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Effect of modified spacing arrangements, fertilizer use and legume intercrop on prevalence of cassava brown streak disease in Western Kenya

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Cassava is an important food security crop in Western and Coastal counties of Kenya. As a food security crop, it is continuously cultivated with minimal inputs. Its production is constrained by factors like declining soil fertility, poor agronomic practices, pests and diseases. Cassava brown streak disease (CBSD) is a viral infection attacking the cassava crop causing yield losses of up to 100%. The current study was intended to determine the effect of planting technologies on the prevalence of CBSD in two agro-ecological zones of Western Kenya: lower midland (LM1) and upper midland (UM1). Various spacing arrangements, four fertilizer regimes, legume intercrop and improved cassava cultivars were tested in a randomised complete block design (RCBD) with each site as a replicate. Data was collected on pathogen population and disease incidences and severity, and cassava and legumes yields. Results showed no effect of modified spacing and legume intercrop on CBSD incidence. However, incidences varied by cassava cultivar (9 to 59%) and fertilizer application (3 to 41%). Low CBSD incidences (3 to 16%) were observed over time in management strategies involving fertilizer NPK 17:17:17 suggesting that vigour enhancement may have contributed to low CBSD incidences. Low incidence of CBSD on improved cultivars indicates that CBSD can be mitigated through crop improvement technologies such as breeding for resistance to diseases. Intercropping cassava with beans and modification of spacing did not demonstrate an effect on CBSD incidence. However, 2 m× 0.5 m spacing arrangement can compensate for rising land pressure in Western Kenya and areas facing similar problem.

Key words: Cassava, cropping arrangements, intercrop, yields, cassava brown streak disease (CBSD), Western Kenya.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is widely cultivated in Asia, Africa and Southern and Central America. Sub Saharan Africa (SSA) is the world's largest cassava producer and its production is estimated at 57% (160 million tonnes) of total cassava produced worldwide. Major cassava producers in Africa include Nigeria, Democratic Republic of Congo, Ghana, Angola and Mozambique, (FAOSTAT, 2015). In East Africa, Tanzania, Rwanda and Uganda are the major producers of cassava. Kenya's annual cassava production is relatively low at 0.8 million tonnes (FAOSTAT, 2015; MoA, 2015) and supports the livelihood of 2.5 million people in eastern, coastal and western regions of the country (MoA, 2012). Low yield in Kenya is due to declining soil fertility (MoL, 2009; Anneke et al., 2010; Mutoko et al., 2014), lack of high yielding cultivars (Mwango'mbe et al., 2013), poor agronomic practices, pests and diseases (Braima et al., 2000; Munga et al., 2012). Cassava brown streak disease (CBSD) is an important disease prevalent in Eastern, Central and Southern Africa and is caused by two species of *Ipomovirus*; cassava brown streak virus and Ugandan cassava brown streak virus (Mbanzibwa et al., 2011; Winter et al., 2010). The disease is spread by planting infected cuttings (Storey, 1936; Mohammed et al., 2012) and whiteflies (*Bemisia tabaci*) within the field (Storey, 1939). Various management strategies including evaluation of germplasm in different agro-ecological zones and breeding for resistance have been attempted with limited success. Since CBSD was first reported in Northern Tanzania (Storey, 1936), the disease has been endemic to the East African coast (Storey, 1936; Hillocks et al., 2001). However, with less restrictive quarantine measures (FAO, 2013), the disease has now spread to other East African countries (Legg and Boumeester, 2010) including Uganda, Kenya and Burundi and even in areas beyond the coastal strip where the disease is endemic (Alicai et al., 2007). In Western Kenya, Mware et al. (2009) reported disease incidences of between 64 and 100% with a severity score of 2 to 3 on a scale of 1 to 5 in Bondo and Teso areas of Siaya and Busia Counties, respectively. Osogo et al. (2014) reported disease incidences of 30% in Busia County with severity score of 2 to 4.

An effective method of controlling diseases in cassava plants is the use of resistant cultivars. Improved Cassava Mosaic Disease (CMD) resistant cultivars are available and widely cultivated in Western Kenya. Unfortunately, the CMD resistant cultivars have not been consistent in their tolerance to CBSD (Obiero et al., 2010). Efforts to mitigate CBSD by developing tolerant cultivars are ongoing (Ogwok et al., 2012; Vanderschuren et al., 2012; Rwegasira and Chrissie, 2012; Abaca et al., 2013; Woyengo et al., 2013), meanwhile farmers continue to plant susceptible cultivars.

