
CASSAVA PROGRAM DISCUSSION PAPERS

Results of Cassava Demonstration Trials in the Ayeyarwady Region in 2019

Tin Maung Aye, Nilar Aung,
Dominic Smith and Lava Yadav
Discussion Paper Number 14
May 2020



THE UNIVERSITY OF QUEENSLAND

A U S T R A L I A

School of Agriculture and Food Sciences

ISSN: 2209-2684

Results of Cassava Demonstration Trials in Ayeyarwady Region in 2019¹

Tin Maung Aye², Nilar Aung³, Dominic Smith⁴ and Lava Yadav⁵



DISCLAIMER AND CONFIDENTIALITY

Although the authors have used their best efforts to ensure that the contents of this report are correct at the time of reporting, it is impossible to cover all situations. The information is distributed on an ‘as is’ basis, without warranty. The authors shall not be responsible for any liability, loss of profit or other damages caused or alleged to have been directly or indirectly caused by following information included in this report.

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*

² Independent Consultant

³ Department of Agriculture, Ayeyarwady Division, Myanmar

⁴ School of Agriculture and Food Sciences, University of Queensland, Australia

⁵ School of Agriculture and Food Sciences, University of Queensland, Australia

EXECUTIVE SUMMARY

The Ayeyarwady region is one of the key cassava producing regions in Myanmar. Farmers in this region generally favour cassava over other cash crops due to its potential for generating higher yields and also its adaptability to a wide range of agro-climatic conditions. Market integration and policy incentives have changed the cassava production system from the traditional extensive system to those characterised by intensive monoculture practices. While increased adoption and expansion of cassava has contributed to reduced rural poverty in the region, challenges related to low crop productivity still remain.

Cassava has been designated a priority crop in Hinthada and Patheingyi districts both for its contribution to household food security as well as its ability to contribute to better incomes through sale to the starch processing industry. However, limited access to high-yielding varieties, shortage of good planting materials, and poor nutrient management are some of the key constraints limiting cassava production for smallholders.

In recognition of these constraints, the activities conducted under this project were designed to demonstrate and promote cultivation practices for increasing cassava yields primarily through capacity building activities. The key activities included a 'training of trainers' program and demonstration trials to assess fertiliser responses, optimal planting methods and good planting material multiplication practices. Additionally field days were also conducted with multiple stakeholders related to the cassava sector including farmers, traders and processors as well as DOA extension staff. In addition to educating participants on the results of the demonstration trials, the activities also encouraged dialogue between the stakeholders to share ongoing problems across the different sectors of the industry chain, while allowing them to realise potential areas for improvement. Furthermore, this participatory approach progressed as a step towards achieving the ultimate goal of developing a locally appropriate model where cassava farmers are linked with the private sector (processors and agro-input dealers) to build a more sustainable system for enhancing the cassava sector while emphasising the welfare of poor cassava farmers.

The fertiliser demonstration trials revealed significant impact of fertilization upon cassava root yields and starch content. The highest root yield and starch content was associated with a high rate of balanced NPK (250kg of Urea+ 125kg of TSP+ 250kg of KCl per ha) application followed by lower rates of NPK (125kg of Urea+ 62.5kg of TSP+ 125kg of KCl per ha) and (125kg of Urea+ 62.5kg of TSP+ 125kg of KCl + FYM 5 tons per ha). A low rate of NPK without K (125kg of Urea+ 62.5kg of TSP per ha) showed no difference with the existing practice of farmers involving 75kgs of Urea per ac. However, it still resulted in significantly higher yields in relation to the control which involved no fertiliser application. Furthermore, the economic analysis related to the different fertiliser treatments revealed that despite higher production costs (per ton) related to the use of FYM and high rates of NPK, they also produced highest net incomes.

The demonstration trials on planting methods revealed higher productivity from the ridge method in relation to the mound method. The ridge method was also regarded to be superior due to its lower labour requirement, particularly given the shortage of farm labour for smallholders in the Ayeyarwady region. There is potential for farmers to save a significant amount of time as ridges can also be made using tractors. Furthermore, the ridge method was

considered to enable easier fertiliser application and weed control. However, some farmers still prefer to plant cassava on mounts particularly in low lying areas that have higher risks of floods.

Recommendations made to farmers for increasing yields should ensure that local challenges as well as farmer preferences are taken into account. As such costs related to cultivation practices including planting costs, fertiliser costs, etc. must be considered while acknowledging local constraints such as limited accessibility to agro-inputs which are common in rural areas. While cassava varieties with high yield potential (for example KU50 and Rayong 9) for starch processing are generally recommended to farmers, it is important to acknowledge that cassava still remains an important food source for certain rural communities. This implies that in addition to varieties best suited for starch processing, research on edible varieties are also important in order to boost food security in these areas.

Similarly while the fertiliser demonstration trials enabled identification of fertiliser types and rates for achieving higher yields, it is equally important to acknowledge the issue related to limited access to the formulations that may be recommended. Farmers claimed to have access to N and K straight fertilisers through their local markets however this was not case with P fertilisers. Furthermore, while some compound NPK formulations are available through local suppliers, the recommended ratios of N, P, and K are generally not available.

With regards to the choice of planting method, despite clear advantages of the ridge method, many farmers appeared to retain the traditional practice of the mount method. This was found to be linked to the existing system of paying farm labourers. The system at present is designed to pay workers on a 'per mount' basis which is not compatible with the ridge method resulting in its reduced adoption. Additionally, the higher yield related to the ridge method was found to be related to the higher density of plants in a given area. This was found to be a deterrent to farmers that relied on purchased planting materials as it increased their planting costs.

To meet the increasing demand for new high yielding cassava varieties, they have been imported from neighbouring countries such as Thailand and China; however the importation has generally been without adequate control measures such as the implementation of necessary quarantine measures. This has resulted in increased incidence of various types of pests and diseases that are capable of reducing yields significantly. The most important pests found in Ayeyarwady region include whiteflies, mealybugs, red mites, scale insects, and termites. Cassava bacterial blight (CBB), witches' broom disease, and root rot disease are also major diseases, all of which can cause tremendous damage on cassava production. In order to minimise risks special care must be taken when transporting planting materials between regions as well as among farms.

Securing better livelihoods through the cassava crop certainly requires introduction of modern technologies that reduce production costs and increase yields, but it is also important to complement such technologies with policies that help reduce price volatility. With growing interest from farmers for adopting cassava along with a gradual increase in yields, the higher supply is likely to reduce market prices in the absence of increased demand. As such trade links with international markets must be developed to take advantage of the high demand for cassava in neighbouring countries, particularly China. Ultimately, it is essential to develop a comprehensive national cassava strategy to help the sector grow while subsequently contributing to the livelihoods of poor cassava farmers.

INTRODUCTION

The Ayeyarwady region is one of the key cassava producing regions in Myanmar. In this region, cassava is the most widely cultivated annual crop in upland areas where rainfed agriculture predominates. Many farmers prefer to grow cassava over other cash crops as cassava is relatively undemanding in terms of inputs (such as fertilisers, water, and labour, etc.). While the present farm landscape also comprises of other upland crops such as chili, maize, pulses, sugarcane, and tomato, cassava is by far the most important upland crop.

