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Identifying cassava production constraints, farmers preferences, and cassava mosaic disease perceptions in Togo: insights for a participatory breeding approach

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Abstract

Background Cassava is a crucial food security crop in Togo and the most significant root crop in terms of area under cultivation and production volume. However, its production is predominantly carried out by subsistence farmers using low-yielding landraces. Several constraints impede cassava production, threatening its sustainability in the country. The low adoption of improved varieties developed by the International Institute of Tropical Agriculture (IITA) underscores the need for a participatory approach to research and development. This study aimed to identify the cassava varieties grown, major production constraints, farmers' trait preferences, and perceptions of Cassava Mosaic Disease (CMD) through Participatory Rural Appraisal (PRA).

Methods The study employed a multistage random sampling procedure to select regions, districts, and villages based on cassava production levels. The survey involved 83 men and 57 women in group interviews and 600 farmers in individual interviews: 200 in the forest–savanna transition, 180 in the rainforest, 120 in the wet savanna, and 100 in the dry savanna. Content analysis was used for qualitative data, and quantitative data were analyzed using descriptive statistics and comparative analyses, including Chi-square tests to assess differences in perceptions and preferences.

Results The PRA revealed key constraints to cassava production, including inadequate capital, CMD, post-harvest physiological deterioration (PPD), and the non-availability of clean planting materials. Traits such as high yield, pest and disease resistance, early maturity, high dry matter content, delayed root deterioration, poundability, and taste were highly valued by farmers. CMD was identified as a significant disease, causing yield losses, with various causes and management practices reported. The study highlighted the necessity for a sustainable cassava seed system, as farmers pointed out the lack of improved varieties and clean planting materials.

Conclusion This study provides essential insights into cassava farming practices, production constraints, and farmers' preferred traits, laying the groundwork for a participatory breeding program in Togo. Addressing low-yielding varieties and diseases, particularly CMD, is critical for enhancing cassava production and ensuring food security.

Keywords Cassava, Participatory rural appraisal, Farmers' preferences, Constraints, Cassava mosaic disease, Togo

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Background

Cassava stands as a pivotal food security crop in Togo, and the most valued root crop in terms of area under cultivation and total production [11, 31]. Cassava is mostly grown in the forest zones which accounts for 85% of total production [11]. However, its production remains dominated by low-yielding landraces and by subsistence farmers [15, 19]. Cassava production is also affected by several constraints, which may undermine the sustainability of cassava production in the country. Moreover, the national cassava breeding program invests a lot of effort in evaluating the adaptability of improved varieties from the International Institute of Tropical Agriculture (IITA and focuses on yield and disease resistance as selection criteria, which probably do not match all farmers' preferred traits in Togo. Farmers' participation in formal plant breeding programs is low and their knowledge has not been utilized,as a result, adoption of new varieties bred through the formal process has been low [17]. In contrast, to formal breeding, client-oriented participatory breeding improves breeding efficiency, accelerates adoption, leads to more acceptable varieties, promotes genetic diversity, and saves time and resources [10].

Participatory research facilitates the integration of farmers' indigenous technical knowledge, the identification of their criteria, and the prioritization of research agendas. Adoption decisions are typically influenced by three key factors: economic constraints, the diffusion of innovation, and the "adopter perception" [28]. Ndeko [24] highlighted the significance of ecological zones in explaining the adoption of improved technologies among farmers. They proposed that farmers residing in distinct ecological zones might embrace improved technologies differently due to environmental variations. If the developed technologies are not suitable for the prevailing conditions in these zones, adoption rate can be low. Therefore, it is essential for the development of improved crop varieties and other technologies to be tailored to the specific conditions of each ecological zone. From the point of breeding, to assess the usefulness of any given landrace, there is a need to determine the attributes that are responsible for farmers' choices through participatory approaches [10]. A farmer's decision to adopt a particular cassava variety is influenced by some factors such as high yield, early maturity, low cyanide content, root quality, and flesh root color [4]. In many national breeding programs where the farmers have been involved in the breeding process, improvements have been observed in the adoption and release of new varieties [3, 21]. Farmers' participation guarantees that the newly developed varieties will be easily adopted, and farmers could play a key role in the diffusion of these varieties [18].

