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Evaluation of Newly Released Cassava Varieties for Yield Performance, Reactions to Cassava Diseases and Farmers' Preference in Adjumani District of Uganda

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Abstract

Cassava viral diseases particularly cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) have put pressure on cassava breeders to develop varieties that are resistant/tolerant to them. Several cassava varieties have been rolled out to farmers with the latest being NAROCASS series that are tolerant to these diseases. The yield performance of these new varieties have not been documented in some sub zones like Adjumani district that falls within a major West Nile agro-ecology of Uganda. Therefore this study sought to established yield performances of, reactions to major diseases, and farmers' preference to these newly released cassava varieties in Adjumani. Results showed significant ($P \leq 0.05$) differences among cassava varieties and experimental sites for all the parameters evaluated. Average yield performance by varieties were in the order of a local cassava—*Alifasia* (8.7 t/Ha) lowest, NAROCASS 2 (18.55 t/Ha), NASE 14 (33.97 t/Ha), NASE 19 (41.26 t/Ha), and NAROCASS 1 (41.71 t/Ha) highest. CMD foliar symptom was present at all sites on a local cassava—*Alifasia,* and on NAROCASS 1 in Ayiri parish, Ukusijoni sub-county. CBSD foliar symptoms were observed on off-types (TME 14) in the plot of NASE 14 in Miniki Parish only whereas CBSD root necrosis was observed at all sites on the local cassava—*Alifasia*, and on NASE 19 in Maaji parish, Ukusijoni sub-county. Cassava root rot disease was localised in Ukusijoni sub-county only. Farmers' preferences to these newly released cassava varieties were in the order of NASE 19 (40.96%), NAROCASS 1 (24.86%), NAROCASS 2 (15.82.28%), NASE 14 (15.54%), and a Local cassava—*Alifasia* (2.83%). Result from this study strengthens the information gap in the breeding process towards developing a cassava variety with farmer-preferred attributes, and can also inform the utilisation of these improved cassava varieties in Adjumani district.

Keywords: cassava varieties, cassava brown streak disease, cassava mosaic disease, farmers' preference, yield performance, new varieties, Adjumani

1. Introduction

Cassava (*Manihot esculenta*, Cranz) is an important root crop for food security and income generation in Sub Saharan Africa (SSA) whose potential suits the poor and marginalised farming communities (Dixon et al., 2003). The crop also has a lot of industrial applications within the SSA region and worldwide, is the third most key food source in the tropics after rice and maize and it is the staple food of at least 500 million people (Cock, 1985). Cassava has also been experimented as a potential source of bio-fuel crop in the People's Republic of China (Jansson et al., 2009). In Uganda, it's the second most important crop after banana (Ssemakula et al., 2004), and in West Nile region it is the primary crop for both food security and income generation with Arua and Yumbe investment profiles stating its importance at 53% and 38% respectively but being the highest among the crop

commodities in these districts (UIA and UNDP Report, 2019a, 2019b). Cassava has also been reported by most districts of Northern Uganda, including Adjumani as a cash crop (Mwongera et al., 2014).

In Uganda and in West Nile region cassava crop production faces a number of challenges ranging from pests and diseases (Alicai et al., 2007; Abaca et al., 2014), subsistence farming with both landraces and improved varieties under production with varying levels of cyanide content (Oloya et al., 2017), postharvest physiological deterioration (Beeching et al., 1998; Tumuhimbise et al., 2015), and unreliable marketing strategies (Roothaert & Magado, 2011) amongst others. Of all these challenges in cassava production and marketing, cassava viral diseases, particularly cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) have been recognised as the greatest challenge (Kizito et al., 2005; Alicai et al., 2007). These viral diseases has encouraged a continuous cassava breeding efforts in Uganda (Kawuki et al., 2016) with several varieties being released such as the NASE (Namulonge Selection) series to the current NAROCASS (NARO Cassava) series.