Cassava has been designated a priority crop in Hinthada and Patheingyi districts both for its contribution to household food security as well as its ability to contribute to better incomes through sale to the starch processing sector. While increased adoption and expansion of cassava has contributed to reduced rural poverty, challenges related to low crop productivity still remain. Limited access to high-yielding varieties, shortage of good planting materials, and poor nutrient management are some of the key constraints limiting cassava production for smallholders. Additionally, in the absence of mechanization, cultivation activities related to land preparation, sowing, crop management, and harvesting are labour intensive. Also, a growing number of farmers are being confronted with land degradation issues, excessive production costs and indebtedness, especially amongst smallholder farmers.

In recognition of these constraints, the activities conducted under this project were designed to demonstrate and promote cultivation practices for increasing cassava yields primarily through capacity building activities. The key activities included a ‘training of trainers’ program and demonstration trials to assess fertiliser responses, optimal planting methods and good planting material multiplication practices. Additionally field days were also conducted with multiple stakeholders related to the cassava sector including farmers, traders and processors as well as DOA extension staff. In addition to educating participants on the results of the demonstration trials, the activities also encouraged dialogue between the stakeholders to share ongoing problems across the different sectors of the industry chain, allowing them to realise potential areas for improvement. Furthermore, this participatory approach progressed as a step towards achieving the ultimate goal of developing a locally appropriate model where cassava farmers are linked with the private sector (processors and agro-input dealers) to build a more sustainable system for enhancing the cassava sector while emphasising the welfare of poor cassava farmers.

In this paper we detail the capacity building activities with particular emphasis on the results of the cassava demonstration trials. The paper also reports on the potential challenges associated with the adoption of the recommended cassava cultivation practices as revealed through discussions between the different stakeholders during the field days. Finally, the paper lists and discusses a range of cassava related pests and diseases that have been detected in the Ayeyarwady region.

OBJECTIVES

The main objective of the cassava demonstrations was to showcase the performance of improved cassava varieties, alternative planting methods, and better fertilization practices for increasing cassava yields in a sustainable and profitable manner.

The specific objectives of cassava research activities were as follows:

1. To establish field demonstrations in collaboration with local cassava processors, cassava traders and agro-input suppliers.
2. To use a participatory approach for monitoring agronomic parameters and incidence of pests and diseases on cassava plants.
3. To train DOA extension and agricultural researchers, local cassava processors, and champion farmers on both the technical aspects of cassava cultivation and the effective transfer of production technologies to other cassava farmers.
4. To learn about the constraints and opportunities for sustainable intensification of cassava production systems.
5. To enhance the development of local solutions and enable lessons to be shared across other similar regions in Myanmar through regional partnerships.

PROJECT LOCATION

Ayeyarwady region is Myanmar’s most populated region with an estimated population of 6.32 million. This region shares a border with Rakhine, Bago, and Yangon. Ayeyarwady region also has the highest rural population with 88% of people living in rural areas. It consists of 26 townships and covers a total area of 35,964 square kilometres. Ayeyarwady region has a long history of cassava production with Patheingyi and Hinthada as two of the most important districts in relation to cassava production. A majority of farmers in these two districts rely on cassava for their livelihoods.

After consultations with regional Department of Agriculture (DOA) officers and village leaders in both districts, three townships were selected for the research activities. The selected townships were Hinthada and Lemyethna townships in Hinthada district and Kyonpyaw township in Patheingyi district (Figure 1).



Figure 1: Location of townships selected for research activities in the Ayeyarwady region

CASSAVA PRODUCTION

In Myanmar cassava has been grown as a food crop for several decades. Recent years have witnessed increased adoption of cassava with over 30,000 smallholders growing them at present. While this has resulted in increased production levels, the higher output has been attributed to increased adoption by farmers and to an expansion of production area rather than increased yields (

Table 1). In the 2018/19 growing season, Myanmar produced 401,204 tons of fresh cassava roots from a total of 58,232 hectares of harvested area. This denotes an average national yield less than 15 tons per hectares (DOA, 2019); a relatively minor improvement from the average of 10.4 tons per hectare achieved 30 years ago, especially when compared to its potential of up to 80 tons per hectare (FAO, 2013).

Ayeyarwady is second largest cassava producing region in Myanmar with yields comparable to the national average. The role of cassava has evolved in this region from a neglected food crop to an industrial cash crop, especially for smallholder farmers.

Table 1: Harvested area, yield, and production of cassava in Myanmar

Region/State	Harvested area (ha)		Average yield (tons/ha)		Production (tons)	
	1988/89*	2018/19**	1988/89*	2018/19**	1988/89*	2018/19**
Ayeyarwady	3,664	12,744	10.6	14.78	38,787	188,355
Bago	555	130	5.7	21.33	3,175	2,773
Chin	7	80	3	4.35	21	348
Kachin	174	15,409	7.2	9.93	1,260	153,034
Kayah	-	-	-	-	-	-
Kayin	30	1,113	12.9	13.40	388	14,911
Magway	-	-	-	-	-	-
Mandalay	-	-	-	-	-	-
Mon	109	293	11.9	14.43	1,303	4,228
Rakhine	60	292	3.9	6.31	233	1,842
Sagaing	30	1658	15	8.78	450	14,563
Shan	0.4	314	1.5	7.58	0.6	2,380
Thanintharyi	555	700	10.5	12.89	5,819	9,023
Yangon	416	654	16.3	14.90	6,794	9,747
Total	5,602	33,387	10.4	14.78	58,232	401,204

Sources: *U Tun Than 1990; **DOA 2019

Patheingyi and Hinthada districts dominate cassava production in the Ayeyarwady region with more than 90% of total production (188,355 tons) originating from within these two districts in the 2018/2019 growing season (Figure 2).

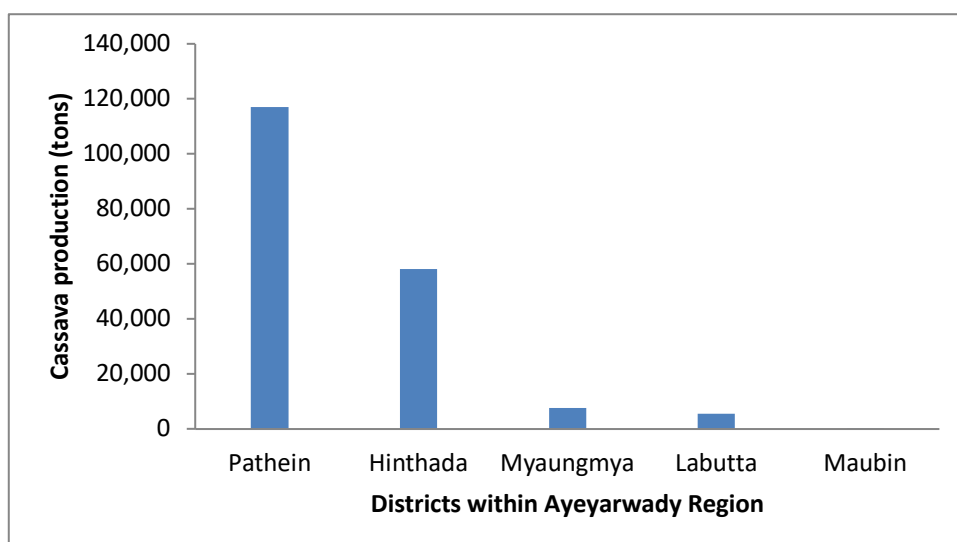


Figure 2: Cassava production (tons) by district in the Ayeyarwady region (2018/2019)

Pathein district produces over 60% of the total cassava output from within the Ayeyarwady region and has a slight edge over other districts in terms of average yield (Table 2). Hinthada is responsible for 30% of cassava output while the amounts produced by the remaining districts are only marginal in relation to the two dominant districts.