In Western Kenya cassava is grown during the first two months after the onset of the long rain (March to June) and short rain seasons (August to November). The crop is usually propagated by stem cuttings and stays in the field for one year hence receiving two peak periods of rain during its growth cycle. Propagation by stem cuttings enhances disease build up in the subsequent cropping cycle (Yadav et al., 2011). Crop protection practices such as intercropping (Boudreau, 2013), efficient use of nutrients, and planting disease-resistant cultivars (Anneke, 2010; Fairhurst, 2012) can contribute to disease mitigation (Giller et al., 2011), improved crop productivity (FAO, 2013) as well as help attain food security (Agegnehu et al., 2008; Dietrich et al., 2012).

The main objective of this study was to determine the effect of modified spacing arrangements, fertilizer use and legume intercrop on prevalence of cassava brown streak disease in Western Kenya.

MATERIALS AND METHODS

Experimental sites

This on-farm study was conducted in Busia (Mundika N00° 06' 44.154", E034° 27' 16.794"), Kakamega (Elwakana N00°16' 46.44", E34° 33' 15.24"), Vihiga (Demesi N00°6' 20.04", E34° 44' 24.64") and Bungoma (Lutacho N00° 40' 26", E034° 48' 58") counties of Western Kenya. Altitude ranged between 1330 and 1611 masl. The selected sites are characterised by bi-modal rainfall distribution which allows for crops to be grown twice a year; during the long rains (March to June) and the short rains (August-November).

Experimental design

A randomized complete block design (RCBD) was adopted with each site being a replicate. The gross plot size of experimental plots was 4 m × 7 m and the net plot size was 3 m × 3 m. Plots were separated by 1-m wide pathways for accessibility.

Experimental treatments consisted of three cultivars of cassava: MM96/4271 (NASE 14) and Migyera (TMS 30572) which are resistant to CMD and Merry Kaluore as a local susceptible cultivar. Improved cultivars MM96/4271 and Migyera were intercropped with a grain legume (bean, *Phaseolus vulgaris* L.) commonly grown (cultivar KK8) in the experiment sites and three fertilizer applications: NPK 17:17:17, NPK 17:17:17+K, and NPK 17:17:17+N+K were used (Table 1).

MM96/4271 and Merry Kaluore were planted in mono crop (plots 1 and 2) using 1 m × 1 m spacing to compare the effect of using improved (CMD resistant) and local cassava cultivar under non-fertilized condition.

Spacing arrangement was modified to 2 m × 0.5 m where cultivar MM96/4271 was planted without intercrop (plot 3) and with intercrop (plots 5, 6 and 8). The most recent improved cassava cultivar Migyera was planted in plot 7 using NPK 17:17:17+K to compare the effect of planting improved cassava cultivar under near optimal mineral fertilization.

One kilogram (equivalent to 200 kg/ha) of fertilizer NPK (17:17:17) was spread evenly in three plots (5, 6, 7 and 8). Plots 6, 7 and 8 also received 1 kg each of Murate of potash (KCl). In addition, one plot (plot 8) received 1 kg of CAN (Table 1). All the inputs were incorporated into the soil by shallow digging with care not to cross to neighbouring plots.

The trial was established in September, 2014 at the onset of rain

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Table 1. Treatments used in planting technologies trial.

Plot number	Management strategy			
	Cultivar	Spacing (m^2)	Fertilizer	Intercrop
1	Merrykaluore	1 × 1	No	No
2	MM96/4271	1 × 1	No	No
3	MM96/4271	2 × 0.5	No	No
4	MM96/4271	2 × 0.5	No	KK8
5	MM96/4271	2 × 0.5	NPK 17:17:17	KK8
6	MM96/4271	2 × 0.5	NPK 17:17:17+K	KK8
7	Migyera	2 × 0.5	NPK 17:17:17+K	KK8
8	MM96/4271	2 × 0.5	NPK 17:17:17+N+K	KK8

Figure 1. Picture showing cassava-bean intercrop arrangement.

in the short rain season. Fresh cuttings of about 20 cm were planted by burying most of the cassava cutting at an angle. Three rows of beans were planted in between cassava rows at spacing of 50 cm between rows × 10 cm between plants (Figure 1).

The rows of beans were reduced to two during the long rain season (April) of 2015 and were planted 75 cm inwards from the cassava rows to cater for the cassava canopy.

