# CASSAVA PROGRAM DISCUSSION PAPERS

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# Fertiliser Use Patterns of Smallholder Farmers- Implications for Private Sector Involvement in Technology Dissemination[1]

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## Introduction

The recent boom in the global market for cassava has created livelihood opportunities for many smallholders in Southeast Asia. Research over many years by public agencies has generated an abundance of technologies that could enhance the productivity and sustainability of these cassava producers. While national government policies have not prioritised the dissemination of these technologies, we hypothesise that, in particular contexts, private-sector value-chain actors have incentives to invest in the promotion of suitable varieties, fertiliser regimes, pest control methods, and other production practices. In other contexts, however, there is little incentive for private-sector involvement, and support from public-sector or non-government actors will be required.

In this paper we examine the fertiliser use patterns of smallholder cassava farmers across sites in Indonesia, Vietnam, Laos and Cambodia based on the results of an extensive household survey conducted in 2017. We combine these with the results of fertiliser trials conducted across 7 sites between 2016 and 2018 to propose potential business models for private sector involvement in development and dissemination of improved fertiliser formulations across the sites.

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[1] This series ***Cassava Program Discussion Papers*** presents results of the Australian Centre for International Agricultural Research (ACIAR) supported projects ASEM /2014/053 *Developing cassava production and marketing systems to enhance smallholder livelihoods in Cambodia and Lao PDR* and AGB/2012/078 *Developing value-chain linkages to improve smallholder cassava production systems in Vietnam and Indonesia*

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## Household Survey Locations

Household surveys in **Sikka, Indonesia** were conducted across four communes, Kangae and Kewa Pante in the lowlands and Koting and Nita in the uplands. As a result of relatively small sample sizes across communes much of the survey data is analysed between lowland communes with a total of 60 households and upland communes with 54 households.

*Table 1:Households by Survey locations – Sikka, Indonesia*

| Communes | Number of household surveys | Region | Total |
|---|---|---|---|
| Kangae | 59 | Lowland | 60 |
| Kewa Pante | 1 | | |
| Koting | 16 | Upland | 54 |
| Nita | 38 | | |
| **Total** | **114** | **Total** | **114** |

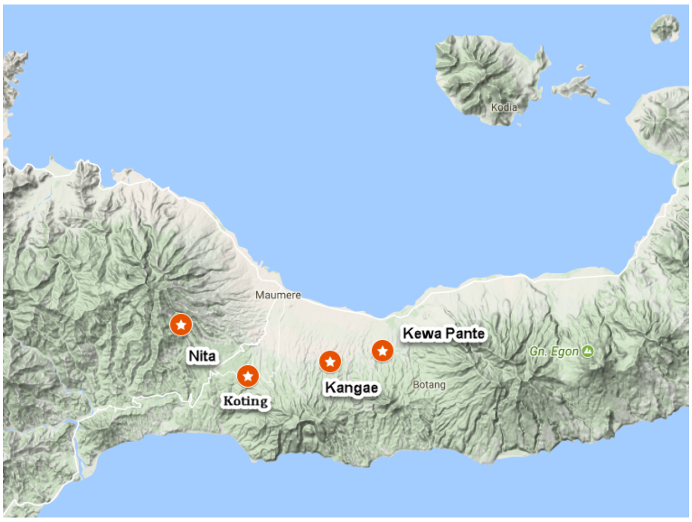

*Figure 1: Survey Sites, Sikka, Indonesia*

In **North Sumatra**, **Indonesia** household surveys were conducted in four districts, Papak Bharat, Pematang Siantar, Simalungun and Toba Samosir, with the majority of surveys (over 80%) conducted in Simalungun. The total usable sample size included 138 households.

*Table 2: Households by  Survey locations – North Sumatra, Indonesia*

| Districts | Number of household surveys |
|---|---|
| Simalungun | 111 |
| Toba Samosir | 17 |
| Pematang Siantar | 9 |
| Pakpak Bharat | 1 |
| **Total** | **138** |


*Figure 2: Survey Sites, North Sumatra, Indonesia*

Field research was undertaken in four communes in **Dak Lak, Vietnam**. These included Ea Sar and Ea So communes in Ea Kar District and Yang Kang (Dang Kang) and Cu Kty Communes in Krong Bong District. Ea Kar and Krong Bong districts were chosen for field research as they will be key locations of project activities moving forward.

*Table 3: Households by Survey locations – Dak Lak, Vietnam*

| Communes | Number of household surveys |
|---|---|
| Cu Kty | 63 |
| Dang Kang | 62 |
| Ea Sar | 65 |
| Ea So | 63 |
| **Total** | **253** |


*Figure 3: Survey Sites, Dak Lak, Vietnam*

In **Son La**, household surveys were undertaken in Chieng Chan, Na Ot, Pung Tra and Bo Muoi communes. In each commune, 32 households were surveyed in each of the two selected villages. In each commune the choice of villages was made in order to have one mid-land village close to the commune centre and one more highland village far from the commune centre. Within each village respondents were selected randomly amongst households producing cassava.

*Table 4: Households by Survey locations – Son La, Vietnam*

| Communes | Number of household surveys |
|---|---|
| Bo Muoi | 65 |
| Chieng Chan | 64 |
| Na Ot | 64 |
| Pung Tra | 64 |
| **Total** | **257** |


*Figure 4: Survey Sites, Son La, Vietnam*

In **Cambodia**, household surveys were undertaken in Kratie and Stung Treng provinces. Within Kratie the interviews were conducted in Snuol and Chitr Borie districts, and within Stung Treng they were conducted in Siem Bouk District. The useable sample was more or less divided evenly across the surveyed districts.