Table 2: Cassava production across districts within the Ayeyarwady region (2018/2019)

District	Harvested area (ha)	Average yield (tons/ha)	Production (tons)
Pathein	7,499	15.60	116,970
Hinthada	4,260	13.63	58,083
Myaungmya	516	14.80	7,635
Labutta	463.5	12.08	5,598
Maubin	5.5	12.55	69
Total	12,744	14.78	188,355

Source: DOA 2019

CAPACITY BUILDING FOR LOCAL AGRICULTURE EXTENSION WORKERS, CHAMPION FARMERS, AND PROCESSORS

A four day training of trainers (ToT) program was held in Hinthada district with the support of the local DOA staff between the 23rd and 26th of April 2019 (Figure 3). In addition to classroom based training sessions at the DOA Hinthada office practical training sessions were also conducted in Sharkae village (Figure 4 and Figure 5). The purpose of the ToT session which was attended by a total of 14 participants (9 females and 5 males) was to improve the technical knowledge of sustainable intensification of cassava production technologies for local DOA agricultural practitioners, champion farmers⁶, and processors in the Ayeyarwady region. The participants were taught about sustainable cassava production technologies which included selection of suitable cassava varieties, good planting material multiplication practices, proper planting techniques, optimal fertiliser application and soil fertility management practices,

⁶ Champion farmers are characterised as progressive farmers supporting new ideas and willing to test new technologies. They are also generally capable of influencing and encouraging other farmers to adopt new practices.

awareness of emerging pests and diseases and their control methods, knowledge related to costs of production, etc. Through the demonstration trials in the field, participants were trained to identify soil problems as well as pests and diseases on cassava plants.



Figure 3: Group photo of participants with DOA in Hinthada district and the township manager at TOT training in Ayeyarwady region



Figure 4: Classroom session at DOA Hinthada Office



Figure 5: Practical session at the cassava field during ToT training

There was active participation from the participants during both the classroom and field training sessions. The sessions were regarded as being very informative and enabled participants to set up on-farm demonstration trials. In addition they have also been involved in sharing their technical knowledge and experiences with other farmers in neighbouring villages.

CASSAVA DEMONSTRATIONS TRIALS IN 2019/2020

Despite the prevalence of cassava across the Ayeyarwady region for the last several decades, prevailing yields have been quite low for most farmers (<15 tons/ha); especially when compared to their potential which ranges between 35 and 45 tons/ha. With the selection of appropriate high yielding varieties along with best crop management practices, the agro-climatic conditions in Ayeyarwady have the potential to produce significantly higher yields. The ToT program followed along with the demonstration trials were aspired to instil this realisation upon the participants and furthermore spread the knowledge to the wider farming communities.

During the ToT program, the next stage of project activities in relation to choosing sites for conducting the demonstration trials and the types of cassava demonstrations to conduct for the 2019 growing season were discussed with local processors and farmers (Figure 6). The three types of cassava demonstrations agreed upon included 1) balanced fertiliser application trials, 2) trials on cassava planting methods, and 3) multiplication of promising cassava varieties. The names of farmers and processors who participated in the cassava demonstration trials along with their respective locations (village names) are presented in Appendix A.



Figure 6: Discussions being held with farmers and local processors on cassava demonstration trials.

ON-FARM FERTILISER TRIALS

The aim of the on-farm fertiliser trials was to examine fertiliser responses (application of balanced NPK combinations) to understand the optimal fertiliser rates for maintaining soil fertility and achieving high yields.

In recent years, many farmers have been found using mineral and compound fertilisers (15N-15P₂O₅-15 K₂O and 10N-10P₂O₅-5 K₂O). On the contrary only a handful are able to apply farmyard manure as a source of organic fertiliser for their cassava crops since many of these farmers do not own cattle or buffalos. With the popularity of Urea for crop cultivation in Ayeyarwady, farmers are known to apply high amounts of Urea, while the cassava crop is devoid of P and K.

Fertiliser demonstrations were conducted on farmer fields in Hinthada and Kyonpyaw townships. The trials involved a total of six treatments:

1. Balanced NPK High rate (250kg of Urea+125kg of TSP+250kg of KCl per ha)
2. Balanced NPK Low rate (125kg of Urea+62.5kg of TSP+125kg of KCl per ha)
3. Balanced NPK Low rate plus Manure (125kg of Urea+62.5kg of TSP+125kg of KCl + FYM 5 ton per ha)
4. NP Low rate without K (125kg of Urea+62.5kg of TSP per ha)
5. Farmers' practice (187.5kg of Urea per ha)
6. Control (No fertiliser application)

Straight fertilisers were used for the NPK demonstration trials (i.e. Urea = 46% N, TSP = 46% P₂O₅, and KCl = 60% K₂O). Urea and KCl fertilisers were applied twice to achieve better fertiliser use efficiency: half during the planting period and the remainder 4 to 5 weeks after

weeding. TSP fertiliser and manure FYM were applied only at the time of planting. The trials were harvested and fresh root yield and starch content (%) measured.

In Kyonpyaw Township, a total of six farmers & processors from Sharkhe village joined the fertiliser trials. They planted cassava on fields with the same type of soil (sandy loam soil). All of the six demonstration farms were involved in conducting the six treatments including the control, and the Bangkok variety was used for the fertiliser trials.

According to the results of the fertiliser trials in Sharkhe village, visually, the cassava plant appears to be highly responsive to fertiliser application (Figure 7).



Figure 7: Effect of NPK fertilisers on cassava plant growth (plants without fertilisers - in front; plants with fertilisers – in the back)

Test Statistic:

Given the small sample size of the demonstration trials, statistical difference between fertiliser treatments could not be established with a high degree of power. The test statistic used for making comparisons of cassava root yields and starch content across fertiliser treatments is the Kruskal-Wallis H test (K-W) using statistical software STATA (www.stata.com). Kruskal-Wallis H is a non-parametric test that adopts the ranking method without any distributional assumptions imposed by parametric tests. More specifically, the normality assumption is not imposed. Furthermore, an advantage of the ranking method is that the test is less sensitive to outliers. The Kruskal-Wallis H test is regarded as an extension of the Mann-Whitney U test allowing for comparisons of more than two independent groups. The omnibus test statistic however only indicates whether or not any two groups (of the multiple groups included) are different from one another, without indicating which groups they are.

A Dunn's test is considered to be an appropriate post hoc test to make multiple pairwise comparisons when a Kruskal-Wallis test is rejected. As such a Dunn's test was performed using the `dunntest` package in STATA (Dinno 2015) where the p-values for pairwise comparisons were adjusted using Bonferroni corrections.

