

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 Meanchey	Anlong Veang
Dak Lak	Madrak	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 Hinh	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.

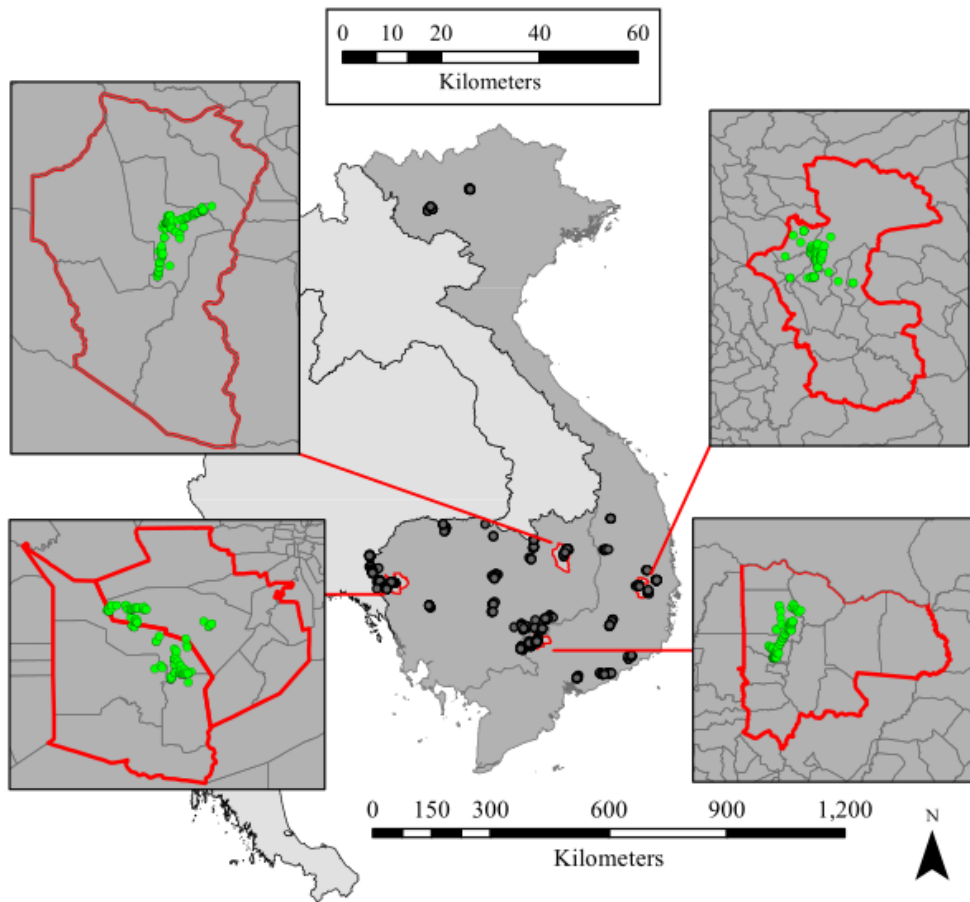
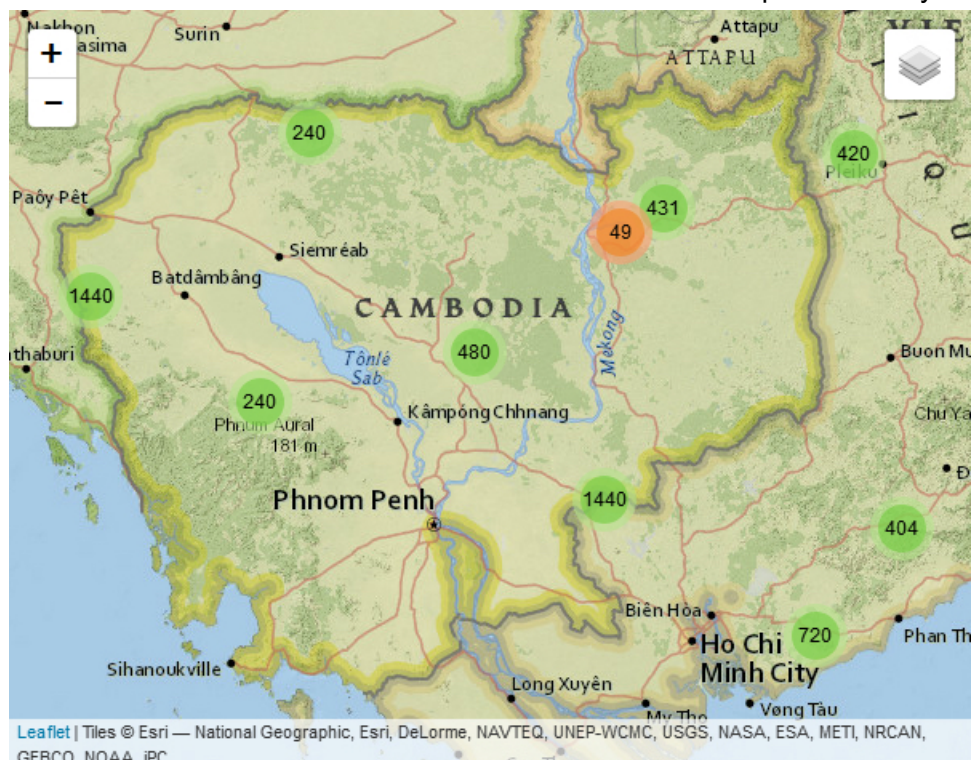