The failure to integrate CMD-resistant cassava cultivars in Togo results from the characters not matching the characteristics that are most desirable to farmers. CMD is not controlled properly in Togo because farmers lack proper knowledge and training. This study conducts a large-scale survey in Togo to gather vital information about farmers' preferences for cassava cultivars and their knowledge of CMD. This participatory approach aimed to reveal the potential constraints to the production of cassava in Togo. Therefore, the PRA was designed to: (i) identify key constraints limiting cassava production, (ii) identify cassava varieties grown and farmers' preferred traits, and (iii) ascertain farmers' perceptions of CMD. This information will help to lay up the foundation of a national breeding program in defining priority constraints and traits, and in developing breeding strategies to develop improved varieties that are high yielding, adapted to target environments, resistant to CMD, and preferred by farmers, market, and consumers. Knowledge about how viruses are transmitted and their infection cycle is important to control the spread of the disease, as no approved or reliable antiviral products are generally available. When managed poorly, CMD and other viruses can cause a complete loss of cassava yields; it is, therefore, important to understand what farmers know about CMD, their perceptions about how infection affects cassava yields, how they currently manage the disease, their criteria for selecting cassava cultivars, and how they source planting materials. Building knowledge among farmers is probably the most important strategy for controlling CMD, and the first step in building this knowledge is to understand the current state of farmers' knowledge.

This paper is structured as follows: Introduction, Materials and methods, Results, and the Discussion section.

Methods

Study area

The study was conducted in four agroecologies in Togo where cassava is extensively cultivated; forest–savanna transition (FST), rain forest (RF), wet savanna (WS), and dry savanna (DS) zones (Table 1). The provinces, districts, and villages targeted were selected based on their cassava production level, and the existence and strength of farmers' associations. The FST is made of shrubby vegetation with few trees while the RF is characterized with rain forest vegetation. The WS zone has more shrubby vegetation while the DS zone has herbaceous vegetation. The forest zones share a sub-tropical climate with a bimodal rainfall pattern. The savanna zones are characterized by a sudano-sahelian climate with one long rainy season and one long dry season [7]. The average annual rainfall is about 1200 mm in the forest–savanna

Table 1 Agroecological zones, regions, provinces and districts selected for the PRA

Agroecological zone	Region	Province	District	Village
Forest–savanna transition	Maritime	Zio Sud	Tsévie	Davié, Wli
		Zio Nord	Agbelouve	Gapé Assikévé
		Yoto	Tabligbo	Afikoukondji Adagbakondji
		Vo	Vogan	Aneve, Sokome
		Ave	Kévé	Kévé centre
		Lacs	Aklakou	Hlandé
Rain forest	Plateaux Ouest	Agou	Agou	Agou
		Kloto	Kpalimé	Salifoucopé
		Adeta	Adéta	Adéta centre
		Danyi	Apéhémé	Kpéto, Wétropé
Wet savanna	Centrale	Blitta	Blitta	Wéli, Yégue, Assoukoko,
		Sotouboua	Sotouboua	Nima
		Tchaoudjo	Sokodé	Lamatéssi
Dry savanna	Kara and Savane	Assoli	Bafilo	Bafilo centre, Daoudè
		Bassar	Bassar	Bassar

transition zone, 1400 mm in the forest and wet savanna zones, and 1300 mm in the dry savanna zone, with average temperatures of 28, 24, 27, and 28 °C, respectively [31].