*Table 5: Households by Survey locations – Cambodia*

| Districts | Number of household surveys |
|---|---|
| Chitr Borie | 101 |
| Siem Bouk | 110 |
| Snuol | 100 |
| **Total** | **311** |

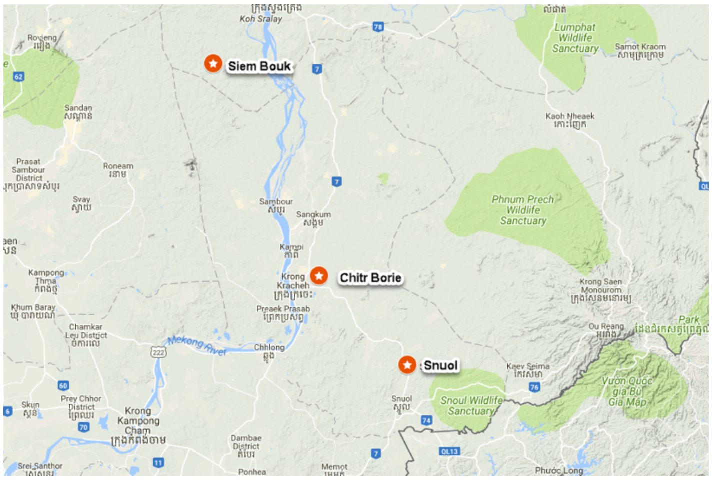

*Figure 5: Survey Sites, Cambodia*

In **Laos**, the household surveys were undertaken in Bolikhamsay and Xaybouly provinces. Within Bolikhamsay the interviews were conducted in Bolikhan and Viengthong districts and within Xaybouly it was conducted in Kenthao and Paklai districts. A total of 360 households were surveyed across the four districts.

*Table 6: Households by Survey locations – Laos*

| Districts | Number of household surveys |
|---|---|
| Bolikhan | 90 |
| Kenthao | 90 |
| Paklai | 90 |
| Viengthong | 90 |
| **Total** | **360** |

*Figure 6: Survey Sites, Laos*

## Fertiliser adoption, awareness and correct application

Results of fertiliser adoption across all surveyed sites suggests that the use of inorganic fertilisers is more common than the use of organic fertilisers. However, there is significant variation across sites in terms of the adoption rates and application practices.

Inorganic fertiliser adoption rates are relatively high for both sites in Vietnam, with slightly higher adoption rates for Dak Lak at 85% compared to 74% for Son La. The rate of inorganic fertiliser adoption also do not vary across income quartiles for both sites in Vietnam. Only 6.3 percent of farmers in **Dak Lak** apply organic fertilisers while this rate is much lower at 1.2% in **Son La**.

Across the two survey sites in Indonesia, the inorganic fertiliser adoption rate in North Sumatra at 95% is almost twice as high compared to the 50% adoption rate in Sikka. For North Sumatra, relatively fewer farmers from the first quartile indicate applying inorganic fertilisers in relation to the higher income groups. It may be argued that greater likelihood of unaffordability may have resulted in this income group's lower fertiliser adoption rate. The proportion of farmers using inorganic fertilisers across the second, third and fourth quartiles however are not statistically different from one another.

In contrast to North Sumatra, the highest income quartile in Sikka reported the lowest proportion of farmers (32.1%) adopting inorganic fertilisers. A possible explanation for this occurrence may be the low priority given to cassava by the wealthier farmers who may be better situated to exploit off-farm opportunities by diverting some resources away from cassava production.

With almost 33% applying organic fertilisers in North Sumatra and over 20% in Sikka, organic fertiliser application rates are also the highest for the Indonesian sites compared to other regions.

Inorganic Fertiliser adoption in Cambodia is extremely low at under 6% while it is almost non-existent in Laos. Similar to the findings in Sikka, the adoption rates for Cambodia are lower for the two lower income quartiles compared to their richer counterparts.

*Table 7: Fertiliser Practice, by Region*

| Region | Sikka | North Sumatra | Laos | Cambodia | Son La | Dak Lak |
|---|---|---|---|---|---|---|
| **Do you apply organic fertiliser to your cassava?** | 20.72% | 32.61% | 0.3% | 1.29% | 1.2% | 6.3% |
| **Do you apply inorganic fertiliser to your cassava?** | 50.00% | 94.93% | 0.3% | 5.79% | 73.9% | 85.4% |

*Table 8: Proportion of farmers adopting Inorganic fertiliser by region, per income quartile*

| Income Grouping | Sikka | North Sumatra | Cambodia | Son La | Dak Lak |
|---|---|---|---|---|---|
| **Quartile 1** | 50.0% | 88.2% | 3.80% | 70.30% | 81.00% |
| **Quartile 2** | 55.2% | 97.2% | 6.40% | 78.50% | 81.30% |
| **Quartile 3** | 58.6% | 94.1% | 1.30% | 73.40% | 88.90% |
| **Quartile 4** | 32.1% | 100% | 11.70% | 73.40% | 90.50% |

There is much variation across the surveyed regions with regards to both the choice of fertilisers as well as periods of application. For Dak Lak, the most popular times for fertiliser application are during planting and once after planting. During planting, the most popular type of fertiliser used is Phosphorous, which is applied by almost 41% of farmers followed by NPK which is applied by another 18%. NPK is the most popular fertiliser for the first application after planting, with almost 45% applying them while a further 12% also applies a second round. There is hardly any fertiliser application of any type for a third time or before planting.