Figure 2. Distribution of clustered SLCMV-infected (orange) and non-infected (green) plants in Southern Vietnam and Cambodia. Numbers indicate the number of plants surveyed.



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 asymptomatically 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.

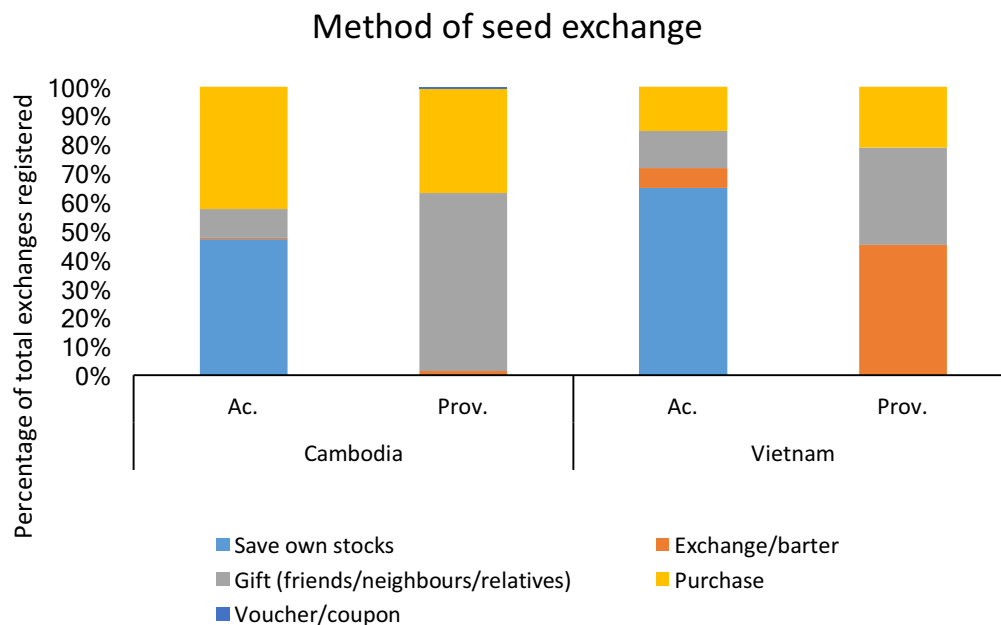


Figure 3. 100% stacked chart of stake exchange methods from the National surveys. ‘Ac.’ indicates seed acquisition, ‘Prov.’ indicates seed provision to others.