Sampling procedures

Multistage and purposive sampling techniques [16] were used in selecting the survey sites to capture maximum variability in agroecological and socioeconomic environments. In the first stage, four agroecologies representing the major cassava production zones in Togo were purposively selected. In the second stage, six provinces depicting high production levels were sampled in the FST, four in the RF, three in the WS, and two within the DS resulting in a total number of 15 provinces. Two districts were sampled per province based on the cassava production level, for a total of 30 districts in the third stage. Two villages per district were selected at random, for a total of 60 villages in the fourth stage. Villages considered for random sampling in the respective district were depicting high cassava production.

The survey team was guided by some prior knowledge of the distribution and importance of cassava obtained from the Direction of National Agricultural Statistics and from the agricultural extension officers. Preliminary visits were made to discuss with the extension agents and the farmers. These visits provided opportunities to pretest the questionnaire and at the same time to collect preliminary data on cassava production system and constraints. According to the national statistics data [11] the mean number of cassava farmers per village ranges from 75 to 110 in the surveyed area. Fifteen (15) farmers from each of the eight districts sampled were targeted for focus group discussions. Overall, 83 adult men and 57 women farmers (Table 2) were involved in focus group sessions. Subsequently, from a list of cassava farmers provided by the agricultural extension service, 600 farmers, of which 200 in FST, 180 in the RF, 120 in WS, and 100 in DS were randomly selected for the survey.

Data collection

The PRA was conducted through focus group discussion (FGD) and individual interviews with the facilitation of extension agents, lead farmers, and village chiefs. A checklist was designed to guide the discussions during the focus group sessions [1]. For the formal survey, a questionnaire was designed and pre-tested on 40 farmers across the country to validate the importance of the variables and the possible responses in addressing the survey objectives, and later revised to incorporate emerging issues from the pre-testing before its administration to farmers as suggested by Dao et al. [10]. Farmer training centers were used as sites for the FGD sessions while the individual interviews were carried out in farmers' fields. In total, two FGDs were held in each agroecological zone, making a total of eight FGDs for the whole study across the country (Table 2). Each FGD was constituted of 18 participants, namely a breeder, one agronomist, one agricultural extension officer, and 15 farmers. Data collected were: socio-demographic characteristics of farmers, cassava cultivars grown and their characteristics, main constraints to cassava production, and preferences for new

Table 2 Sites and number of farmers involved in the focus group discussions sessions

Agroecological zone	District	Name of the community	No[a]. of FGD	Male	Female	Total
Forest–savanna transition	Tsévié	Ewé	1	10	05	15
	Vogan		1	07	08	15
Rain forest	Agou	Ewé	1	12	06	18
	Danyi		1	09	10	19
Wet savanna	Assoukoko	Ewé	1	15	05	20
	Sotouboua	Kabyè	1	10	08	18
Dry savanna	Daoudè	Kotokoli	1	08	07	15
	Bassar	Bassar	1	12	08	20
Total	8	5	8	83	57	140

[a] No. of FGD: number of focus group discussion

cassava variety development. They were then asked to score and rank factors under discussion using the pair-wise ranking method.

In addition, farmers were presented with plants exhibiting typical severe CMD symptoms [8] during the FGD sessions. This was done to assess farmers' knowledge and perception of CMD. Subsequently, the questionnaires were administered to farmers individually to confirm and supplement the findings from the FGD by a team that comprised agricultural extension agents and a breeder.

Data analysis

Qualitative data collected from both focus group sessions and individual questionnaires were summarized using content analysis [9, 26]. Descriptive statistics and ANOVA of traits related to the total land size, land allocated to cassava, and cassava yield were performed using SAS version 9.4. The mean rank of each factor under discussion during the focus group sessions was computed and these factors were ranked in order of importance for each agroecology using the Excel package. The lower the mean rank, the more important the trait, and vice-versa. The formal survey data were also computed for each agroecological zone and analyzed in SPSS version 16th. Comparative descriptive statistics were performed, and results related to production constraints and farmers' preferences were presented as percentages. The Chi-square test was run to test whether farmers' preferences for a particular cultivar and perception of production constraints mentioned during the individual questionnaires were related to agroecology [24]. Since multiple farmers were involved in the rankings of cassava production constraints and farmers' preferred traits, the degree of agreement among farmers' rankings was assessed using Kendall's coefficient of concordance (W). A value of 1 for 'W' indicates perfect agreement among all rankers. A comparison of farmers' rankings among the four agroecologies was done using Spearman's coefficient of correlation [21].