The results of the fertiliser trials as shown below in Table 3 clearly demonstrate the positive impact of fertilisers on cassava yield and starch content.

By rejecting the Kruskal-Wallis test (K-W test: $\chi^2(1) = 18.615$, $p = 0.002$) at the 5% level of significance we confirm that at least one of the treatment groups is statistically different from another. The pairwise comparisons provided by the Dunns test (as shown in Appendix E) show that the root yields for treatment 1 and treatment 3 are significantly higher than the control treatment at the 5% level of significance. Higher root yields are also observed over the control treatment for treatments 2 and 5, but only at the 10% level of significance. At a p-value of 0.2, farmers' existing practice of applying 187.5 of Urea per ha is found not to produce higher root yields relative to the control treatment of no fertiliser application. Furthermore, the pairwise comparisons also do not find any statistically significant yield differences across any of the non-control treatments.

Based upon average yields, a high rate of balanced NPK fertiliser (250kg of Urea+ 125kg of TSP+ 250kg of KCl per ha) produced the highest fresh root yield as well as the highest starch⁷ content among all treatments. The superiority of this particular fertiliser over others was observed across all but one of the farmer fields. The second highest yield and starch content was achieved under treatments two and three. The average yields and starch content were similar between the application of the low rate of balanced NPK (125kg of Urea+ 62.5kg of TSP+ 125kg of KCl per ha) and low rate of balanced NPK plus Manure (125kg of Urea+ 62.5kg of TSP+ 125kg of KCl + FYM 5t per ha).

The combined mineral NPK fertilisers and FYM was found to be superior to the current practice adopted by farmers (187.5 of Urea per ha), however no improvement was observed with the exclusion of K fertilisers. As such the K fertiliser appears to be an important contributor to increased yields as well as starch content.

Table 3: Results of the fertiliser demonstration trials in Sharkhe (2019/2020)

Farmer ID/ Treatment	Yield (tons/ha)							Starch Content (%)						
	MS	KYK	AM	ST	TW	TA	Avg	MS	KYK	AM	ST	TW	TA	Avg
1	34	30	27	27	36	25	30	29	31	31	31	31	31	31
2	26	27	23	20	35	22	26	29	31	31	31	29	27	30
3	27	28	28	21	38	25	28	29	31	31	31	29	29	30
4	25	27	22	19	30	21	24	29	31	31	27	29	27	29
5	25	28	26	24	27	20	25	29	31	31	27	27	27	29
6	16	19	19	13	4	16	15	27	29	31	27	27	27	28

Note: Each column represents the farmer involved in conducting the demonstration trial along with the yield and starch content results.

The impact of fertilisers on starch yields as shown in Table 4 and Figure 8 demonstrate the superiority of applying a high rate of balanced NPK fertiliser. By rejecting the Kruskal-Wallis test (K-W test: $\chi^2(1) = 19.107$, $p = 0.002$) at the 5% level of significance we confirm that at least one of the treatment groups is statistically different from another. The pairwise comparisons using the Dunn's test indicate starch content to be higher at the 5% level of

⁷ According to the Kruskal-Wallis test results (K-W test: $\chi^2(1) = 9.361$, $p = 0.095$) we fail to reject the null hypothesis at the 5% level of significance and conclude no statistically significant differences in starch content across any of the treatment groups.

significance for treatments 1 and 3 in relation to the control treatment (as shown in Appendix F). Higher starch content was also observed for treatment 2 over the control treatment but only at the 10% level of significance. As such neither the current farmers' practice nor the application of NPK without K produced statistically higher starch yields compared to the control treatment.

Table 4: Starch yield (tons/ha) of 6 fertiliser demonstration trials in Sharkhe (2019/2020)

Farmer ID/ Treatment	Starch yield (tons/ha)						
	MS	KYK	AM	ST	TW	TA	Average
NPK High	9.7	9.3	8.3	8.4	11.3	7.8	9.2
NPK Low	7.5	8.4	7.1	6.2	10.2	6.0	7.6
NPK Low + FYM	7.9	8.8	8.7	6.6	11.1	7.2	8.4
NP without K	7.1	8.3	6.9	5.2	8.7	5.5	6.9
Farmers' practice	7.2	8.7	8.1	6.5	7.3	5.5	7.2
No fertiliser	4.3	5.5	5.8	3.4	1.2	4.4	4.1

Note: Each column represents the farmer involved in conducting the demonstration trial along with the starch yield results.

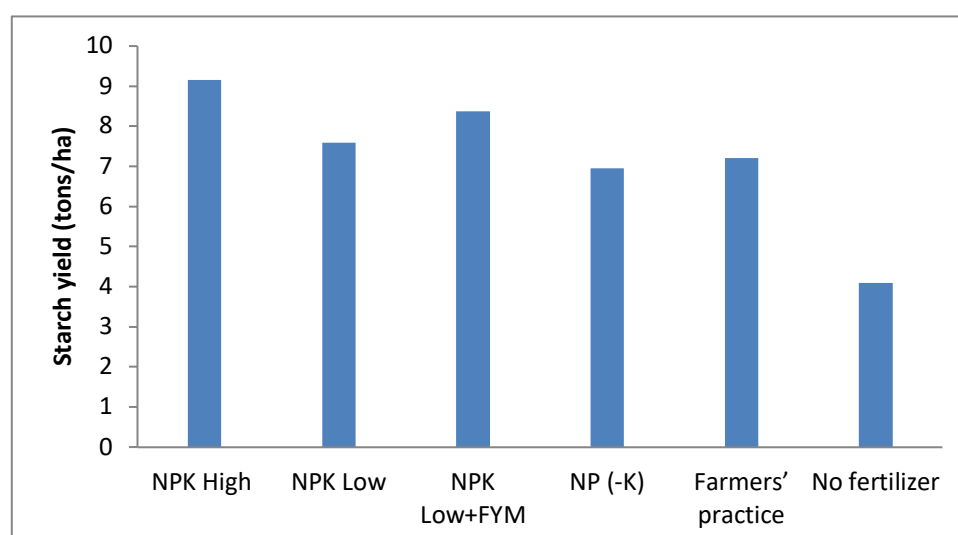


Figure 8: The effect of NPK fertilisers on the starch yields of cassava

Following the results of the fertiliser trials which demonstrated differential impacts of alternate fertilisers and their application rates upon cassava root yields, starch content and starch yields, the next stage of the analysis involved an economic evaluation of the trial results by taking into account the financial costs and hence profitability related to each of the fertiliser treatment scenarios.

Estimated total production costs (Kyat/ha) for the treatments corresponding to the different fertilisers used are shown in Table 5. The categories of production costs included are land preparation costs, planting costs, weeding costs, earthen up⁸, and most importantly fertiliser costs. Planting, weeding and earthen up costs are assumed to be similar across all treatments.

⁸ Earthen up (or hill up) is an agronomic technique that involves piling up soil around the stem of a cassava plant as it grows.

Furthermore, as farmers generally use their own cassava stems for planting, planting materials are regarded as having no additional costs. It is common for farmers to keep their cassava stems for more than two months before planting. Harvesting costs are dependent upon those determined by the local processors/agents when they arrive at the farmer's fields for collection (Figure 9). Therefore, the costs of planting materials and harvesting have been excluded from the total production costs. Finally, the fresh root price of 122,478 kyat/ton utilized for the calculations was based upon the prevailing prices during the current year's harvest season.