The most common fertiliser formulation used by farmers in Dak Lak was 16:16-8, a formulation which is not optimal for cassava production. Furthermore, a high proportion of farmers did not know what the fertiliser formulation that they utilised was.

*Table 9: Proportion of farmers using inorganic fertiliser by type and application time – Dak Lak*

| Fertiliser application period | Proportion of farmers using inorganic fertiliser by type and application time (%) | | | |
|---|---|---|---|---|
| | NPK | Urea | Potassium | Phosphorous |
| **Application before planting** | 0 | 0 | 0 | 0.4 |
| **Application during planting time** | 18 | 2 | 1.2 | 40.8 |
| **First application after planting** | 44.6 | 5.6 | 2 | 1.2 |
| **Second application after planting** | 12 | 1.2 | 3.6 | 0 |
| **Third application after planting** | 0 | 0 | 0 | 0 |

*Table 10: Proportion of fertiliser users utilising different types of NPK at different times – Dak Lak*

| Formula | Application during planting time | First application after planting | Second application after planting |
|---|---|---|---|
| **16-16-8** | 53.8% | 73.8% | 70.0% |
| **15-5-20** | 7.7% | 2.4% | 5.0% |
| **17-17-8** | 3.8% | 2.4% | |
| **16-8-16** | - | - | 5.0% |
| **13-15-0** | 3.8% | - | - |
| **20-10-20** | - | 1.2% | - |
| **20-16-0** | - | 1.2% | - |
| **8-16-20** | - | 1.2% | - |
| **Don't know** | 30.8% | 17.9% | 20.0% |

Similar to Dak Lak, during planting and once after planting are also the most popular fertiliser application periods for cassava farmers in Son La. During planting, the most popular type of fertiliser used is NPK, which is applied by over 71% of farmers. Only about 12% of farmers apply a single round of fertilisers after planting and the fertiliser that is most popular for this application is Urea. Fertiliser application at any other times apart from these two periods is extremely rare.

The most common fertiliser formulation used by farmers in Son La was 5-10-3, a formulation which is not optimal for cassava production. Almost 30 percent of farmers did not know what the fertiliser formulation that they utilised was.

*Table 11: Proportion of farmers using inorganic fertiliser by type and application time – Son La*

| Fertiliser application period | Proportion of farmers using inorganic fertiliser by type and application time (%) | | | |
|---|---|---|---|---|
| | NPK | Urea | Potassium | Phosphorous |
| **Application before planting** | 0.8 | 0 | 0 | 0 |
| **Application during planting time** | 71.2 | 0 | 0.4 | 0 |
| **First application after planting** | 0.4 | 11.9 | 0.4 | 0 |
| **Second application after planting** | 0 | 0 | 0 | 0 |
| **Third application after planting** | 0 | 0 | 0 | 0 |

*Table 12: Proportion of fertiliser users utilising different types of NPK at different times –Son La*

| Formula | Application before planting | Application during planting time | 1st application after planting | 2nd application after planting | Third application after planting |
|---|---|---|---|---|---|
| **5-10-3** | 50% | 60.3% | - | - | - |
| **3-10-3** | - | 0.6% | - | - | - |
| **Don't Know** | 50% | 39.1% | 100% | - | - |

Of all surveyed regions, North Sumatra has the highest rate of fertiliser (organic and inorganic) adoption. The most popular time for inorganic fertiliser application is the first application period after planting followed by the second application period after planting and the period during planting itself. NPK and Urea are the two most popular fertilisers utilized while only a handful of farmers use Potassium or Phosphorous. During the planting period 39.5% claim to apply NPK fertilisers while a similar proportion, 37.6% apply Urea. The proportion of farmers applying these fertilisers are doubled during the first application period after planting where 76.6% apply NPK while 80.7% apply Urea. A relatively high proportion of farmers continue applying fertilisers a second time after planting with 65.7% applying NPK and about 65% applying Urea. Fertiliser application before planting or for a third time after planting is quite rare.
The most common NPK formulation applied at any period is 15-15-15 while 15-16-15 is also relatively popular particularly for application during the planting period. There are a number

of farmers that are unable to remember/ identify the type of NPK fertiliser they have utilized, although this group is much smaller in relation to those in other surveyed sites.

*Table 13: Proportion of farmers using inorganic fertiliser by type and application time – North Sumatra*

| Fertiliser application period | Proportion of farmers using inorganic fertiliser by type and application time (%) | | | |
|---|---|---|---|---|
| | NPK | Urea | Potassium | Phosphorous |
| Application before planting | 0.7 | 0.7 | 0 | 0 |
| Application during planting time | 39.5 | 37.6 | 0.7 | 2.9 |
| First application after planting | 76.6 | 80.7 | 2.8 | 7.1 |
| Second application after planting | 65.7 | 64.9 | 1.4 | 5.7 |
| Third application after planting | 2.8 | 2.9 | 0 | 0 |

*Table 14: Proportion of fertiliser users utilising different types of NPK at different times – North Sumatra*

| Formula | Application before planting | Application during planting time | First application after planting | Second application after planting | Third application after planting |
|---|---|---|---|---|---|
| 15-15-15 | 100% | 78.8% | 78.2% | 80.3% | 100% |
| 16-16-16 | - | 1.9% | 3.8% | 3.3% | - |
| 15-16-15 | - | 19.2% | 1.3% | - | - |
| 15-15-16 | - | - | - | 3.3% | - |
| Panama 150, KCl 75 | - | - | 1.3% | - | - |
| Don't Know | - | - | 15.4% | 13.1% | - |