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.

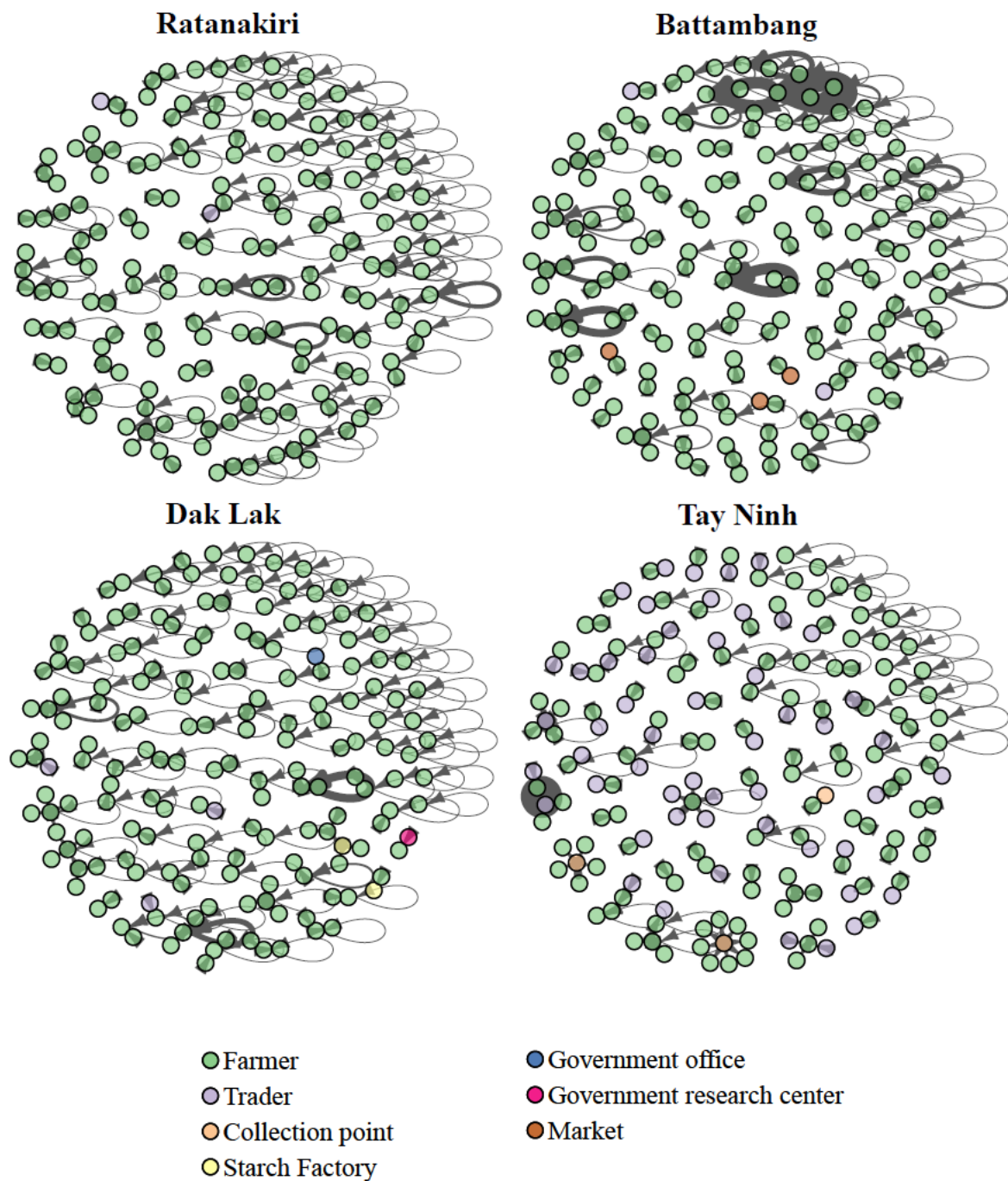


Figure 4. Network representations of stake provisioning in 4 ‘zoom-in’ sites of Cambodia and Vietnam in 2016. Arrows indicate directionality of exchange, while line weight indicates relative volume. Node color denotes type of actor involved in exchange (see legend). Self-loops indicate provision from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