During the breeding process, preliminary and advanced yields trials, in addition to multi location trials are established by the researchers from the National Programme in collaboration with the Teams from the Zonal Research Institutes to allow for participatory evaluation of yields, response to pests and diseases, and response to environmental factors by these new varieties prior to their release. In doing such, the National Agricultural Research Institutes (NARIs) such as National Crops Resources Research Institute (NaCRRI) that houses the National Roots and Tuber Crops Program considers West Nile region that is composed of 11 districts and three agro-ecological zones as a single unit for these multi-locational studies at Abi Zonal Agricultural Research and Development Institute (ZARDI). This implies that, there is an urgent need to test the yields performance and reactions to pests and diseases of these newly released cassava varieties in different locations (sub zones) of West Nile region. Therefore, the specific objectives of this study were to: i) determine the yields performance of the newly released cassava varieties within Adjumani district; ii) test the response of these newly released cassava varieties to cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) in different locations within Adjumani; and iii) conduct farmers' participatory evaluation to examine their preference of these new cassava varieties in their different locations within Adjumani district.

2. Materials and Methods

2.1 Study Locations

The study was conducted in three sub counties of Ukusijoni, Itirikwa, and Dzaipi. From each sub county four Parishes were selected: Ayiri, Payaru, Kiraba, and Maaji Parishes for Ukusijoni; Kolididi, Baratuku, Mungula, and Zoka Parishes for Itirikwa; Adidi, Ajugopi, Lugwangwa, and Miniki Parishes for Dzaipi for 2018/19 season. However, experimental sites were reduced to one parish in each sub county: Ayiri parish for Ukusijoni, Mungula parish for Itirikwa and Miniki Parish for Dzaipi for 2019/2020 seasons. The decision to reduce the experimental sites from 12 to 3 parishes between the two seasons was guided by the Project Management Unit of the Project for the Restoration of Livelihoods in the Northern Region (PRELNOR) due to limited resources to cover all these sites in the second season.

2.2 Study Materials and Period

Three newly released cassava varieties comprising of NAROCASS 1, NAROCASS 2, and NASE 19; NASE 14 that has been widely adopted in the region; and a local check (*Alifasia*) were used in this study. The breeders' seeds of these three newly released cassava varieties were acquired from the National Root and Tuber Crop Programme based at the National Crops Resources Research Institute (NaCRRI), NASE 14 was sourced from Abi ZARDI and the Local cassava (*Alifasia*) was sourced from within Adjumani district. The study was run for two consecutive years of 2018/19 and 2019/20 seasons.

2.3 Experimental Design, Data Collection and Analysis

The study was established in a randomised complete block design (RCBD) across all the experimental sites. A spacing of 1 × 1 metre was used. A data collection schedules of 3, 6, 9, and 12 months after planting (MAP) were used. At 3, 6, and 9 MAP foliar data sets were collected on plant germination count per plot, plant height, cassava mosaic disease (CMD) incidence and severity, cassava brown streak disease (CBSD) incidence and severity, and farmers' preference of the plant types. CMD and CBSD severity were scored as described by Gondwe et al. (2005). At 12 MAP, a destructive sampling was used to collect the data; 10 plants were randomly selected and harvested from each experimental plot and data such as number of tuber per plant, weight of tuber per plant, lengths of longest and shortest roots, shoot biomass weight per plant and harvest index were collected. Harvest index was computed as the ratio of the weight of the roots to the total biomass weight (weight of roots plus stool). Cassava brown streak disease (CBSD) root necrosis assessment was also conducted as previously

described by Abaca et al. (2012a, 2012b) to determine the varietal response to CBSD in Adjumani district. Farmers' preference to these newly released varieties was assessed through lining up. Briefly, after harvesting the 10 plants of each plots, the fresh roots and shoot (planting materials) were bulked, farmers were asked to taste the fresh roots and observed the plant characteristics, and lined up in close proximity their variety of choice. The mean of the collected data was summarised in an excel file and subjected to PAST3 and R software for statistical analyses based on sub-counties, parishes and varieties as presented in the result section below.