Table 5: Estimate of production costs for different fertiliser use (kyat/ha) and fresh root price (kyat/ton) during the harvest season in 2020

Item	High NPK	Low NPK	Low NPK + FYM	NP without K	Farmers' practice	No fertiliser
Planting materials	na	na	na	na	na	na
Land preparation	111,150	111,150	111,150	111,150	111,150	111,150
Planting	29,640	29,640	29,640	29,640	29,640	29,640
Weeding	177,840	177,840	177,840	177,840	177,840	177,840
Earthen up	180,310	180,310	180,310	180,310	180,310	180,310
Fertilisers	353,210	176,605	307,021	102,505	103,740	0
Harvesting	na	na	na	na	na	na
Production cost	852,150	675,545	805,961	601,445	602,680	498,940
Root price	122,478	122,478	122,478	122,478	122,478	122,478



Figure 9: A processor loading up harvested roots from a farmer's field for starch processing

As a result of variable yields achieved by farmers for the different fertiliser treatments, it is no surprise that the total costs of production per ton of fresh roots produced also varies across

Table 6. For some farmers, producing a ton of cassava without fertilisers was significantly more costly than when fertilisers were applied. However it should be noted that the extremely low yield by TW without fertiliser application greatly influences the average unit production costs for this treatment (removing this outlier reduces the average per unit cost for this treatment to 31,694). On average the use of FYM appears to be more expensive to produce one ton of cassava roots compared with using just mineral fertilisers. Regardless of the different per unit production costs related to the different fertiliser treatments, the correct metric for deciding on the optimal fertiliser treatment to adopt is the net income per hectare as shown in Table 7. The net income per hectare is lowest for the no fertiliser treatment. Even when removing the outlier related to farmer TW, we get an average net income per hectare that is only 1,509,277 which ranks the lowest of all treatments. Despite the higher production costs (per unit) related to the use of FYM and high rates of NPK, these two treatments are also associated with the highest net incomes.

Table 6: Production costs (kyat/ton) of individual farmers using different fertiliser treatments

Farmer ID/ Treatment	Production cost (kyat/ton)						
	MS	KYK	AM	ST	TW	TA	Average
NPK High	26,011	29,288	32,673	32,205	24,068	34,746	29,832
NPK Low	26,678	25,559	30,191	34,562	19,680	31,208	27,980
NPK Low + FYM	30,493	29,286	29,537	39,261	21,550	33,192	30,553
NP without K	25,081	23,234	27,923	32,030	20,644	29,908	26,470
Farmers' practice	24,950	22,150	23,837	25,568	22,785	30,306	24,933
No fertiliser	32,208	27,018	27,689	40,116	114,527	31,439	45,500

Table 7: Net income (kyat/ha) of individual farmers using different fertiliser treatments

Farmer ID/ Treatment	Net income (kyat/ha)						
	MS	KYK	AM	ST	TW	TA	Average
NPK High	3,249,984	2,788,242	2,408,560	2,456,326	3,583,124	2,212,595	2,783,139
NPK Low	2,494,637	2,634,262	2,123,529	1,767,118	3,628,783	2,031,670	2,446,667
NPK Low + FYM	2,500,150	2,637,325	2,607,931	1,756,709	3,881,702	2,229,474	2,602,215
NP without K	2,401,817	2,641,874	2,094,398	1,746,560	3,050,951	1,914,355	2,308,326
Farmers' practice	2,422,594	2,807,174	2,564,668	2,349,107	2,711,642	1,884,915	2,456,683
No fertiliser	1,437,995	1,812,777	1,756,437	1,053,414	35,621	1,485,761	1,263,668

Estimated total production costs (Kyat/ha) for different fertilisers used are shown in Table 6. The total production costs vary among treatments. Most farmers used their own cassava stems as planting materials with no extra cost. Usually farmers keep their cassava stems for more than 2 months before planting. At harvest time, local processors/agents come to harvest cassava with their own designated costs (Figure 9). Therefore, the costs of planting materials and harvesting have been excluded in the total production costs. The fresh root price was 122,478 kyat per t during this year's harvest season.

Net cost per unit produced (kyat/t) and net income of the 6 farmers were calculated. Tables 7 and 8 show the effect of different fertilisers on production cost (kyat/t) and net income (kyat/ha) (2019/2020). Generally, fresh root production costs vary among farmers. Some farmers producing one ton of cassava without fertiliser was more costly than farmers producing one ton of cassava with fertilisers. However, using FYM may have made it more expensive to

produce one ton of cassava roots compared with using just mineral fertilisers. Without fertilisers, the yield per hectare was low for some farmers (Table 4). However, the cost of cultivation is also relatively high for farmers. The results suggest that farmers can achieve a higher net income with right fertiliser application. (Table 8). The results also suggest that farmers can receive the highest net income from cassava with high NPK application.

ON-FARM PLANTING METHODS

The aim of this demonstration was to showcase different cassava planting methods in order to determine the method best able to increase productivity while reducing production costs. In Ayeyarwady, farmers have traditionally been utilising the ‘mount method’ for planting cassava with two stakes per mount in either a slant (incline) or vertical planting position. The plant populations resulting from this technique are usually low (<5,000 plants per ha) as the distance between the mounts are about 2 meters (although this distance is known to vary between 1.5 and 3 meters). Since the beginning of the cassava project in Ayeyarwady, the ‘ridge method’ has been introduced. In this method cassava stakes are planted vertically in rows. The plant population density associated with this method is about 10,000 plants per ha (1 meter X 1 meter). In less fertile areas, the plant density may be as high as 12,500 per hectare where ridges are used.

The demonstrations on farmer fields in Hinthada and Kyonpyaw townships involved the mount and ridge methods (Figure 10). The name of farmers participating in these demonstrations and their respective locations are presented in Appendix B.



Figure 10: Planting method demonstration trials in Kyonpyaw Township

A total of six farmers were involved in the trials although only five of the demonstrations were successful. At the start of the trials three farmers were provided with the Bangkok variety and the other three with the Malaysia variety. Additionally, each of the farmers were involved in adopting both the ridge method as well as the mount method. According to the results, the ridge method produced consistently higher root yields compared to the traditional mount method for both Bangkok and Malaysia varieties (Table 8).

As the ridge and mount methods require different techniques and resources, the associated costs of production also vary. Table 9 lists the cost estimates of the various cultivation activities associated with these two techniques. In general it shows that costs of production related to the ridging method may be lower while producing higher yields.

An attractive feature of the ridge method is the lower labour requirement in relation to the mount method, particularly given the shortage of farm labour for smallholders in the Ayeyarwady region. Farmers could save a significant amount of time as the ridges can also be made through the use of tractors. Furthermore the ridge method enabled easier application of fertilisers and weed control. However, some farmers still prefer to plant cassava on mounts in particularly in low lying areas that have higher risks of floods.