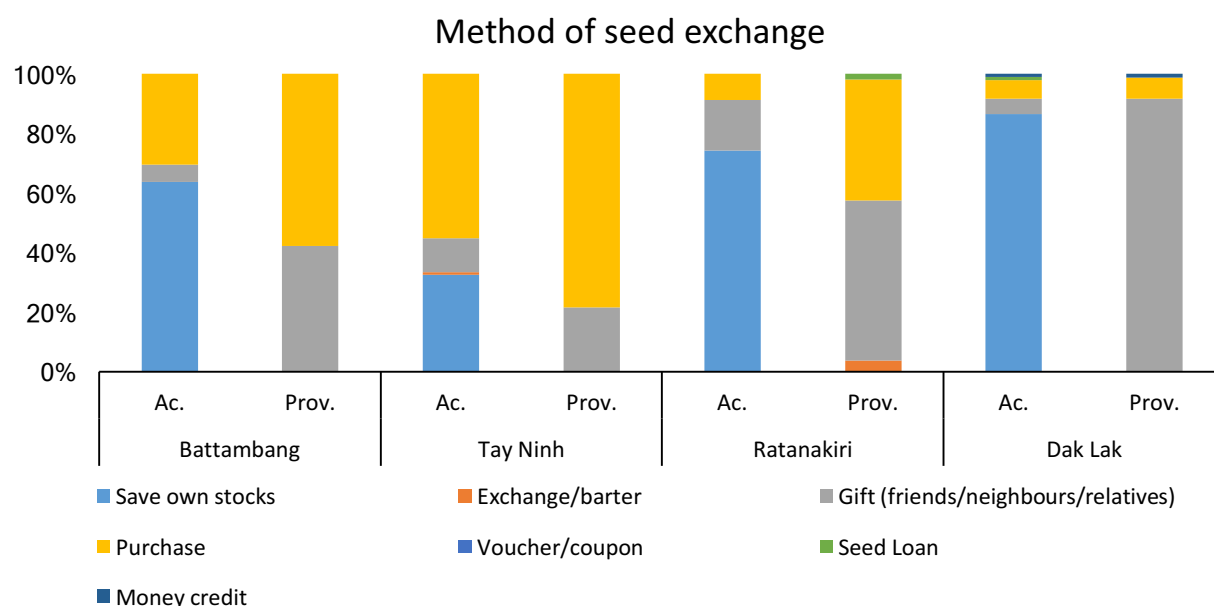


Figure 5. 100% stacked chart of methods of seed exchange in zoom-in surveys. ‘Ac.’ indicates seed acquisition, ‘Prov.’ indicates seed provision to others.

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.

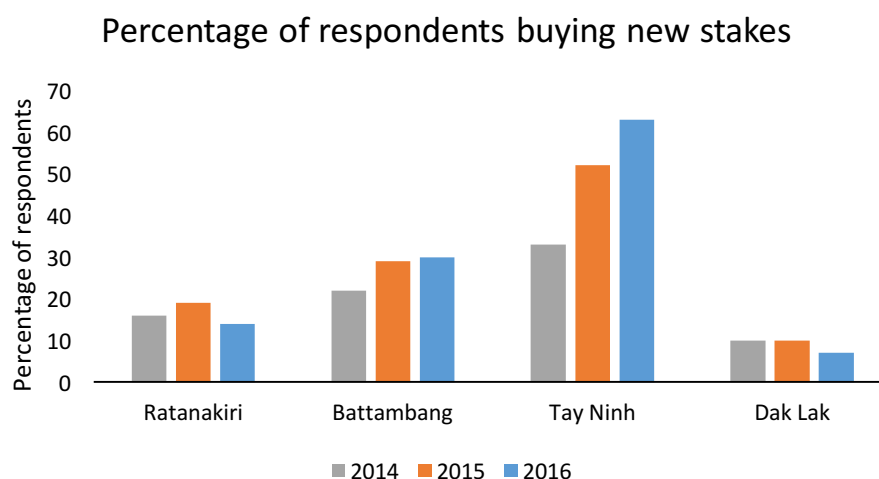


Figure 6. Percentage of respondents reporting buying stakes in the last 3 production seasons.