Results

Socio-demographic characteristics of farmers surveyed

Overall, 60% of farmers interviewed were male and 40% were female. The majority of farmers (78.5%) were adults (˃ 35 years old) while the remaining farmers had ages between 20 and 35 years. Most of the farmers (81.5%) were married while the remaining were either single (16.67%) or widowers (1.83). Of the cassava farmers surveyed, the majority (66.16%) had no formal education. About 82% of the cassava farmers had at least 15 years of experience in cassava growing (Table 3).

Practices in cassava cultivation and cropping calendar

Cassava is grown twice (from April to middle July and in middle September) in the forest agroecologies experiencing two rainy seasons, while in the savanna zones, it is cultivated once (from June to August) in a year. The cassava cropping started with land preparation (clearing and plowing) in March and April (forest zones), June and July (savanna zones) using hoes, axes, and to a lesser extent tractors (forest zones). Then planting of cassava stakes of about 30 cm was done on ridges or mounds, horizontally in the savanna zones, whereas in the forest zones stakes are vertically planted on the soil. Weeding was done usually thrice in the forest zones manually at irregular frequencies starting from 2 months after planting. However, farmers in the savanna zones reported that they weeded their cassava fields a maximum of twice a year, starting from 2 months after planting. Farmers also reported that land preparation, planting, and activities related to weeding and harvesting were mostly done by men, women, and children of each household. However, during the period of intensive farm activities and funerals most of the cassava farmers relied on hiring labor. In

Table 3 Socio-demographic characteristics of interviewed cassava farmers in Togo

Socio-demographic characteristics	Agroecological zone				Total	Percentage (%)
	FST	RF	WS	DS		
Age						
20–35 years	50	35	23	21	129	21.5
> 35 years	150	145	97	79	471	78.5
Total	200	180	120	100	600	100.0
Gender						
Male	105	100	90	65	360	60.0
Female	95	80	30	35	240	40.0
Total	200	180	120	100	600	100.0
Marital status						
Married	145	137	113	94	489	81.5
Single	48	40	7	5	100	16.6
Widow (er)	7	3	0	1	11	1.8
Total	200	180	120	100	600	100.0
Education						
No schooling	130	115	88	64	397	66.2
Primary school	40	35	20	25	120	20.0
Secondary school	19	25	5	9	58	9.7
Tertiary	11	5	7	2	25	4.1
Total	200	180	120	100	600	100.0
Experience in cassava growing						
≤ 15 years	30	23	11	05	69	11.5
15–30 years	150	138	105	94	487	81.1
˃ 30 years	20	19	4	1	44	7.3

FST: forest–savanna transition, RF: rain forest, WS: wet savanna, DS: dry savanna

addition, cassava farmers reported that neither fertilizers nor pesticides were applied. However, in the forest zones where cassava is generally mixed with maize, cassava plants benefit from inorganic fertilizers applied to maize plants. Harvest was done throughout the year with a peak between February and April, thus about 10–11 months after planting in the forest zones. Unlike in the forest zones, cassava is usually harvested throughout the year in the savanna zones, with a peak between June and July.

Farm characteristics

The average total farm size varied from 2.5 hectares in forest–savanna transition (FST) to 4.5 in the rain forest zone (RF). Analysis of variance revealed a significant difference between agroecologies ($p=0.001$). The cassava farm size varied from 0.5 hectares in the savanna zones to 1.45 hectares in the forest zone. The cassava farm size also differed significantly from one agroecology to another ($p=0.001$). Overall, 71% of farmers practiced intercropping, 14% practiced mono-cropping and the remaining (15%) practiced both. The majority of farmers in the FST (83.5%) and in the RF (90%) practiced intercropping. Ten percent (10%) of farmers cultivated cassava in monoculture, while 90% practiced intercropping in the forest transition. About 50% and 60% of the farmers practiced intercropping, respectively, in the wet and dry savanna zones. There were few farmers (15 and 13.25%, respectively) practicing monoculture in savanna zones. In the RF, intercropping (90%) was the most practiced system followed by mono-cropping (10%) (Table 4).