Similar to North Sumatra, the most popular time for inorganic fertiliser application in Sikka is also the first application period after planting followed by the second application period after planting and the period during planting itself. In addition, NPK and Urea are also the two most popular fertilisers utilized. Despite this similarity, the proportion of farmers applying them are significantly lower in relation to North Sumatra. During the planting period only 6.2% claim to apply NPK fertilisers while 4.4% apply Urea. The proportion of farmers applying these fertilisers are significantly higher during the first application period after planting where 28.2% apply NPK and 35.4% apply Urea. A handful of farmers continue with a second application after planting with about 8% applying NPK and a little over 5% applying Urea. While no farmers in Sikka are involved in a third round of fertiliser application after planting there are a handful that do apply them before planting. The only NPK formulation applied by Sikka farmers is 15-15-15.

*Table 15: Proportion of farmers using inorganic fertiliser by type and application time – Sikka*

| Fertiliser application period | Proportion of farmers using inorganic fertiliser by type and application time (%) | | | |
|---|---|---|---|---|
| | NPK | Urea | Potassium | Phosphorous |
| Application before planting | 3.6 | 2.7 | 0 | 0 |
| Application during planting time | 6.2 | 4.4 | 0 | 0.9 |
| First application after planting | 28.2 | 35.4 | 0 | 0.9 |
| Second application after planting | 7.9 | 5.3 | 0.9 | 0.9 |
| Third application after planting | 0 | 0 | 0 | 0 |

*Table 16: Proportion of fertiliser users utilising different types of NPK at different times – Sikka*

| Formula | Application before planting | Application during planting time | First application after planting | Second application after planting | Third application after planting |
|---|---|---|---|---|---|
| 15-15-15 | 100% | 100% | 100% | 100% | - |

The fertiliser (organic and inorganic) application rates are very low for Cambodia with only a handful claiming to have applied them. In term of inorganic fertilisers, the most popular time for inorganic fertiliser application is the first application period after planting followed by the period during planting itself. There are also a handful of farmers that apply fertilisers before planting. NPK is the dominant fertiliser used by all households and NPK formulation that is most common is 20-20-15. However there exists a high proportion of farmers unable to identify/ remember the NPK formulation that was used.

*Table 2: Proportion of farmers using inorganic fertiliser by type and application time – Cambodia*

| Fertiliser application period | Proportion of farmers using inorganic fertiliser by type and application time (%) | | | |
|---|---|---|---|---|
| | NPK | Urea | Potassium | Phosphorous |
| Application before planting | 2.7 | 0 | 0 | 0 |
| Application during planting time | 2.9 | 0.3 | 0 | 0 |
| First application after planting | 4.2 | 0 | 0 | 0 |
| Second application after planting | 0.3 | 0 | 0 | 0 |
| Third application after planting | 0 | 0 | 0 | 0 |

*Table 3: Proportion of fertiliser users utilising different types of NPK at different times – Cambodia*

| Formula | Application before planting | Application during planting time | First application after planting | Second application after planting | Third application after planting |
|---|---|---|---|---|---|
| **13-3-3** | | 11.1% | 8.3% | | |
| **16-20-00** | | 11.1% | 8.3% | | |
| **20-20-00** | | 11.1% | | | |
| **20-20-15** | | 33.3% | 58.3% | 100% | |
| **20-20-16** | | 11.1% | | | |
| **15-15-15** | | | 8.3% | | |
| **Don't Know** | | 22.2% | 16.7% | | |

Table 19 shows NPK fertiliser use in kilograms per hectare by farmers that reported adopting NPK fertilisers. Significant variations in fertiliser usage per hectare across income quartiles is not so apparent across income groups for most surveyed regions. Only in Son La did we find some significant variation where the level of NPK fertiliser use per hectare was significantly higher for the lowest income group compared to the third and fourth income quartiles. It is probable that the higher intensity of fertiliser usage by the lowest income quartile is because this group is most dependent upon farm outputs while the higher income groups generally obtain a significant portion of their income from non-farm sources.

*Table 4: Quantity of NPK in kgs applied per hectare by region, per income quartile*

| Income Grouping | Sikka | North Sumatra | Cambodia | Son La | Dak Lak |
|---|---|---|---|---|---|
| **Quartile 1** | 238.3 | 550.0 | 31.9 | 458.0*** | 223.1 |
| **Quartile 2** | 145.2 | 444.4 | 51.5 | 342.5 | 322.3 |
| **Quartile 3** | 144.4 | 396.8 | 29.2 | 271.8* | 381.3 |
| **Quartile 4** | 177.3 | 462.7 | 107.8 | 290.1** | 388.2 |
| **Average** | 175.5 | 459.8 | 68.1 | 339.1 | 338.1 |

*Significant at the 10% level; **Significant at the 5% level; ***Significant at the 1% level

While the rate of adoption of inorganic fertilisers vary significantly across the different survey sites, overall the adoption rates are very low. There is much room for improvement in not only boosting the adoption rates but also improving the optimal application methods through application of appropriate NPK formulations in the best time periods.

In many cases farmers are not even able to identify the NPK formulations that are used. A majority of farmers from all survey regions admitted to not understanding what the NPK values stand for. The poorest cases were Laos and Cambodia both containing around one percent of farmers capable of understanding this notation with the best cases in the two Indonesian sites. However with 27% and 36% in Sikka and North Sumatra respectively that are able to decipher the meaning of NPK, clearly there is an opportunity for fertiliser companies to develop more appropriate formulations suitable for cassava production.