Field selection and land preparation for the on-farm trials and maintenance of the trial were done by the farmers. Planting was done by farmers, agriculture extension officers and researchers.

Scoring pests and diseases

Data on pests, diseases and other relevant agronomic parameters such as emergence and plant height was collected on cassava. Damage by important cassava pest like Cassava Green Mites (CGM) and by diseases such as Cassava Anthracnose Disease (CAD), Cassava Mosaic Disease (CMD), Cassava Brown Streak Disease (CBSD) and Cassava Bacterial Blight (CBB) (IITA, 1990; Legg et al., 2006) was calculated as a proportion:

Disease incidence = Number of infected plants / Total Number observed × 100

Percentage of green mite infested plants was calculated as follows:

Percentage of infested plants = Number of plants with CGM damage / Total Number observed × 100

Severity for both pests and diseases was scored on a scale of 1 to 5 where 1 represents no symptom and 5 represents severe infection/infestation (Hahn et al., 1980; Muimba, 1982; Muyolo 1984; Legg and Bouwmeester, 2010) at 3, 6 and 9 months after planting.

Total count of whiteflies (*B. tabaci*) per plot was recorded between 0600 and 0800 h when the insects are fairly immobile (Ariyo et al., 2005).

Yield data

At harvest, all roots in the net harvestable area were harvested and counted. The harvested roots were sorted into two groups; marketable roots and non-marketable roots. Marketable roots are those roots that can be sold while non-marketable roots, cannot be sold and include small roots, roots damaged by pests or harvesting implements and rotten roots. Fresh weight for both marketable and non marketable roots was recorded and used to calculate fresh cassava yield in tons per hectare.

Yields for beans were recorded at harvest maturity but before shattering. Seed weight was taken after seeds had been threshed, winnowed and dried to moisture content of 14% as recommended

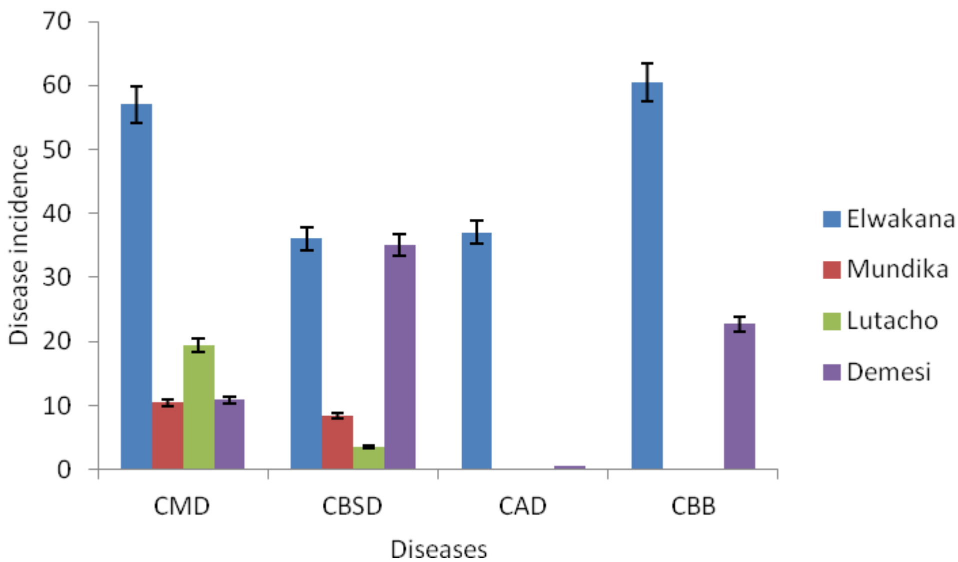

Figure 2. A bar graph showing other diseases observed on cassava across sites.

by Ogutu et al. (2012).

Statistical analyses

Generalised linear models (GLM) procedure of the SAS package version 9.1 was used to compare means by testing for effect of site, modified spacing, fertilizer use and cultivar on CBSD prevalence, cassava fresh yields and legume yields. Least significant difference was used to separate significant difference at p=0.05.

RESULTS

Pests observed on planting technologies trial

Mean whitefly populations per plot for the cropping period ranged between 1 and 14 across sites (Lutacho < Demesi < Mundika < Elwakana) but were similar for the three cassava cultivars and fertilizer levels. Whitefly populations on individual plants ranged between 0 and 62 as follows: Lutacho (0-6), Mundika (0-27), Demesi (7-30), and Elwakana (10-62).