3. Results

3.1 Yields Performance of Newly Released Cassava Varieties

Cassava yields and yield related parameters that were evaluated at 12 MAP varied significantly ($p \leq 0.05$) by experimental sites, cassava varieties and seasons. Cassava yields and yield parameters variations across experimental sites and season are summarised in Table 1. Cassava yield rankings by parishes for each sub country are also summarised in Table 1. Briefly, for Ukusijoni sub-county the cassava yield was highest in Ayiri (46.22 t/Ha), Kiraba (38.03 T/Ha), Maaji (37.75 t/Ha) and Payaru (37.13 t/Ha) parishes in that order; for Itirikwa sub-county it was in the order of Baratuku (41.08 t/Ha), Mungula (37.98 t/Ha), Kolodidi (37.22 t/Ha) and Zoka (19.93 t/Ha) parishes; and for Dzaipi it followed Ajugopi (29.77 t/Ha), Loguangwa (25.68 t/Ha), Miniki (22.23 t/Ha) and Adidi (19.93 t/Ha) parishes, all for 2018/19 season. Overall, the highest number of fresh roots per plants was recorded in Kiraba, Ajugopi, and Miniki parishes in 2018/19 season; highest weight of root per plant was recorded in Ayiri parish in 2018/19 season while the lowest was recorded in Zoka parish for the same season; and the highest fresh root yields was recorded in Ayiri parish while the lowest was recorded in Zoka parish all for 2018/19 season (Table 1). Across locations and seasons irrespective of the varieties evaluated, cassava yields ranged between 21.22 and 36.93 t/Ha in Itirikwa and Ukusijoni respectively, with a mean of 29.18t/Ha (Table 2). Fresh root yields decreased from 2018/19 to 2019/20 seasons for Ukusijoni and Itirikwa sub counties but increased for the same period in Dzaipi sub-county (Table 2). Fresh root weight per plant ranged from 3.04kg to 5.02kg both values were recorded in Dzaipi for 2018/19 and 2019/20 seasons respectively with a mean of 4.69kg (Table 2). Average length of roots ranged between 47.00 cm to 68.83 cm all in Dzaipi sub-county with a mean of 57.08 cm. By cassava variety, yields ranged from 5.46t/Ha to 44.38t/Ha for the local cassava—*Alifasia* and NASE 19 respectively, with a mean yields by variety stood at 28.68t/Ha (Table 3). Average fresh root weight per plant ranged from 1.95kg to 7.1kg for the local cassava—*Alifasia* and NASE 19 respectively with a mean of 4.01kg (Table 3).

Table 1. Cassava yields and yields parameters variation across experimental sites and season

Season	Sub-county	Parish	Av. No of fresh roots/plant	Av. Wt of fresh roots/plant	Av. Fresh roots Yields (t/Ha)	Av. Longest roots length (cm)	Av. Shortest roots length (cm)	Yield Rankings by parishes
2018/19	Ukusijoni	Maaji	8	4.7	37.75	47.72	11.78	5
		Ayiri	9	**5.78**	**46.22**	55.78	**14.79**	**1**
		Kiraba	**10**	4.75	38.03	47.89	12.15	3
		Payaru	9	4.64	37.13	53.36	13.14	7
	Itirikwa	Kolididi	9	4.65	37.2	55.23	13.47	6
		Baratuku	9	5.13	41.08	52.52	13.61	2
		Zoka	7	2.42*	19.39*	48.63	14.01	12
		Mungula	8	4.75	37.98	54.79	14.08	4
	Dzaipi	Adidi	8	2.49	19.93	42.53*	11.86	11
		Loguangwa	7	3.21	25.68	45.67	12.42	9
		Ajugopi	**10**	3.72	29.77	52.37	10.68	8
		Miniki	**10**	2.78	22.23	47.43	11.01	10
2019/20	Ukusijoni	Ayiri	8	4.92	36.93	56.37	11.13	1
	Itirikwa	Mungula	8	4.13	21.22	66.32	9.23*	3
	Dzaipi	Miniki	7	5.02	29.39	**68.83**	9.59	2
Overall mean			**8**	**4.33**	**32.90**	**53.78**	**12.41**	

Note. Bold values: highest values; *: lowest value.

Table 2. Cassava yields and yield related parameters observed from three sub counties of Adjumani

Yield parameters	Sub Counties						Overall mean
	Ukusijoni		Itirikwa		Dzaipi		
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	
Av. No of fresh roots/plant	**9**	8	8	8	**9**	7	**8**
Av. Wt of fresh roots/plant	4.97	4.92	4.24	4.13	3.05	**5.02**	**4.39**
Av. Fresh root yields (t/Ha)	**39.78**	36.93	33.91	21.22	24.40	29.39	**30.94**
Av. Longest roots (cm)	51.19	56.37	52.79	66.32	47.00	**68.83**	**57.08**
Av. Shortest roots (cm)	12.97	11.13	13.79	**9.23**	11.49	9.59	**11.37**

Note. Av: average; No: number; Wt: weight; Bold values: highest values for the different parameters.