In addition, from the survey, maize, legumes (beans, soybeans, and cowpea), yam, sweet potato, and plantain were mostly intercropped with cassava across the country. However, some farmers across the country mixed cassava with banana, vegetables, and pineapple. In the forest zones most of the farmers usually mixed cassava with maize and plantain, whereas in the savanna zones, cassava was mainly mixed with yam and sweet potato.

The average cassava fresh root yield in the survey areas is 13.2 t ha^{-1}, with the lowest being 9 t ha^{-1} in the DS and the highest being 17 t ha^{-1} in the FST. ANOVA revealed significant differences between agroecologies ($p=0.01$) (Table 4).

Concerning the sources of cassava planting materials, almost all the farmers (96.6%) reported that the availability of clean planting materials (stakes) was a problem.

Table 4 Farm characteristics across four agroecologies in Togo

Agroecology	Farm size		Farming systems			Cassava yield estimated (t ha^{-1})
	Total farm size (ha)	Area allocated to cassava (ha)	Monocropping (%)	Mixed cropping (%)	Monocropping and mixed cropping	
FST	2.5[a]	1.5[a]	16.5	83.5	0	17.0[a]
RF	3.0[b]	1.5[a]	10.0	90.0	0	16.0[a]
WS	4.5[c]	0.5[c]	15.0	60.0	25	11.0[b]
DS	4.3[c]	0.5[b]	13.3	50.0	36.7	9.0[c]
Mean	3.5	1.0	13.7	70.8	15,5	13.2
LSD	0.2	0.1	–	–	–	1.8
p value	< 0.001	< 0.001	–	–	–	0.045

LSD: least significant differences of means (5% level); FST: forest–savanna transition; RF: rain forest; WS: wet savanna; DS: dry savanna; means within a column followed by the different letter are significantly different

Most farmers obtained planting materials from their fields (68%) and neighbors (28%). However, farmers were not sure of the health status of the planting materials they had been planting. A few farmers (5%) obtained planting materials from the National Cassava Breeding Unit by collaborating on on-farm testing of new cassava varieties. In the FST, 10% of the farmers purchased their planting materials from the research institute, while the remaining farmers acquired their planting materials either from their fields (80%) or neighbors (10%). In the RF, 45.5% of the farmers acquired the planting materials from neighbors while the rest sourced their planting materials either from their fields (50%) or the research institutes (4.5%). From the survey, 39% of the farmers interviewed in the WS, obtained their planting materials from neighbors fields while the remaining acquired them from the research institute (2%) and their fields (59%). In the DS, most farmers (85%) sourced the planting materials from their fields and neighbors (15%) (Fig. 1).

Cassava production constraints

Across the agroecologies, inadequate capital, cassava mosaic disease, post-harvest physiological deterioration (PPD), inadequate processing method, and non-availability of clean planting materials were key constraints to cassava production. Other constraints had varied rankings in all the agroecologies indicating the different levels of their importance among farmers (Table 5). However, at the agroecological zone level, weeds, cassava mosaic disease, and PPD were of priority to the farmers in the FST. The most important constraints in the RF identified by farmers were PPD, inadequate capital, inadequate processing methods, cassava mosaic disease, and weeds. Within the wet savanna, inadequate capital, wild animals and livestock, use of low-yielding varieties, non-availability of clean planting materials, use of late bulking cassava varieties, and cassava mosaic disease were of priority to the farmers. Wild animals and livestock, inadequate capital, late bulking cassava varieties, cassava mosaic disease, and the non-availability of clean planting materials were the most important constraints within the DS.

