | Pupa |
| ID 95 | Asiali1 | Cassava | Van Yen | F7-A | Adults |
| ID 96 | Asiali1 | Cassava | Van Yen | F7-B | Pupa |
| ID 97 | Asiali1 | Cassava | Van Yen | F10-A | Adults |
| ID 98 | Asiali1 | Cassava | Van Yen | F10-B | Pupa |
| ID 99 | Asiali1 | Cassava | Van Yen | F13-A | Adults |
| ID 100 | Asiali1 | Cassava | Van Yen | F13-B | Pupa |
| ID 101 | Asiali1 | Cassava | Van Yen | F1-B | Pupa |
| ID 102 | Asiali1 | Cassava | Van Yen | F4-A | Adults |
| ID 103 | Asiali1 | Cassava | Tan Bien | F1-B | Adults |
| ID 104 | Asiali1 | Cassava | Tan Bien | F4-A | Adults |
| ID 105 | Asiali1 | Cassava | Tan Bien | F4-B | Adults |
| ID 106 | Asiali1 | Cassava | Ham Thuan Nam | F1-A | Adults |
| ID 107 | Asiali1 | Cassava | Ham Thuan Nam | F4-A | Adults |
| ID 108 | Asiali1 | Cassava | Bac Binh | F1-A | Adults |
| ID 109 | Asiali1 | Cassava | Huyen M'Drak | F13-A | Adults |
| ID 110 | Asiali1 | Cassava | Huyen M'Drak | F13-B | Pupa |
| ID 111 | Asiali1 | Cassava | Bac Binh | F4-A | Adults |
| ID 112 | Asiali1 | Cassava | Ham Tan | F7-A | Adults |
| ID 113 | Asiali1 | Cassava | Ham Tan | F10-A | Adults |
| ID 114 | Asiali1 | Cassava | Ham Tan | F13-A | Adults |
| ID 115 | Asiali1 | Cassava | Long Thanh | F1-A | Adults |
| ID 116 | Asiali1 | Cassava | Long Thanh | F2-B | Adults |
| ID 117 | Asiali1 | Cassava | Long Thanh | F3-A | Adults |
| ID 118 | Asiali1 | Cassava | Long Thanh | F5-A | Adults |
| ID 119 | Asiali1 | Cassava | Tan Chau | F7-A | Adults |
| ID 120 | Asiali1 | Cassava | Tan Chau | F10-B | Adults |
| ID 121 | Asiali1 | Cassava | Huyen Eakar | F1-A | Adults |
| ID 122 | Asiali1 | Cassava | Huyen Eakar | F1-B | Pupa |
| ID 123 | Asiali1 | Cassava | Huyen Eakar | F4-A | Adults |

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|--------|---------|---------|---------------|-------|--------|
| ID 124 | Asiali1 | Cassava | Chu Prong | F13-A | Adults |
| ID 125 | Asiali1 | Cassava | Huyen Eakar | F7-A | Adults |
| ID 126 | Asiali1 | Cassava | Dak G'long | F7-B | Pupa |
| ID 127 | Asiali1 | Cassava | Huyen Eakar | F10-A | Adults |
| ID 128 | Asiali1 | Cassava | Huyen Eakar | F10-B | Pupa |
| ID 129 | Asiali1 | Cassava | Huyen Eakar | F13-A | Adults |
| ID 130 | Asiali1 | Cassava | Huyen Eakar | F13-B | Pupa |
| ID 131 | Asiali1 | Cassava | Tan Chau | F1-A | Adults |
| ID 132 | Asiali1 | Cassava | Tan Chau | F1-B | Adults |
| ID 133 | Asiali1 | Cassava | Tan Chau | F4-A | Adults |
| ID 134 | Asiali1 | Cassava | Tan Chau | F13-A | Adults |
| ID 135 | Asiali1 | Cassava | Ham Thuan Nam | F7-A | Adults |
| ID 136 | Asiali1 | Cassava | Ham Thuan Nam | F7-B | Adults |
| ID 137 | Asiali1 | Cassava | Ham Thuan Nam | F10-A | Adults |
| ID 138 | Asiali1 | Cassava | Ham Thuan Nam | F10-B | Adults |
| ID 139 | Asiali1 | Cassava | Ham Thuan Nam | F13-A | Adults |
| ID 140 | Asiali1 | Cassava | Ham Thuan Nam | F13-B | Adults |
| ID 141 | Asiali1 | Cassava | Ham Tan | F1-A | Adults |
| ID 142 | Asiali1 | Cassava | Ham Tan | F1-B | Adults |
| ID 143 | Asiali1 | Cassava | Ham Tan | F4-A | Adults |
| ID 144 | Asiali1 | Cassava | Ham Tan | F4-B | Adults |
| ID 145 | Asiali1 | Cassava | Tan Bien | F7-A | Adults |
| ID 146 | Asiali1 | Cassava | Tan Bien | F7-B | Adults |
| ID 147 | Asiali1 | Cassava | Tan Bien | F10-A | Adults |
| ID 148 | Asiali1 | Cassava | Tan Bien | F10-B | Adults |
| ID 149 | Asiali1 | Cassava | Tan Bien | F13-A | Adults |
| ID 150 | Asiali1 | Cassava | Tan Bien | F13-B | Adults |