Whiteflies are important pests since they transmit CBSD; however CGM was also found to be prevalent at Mundika (16.7%), Demesi (20.8%) and Elwakana (66.6%) sites. Improved cultivars Migyera and MM96/4271 had more CGM infested plants (45.3 and 27%, respectively) compared to the local cultivar Merry Kaluore which had 1%. The highest number (50%) of CGM infested plants was recorded in plots where NPK 17:17:17 + KCl + CAN fertilizers were used. The 2 m × 0.5 m cropping arrangement recorded more plants with CGM infestation per given time of evaluation than 1 m × 1 m cropping arrangement.

Diseases observed in planting technologies trial

Disease incidence varied across sites (p<0.05**, Mean≤60%) with CMD, CBSD occurring in all sites. Disease incidences were the highest at Elwakana site (CBB 60%, CMD 57%, CAD 37%, CBSD 36%) followed by Demesi (CBSD 35.1%, CBB 22.7% and CMD 10.9%). Mundika and Lutacho sites had low (<19%) disease incidences (Figure 2).

CBSD symptoms observed on planting technologies trials

Foliar symptoms of CBSD were observed across sites. Mundika and Lutacho sites had the lowest foliar incidences of CBSD (<11%), while Demesi and Elwakana had the highest incidences (36 to 50%). All the four sites had CBSD severity score of 2.

The only root symptom observed on all cultivars across sites was root necrosis. Cultivar Merry Kaluore had the highest number (mean) of damaged roots (13) followed by improved cultivars MM96/4271 (6) and Migyera (2). The severity score for root necrosis for Merry Kaluore was 3 across sites, while MM96/4271 and Migyera had root severity score of 2. Demesi site was not evaluated for root necrosis, because the farmer harvested early.

Effect on different planting technologies on CBSD incidence

Although statistically, there was no significant difference

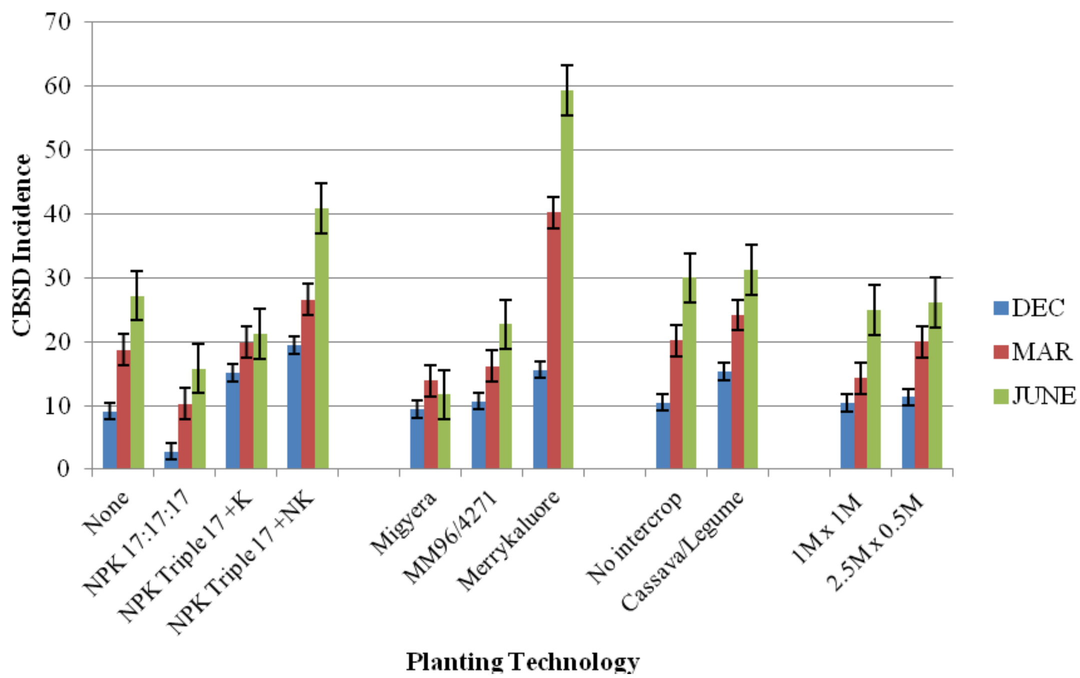

Figure 3. CBSD incidence in relation to planting technology.