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	Asiall1	Cassava	Memot	F1-A	Adults
ID 2	Asiall1	Cassava	Memot	F4-A	Adults
ID 3	Asiall1	Cassava	Memot	F7-A	Adults
ID 4	Asiall1	Cassava	Memot	F10-A	Adults
ID 5	Asiall1	Cassava	Memot	F13-A	Adults
ID 6	Asiall1	Cassava	Samdan	F1-A	Adults
ID 7	Asiall1	Cassava	Samdan	F4-A	Adults
ID 8	Asiall1	Cassava	Samdan	F7-A	Adults
ID 9	Asiall1	Cassava	Samdan	F10-A	Adults
ID 10	Asiall1	Cassava	Samdan	F13-A	Adults
ID 11	Asiall1	Cassava	Thuan Chau	F5-A	Adults
ID 12	Asiall1	Cassava	Thuan Chau	F5-B	Pupa
ID 13	Asiall1	Cassava	Thuan Chau	F7-B	Pupa
ID 14	Asiall1	Cassava	Thuan Chau	F10-A	Adults
ID 15	Asiall1	Cassava	Thuan Chau	F10-B	Pupa
ID 16	Asiall1	Cassava	Thuan Chau	F13-A	Adults
ID 17	Asiall1	Cassava	Thuan Chau	F13-B	Pupa
ID 18	Asiall1	Cassava	Thuan Chau	F15-A	Adults
ID 19	Asiall1	Cassava	Thuan Chau	F15-B	Pupa
ID 20	Asiall1	Cassava	Long Thanh	F1-B	Adults
ID 21	Asiall1	Cassava	Long Thanh	F2-A	Adults
ID 22	Asiall1	Cassava	Long Thanh	F3-B	Adults
ID 23	Asiall1	Cassava	Long Thanh	F4-A	Adults
ID 24	Asiall1	Cassava	Long Thanh	F5-B	Adults
ID 25	Asiall1	Cassava	Bac Binh	F7-A	Adults
ID 26	Asiall1	Cassava	Bac Binh	F7-B	Adults
ID 27	Asiall1	Cassava	Bac Binh	F10-A	Adults
ID 28	Asiall1	Cassava	Bac Binh	F10-B	Adults
ID 29	Asiall1	Cassava	Bac Binh	F13-A	Adults
ID 30	Asiall1	Cassava	Bac Binh	F13-B	Adults
ID 31	Asiall1	Cassava	Dambae	F4-A	Adults
ID 32	Asiall1	Cassava	Dambae	F7-A	Adults
ID 33	Asiall1	Cassava	Romeas Haek	F4-A	Adults
ID 34	Asiall1	Cassava	Dambae	F13-A	Adults
ID 35	Asiall1	Cassava	Koun Mom	F7-A	Adults
ID 36	Asiall1	Cassava	Koun Mom	F10-A	Adults
ID 37	Asiall1	Cassava	Ham Thuan Nam	F4-B	Adults
ID 38	Asiall1	Cassava	Snoul	F1-A	Adults
ID 39	Asiall1	Cassava	Snoul	F13-A	Adults
ID 40	Asiall1	Cassava	Snoul	F10-A	Adults
ID 41	Asiall1	Cassava	Romeas Haek	F4-A	Adults
ID 42	Asiall1	Cassava	Romeas Haek	F4-B	Adults
ID 43	Asiall1	Cassava	Romeas Haek	F7-A	Adults
ID 44	Asiall1	Cassava	Romeas Haek	F10-A	Adults
ID 45	Asiall1	Cassava	Steung Treng	F1-A	Adults
ID 46	Asiall1	Cassava	Romeas Haek	F1-A	Adults
ID 47	Asiall1	Cassava	Steung Treng	F13-A	Adults
ID 48	Asiall1	Cassava	Baray	F1-A	Adults
ID 49	Asiall1	Cassava	Baray	F13-A	Adults
ID 50	Asiall1	Cassava	Baray	F7-A	Adults
ID 51	Asiall1	Cassava	Krong Pa	F1-A	Adults
ID 52	Asiall1	Cassava	Krong Pa	F4-A	Adults
ID 53	Asiall1	Cassava	Krong Pa	F7-A	Adults
ID 54	Asiall1	Cassava	Krong Pa	F10-A	Adults
ID 55	Asiall1	Cassava	Krong Pa	F13-A	Adults
ID 56	Asiall1	Cassava	Sa Thay	F1-A	Adults
ID 57	Asiall1	Cassava	Sa Thay	F4-A	Adults
ID 58	Asiall1	Cassava	Sa Thay	F7-B	Pupa
ID 59	Asiall1	Cassava	Sa Thay	F10-B	Adults