Table 8: Root yields of planting method trials (2019/2020)

Planting method	Root yield of Bangkok (tons/ha)				Root yield of Malaysia (tons/ha)		
	TW	AM	TA	Average	MMK	UAM	Average
Ridge	36	27	25	29.3	23	25	24
Mount	15	20	16	17	21	23	22

Table 9: Cost of productions by planting with mount method and ride method (kyat/ha)

Activity	Mount	Ridge
Land preparation	118,560*	111,150
Plant material	na	na
Planting	na	44,830
Weeding (and hill up)	577,980**	358,644
Fertilisers (250Urea: 125TSP: 250KCl/ha)	353,210	353,210
Total production cost	1,049,750	867,834

*including cost of planting;

**including cost of hill up

MULTIPLICATION OF PROMISING CASSAVA VARIETIES

This demonstration was designed to present optimal methods for achieving rapid multiplication of promising cassava varieties. Farmers usually plant locally available cassava varieties (which are simply labelled as ‘local varieties’), although many of these varieties are indeed not local and have been introduced from Thailand over the past few decades. A few farmers still grow ‘sweet varieties’ for direct human consumption. Generally, these varieties for direct consumption have low dry matter and starch content as well as low hydrogen cyanide (HCN) concentrations. However most farmers prefer to grow cassava varieties that produce high root yield and starch content that are favoured for industrial purposes. At present popular varieties in Ayeyarwady region for starch production include Malaysia, Bangkok and Japan varieties, but farmers are keen on adopting newer varieties that are best suited to their specific agro-ecological conditions.

Since 2010, high-yielding cassava varieties have been introduced and tested on farmer fields in Ayeyarwady. Farmers as a result appear to be quite aware of the higher yields and starch content of industrial varieties such as Rayong 9, KU50, and Rayong 72 compared to local varieties. KU50 and Rayong 9 are better for starch processing due to their high HCN content in their roots. However, Rayong 72 can be used both for starch processing as well as for direct human consumption and feeding animals. On-farm multiplication of planting materials of high yielding cassava varieties including Rayong 9, KM 98-1, KU50, and Rayong 72 were demonstrated in the 2019 growing season (Figure 11). The names of farmers who participated in the demonstrations along with their respective locations (village names) are presented in Appendix C.



Figure 11: On-farm multiplication of Rayong 9 in Laymyethna Township

CASSAVA FIELD DAYS

Through discussions with local authorities and DOA officers, a cassava field day was held on the 20th of January 2020 at Sharkhe village, Hinthada Township (Figure 12). More than 50 participants attended the field day in Sharkhe village which also included experts from the CIAT cassava program in Asia. Similar farmer field days were also organized in Lemyethna township and Kyonpyaw Township which were hosted by Hinthada DOA office. The purpose of the field day was to present the results of the demonstration trials, i.e. optimal fertiliser applications, the performance of suitable planting methods, and appropriate methods for planting material multiplication. These were followed by detailed explanations and discussions of the results and recommendations practices. The field days also included visits to cassava farmer fields and local processing facilities in the project's target areas which were organized by the DOA Hinthada office.



Figure 12: Farmers, processors, and DOA officials attending the field day in Hinthada district

There was high enthusiasm from the participating farmers as well as members of the cassava grower, miller and trader association in learning about the demonstration trials and their results. The DOA extension workers, local farmers, and processors were all actively involved in jointly evaluating the results of the cassava demonstration trials (Figure 13 and Figure 14). In addition to farmers, the field days also provided a valuable experience to the DOA extension officers to be educated in identification of cassava varieties, optimal planting methods, fertiliser responses, as well as methods used for measuring root yields and starch content after harvesting.



Figure 13: Evaluation of cassava demonstration trials by local farmers and processors



Figure 14: Evaluation of cassava demonstration trials by DOA extension workers in Hinthada township

One of the key benefits of the field day was the opportunity it provided participants representing different stakeholder groups to share their own experiences and discuss the situation of cassava cultivation and processing in the Ayeyarwaddy region. While enabling the participants to understand general problems across the different sectors of the industry chain, it also allowed them to realise potential areas for improvement. Most farmers during the field day appeared to understand that their cassava productivity had been significantly lower than its potential as a result of reduced access to optimal varieties, agro-inputs, and information on crop management techniques.

With regards to the demonstration trials exhibiting planting methods, despite the evidence supporting the superiority of the ridge method over the mount method, many farmers were found to retain this practice. It was revealed during the discussions that the continuation of the mount method was not because of the lack of knowledge regarding the higher productivity of the ridge method, rather it was the adverse incentives being generated by existing arrangements for hiring farm labour. In the existing systems, instead of being paid a daily wage, hired farm workers were offered approximately 120 kyats per mount created and planted. The lack of a payment system for the ridge method appeared to be central to the reduced adoption of this method.

The fertiliser demonstration trials were able to convince participants of the importance of balanced NPK fertilisers and their impact upon root and starch yields. According to the farmers, N and K straight fertilisers (Urea and Murate of potash) are available in local markets but this is not the case with P fertiliser (TSP), and can only be accessed in a few commercial towns in Myanmar including Yangon. It had become common for fertiliser suppliers and companies to sell imported compound fertilisers such as NPK compound in rural areas (for example, 15-15-15 and 10-10-5). However these fertilisers did not have suitable ratios of N, P, and K that are recommended for cassava. As such access to optimal fertilisers for cassava cultivation should be prioritised to increase cassava productivity.

Cassava variety trials conducted previously had successfully established higher yields with higher starch content for industrial cassava varieties such as Rayong 9, Rayong 72, and KU50

over the Japan and Bangkok varieties. However, Bangkok and Japan varieties produced higher root yields compared to Nep varieties from Vietnam and NARC-61 from Laos. In addition, Nep and NARC-61 have lower HCN content and hence are better for direct human consumption and for feeding animals. Thai varieties such as KU50 and Rayong 9 could be considered the best high-yielding varieties, however despite the importance of high yielding industrial varieties which many farmers prefer, cassava still remains an important food source mainly for rural communities living in isolated conflict-affected areas of Myanmar.

Some of the champion farmers were already found to be engaged in multiplying high-yielding varieties such as KU50, Rayong 9, Rayong 72, and KM98-1. However, there has been no systematic evaluation performed on their outcomes. Farmers generally assess them based upon visual observations, with an emphasis on their own preferred criteria which include growth rates and root yields. Some farmers were found to prefer Rayong 9 due to its structure which is characterised by reduced branching and straighter stems, while others prefer Rayong 72 and KM98-1 as the stems of these varieties are more erect (straight) and can be used both for direct consumption as well as for sale to starch processing factories.

Farmers were involved in the multiplication of planting materials to expand their own cassava crops but also to sell them to other farmers. The farmers in Kyonpyaw and Hinthada Townships have even received orders of cassava planting materials from farmers in Rakhine State who have shown interest in taking up cassava.

In recent years the demand for processing cassava for producing starch has increased significantly. However challenges remain due to the inability of the cassava processing sector to keep pace similar to other agro-processing industries in Myanmar. Hinthada and Patheingyi districts are significant producers of cassava and have more than 200 starch factories although all processing factories in the Ayeyarwady region are small scale. The only large processing factory is located in Kachin State in Northern Myanmar. The daily cassava processing capacity per processor is quite low and varies between 2.5 tons to 50 tons per day. The factories still rely on old and outdated machinery and produce considerable amounts of solid and liquid wastes. This waste is high in organic matter and HCN content and can be a valuable resource, if the factories possessed the capacity to adequately manage them. In addition to the lack of appropriate technologies and equipment for drying, starch processors also face challenges related to labour shortages, limited capital, and exposure to market volatility.