The results also showed variations in the ranking of production constraints between agroecological zones. In the FST and WS, inadequate capital was perceived as most important, while in the RF; PPD was ranked as the most important (Table 5). However, in DS farmers identified wild animals and livestock as the main constraints to cassava production. The Chi-squared test revealed that there was a significant association between cassava production constraints and agroecology ($\chi^2 = 55.67$, df $= 11$, $p = 0.001$).

The Kendall's test (Table 6) revealed significant differences for 7 out of 12 constraints namely, inadequate capital, inadequate processing methods, PPD, cassava mosaic disease, weeds, drought, and non-availability of clean planting materials in the forest zones. In the savanna zones, 6 out of the 12 constraints identified (inadequate capital, cassava mosaic disease, drought, low-yielding cultivars, non-availability of clean planting material, wild animals, and livestock) were also significant. However, generally, 4 of the 12 production constraints (inadequate capital, cassava mosaic disease, drought, and the non-availability of clean planting materials) were significant, indicating the high level of agreement among farmers' rankings (Table 6).

Generally, high, positive, and significant rank correlations among the agroecologies were observed for six of the 12 production constraints which were, PPD, drought, cassava mosaic disease, weeds, non-availability of clean planting material, and inadequate capital (Table 6). However, weak, positive, and significant rank correlations among the agroecologies were also recorded for low-yielding cultivars and inadequate processing methods. These results indicate that farmers' rankings in the