ID 60	Asiall1	Cassava	Sa Thay	F7-A	Adults
ID 61	Asiall1	Cassava	Chu Prong	F1-A	Adults
ID 62	Asiall1	Cassava	Chu Prong	F1-B	Pupa
ID 63	Asiall1	Cassava	Chu Prong	F4-A	Adults
ID 64	Asiall1	Cassava	Chu Prong	F10-A	Adults
ID 65	Asiall1	Cassava	Chu Prong	F7-A	Adults
ID 66	Asiall1	Cassava	Sa Thay	F13-A	Adults
ID 67	Asiall1	Cassava	Dak G'long	F10-A	Adults
ID 68	Asiall1	Cassava	Dak G'long	F7-A	Adults
ID 69	Asiall1	Cassava	Dak G'long	F10-B	Pupa
ID 70	Asiall1	Cassava	Dak G'long	F13-A	Adults
ID 71	Asiall1	Cassava	Van Yen	F1-A	Adults
ID 72	Asiall1	Cassava	Sala Krau	F7-A	Adults
ID 73	Asiall1	Cassava	Sala Krau	F10-A	Adults
ID 74	Asiall1	Cassava	Sala Krau	F13-A	Adults
ID 75	Asiall6	Cassava	Malai	F1-A	Adults
ID 76	Asiall1	Cassava	Malai	F4-A	Adults
ID 77	Asiall1	Cassava	Malai	F13-A	Adults
ID 78	Asiall1	Cassava	Pailin	F1-A	Adults
ID 79	Asiall1	Cassava	Anlong Veang	F1-A	Adults
ID 80	Asiall1	Cassava	Anlong Veang	F4-A	Adults
ID 81	Asiall1	Cassava	Anlong Veang	F10-A	Adults
ID 82	Asiall1	Cassava	Bac Binh	F4-B	Adults
ID 83	Asiall1	Cassava	Kamrieng	F1-A	Adults
ID 84	Asiall1	Cassava	Tan Chau	F13-B	Adults
ID 85	Asiall1	Cassava	Kamrieng	F7-A	Adults
ID 86	Asiall1	Cassava	Kamrieng	F10-A	Adults
ID 87	Asiall1	Cassava	Kamrieng	F13-A	Adults
ID 88	Asiall1	Cassava	Kravanh	F1-A	Adults
ID 89	Asiall1	Cassava	Kravanh	F4-A	Adults
ID 90	Asiall1	Cassava	Kravanh	F7-A	Adults
ID 91	Asiall1	Cassava	Kravanh	F10-A	Adults
ID 92	Asiall1	Cassava	Baray	F10-A	Adults
ID 93	Asiall1	Cassava	Van Yen	F1-A	Pupa
ID 94	Asiall1	Cassava	Van Yen	F4-B	Pupa
ID 95	Asiall1	Cassava	Van Yen	F7-A	Adults
ID 96	Asiall1	Cassava	Van Yen	F7-B	Pupa
ID 97	Asiall1	Cassava	Van Yen	F10-A	Adults
ID 98	Asiall1	Cassava	Van Yen	F10-B	Pupa
ID 99	Asiall1	Cassava	Van Yen	F13-A	Adults
ID 100	Asiall1	Cassava	Van Yen	F13-B	Pupa
ID 101	Asiall1	Cassava	Van Yen	F1-B	Pupa
ID 102	Asiall1	Cassava	Van Yen	F4-A	Adults
ID 103	Asiall1	Cassava	Tan Bien	F1-B	Adults
ID 104	Asiall1	Cassava	Tan Bien	F4-A	Adults
ID 105	Asiall1	Cassava	Tan Bien	F4-B	Adults
ID 106	Asiall1	Cassava	Ham Thuan Nam	F1-A	Adults
ID 107	Asiall1	Cassava	Ham Thuan Nam	F4-A	Adults
ID 108	Asiall1	Cassava	Bac Binh	F1-A	Adults
ID 109	Asiall1	Cassava	Huyen M'Drak	F13-A	Adults
ID 110	Asiall1	Cassava	Huyen M'Drak	F13-B	Pupa
ID 111	Asiall1	Cassava	Bac Binh	F4-A	Adults
ID 112	Asiall1	Cassava	Ham Tan	F7-A	Adults
ID 113	Asiall1	Cassava	Ham Tan	F10-A	Adults
ID 114	Asiall1	Cassava	Ham Tan	F13-A	Adults
ID 115	Asiall1	Cassava	Long Thanh	F1-A	Adults
ID 116	Asiall1	Cassava	Long Thanh	F2-B	Adults
ID 117	Asiall1	Cassava	Long Thanh	F3-A	Adults
ID 118	Asiall1	Cassava	Long Thanh	F5-A	Adults
ID 119	Asiall1	Cassava	Tan Chau	F7-A	Adults
ID 120	Asiall1	Cassava	Tan Chau	F10-B	Adults
ID 121	Asiall1	Cassava	Huyen Eakar	F1-A	Adults
ID 122	Asiall1	Cassava	Huyen Eakar	F1-B	Pupa
ID 123	Asiall1	Cassava	Huyen Eakar	F4-A	Adults