*Table 20: Understanding of NPK values, by Region*

| Region | Sikka | North Sumatra | Laos | Cambodia | Son La | Dak Lak |
|---|---|---|---|---|---|---|
| **Do you understand what the NPK values mean on the fertiliser you apply?** | 27.03% | 36.23% | 0.8% | 1.29% | 11.3% | 11.5% |

The exposure to fertiliser application is also quite low across all surveyed sites. Despite extremely low fertiliser adoption rates, the highest level of exposure to fertilisers is claimed by farmers in the Cambodian site with almost 25% claiming to have seen a fertiliser trial on cassava. A low proportion of only 4.4% of farmers having seen a fertiliser trial in Laos is in line with the extremely low adoption rates. However even in the Indonesian sites with relatively high adoption rates, the number of farmers claiming to have seen a fertiliser trial on cassava is very low with reported levels of only 12% in North Sumatra and 7.2% in Sikka.

Despite the dire situation with regards to the level of exposure with fertilisers and their extremely low application rates, there is much room for optimism with very high proportions of farmers interested in either visiting a fertiliser demonstration trial or even willing to conduct such trials on their own lands.

*Table 21: Fertiliser Trial, by Region*

| Region | Sikka | North Sumatra | Laos | Cambodia | Son La | Dak Lak |
|---|---|---|---|---|---|---|
| **Have you ever seen a fertiliser trial on cassava?** | 7.21% | 12.32% | 4.4% | 24.44% | 11.7% | 9.1% |
| **Are you interested in visiting a fertiliser demonstration trial to see the result on production and returns?** | 85.71% | 82.61% | 50.8% | 82.32% | 91.1% | 75.1% |
| **Are you interested in conducting a trial on your own land?** | 83.04% | 60.14% | 48.6% | 64.95% | 87.5% | 58.9% |

## Fertiliser Trial Results

During 2017-2018 season 7 demonstrations for fertilizer application were conducted in Vietnam at 2 provinces, Dak Lak and Son La.
In Dak Lak, 5 different fertilizer rate (i.e. No fertilizer, 90N-60$P_2O_5$-90$K_2O$, 99N-66$P_2O_5$-99$K_2O$, 108N-72$P_2O_5$-108$K_2O$, 117N-78$P_2$O5-117$K_2O$) were compared with Farmers' practice (i.e.100kg Phosphorous fertilizer + 250kg NPK (15-5-20) kg $ha^{-1}$). The trails were conducted in two different soil types (i.e. Ferrasol and Acrisol), with three different planting density, 15625, 12500 and 10000 Plants $ha^{-1}$. Fertilizer X planting density interaction was not significant for fresh root yield (P=0.903) (Table 21). Fresh root yield ranges from 19.15 to

45.37 t $ha^{-1}$ across all treatment and locations. Furthermore, fresh root yield on an average 1.3-fold higher in Ferrasol compared to Acrisol. Fertilizer X planting density interaction was not significant for starch content (P=0.935). However, farmers' practice (i.e. considering that farmers applying some fertilizer) yielded 1.15-fold higher compared to 'no application' of fertilizer; and 108N-72$P_2O_5$-108$K_2O$ treatment yielded 1.51-fold higher compered to farmers' practice when compered across all sites and all planting densities.
Starch content ranges from 28.5 to 31.2% across all treatment and locations (data not shown). Medium rate fertilizer application, 108N-72$P_2O_5$-108$K_2O$, resulted in highest starch content (31.4 %) when planted at 12000 Plants $ha^{-1}$.

*Table 21: Average fresh root yield (t/ha) at 5 different fertilizer rate (P0, No fertilizer; P1, 90N-60$P_2O_5$-90$K_2O$; P2, 99N-66$P_2O_5$-99$K_2O$; P3, 108N-72$P_2O_5$-108$K_2O$; P4, 117N-78P2O5-117$K_2O$) were compared with Farmers' practice (P5,100 kg Phospherous fertilizer + 250kg NPK (15-5-20) kg $ha^{-1}$). The trails were conducted in two different soil types (i.e. Ferrasol and Acrisol), with three different planting density, high, 15625, medium, 12500 and optimum, 10000 Plants $ha^{-1}$ in two different soil types in Dak Lak (2017-18)*

| Density/ Soil type Fertilizer | High | | Medium | | Optimum | |
|---|---|---|---|---|---|---|
| | Acrisol | Ferrasol | Acrisol | Ferrasol | Acrisol | Ferrasol |
| P0 | 19.15 | 24.29 | 19.67 | 32.87 | 18.31 | 23.77 |
| P1 | 28.66 | 39.40 | 32.52 | 44.58 | 30.96 | 40.87 |
| P2 | 30.84 | 40.30 | 30.27 | 44.08 | 27.55 | 41.63 |
| P3 | 37.14 | 42.64 | 33.81 | 44.31 | 33.93 | 44.00 |
| P4 | 35.75 | 44.04 | 33.49 | 45.21 | 33.17 | 45.37 |
| P5 | 24.89 | 31.30 | 22.56 | 37.37 | 19.56 | 22.57 |
| Fertilizer | P<.001, L.S.D.= 4.244 | | | | | |
| Density | P= 0.213, L.S.D.= 3.001 | | | | | |
| Soil type | P<.001, L.S.D.= 2.599 | | | | | |
| Fertilizer x Density | P= 0.903, L.S.D.= 7.351 | | | | | |
| Fertilizer x Soil type | P= 0.897, L.S.D.= 5.198 | | | | | |
| Fertilizer x Density x Soil type | P= 0.992, L.S.D.= 9.003 | | | | | |