(p>0.05) in incidence of CBSD in planting technologies involving modified spacing and legume intercrop, it varied for planting technologies involving improved and local cassava cultivar and also fertilizer application (Figure 3).

CBSD incidence in relation to cassava cultivar

Disease incidence varied by cultivar from 9 to 59%. At 9 months after planting (MAP), the local cultivar (Merry Kaluore) had high incidence of CBSD (59%) while the two improved cultivars; MM96/4271 and Migyera had low CBSD incidences of 23 and 12%, respectively (Figure 3). The severity score was 2.

CBSD incidence in relation to fertilizer application

Low CBSD incidences ranging between 3 and 16% were observed over time for management strategies involving fertilizer NPK 17:17:17. During the cropping period, the incidence of CBSD did not vary (15 to 21%) for fertilizer application NPK 17:17:17+ K, while for NPK 17:17:17 + N + K, disease incidence ranged between 20 and 41% (Figure 3).

CBSD incidence in relation to spacing arrangement

Disease incidence did not vary by spacing. For spacing arrangement of 1 m × 1 m, CBSD incidence ranged from 10 to 25%, while for 2 m × 0.5 m spacing arrangement it ranged from 11 to 26% across sites (Figure 3).

CBSD incidence in relation to intercropping

Disease incidence on leaves did not vary for cassava-bean intercrop (15 to 31%) or for cassava monocrop (11 to 30%) (Figure 3). Root symptoms of CBSD observed on cassava planted in cassava-bean intercrop at Lutacho and Elwakana sites had severity score of 2 and 3, respectively.

Effect of planting technologies on cassava yields

Cassava yields for panting technolgies tested ranked in ascending order were: Mundika (2.4 to 9.4 tons/ha)>Lutacho (6.1 to 16.9 tons/ha)>Elwakana (15 to 29 tons/ha). For management strategy where fertilizer NPK 17:17:17 and KCl were used, Elwakana site had higher (22.5 tons/ha) cassava yields than Mundika (5.3 tons/ha) and Lutacho (6.1 tons/ha) sites. Mundika had the lowest (4.7 tons/ha) cassava yields for cassava intercropped with beans. Cassava planted in 2 m × 0.5 m spacing yielded higher (mean 13.2 ton/ha) than in 1 m × 1 m (mean 9.3 tons/ha) spacing. At Elwakana, planting technology involving improved cultivar MM96/4271 planted using fertilizer NPK 17:17:17, CAN and KCl had the highest yields of 29 tons/ha (Table 2). Grain yields for beans intercropped with cassava cultivar Migyera were

Table 2. CBSD incidences and yield of cassava planted using different planting technologies across sites.

Site	Fertilizer regime			Intercrop		Spacing	
	NPK 17:17:17	NPK 17:17:17 + KCl	NPK 17:17:17 + CAN + KCl	No intercrop	Intercrop	1 m × 1 m	2.0 m × 0.5 m
Mundika	8.6 (10.3)	5.3 (16.6)	9.4 (26.5)	2.4 (26.4)	4.7 (26.9)	8.8 (15.6)	2.4 (15.3)
Elwakana	17.5 (16.3)	22.5 (21.2)	29 (40.9)	20 (30.1)	17 (31.2)	15 (25.2)	20 (26.9)
Lutacho	10.9 (2.8)	6.1 (15.4)	11.3 (19.7)	16.9 (10.9)	15 (15.3)	11.8 (9.5)	16.9 (10.9)

Figures in brackets are CBSD incidences.

higher (1.2 t/ha) than for those intercropped with MM96/4271 (0.8 tons /ha).

DISCUSSION

The application of chemical fertilizers has been reported to have an effect in controlling pests and diseases to a reasonable extent (Ezulike and Ugwu, 2005; Amtmann et al., 2008; Satti, 2012). Plant vigour enhancement due to fertilizer use has been explained as the cause behind ability of plants to withstand pests and diseases (Neuenschwander et al., 1990; Satti, 2012). The effect of NPK fertilizer application on pests and disease incidences and severity in the trials varied depending on site and cultivar. High incidence of CGM at Demesi and Elwakana sites could be attributed to the spread of the pest from neighbouring cassava field (Yaninek, 1989) since green mites are specific to *Manihot* species (Kogan et al., 1999). Improved cassava cultivars had higher percentage of CGM infested plants than local cultivar Merry Kaluore suggesting that the mites have preferences for some cultivars.