Table 3. Cassava yields and yield related parameters from the newly released cassava varieties in Adjumani;

Yield parameters	Cassava Varieties										Overall Mean
	LOCAL		NASE 14		NAROCASS 1		NAROCASS 2		NASE 19		
	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	2018/19	2019/20	
Av. No of fresh roots/plant	6	3	**10***	8	9	9	8	7	8	**10***	**7.00**
Av. Wt of fresh roots/plant	2.8	1.95	3.85	5.2	5.8	5.79	2.77	2.96	4.99	**7.1***	**4.01**
Av. Fresh root yields (t/Ha)	11.94	5.46	31.06	36.87	**46.42***	41.71	22.13	14.96	38.13	44.38	**27.40**
Av. Longest roots (cm)	43.26	37.56	49.51	68.43	58.2	65.93	42.38	62.24	55.57	**81.4***	**53.68**
Av. Shortest roots (cm)	11.94	10.81	11.44	10.78	13.89	**8.73***	11.84	8.85	13.53	11.24	**11.59**

Note. Av: average; No: number; Wt: weight; Bold values: highest values for the different parameters.

3.2 Reactions to Cassava Diseases by These New Cassava Varieties Across the Study Sites

The major cassava diseases that these new cassava varieties reacted to were cassava mosaic disease (CMD), cassava brown streak disease (CBSD), and cassava root rot disease (CRRD) but their reactions varied across locations and varieties (Table 4). CMD was present at all sites on the local cassava—*Alifasia* with the disease incidence of 100% and severity score of 4 for both 2018/19 and 2019/20 seasons, and only on NAROCASS 1 (23% and score of 3) during the 2019/20 season for the first 6 months and later recovered in Ayiri parish, Ukusijoni sub county (Table 4).

CBSD root necrosis was observed in all the sites of Ukusijoni and Dzaipi sub counties and only in Kolididi parish of Itirikwa subcounty on the local cassava—*Alifasia* (84% with a score of 4; 90% with a score of 4) for the 2018/19 and 2019/20 seasons respectively (Table 4), and on NASE 19 (12.3% with a score of 3) only in Maaji parish of Ukusijoni subcounty (Figure 1) for 2018/19 season. CBSD wasn't observed across all sites except on one plot of NASE 14 in Miniki parish for the 2019/20 season. However, on close examination of this plot, we discovered that the three plants with visible CBSD foliar symptoms were off-types of TME 14, a cassava variety that had succumb to CBSD severely.

CRRD was present on NAROCASS 1 (23% with a score of 3, and 33% with a score of 3) for 2018/19 and 2019/20 seasons and on NASE 19 (13% with a score of 2) in 2018/19 season but restricted to Maaji and Ayiri parishes of Ukusijoni sub-county (Table 4).

Figure 1. CBSD root necrosis on NASE 19 (A) in Maaji Parish and on Local—*Alifasia* (B) in Ayiri Parish, Ukusijoni sub-county

3.3 Farmers' Preference to Cassava Varieties Across Study Sites

Farmers' preferences to these newly released varieties varied by locations, gender and seasons (Table 5). For 2018/19 season, farmers preferred NASE 19 (42.29%), NAROCASS 1 (26.88%), NASE 14 (16.6%), NAROCASS 2 (10.28%) and Local (0.04%) in that order whereas for 2019/20 season the order of preference changed to NASE 19 (38.78%), NAROCASS 2 (29.59%), NAROCASS 1 (18.37%), NASE 14 (13.27%) and local (0%). Overall, NASE 19 was a number one choice in all the experimental sites except in Ayiri parish during 2019/20 seasons. Farmers supported their preferences to these new varieties by providing several reasons: yields, planting materials characteristics, tolerance to CBSD, dry matter content, root size and shape, plant vigour to smoothen weeds, early maturity, experience in growing that particular variety, sweetness, susceptibility to CMD, ready market for the stems amongst others.

Table 4. Incidence and Severity of major cassava diseases identified during this study in Adjumani district

Cassava Variety	2018/19 Season								2019/20 Season							
	CBSD-fi (%)	CBSD-fs Score	CBSD-ri (%)	CBSD-rs Score	CMD-i (%)	CMD-s Score	CRRD-i (%)	CRRD-s Score	CBSD-fi (%)	CBSD-fs Score	CBSD-ri (%)	CBSD-rs Score	CMD-i (%)	CMD-s Score	CRRD-i (%)	CRRD-s Score
ALFASIA	0	1	84	4	100	4	0	1	0	1	90	4	100	4	0	1
NASE 14	0	1	0	1	0	1	0	1	12	3	0	1	0	1	0	1
NAROCASS 1	0	1	0	1	0	1	23	3	0	1	0	1	23	3	33	3
NAROCASS 2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
NASE 19	0	1	12.3	3	14	2	13	2	0	1	0	1	0	1	0	1