In Son La, 5 different fertilizer rate (i.e. No fertilizer, 300 kg $ha^{-1}$ NPK (5-10-3), 600 kg ha-1 NPK (5-10-3), 40N -10P-40K + 80 kg Kali Clorua, fertilizer deep placement, 40N-10P-40K + 80 kg Kali Clorua) were compared. Fertilizer X location interaction was significant (P<0.001) (Table 22) as fertilizer responded differently in different locations. Across all locations, no fertilizer (without any fertilizer application) treatment produced lowest yield (17.8 t $ha^{-1}$) and 600 kg $ha^{-1}$ NPK (5-10-3) produced the highest (19.8 t $ha^{-1}$).

*Table 22: Average fresh root yield (t/ha) at 5 different fertilizer rate (P0, No fertilizer; P1, 300 kg $ha^{-1}$ NPK (5-10-3); P2, 600 kg $ha^{-1}$ NPK (5-10-3); P3, 40N -10P-40K + 80 kg Kali Clorua; P4, fertilizer deep placement, 40N-10P-40K + 80 kg Kali Clorua) at four communes in SonLa districts (2017-18)*

| Fertilizer | Bo Muoi | Chieng Chan | Na Ot | Pung Tra |
|---|---|---|---|---|
| P0 | 23.43 | 15.91 | 19.80 | 12.20 |
| P1 | 23.21 | 17.19 | 21.16 | 16.28 |
| P2 | 22.20 | 18.87 | 21.59 | 16.67 |
| P3 | 18.28 | 19.53 | 18.47 | 22.37 |
| P4 | 17.10 | 20.69 | 15.38 | 18.37 |
| Fertilizer | P<.001 L.S.D.= 1.075 | | | |
| Commune | P<.001 L.S.D.= 0.962 | | | |
| Fertilizer x Commune | P<.001 L.S.D.= 2.151 | | | |

In Indonesia, North Sumatra, Siantar, to demonstrate effect of fertilizer 7 different fertilizer rate (i.e. Phonska 200 kg $ha^{-1}$, Phonska 200 kg $ha^{-1}$ with 125 Urea kg $ha^{-1}$ 125 KCl kg $ha^{-1}$, Phonska 200 kg $ha^{-1}$ with 5 t $ha^{-1}$ manure, 10 t $ha^{-1}$ manure, Phonska 200 kg $ha^{-1}$ with 25 Urea kg $ha^{-1}$ 50 KCl kg $ha^{-1}$, Urea 100 kg $ha^{-1}$ with 100 kg $ha^{-1}$ SP36 and Urea 200 kg $ha^{-1}$ with 100 kg $ha^{-1}$ SP36) were applied to two varieties, Malang 6 and Malaysia in a three replicate plot experiment. Fertilizer treatment x variety interaction was not significant for fresh root yield (P=0.577) (Table 23). However, fresh root yield on an average 1.3-fold higher for Malang 4 compared to Malaysia.

*Table 23: Average fresh root yield (kg/plot) of two varieties (Malang 4 and Malaysia) with 7 different fertilizer treatments- P1, 200 kg Phonska/ha; P2, Phonska 200 kg + 125 kg Urea + 125 kg KCl/ha; P3, Phonska 200 kg + 5 t manure/ha; P4, Manure 10 t/ha; P5, Phonska 200 kg +25 kg Urea + 50 kg KCl/ha; P6, 100 kg Urea + 100 kg SP-36/ha and P7, 200 kg Urea + 100 kg SP-36/ha in Siantar, North Sumatra (2017-18).*

| Fertilisers/ Varieties | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
|---|---|---|---|---|---|---|---|
| Malang 4 | 86.7 | 87.7 | 74.3 | 90.7 | 82.0 | 87.3 | 91.7 |
| Malaysia | 69.3 | 61.3 | 57.0 | 55.0 | 96.3 | 63.0 | 62.3 |
| Varieties | P=0.009, L.S.D.= 14.08 | | | | | | |
| Fertilizer | P=0.724, L.S.D.= 26.34 | | | | | | |
| Varieties x Fertilizer | P=0.577, L.S.D.= 37.25 | | | | | | |

In Cambodia, 2 demonstrations were conducted to show the benefit of fertilizer application against farmers' practice at Snoul and Chet Borei Districts. Five different fertilizer rate (i.e. N80 P20 K80, N40 P10 K40, N40 P10 K0, N40 P10 K40 + Cow Manure 5 t $ha^{-1}$, Farmer practice- 20-20-15 = 100 kg $ha^{-1}$) were compared with No fertilizer application. Root yield was significantly different ($p<0.001$) between two locations (Table 24). However, there was no difference between the treatments in each location due to large variability caused by biotic (root rot, CMD and CWBD) stresses. The average fresh root yield was 1.4- to 2.2-fold higher in the Snoul District compared to Chet Borei District. The highest yield (26.3 ± 6.7 t $ha^{-1}$, Snoul) was achieved with highest fertilizer rate, however, in Chet Borei District highest yield was 17.6 ± 1.0 t $ha^{-1}$ with moderate fertilizer application. In general fertilizer application yielded higher fresh root compared to Farmers' practice and without any fertilizer application.
Fertilizer treatment responded similarly in both location and starch content was significantly different ($p<0.001$) between two locations (data not shown). Application of fertilizer increased starch content in all treatments ranged from 22.1 to 28.9 %.