ID 124	Asiall1	Cassava	Chu Prong	F13-A	Adults
ID 125	Asiall1	Cassava	Huyen Eakar	F7-A	Adults
ID 126	Asiall1	Cassava	Dak G'long	F7-B	Pupa
ID 127	Asiall1	Cassava	Huyen Eakar	F10-A	Adults
ID 128	Asiall1	Cassava	Huyen Eakar	F10-B	Pupa
ID 129	Asiall1	Cassava	Huyen Eakar	F13-A	Adults
ID 130	Asiall1	Cassava	Huyen Eakar	F13-B	Pupa
ID 131	Asiall1	Cassava	Tan Chau	F1-A	Adults
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ID 133	Asiall1	Cassava	Tan Chau	F4-A	Adults
ID 134	Asiall1	Cassava	Tan Chau	F13-A	Adults
ID 135	Asiall1	Cassava	Ham Thuan Nam	F7-A	Adults
ID 136	Asiall1	Cassava	Ham Thuan Nam	F7-B	Adults
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ID 143	Asiall1	Cassava	Ham Tan	F4-A	Adults
ID 144	Asiall1	Cassava	Ham Tan	F4-B	Adults
ID 145	Asiall1	Cassava	Tan Bien	F7-A	Adults
ID 146	Asiall1	Cassava	Tan Bien	F7-B	Adults
ID 147	Asiall1	Cassava	Tan Bien	F10-A	Adults
ID 148	Asiall1	Cassava	Tan Bien	F10-B	Adults
ID 149	Asiall1	Cassava	Tan Bien	F13-A	Adults
ID 150	Asiall1	Cassava	Tan Bien	F13-B	Adults