Overall, the current cassava industry appears to be causing negative impacts upon the surrounding environments. The outdated cassava processing machinery and the lack of appropriate waste water management systems have a negative impact on natural resources, such as soil and water. Additionally, the cultivation practices without adequate soil conservation measures negatively impact on soil fertility and also result in soil erosion. While the cumulative impacts related to environmental pollution or biodiversity destruction may not be as severe as those from other industries, there is certainly much improvement to be made in terms of by-products and waste-water management along with appropriate soil conservation measures.

During the field day, many farmers also complained about the lack of a stable market for cassava roots. As a result of the low price being offered by processors, some farmers have even been compelled to cease cassava production altogether. The current cassava production and processing is almost entirely dependent on national demand, with little trade links with neighbouring countries such as Bangladesh, China, and Thailand. Therefore, fluctuations of

cassava prices in international markets do not have a strong influence on cassava production and processing within Myanmar.

EMERGING INSECTS AND DISEASES ON CASSAVA IN AYEYARWADY REGION

The level of interest for growing cassava has been increasing over the years. Furthermore, with the knowledge of high yielding varieties capable of producing higher starch yields, the demand for new varieties have also been on the rise. To meet this demand some commercial enterprises and cassava association members have been involved in importing them into Myanmar from neighbouring countries such as Thailand and China. However without adequate control measures in place the importation has generally taken place without the necessary quarantine measures.

The Hinthada DOA cassava team have been monitoring the emergence of cassava pests and diseases in Ayeyarwady region and their incidence appear to be on the rise, which calls for more research and appropriate control strategies (Figure 15). The most important pests found in Ayeyarwady region include whiteflies, mealybugs, red mites, scale insects, and termites. Cassava bacterial blight (CBB), witches' broom disease, and root rot disease are also major diseases, all of which can cause tremendous damage on cassava production. Fortunately the cassava virus disease has yet to be found in the Ayeyarwady region. Regardless, with higher incidence of pests and diseases, special care must be taken when transporting planting materials between regions as well as among farms.



Figure 15: Monitoring of emerging insects and diseases on cassava by DOA officers in Hinthada township

1.1 Whiteflies

Whiteflies are considered to be one of the most damaging insects to the cassava plant. In addition to feeding on the plant they also transmit viruses. The whitefly species, *Aleurodicus disperses*, or spiraling whitefly, is currently found in the Ayeyarwady region (Figure 16), where it can cause serious feeding damage and possible cassava yield losses. Another whitefly species, *Bemisia tabaci*, the vector of several serious virus diseases in Africa and other parts of South and Southeast Asia, has not yet been found in Myanmar. The control of high populations of whiteflies involves spraying insecticides, although some consider these measures to be ineffective as the whitefly species can double their population in only 4.2 days. Proper control methods are not available for cassava farmers in Myanmar.



Figure 16: Spiraling whitefly found on cassava in Hinthada Township

1.2 Cassava mealybugs

Of the approximately 15 species of mealybugs found in cassava plants, several species of mealybugs have been identified in Myanmar, including *Phenacoccus manihoti*, *Phenacoccus gossypii*, *Phenacoccus grenadensis*, and *Phenacoccus jackbeardsleyi*. Nymphs and eggs of mealybug are found on cassava plants especially during the dry season (Figure 17). Shortly after initiating feeding, the young nymphs produce a white waxy material which forms a cover over the insects. These mealybugs cause two types of damage to cassava: 1) Direct damage caused by their feeding habits resulting in leaf yellowing and defoliation and 2) Indirect damage caused by the build-up of sooty mould on the leaf surface due to the mealybugs' excrements, resulting in reduced leaf photosynthesis.

The species causing major damage to cassava in Southeast Asia is *Phenacoccus manihoti*. The species was accidentally introduced into Thailand and has spread throughout Southeast Asian countries. It has been found that the parasitoid, *Anagyrus lopezi*, a tiny wasp, is highly effective

in attacking the *Phenacoccus manihoti* mealybug. The parasitoid however has not been seen in the Ayeyarwady region.



Figure 17: Nymphs and eggs of mealybug found on cassava in Hinthada Township

1.3 Cassava Bacterial Blight (CBB)

The Cassava Bacterial Blight disease is widespread and can be particularly serious during the rainy season in the Ayeyarwady region (Figure 18). The disease is caused by the bacteria *Xanthomonas axonopodis* pv. *Manihotis*. Symptoms of the disease include the presence of water-soaked angular spots, and necrosis of leaves. The branches may partially or totally wilt and gum exudates may appear on the main stem or immature branches. There may be stem die-back and necrosis of some vascular strands of the stems and roots. Die-back of cassava due to CBB disease have been found in Kyonpyaw Township (Figure 19).



Figure 18: Cassava Bacterial Blight found in Lemyethna Township



Figure 19: Die-back of cassava due to Cassava Bacterial Blight disease in Kyonpyaw Township

1.4 Cassava root rots

The cassava root rot disease is found mainly in heavy and poorly drained soils, and generally intensifies during periods of intense rainfall. The root rot disease can be caused by a wide range of fungal and/or bacterial pathogens that attack cassava, and cause root deterioration. The most common root rots are caused by a variety of species within the genus *Phytophthora*, especially *Phytophthora drechsleri*. The disease can attack both young and mature plants, causing sudden

wilting, severe defoliation, and soft root rot. The infected roots exude a pungent, watery liquid, and can decompose completely.

1.5 Witches' broom disease

Recently, symptoms of the new Witches' Broom disease have been observed in cassava plants in the Ayeyarwady region, especially in Kyonpyaw and Laymyetna Townships. Cassava plants reveal excessive sprouting of small leaves with short petioles (Figure 20). In general, plants are dwarfed and show an exaggerated proliferation of buds, as well as shoots and small branches growing from a single stake. Sprouts have short internodes and many small leaves. If plants are infected early in the growth cycle, they remain stunted. This disease is mainly transmitted through the use of stakes cut from infected plants. To prevent the disease from spreading, the recommended control measures are not available for farmers in Myanmar.



Figure 20: Cassava Witches' Broom Disease found in Kyonpyaw Township

CONCLUSIONS

The Ayeyarwady region is one of the main cassava producing regions in Myanmar with farmers highly dependent upon the crop for sustaining their livelihoods. While the increased adoption and expansion of cassava has contributed to reduced rural poverty, at an average root yield less than 15 tons per hectare, significantly higher economic prosperity is yet to be realised through increased productivity.

The activities conducted under this project were designed to demonstrate and promote cultivation practices for increasing cassava yields primarily through capacity building exercises. The key activities included a training of trainers program, demonstration trials to assess fertiliser responses, optimal planting methods and good planting material multiplication practices. Additionally field days were also conducted with multiple stakeholders related to the cassava sector including farmers, traders and processors as well as DOA extension staff. The purpose of the field days were not only to educate participants on the results of the demonstration trials but also to encourage dialogue between stakeholders to

understand general problems across the different sectors of the industry chain, while allowing them to realise potential areas for improvement.