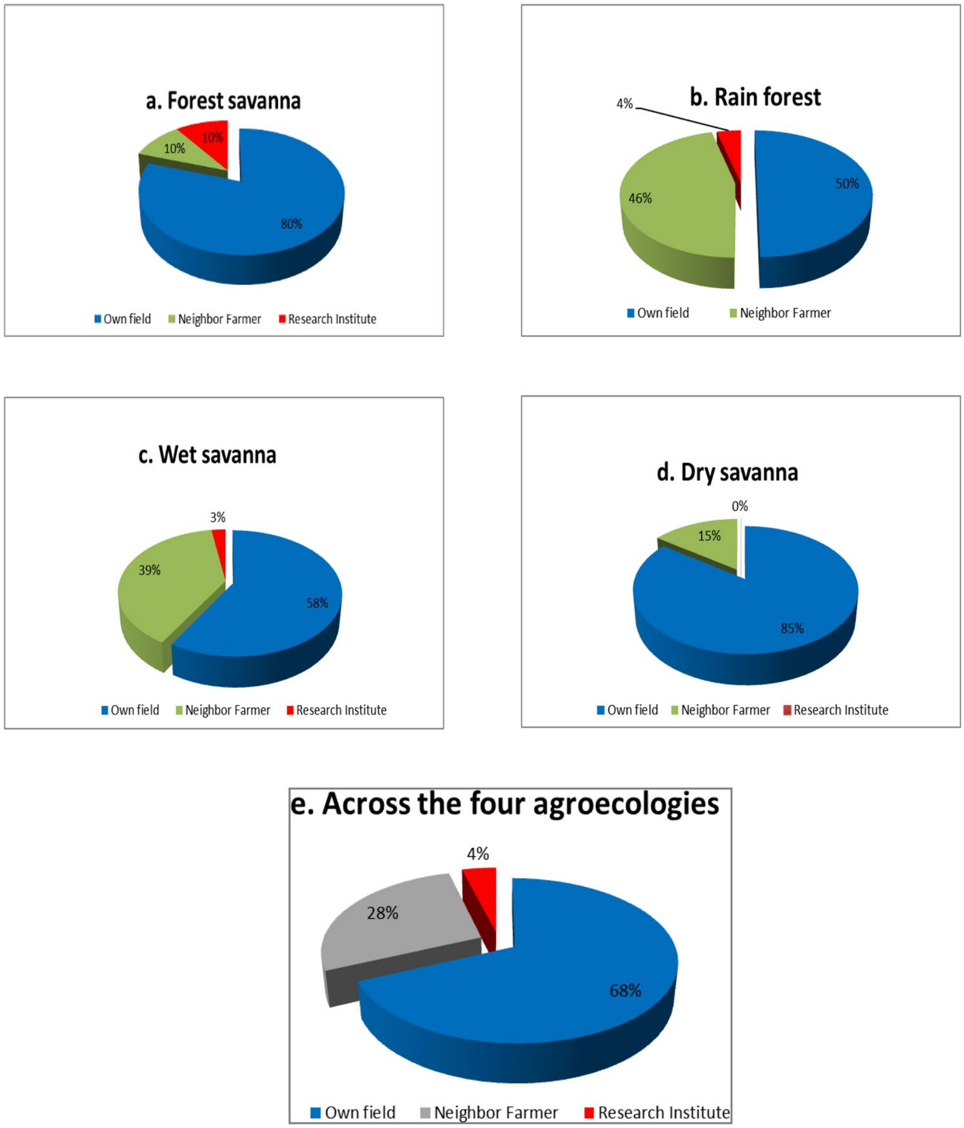

Fig. 1 Sources of cassava planting materials across four agroecologies in Togo

agroecologies were not random and highly agreed with each other. The rank correlations on labor shortage and late bulking cultivars were negative and non-significant indicating that the rankings of these constraints in the agroecologies were random and rarely agreed with each other (Table 6).

Farmers' preferred traits

Farmers had similar preferences as agronomic and culinary quality traits were mostly listed by farmers (Table 7). Generally, high yield, early maturity, resistance to pests and diseases, delayed deterioration of roots after harvest, and high dry matter were the five most important agronomic traits. For the culinary traits, 2 out of 5 traits namely poundability and good taste were of priority to farmers. In addition, secondary traits mentioned were long underground storage roots ability, root flesh color, regular root shape, late bulking, and large root size.

In the FST, agronomic traits such as yield, early maturity, pests and disease resistance, dry matter content, and suitability for intercropping, were of great importance to farmers (Table 7). Poundability, followed by good taste were the most important culinary traits in this zone. Root flesh color was the greatest trait under the secondary traits category, followed by large root size and regular shape of roots.

Concerning the RF, the most important agronomic traits identified were high yield, delayed deterioration of

Table 5 Cassava production constraints across four agroecologies of Togo

Production constraints	FST ($N=200$)		RF ($N=180$)		WS ($N=120$)		DS ($N=100$)		Overall	
	Mean[a] rank	Per[b]c & Rank	Mean[a] rank	[b]Perc. & Rank	Mean[a] rank	Perc[b] & Rank	Mean[a] rank	Perc[b] & Rank	Mean[a] rank	Perc[b] & Rank
Inadequate capital	1.90	93.2 (1)	1.95	89.7 (2)	1.93	94.5 (1)	1.85	95.6 (2)	1.90	93.25 (1)
Inadequate processing methods	2.10	87 (2)	2.20	85 (3)	5.13	9.5 (11)	3.45	42.9 (9)	3.22	77.5 (4)
Labor shortage	6.8	34 (12)	5.4	63.2 (9)	3.45	34.92 (8)	3.63	21(10)	4.82	38.28 (11)
PPD	4.50	74.8 (5)	1.90	90.1 (1)	3.24	42.7 (7)	2.85	60.2 (6)	3.12	66.95 (3)
Cassava mosaic disease	4.38	82.5 (4)	2.45	80.2 (4)	3.17	50.4 (6)	2.11	70.9 (4)	3.02	71 (2)
Weeds	3.50	85.3 (3)	3.82	75 (6)	4.16	23.45 (9)	4.0	12 (11)	3.87	48.93 (8)
Drought	4.80	65.7 (6)	5.10	55 (10)	4.67	17.4 (10)	3.34	53.6 (8)	4.47	47.92 (10)
Poor extension contact	6.25	45 (10)	5.55	50 (11)	5.20	4.5 (12)	4.1	7 (12)	5.27	26.62 (12)
Low yielding varieties	5.10	47.3 (9)	4.10	72.3 (7)	2.25	75.4 (3)	3.14	57.4 (7)	3.64	63.1 (7)
Non-availability of clean planting materials	5.00	50.1 (8)	3.12	78.4 (5)	2.57	60.6 (4)	2.57	65.7 (5)	3.31	63.7 (5)
Late bulking varieties	4.9	54.6 (7)	4.14	64.5 (8)	3.12	55.34 (5)	1.95	74.6 (3)	3.52	62.26 (6)
Wild animals and livestock	6.55	41 (11)	6.40	35(12)	2.10	90.75 (2)	1.82	92.5 (1)	4.21	57.31 (9)
W ($p<0.001$)	0.976		0.952		0.974		0.934		0.959	