Note. . CBSD-fi: cassava brown streak disease foliar incidence; CBSD-fs: cassava brown streak disease foliar severity; CBSD-ri: Cassava brown streak disease root incidence; CBSD-rs: cassava brown streak disease root severity; CMD-i: cassava mosaic disease incidence; CMD-s: cassava mosaic disease severity; CRRD-i: cassava root rot disease incidence; and CRRD-s: cassava root rot disease severity.

Table 5. Summary of farmers' preferences to the newly released cassava varieties in Adjumani district

Year	Sub-county	Parish	Preference to cassava varieties by farmers									
			NAROCASS 1		NAROCASS 2		NASE 19		NASE 14		LOCALS	
			F	M	F	M	F	M	M	F	F	M
2018/19	Ukusijoni	Maaji	3	1	4	3	4	3	0	0	0	1
		Ayiri	3	3	2	2	6	3	0	0	0	0
		Kiraba	6	2	2	1	4	5	0	0	0	0
		Payaru	4	1	4	2	4	3	4	4	0	0
		Sub total	**16**	**06**	**12**	**08**	**28**	**14**	**04**	**04**	**0**	**1**
	Itirikwa	Kolididi	3	4	0	0	9	2	5	0	0	0
		Baratuku	3	3	0	0	2	2	2	2	0	1
		Zoka	1	3	2	2	4	4	4	1	1	0
		Mungula	1	2	0	0	3	3	2	1	1	1
		Sub total	**8**	**12**	**2**	**2**	**18**	**11**	**13**	**04**	**2**	**2**
	Dzaipi	Adidi	4	4	0	0	3	7	3	2	2	1
		Logwangwa	3	3	0	1	2	4	2	1	0	1
		Ajugopi	4	2	0	1	6	5	3	1	0	1
		Miniki	3	4	1	0	4	5	2	3	0	0
		Sub total	**14**	**12**	**1**	**1**	**15**	**21**	**10**	**07**	**2**	**3**
	2018/19 Sub Total		**38**	**32**	**15**	**11**	**61**	**46**	**27**	**15**	**4**	**6**
			70		**26**		**107**		**42**		**10**	
2018/19 Preference Ranking			**2**		**4**		**1**		**3**		**5**	
2019/20	Ukusijoni	Ayiri	02	01	08	06	04	02	03	02	0	0
	Itirikwa	Mungula	04	03	00	01	08	06	02	03	0	0
	Dzaipi	Miniki	04	04	06	08	10	08	02	01	0	0
2019/20 Sub total			**10**	**08**	**14**	**15**	**22**	**16**	**07**	**06**	**0**	**0**
			18		**29**		**38**		**13**		**0**	
2019/20 Preference Ranking			**3**		**2**		**1**		**4**		**5**	
Grand Total			**48**	**40**	**29**	**27**	**83**	**62**	**34**	**21**	**04**	**06**
			88		**56**		**145**		**55**		**10**	
Overal Preference Ranking			**2**		**3**		**1**		**4**		**5**	

4. Discussions

The main objectives of this study were to determine yields performance of newly released cassava varieties in West Nile region of Uganda, test the reactions of these new cassava varieties to major cassava diseases particularly CMD and CBSD, and conduct participatory evaluation by farmers to assess their preference to these new cassava varieties. This study shares similar finding with that of Abaca et al. (2014) on the variation of yields among newly released cassava varieties across West Nile region that ranged from 22.7 to 53.0 t/ha in 2013 seasons. Yield variations in cassava have been observed in several countries with different factors being advanced for these variations (Nebiyu, 2006; Ntawuruhunga & Dixon, 2010; Suja et al., 2010; Gbadegesin et al., 2010). Ntawuruhunga and Dixon (2010) observed yield variation amongst cassava genotypes in Uganda and pointed that these variations could be attributed to both genetic and environmental factors. The same study also pointed out that root number, length and size make up a significant component of yields in cassava. This current study finds a positive pair wise correlation between root yields and root length, and between root yields and root numbers. Nebiyu (2006) worked on Ethiopian cassava varieties and partitioned the cause of these variations into environmental and genetic factors for the different yield related parameters. Suja et al. (2010) showed that tuberous root dry matter and total dry matter production, crop growth rate, tuberous root bulking rate and harvest index, number of tuberous roots, mean weight of tuberous roots and nutrient uptake showed significant positive correlations with tuberous root yield in Kerala, India. The study of Gbadegesin et al. (2010) in Nigeria indicated that cassava shoot biomass and yields parameters are strongly linked soil properties using Pearson's product Moment Correlation and Multiple regression analytical techniques. Therefore the low yields in Zoka parish can be attributed to both environmental and soil properties, particularly the thick vegetation covers that were cleared from the study site prior to establishing the trial. Therefore, in this current study we can suggest that variations in