*Table 24 Average fresh root yield (t/ha) when exposed to 6 different fertilizer treatments- P0, No fertilizer; P1, Farmer practice-NPK 20-20-15=100kg/ha; P2, N40 P10 K0; P3, N40 P10 K40; P4, N40 P10 K40 + CM 5T/ha; P5, N80 P20 K80 at two sites (Chrova and Dounmeas) of Cambodia (2017-18).*

| Fertilisers/ Locations | P0 | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|---|
| Chrova | 9.7 | 11.8 | 14.2 | 17.6 | 11.0 | 12.9 |
| Dounmeas | 14.0 | 19.3 | 21.2 | 20.3 | 24.2 | 26.3 |
| Fertilizer | P= 0.172, L.S.D.= 6.31 | | | | | |
| Location | P<.001, L.S.D.=3.64 | | | | | |
| Fertilizer x Location | P=0.403, L.S.D.=8.92 | | | | | |

In Laos, 3 demonstrations were conducted to show the benefit of fertilizer application against farmers' practice at at Paklai, Kenthao and Viengthong Districts. Five different fertilizer rate (i.e. N40 P10 K0, N40 P10 K40, N40 P10 K40 + Cow Manure 5 t $ha^{-1}$, Market available fertilizer- 15-15-15 = at 40N-40$P_2O_5$-40$K_2O$, N80 P20 K80) were compared with no fertilizer application.
Fertilizer x variety interaction was not significant. Varieties responded similarly to fertilizer; no fertilizer treatment produced the lowest and high fetilizer produced highest yield (Table 25). Considering all three Districts and 2 varieties included in the trails, highest yield (24.5 t $ha^{-1}$) was achieved by highest fertilizer application. Moderate fertilizer application with manure also yielded (23.6 t $ha^{-1}$) very close to highest rate of fertilizer input. In general fertilizer application yielded higher fresh root compared to Farmers' practice and without any fertilizer application.

Fertilizer application did not show any effect on starch content for both varieties (data not shown). Considering all three districts average starch content was recorded highest in Paklai (26.28 %) followed by Kenthao (25.1%) and Viengthong (23.97%). Average starch content in variety Rayong 11 was 1.4-fold higher compared to KU 50.

*Table 25: Average fresh root yield (t/ha) of two varieties (KU 50 and Rayong 11) with 6 different fertilizer treatments- P0 No fertilizer; P1, 40N-10P-0K; P2 40N-10P-40K; P3 40N-10P-40K + Manure (5t/ha), P4, N-P-K (15-15-15), P5, 80N-40P-80K in Paklai, Kenthao and Viengthong Districts of Laos (2017-18).*

| Fertilisers/ Varieties | P0 | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|---|
| KU 50 | 17.2 | 18.8 | 18.6 | 21.4 | 19.7 | 23.7 |
| Rayong 11 | 18.1 | 22.3 | 25.1 | 27.9 | 23.9 | 28.2 |
| Varieties | | P <.001 | L.S.D.= 2.51 | | | |
| Fertilizer | | P=0.005 | L.S.D.= 4.34 | | | |
| Varieties x Fertilizer | | P=0.808 | L.S.D= 6.14 | | | |

## Implications for Business Models for Technology Dissemination

Currently the adoption of inorganic fertiliser is extremely low in the project sites. The available fertilisers are typically design for rice production and there is limited knowledge within the extension system about the correct NPK balance, how much to apply, when to apply, and how to apply.

There are attractive rates of return at the farm level from the application low levels of fertiliser even at low prices experience in the recent past. However, extreme losses due to disease or flooding can contribute to low returns. Links between fertiliser utilisation and clean planting material of suitable varieties are clear.

There is a stronger incentive for value chain engagement in those locations with starch processors concerned with starch yields and sustainability of their feedstock. At a minimum they should see the importance of ensuring appropriate fertiliser blends are available and continue with demonstrations and promotions.

Provision of credit from processors is risky given an inability to monitor how farmers use. Engagement with support value chain actors is seen as more critical to ensure farmers purchase the correct fertiliser and have access to information.

Treatments for 2018-19 include the demonstrating the response to commercially available fertiliser blends from Thailand in farmers' fields.

The main entry point/partner for an intervention introducing more effective fertiliser treatments in the cassava value chain in Son La could be fertiliser production companies active in Son La and their associated networks of agricultural input supply shops. There is a significant profit incentive for fertiliser companies to promote the wider dissemination and adoption of fertiliser for cassava production as cassava producers use relatively small quantities of . The linkages of fertiliser companies to farmers are strong due to their distribution networks through input supply shops down to the local level.

Engagement and dissemination

| | |
|---|---|
| Value chain characteristics<br>√<br>Strong links between fertiliser companies, input suppliers and farmers | Value Chain Actor advantage<br>√<br>Incentive for fertiliser company to increase sales |
| Technology learnability<br>√ | Technology advantage<br>√ |

Adoption

| | |
|---|---|
| Community learnability<br>√ | Community advantage<br>√ |
| Technology learnability<br>√ | Technology advantage<br>Need to develop appropriate fertiliser formulation for local conditions |

*Figure 7: Engagement, Dissemination and Adoption profile of more effective fertiliser treatments in Son La*

As shown in Figure 7, while the engagement and dissemination incentives are high, the potential level of adoption of fertiliser is currently low due to the non-availability of appropriate formulations of fertiliser for cassava production. One of the key investments in facilitation of the adoption of fertiliser for cassava production will be working together with fertiliser companies to develop appropriate formulations based on trial results.