The fertiliser demonstration trials revealed that proper fertilization can increase soil fertility and increase cassava root yields and starch content. While the importance of NPK fertilisers were observed, it is important to ensure application of specific ratios of N, P, and K recommended for cassava, which are not easily accessible in rural areas. Optimal fertilisation requires site-specific fertiliser recommendations as crop response to fertilisers depends on many factors such as variety, chemical and physical characteristics of soils, and agro-climatic conditions.

The demonstration trials on planting methods revealed the higher productivity resulting from the ridge method over the mount method. With the adoption of ridges, the number of plants per unit area is higher than when raised on mounts resulting in higher yields per hectare. However, for farmers that rely on purchased planting materials, this implies higher initial costs. Also, despite the higher yields and overall lower costs associated with the ridge method the continuation of the mount method was found to be linked to the existing system of paying farm labourers. The system at present is designed to pay workers on a ‘per mount’ basis which is not compatible with the ridge method resulting in its reduced adoption.

Recommendations made to farmers for increasing yields should ensure that local challenges are taken into account and that the measures do not require high levels of investments. As such costs related to cultivation practices including planting costs, fertiliser costs, etc. must all be taken into account. Given the challenges related to labour scarcity resulting in labour being considered the most expensive input, there is much scope for the introduction of labour saving tools and devices. For example along with higher yields and lower costs, the ridge planting method is also superior as tractors can be used for creating them. While increased mechanisation is capable of saving resources while greatly increasing yields, easy accessibility to poor farmers must be a high priority.

The cassava variety demonstration trials conducted in the past have identified varieties such as KU50 and Rayong 9 that are able to promise higher root yields and cassava content. While it is important to focus on introducing high yielding industrial varieties which are preferred by many farmers that have adopted cassava as a cash crop, cassava still remains an important food source mainly for rural communities living in isolated conflict-affected areas of Myanmar. Hence it is important to expand on the development of varieties that are used for direct consumption.

To meet the increasing demand for new high yielding cassava varieties, they have been imported from neighbouring countries such as Thailand and China, however without adequate control measures in place the importation has generally taken place without the necessary quarantine measures. This has resulted in the increased incidence of various types of pests and diseases that are capable of reducing yields. In order to minimise risks special care must be taken when transporting planting materials between regions as well as among farms.

To ensure secure livelihoods from cassava, it is important to promote technologies that reduce production costs and increase yield, but it is equally important to implement policies that help reduce price volatility. With growing interest from farmers for adopting cassava along with a gradual increase in yields, the higher supply is likely to reduce market prices in the absence of increased demand. In line with the third objective of Myanmar’s agriculture development strategy investment plan (2018/19 – 2022/23)⁹, trade links with international markets must be

⁹ The three key objectives of Myanmar’s agriculture development strategy are: 1) Enhanced Governance and Capacity of Institutions Responsible for Agricultural Development 2)

developed. Despite the high demand for cassava in neighbouring countries, particularly China, without adequate market links, there appears to be limited scope for further expansion. Ultimately, developing a national cassava strategy will help the growth of the cassava industry while improving the livelihoods of rural cassava farmers and processors.

Increased Productivity and Farmers' Income, and 3) Enhanced Market Linkages and Competitiveness.

References

Dinno A. (2015). Nonparametric pairwise multiple comparisons in independent groups using Dunn's test. *Stata Journal*. 15: 292–300.

DOA (2019) Crop productions in Myanmar 2018/2019. Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

FAO (2013). "Save and Grow: Cassava, A guide to sustainable production intensification". Food and Agriculture Organization of the United Nations. Rome, 2013.

StataCorp. 2015. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP.

U Tun Than (1992). Cassava Production, Processing, Utilization and Research in Myanmar. In: "Cassava Breeding, Agronomy and Utilization Research in Asia." Proceedings of the 3rd Regional Workshop held in Malang, Indonesia. October 22-27, 1990 (pp 124-143).

Appendices:

A. List of champion farmers and processors who participated in demonstration trials (2019/20)

Name	Township	Village	Position
(ST)	Kyonpyaw	Sharkhe	Champion Farmer
(TW)	Kyonpyaw	Sharkhe	Champion Farmer
(AM)	Kyonpyaw	Sharkhe	Champion Farmer
(MS)	Kyonpyaw	Sharkhe	Champion Farmer
(TA)	Kyonpyaw	Sharkhe	Champion Farmer & Processor
(KYK)	Kyonpyaw	Sharkhe	Champion Farmer & Processor
(UKT)	Kyonpyaw	PaLin	Champion Farmer & Processor
(UKT2)	Kyonpyaw		Champion Farmer & Processor
(UJ)	Kyonpyaw	Balate	Champion Farmer & Processor
(UAM)	Hinthada	Yonthalin	Champion Farmer & Processor
(MMK)	Hinthada	Yonthalin	Champion Farmer & Processor
(US)	Hinthada	Yonthalin	Champion Farmer & Processor
(UTW)	Hinthada	Yonthalin	Champion Farmer & Processor
(TM)	Laymyethna	Khamoutsu	Champion Farmer & Processor

B. List of farmers participating in the planting method trials and their respective locations (2018/2019)

Name	Village	Township	Variety	Remark
(TW)	Sharkhe	Kyonpyaw	Bangkok	Harvested
(AM)	Sharkhe	Kyonpyaw	Bangkok	Harvested
(TA)	Sharkhe	Kyonpyaw	Bangkok	Harvested
(MMK)	Yonthalin	Hinthada	Malaysia	Harvested
(UAM)	Yonthalin	Hinthada	Malaysia	Harvested
(US)	Yonthalin	Hinthada	Malaysia	Failed

C. List of farmers participating in the demonstrations involving multiplication of high-yielding cassava varieties

Name	Village	Township	Variety
(TM)	Khamoutsu	Laymyethna	Rayong 9
MMK	Yonthalin	Hinthada	KM 98-1
UKT2		Kyonpyaw	KU50, Rayong 9
AM	Sharkhe	Kyonpyaw	KU50, Rayong 72
TW	Sharkhe	Kyonpyaw	KU50, Rayong 72

D. Dunn's pairwise comparison of fresh root yields by fertiliser treatment

Fertiliser Treatments	1	2	3	4	5
2	1.430232 (1.000)				
3	0.536337 (1.000)	-0.8939 (1.000)			
4	1.746533 (0.6054)	0.316301 (1.000)	1.210196 (1.000)		
5	1.402727 (1.000)	-0.0275 (1.000)	0.86639 (1.000)	-0.34381 (1.000)	
6	3.960642 (0.001)	2.53041 (0.085)	3.424305 (0.005)	2.214109 (0.201)	2.557914 (0.079)

(p-values in brackets)

E. Dunn's pairwise comparison of starch yields by fertiliser treatment

Fertiliser Treatments	1	2	3	4	5
2	1.057517 (1.000)				
3	0.763763 (1.000)	0.293755 (1.000)			
4	1.733154 (0.623)	0.675636 (1.000)	0.969391 (1.000)		
5	2.026908 (0.320)	0.969391 (1.000)	1.263146 (1.000)	0.293755 (1.000)	
6	2.702545 (0.052)	1.645027 (0.750)	1.938782 (0.394)	0.969391 (1.000)	0.675636 (1.000)

(p-values in brackets)