yields and yield parameters across sites could be attributed to environmental and soil related factors whereas variations amongst cassava varieties could be attributed to genetic factors.

The presence of CMD on NAROCASS 1 only for the first 6 months after plantings shows its potential to recover from the cassava mosaic virus infection. Thresh et al. (1998) made a similar observation that cassava mosaic virus that causes CMD sometimes is not fully systemic within infected plants and the infected plants are able to reverse or recover from such infections. However, it should be noted here that, the ability to recover from CMD infection is mainly associated with the white flies infection compared to the cutting infection. Therefore, it is important for small scale farmers to start with clean planting materials. The presence of CBSD root symptoms without foliar symptoms on Local cassava—*Alfasia* in all sites, and on NASE 19 in Maaji parish, confirms the finding of Abaca et al. (2012b) that different cassava varieties respond to CBSD differently, hence it is not conclusive enough to make decision based on foliar symptoms alone during the seed crop inspection in the fields. The restriction of CRRD to only Ukusijoni subcounty could suggest environmental and soil related variations that occurred between the experimental sites. Akrofi et al. (2018) through their work on CRRD in Ghana reported that the pathogens that cause CRRD (*Botryodiplodia theobromae*; *Fusarium solani*; *Fusarium oxysporum*; *Fusarium semitectum*; and *Sclerotium rolfsii*) are soil borne and thus spread through soil, and that CRRD incidence increases during the rainy season. Additional factors such as cultivation of susceptible cassava varieties, delayed harvesting, cultivating cassava in waterlogged soils, and high weed density were also suggested by their same work in Ghana. Similarly, the work of Makambila (1994) in the Republic of Congo had indicated also indicated high humidity near saturation and a temperature range of 24-28 ^{o}C was required for CRRD to develop. Therefore, examining our study sites, Ukusijoni subcounty (Maaji and Ayiri parishes) where CRRD was restricted had a very high amount of rainfall (same as relative humidity) and would occasionally flood which supports the finding reported in Ghana and Republic of Congo above. The reasons presented by farmers in this present study during participatory evaluation of these newly released cassava varieties confirm the reasons presented by Abele et al. (2008) in Uganda, Kavia et al. (2007) in Tanzania, Udensi et al. (2011) and Nwakor et al. (2011) in Nigeria for factors promoting adoption of new cassava varieties in these countries. The increase in the preference of NAROCASS 2 from 10.28% in 2018/19 season to 29.59% in 2019/20 season agrees with the finding of Kavia et al. (2007) that lack of information on a particular technology and farmers experience about a technology affects its adoption. Growing and observing the performance of NAROCASS 2 in the first season as a new variety in Adjumani could have increased farmers' awareness about it in the second season, thus, the increment in the percentage of its preference. Furthermore, factors such as age, marital status, educational levels, gender, farm size, economics of production of a technology, land ownership, complexity of a technology amongst others have been described as key factors in the adoption a technology by different Authors (Kavia et al., 2007; Udensi et al., 2011; Nwakor et al., 2011; Mwangi & Kariuki, 2015).

4. Conclusion and Recommendations

We have demonstrated in this research that cassava can be grown in any part of Adjumani district including Miniki Parish in Dzaipi sub-county where cassava production has been lowest although variations in yields and yields related parameters from the newly released cassava varieties were great within the district. Similarly, response to cassava diseases varied among locations and varieties with cassava root rot disease being restricted in Ukusijoni sub-county only. Despite the variations in different parameters, farmers were able to make informed decisions and selected NASE 19 and NAROCASS 1 as their best cassava varieties.