Use of NPK 17:17:17 and NPK 17:17:17 + KCl fertilizers resulted in decrease in incidence of green mites. Similar findings of decrease in green mite pressure due to NPK fertilizer application were reported by Anneke et al. (2010).

More plants were infested with CGM in spacing arrangement of 2 m × 0.5 m than 1 m × 1 m spacing. Plants in 0.5 m plant to plant space were very closely knit to each other. This could have contributed to ease of the movement of pests from plant to plant.

One of the major constraints to production of cassava, in sub-Sahara Africa is cassava brown streak disease (Winter et al., 2010; Bigirimana et al., 2011). The disease is transmitted by whiteflies (*B. tabaci*) and use of infected cuttings. Whitefly is the most important vector for cassava viruses and therefore whitefly populations affect CBSD incidence (Thresh and Otim-Nape, 1994; Maruthi et al., 2004). Whitefly population per plant ranged between 0 and 62 and varied by site (Lutacho < Demesi < Mundika < Elwakana). Mundika and Lutacho sites had low CBSD incidence (<11%). Low incidence of CBSD could be associated with low virus pressure because whiteflies must be viruliferous to transmit the virus (Polston and Capobianco, 2013). High CBSD incidences (36 to 50%) at Demesi and Elwakana sites are associated with high virus pressure (Mware et al., 2009; Legg et al., 2011).

Although plants were being evaluated for CBSD, other diseases infecting cassava were also assessed. High incidence of CMD at Elwakana site was associated with influence of whiteflies migrating from infested neighbouring cassava fields, which concurs with the findings of Uzokwe et al. (2016). Disease incidence varied across sites ($p<0.001$, Mean≤60%). High disease incidences at Elwakana and Demesi sites could be due to high whitefly populations while low incidences (≤19%) at Mundika and Lutacho are associated with low whitefly populations.

Local cultivar Merry Kaluore had the highest number of CBSD damaged roots per plot than improved cultivars (MM96/4271 and Migyera). Disease expression (necrosis) in root begins as small yellow/brown corky patches which increase in size and number as the plant grows. In sensitive cultivars, the continued increase in corky patches eventually covers the entire root (Hillocks, 2004). The study findings concluded that Merry Kaluore is among the cultivars that are susceptible to CBSD infection and risks total yield loss due to root necrosis.

Low CBSD incidence was observed in plots where fertilizer NPK 17:17:17 was used. Although the use of fertilizer does not control cassava diseases, its use is more rational when disease-resistant (improved) cultivars are used as they are more responsive to fertilizer application than local cultivars (Anneke et al., 2010; Fairhurst, 2012). Plant vigour enhancement due to fertilizer may have contributed to low disease incidence. Disease incidence did not vary by spacing or where cassava was intercropped with beans. This implies that CBSD cannot be managed by varying the spacing of cassava crops.

Yields for beans intercropped with cassava cultivar Migyera were higher than those intercropped with MM96/4271. Migyera is characterized by an open growth habit which allows for light to penetrate to the ground, while MM96/4271 has compact growth pattern which intercepts light.

Cassava planted using 2 m × 0.5 m spacing arrangement yielded higher (13.2 t/ha) than cassava planted using 1 m × 1 m spacing arrangement (9.3 t/ha). According to FAOSTAT (2015) report in Kenya, average cassava yield for cassava planted in 1 m × 1 m monocrop is 13.5 t ha^{-1}. The insignificant change in cassava yields as well as the increased bean yields is an indication that cassava can be intercropped with beans using 2 m × 0.5 m cropping arrangement without negatively affecting the cassava yields. Similar findings by Pypers et al. (2011) indicated that cropping arrangements of 2 m × 0.5 m increased grain legume yields without negatively affecting cassava yields.

Cassava cultivar MM96/4271 planted using fertilizer NPK 17:17:17 + CAN + KCl had the highest yield of 29 ton/ha. This suggests that the cultivar could be more responsive to fertilizer applied than Migyera and Merry Kaluore (Fairhurst, 2012).

Conclusion

Planting technologies such as fertilizer use, modification of spacing and intercropping cassava with legumes have no effect on prevalence of CBSD. Low incidence of CBSD on improved cultivars indicates that CBSD can be mitigated through crop improvement technologies such as breeding for resistance to diseases.

Contrary to earlier recommendations that cassava should be established at onset of rain (Toro and Atlee, 1980; Ekanayake et al., 1997), the study found that this may be applicable to cassava pure stand cropping and not in cassava-legume intercrop arrangements.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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