The main entry point/partner for an intervention introducing more effective fertiliser treatments in the cassava value chain in Dak Lak could be fertiliser production companies active in Dak Lak and their associated networks of agricultural input supply shops. There is a significant profit incentive for fertiliser companies to promote the widespread dissemination and adoption of fertiliser for cassava production as less than half of cassava producers in The linkages of fertiliser companies to farmers are strong due to their distribution networks through input supply shops down to the local level. Potential partners include the Binh Dien company, based in Ho Chi Minh City, but very active across the central highlands with a high market share (especially for fertilizer for coffee) - Công ty Cổ Phần Phân Bón Bình Điền (http://binhdien.com) . A local potential partner is the HUCO Tay Nguyen company, based in Buon Me Thuot (http://huco.com.vn ).

| Engagement and dissemination | | | Adoption | |
|---|---|---|---|---|
| Value chain characteristics<br>√<br>Strong links between fertiliser companies, input suppliers and farmers | Value Chain Actor advantage<br>√<br>Incentive for fertiliser company to increase sales | | Community learnability<br><br>√ | Community advantage<br><br>√ |
| Technology learnability<br>√ | Technology advantage<br>√ | | Technology learnability<br><br>√ | Technology advantage<br><br>Need to develop appropriate fertiliser formulation for local conditions |

*Figure 8: Engagement, Dissemination and Adoption profile of more effective fertiliser treatments in Dak Lak*

As shown in Figure 8, while the engagement and dissemination incentives are high, the potential level of adoption of fertiliser is currently low due to the non-availability of appropriate formulations of fertiliser for cassava production. One of the key investments in facilitation of the adoption of fertiliser for cassava production will be working together with fertiliser companies to develop appropriate formulations based on trial results.

In Bolikhan district, both the DDD and TTL factories have a strong incentive to be able to purchase a higher quantity of inputs on a more regular basis in order to increase the efficiencies of their operation – DDD has invested in a large drying area and also invested in inputs for farmers while TTL has recently invested in increasing the capacity of their starch processing equipment. DDD and TTL may be potential entry points for the project interventions, but a cautious approach must be taken as may not be the best entry points as they are currently experiencing difficulties in their business activities and they may not be viable partners in the medium-long term.

The potential entry point/partner in Vienthong district is much less clear. The project team has not yet been able to meet with the newly established starch factory to gain information on their operations and their interest in participating in the project. It is reasonable to assume that in common with other starch processors, the starch factory in Vienthong could benefit from increased coordination and information sharing leading to more efficient use of factory capacity

The other potential partner could be the chip trader Xin Xin Laos. They have links through to farmers through network of collectors and contracts with village heads in five villages. However, when interviewed they did not express interest in participating in project activities as they had no land and very limited human and financial resources, and also felt as a 100 percent Chinese owned company that they did not have sufficient links with the local system.

While the engagement and dissemination incentives are high, the potential level of adoption of fertiliser is currently low due to the non-availability of appropriate formulations of fertiliser for cassava production. One of the key investments in facilitation of the adoption of fertiliser for cassava production will be working together with fertiliser companies to develop appropriate formulations based on trial results.

| Engagement and dissemination | | Adoption | |
|---|---|---|---|
| Value chain characteristics<br>Linkages and trust between factories and farmer groups needs to be improved | Value Chain Actor advantage<br>Lack of working capital to invest in dissemination | Community learnability<br><br>√ | Community advantage<br><br>√ |
| Technology learnability<br>√ | Technology advantage<br>√ | Technology learnability<br><br>√ | Technology advantage<br><br>Need to develop appropriate fertiliser formulation for local conditions |

*Figure 9: Engagement, Dissemination and Adoption profile of effective fertilizer treatments in Bolikhamxay*

The main entry point/partner for an intervention introducing more effective fertiliser treatments in the cassava value chain in North Sumatra could the PT Bumi Sari factory and associated agents. There is a significant profit incentive for PT Bumi Sari to promote the widespread dissemination and adoption of fertiliser for cassava production as less than half of cassava producers in order to increase the throughput in their factory.

| Engagement and dissemination | | Adoption | |
|---|---|---|---|
| Value chain characteristics<br>√<br>Strong links between starch factory, agents, traders and farmers. Factory faces limited competition | Value Chain Actor advantage<br>√<br>Incentive for starch factory to increase sales | Community learnability<br><br>√ | Community advantage<br><br>√ |
| Technology learnability<br>√ | Technology advantage<br>√ | Technology learnability<br><br>√ | Technology advantage<br><br>Need to develop appropriate fertiliser formulation for local conditions |

*Figure 10: Engagement, Dissemination and Adoption profile of more effective fertiliser treatments in North Sumatra*

As shown in Figure 10, while the engagement and dissemination incentives are high, the potential level of adoption of fertiliser is currently low due to the non-availability of appropriate formulations of fertiliser for cassava production. One of the key investments in facilitation of the adoption of fertiliser for cassava production will be working together with fertiliser companies to develop appropriate formulations based on trial results.

The main entry point/partner for an intervention introducing more effective fertiliser treatments in the cassava value chain in Kratie could be the newly opened starch factory. There is a significant profit incentive for fertiliser companies to promote the widespread dissemination and adoption of fertiliser for cassava production as currently only a very small proportion of farmers utilize inorganic fertilizers – generally not of an appropriate formulation for cassava production. The starch factory would have an incentive to develop strong relationships and support the dissemination of fertilizers in order to secure supply of input material in the face of competition from Tay Ninh processors.