From the results and discussions section above, we can therefore recommend the following from this study:

(i) Farmers' adoption of a particular cassava varieties results from a combination of several factors that require adequate time for probing. This explains why NAROCASS 2 wasn't selected by farmers despite an increase in its yields in the second season.

(ii) The District Crop Inspectors should not rely upon the CBSD foliar symptoms as the disease may not show foliar symptom but will show root necrosis.

(iii) Itirikwa sub-county should be considered as a cassava seed multiplication site for Adjumani district. This is because although it has a low fresh root yields as shown in Zoka, it supports very high shoot biomass that is good for seed multiplication. Additionally, Itirikwa sub-county has low rate of cassava stem destruction by stray animals during dry season.

(iv) NASE 19 and NAROCASS 1 being the most preferred cassava varieties in Adjumani district, therefore, any agribusiness innovation on cassava in the district can be sought alongside these two varieties.

(v) CBSD and CMD are present whenever cassava is being grown and therefore farmers should be encouraged and supported to cultivate the improved cassava varieties to safeguard their food security and income status.

References

Abaca, A., Kawuki, R., Tukamuhabwa, P., Baguma, Y., Pariyo, A., Alicai, T., … Bua, A. (2012a). Progression of Cassava Brown Streak Disease (CBSD) in Infected Cassava Roots in Uganda. *Uganda Journal of Agricultural Sciences, 13*(1), 45-51.

Abaca, A., Kawuki, R., Tukamuhabwa, P., Baguma, Y., Pariyo, A., Orone, J., … Bua, A. (2012b). Evaluation of Local and Elite Cassava Genotypes for Resistance to Cassava Brown Streak Disease (CBSD) in Uganda. *Journal of Agronomy, 11*(3), 65-72. https://doi.org/10.3923/ja.2012.65.72

Abaca, A., Kiryowa, M., Awori, E., Andema, A., Dradiku, F., Moja, A. S., & Mukalazi, J. (2014). Prevalence of cassava pests and diseases as revealed by adaptive trials in North Western agro-ecological zone of Uganda. *Journal of Agricultural Sciences, 6*(1), 116-122. https://doi.org/10.5539/jas.v6n1p116

Abele, S., Twine, E., Ntawuruhunga, P., Baguma, Y., Kanobe, C., & Bua, A. (2008). *Development and dissemination of improved cassava varieties in Uganda: Analysis of adoption rates, variety attributes and speed of adoption* (No. 307-2016-4961).

Akrofi, S., & Akuoku, K. O. (2018). Farmers' knowledge and perception of the dry cassava root rot disease in Brong Ahafo region of Ghana. *Ghana Journal of Agricultural Science, 52*(1), 33-42.

Alicai, T., Omongo, C. A., Maruthi, M. N., Hillocks, R, J., Baguma, Y., Kawuki, R., … Colvin, J. (2007). Re-emergence of cassava brown streak disease in Uganda. *Plant Disseases, 91*, 24-29. https://doi.org/10.1094/PD-91-0024

Beeching, J. R., Han, Y., Gómez-Vásquez, R., Day, R. C., & Cooper, R. M. (1998). Wound and defense responses in cassava as related to post-harvest physiological deterioration. *Phytochemical Signals and Plant-Microbe Interactions* (pp. 231-248). Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-5329-8_12

Cock, J. H. (1985). *Cassava: New potential for a neglected crop* (p. 191). Boulder, Colorado.

Gbadegesin, A. S., Abua, M. A., & Atu, J. E. (2011). Variation in soil properties on cassava production in the coastal area of southern Cross River state, Nigeria. *Journal of Geography and Geology, 3*(1), 94. https://doi.org/10.5539/jgg.v3n1p94

Jansson, C., Westerbergh, A., Zhang, J., Hu, X., & Sun, C. (2009). Cassava, a potential biofuel crop in (the) People's Republic of China. *Applied Energy, 86*, S95-S99. https://doi.org/10.1016/j.apenergy.2009.05.011

Kavia, F. Y., Mushongi, C. C., & Sonda, G. B. (2007). *Factors affecting adoption of cassava varieties: A case of Cassava Mosaic Disease tolerant varieties in Lake Zone regions-Tanzania* (pp. 1875-1878). 8th African Crop Science Society Conference, El-Minia, Egypt, October 27-31, 2007, African Crop Science Society.

Kawuki, R. S., Kaweesi, T., Esuma, W., Pariyo, A., Kayondo, I. S., Ozimati, A., … Nuwamanya, E. (2016). Eleven years of breeding efforts to combat cassava brown streak disease. *Breeding Science, 66*(4), 560-571. https://doi.org/10.1270/jsbbs.16005

Kizito, E. B., Bua, A., Fregene, M., Egwang, T., Gullberg, U., & Westerbergh, A. (2005). The effect of cassava mosaic disease on the genetic diversity of cassava in Uganda. *Euphytica, 146*(1-2), 45. https://doi.org/10.1007/s10681-005-2959-3

Makambila, C. (1994). The fungal diseases of cassava in the Republic of Congo, Central Africa. *African Crop Science Journal, 2*(4), 511-517.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development, 6*(5).

Mwongera, C., Shikuku, K. M., Twyman, J., Winowiecki, L. A., Ampaire, E. L., Koningstein, M., & Twomlow, S. (2014). *Rapid rural appraisal report of Northern Uganda*. Retrieved October 12, 2020, from https://cgspace.cgiar.org/bitstream/handle/10568/35639/Report_Northern%20Uganda%202014.pdf?sequence=8&isAllowed=y

Nebiyu, A. (2006). Genetic variations in cassava at Jimma, Southwest Ethiopia. *Tropical Science, 46*(3), 171-175. https://doi.org/10.1002/ts.171

Ntawuruhunga, P., & Dixon, A. G. (2010). Quantitative variation and interrelationship between factors influencing cassava yield. *Journal of Applied Biosciences, 26*, 1594-1602.

Nwakor, F. N., Ifenkwe, G. E., Okoye, B. C., Onummdu, F. N., Anyaegbunam, H. N., Ekedo, T. O., & Onyia, C. E. (2011). Socio-economic factors affecting adoption of improved cassava varieties among farmers in Abia State. *Journal of Agriculture and Social Research, 11*(1).

Oloya, B., Adaku, C., Ntambi, E., & Andama, M. (2017). Cyanogenic potential of selected cassava varieties in Zombo District, Uganda. *International Journal of Nutrition and Food Sciences, 6*(3), 144-148. https://doi.org/10.11648/j.ijnfs.20170603.16

Roothaert, R. L., & Magado, R. (2011). Revival of cassava production in Nakasongola District, Uganda. *International Journal of Agricultural Sustainability, 9*(1), 76-81. https://doi.org/10.3763/ijas.2010.0547

Ssemakula, G. N., Sserubomwe, W. S., Bua, A., Jagwe, J., Ferris, R. S. B., & White, J. B. A. (2004). Constraints and potential for cassava commercialization in Uganda. *Proceedings of regional workshop on improving the cassava sub-sector* (pp. 57-60). Nairobi, Kenya.

Suja, G., John, K. S., Sreekumar, J., & Srinivas, T. (2010). Short‐duration cassava genotypes for crop diversification in the humid tropics: Growth dynamics, biomass, yield and quality. *Journal of the Science of Food and Agriculture, 90*(2), 188-198. https://doi.org/10.1002/jsfa.3781

Thresh, J. M., Otim-Nape, G. W., & Fargette, D. (1998). The components and deployment of resistance to cassava mosaic virus disease. *Integrated Pest Management Reviews, 3*(4), 209-224. https://doi.org/10.1023/A:1009626806156

Tumuhimbise, R., Melis, R., & Shanahan, P. (2015). Genetic variation in cassava for postharvest physiological deterioration. *Archives of Agronomy and Soil Science, 61*(9), 1333-1342. https://doi.org/10.1080/03650340.2014.995641

Udensi, U., Tarawali, G., Favour, E., Asumugha, G., Ezedinma, C., Okoye, B., … Dixon, A. (2011). Adoption of selected improved cassava varieties among smallholder farmers in South-Eastern Nigeria. *Journal of Food, Agriculture and Environment, 9*(1), 329-335.

Uganda Investment Authority (UIA) & United Nations Development Programme (UNDP) Report. (2019a). *Arua District Investment Profile*. Retrieved October 12, 2020, from https://www.ugandainvest.go.ug/wp-content/uploads/2019/06/UNDPUg1720-20DistrictProfile_Arua.pdf

Uganda Investment Authority (UIA) and United Nations Development Programme (UNDP) Report. (2019b). *Yumbe District Investment Profile*. Retrieved October 12, 2020, from https://reliefweb.int/sites/reliefweb.int/files/resources/UNDPUg17%20-DistrictProfile_Yumbe.pdf