N: number of respondents; *W*: Kendall's coefficient of concordance; PPD: post-harvest physiological deterioration; [a]mean rank obtained from FGDs sessions (constraint with lowest mean rank is the most important); FST: forest–savanna transition; RF: rain forest; WS: wet savanna; DS: dry savanna. [b]Perc. & Rank = percentage of times the constraint was mentioned by farmers (survey) followed by it rank number in parentheses

Table 6 Concordance of farmers' rankings of main cassava production constraints across four agroecologies in Togo

Production constraints	FST ($N=200$)	RF ($N=180$)	WS ($N=120$)	DS ($N=100$)	Correlation among the four agroecologies
	W	*W*	*W*	*W*	r_s
Inadequate capital	0.93**	0.87*	0.95**	0.91**	0.61**
Inadequate processing methods	0.81*	0.76*	0.51	0.56	0.54*
Labor shortage	0.45	0.34	0.26	0.43	-0.15^{NS}
Postharvest physiological deterioration	0.80*	0.96**	0.34	0.28	0.85**
Cassava mosaic disease	0.83*	0.92**	0.78*	0.90**	0.72*
Weeds	0.75*	0.71*	0.50	0.49	0.65*
Drought	0.76*	0.69*	0.67*	0.69*	0.77*
Poor extension contact	0.48	0.56	0.53	0.60	0.32^{NS}
Low yielding varieties	0.25	0.54	0.67*	0.66*	0.55*
Non availability of clean planting materials	0.77*	0.85*	0.83*	0.81*	0.63*
Late bulking varieties	0.28	0.46	0.48	0.42	-0.35^{NS}
Wild animals and livestock	0.31	0.47	0.90**	0.93**	0.84**

N: number of respondents; *W*: Kendall's coefficient of concordance; rs: coefficient of correlation among agroecologies; asterisks represent a significant percentage of rankings according to Chi-square test, ** significant at $p=0.01$, * significant at $p=0.05$, NS: non-significant

roots after harvest, high dry matter content, pests and diseases resistance, and early maturity. The two most preferred culinary traits mentioned by farmers in the RF were poundability and good taste. Long storage of roots underground ability was the most preferred trait among secondary traits, followed by root flesh color (Table 7).

The preferred agronomic traits identified by farmers in the WS in order of importance were high yield, drought tolerance, early maturing, resistance to pests and diseases, and suitability for intercropping. The taste and the drying ability were of priority to farmers under the culinary traits category, in the WS, while long underground storage root and the regular root shape were important under secondary traits.

Agronomic traits of great importance for farmers in the DS were high yield, early maturity, resistance to pests and diseases, and drought tolerance. Culinary traits such as taste and drying ability and secondary traits such as long underground storage root and regular root shape were of priority to farmers of the DS (Table 7).

Kendall's test of concordance (Table 8) revealed significant differences for 5 out of the 7 agronomic traits namely, yield, early maturity, pests and diseases resistance, dry matter content, and suitability for intercropping. However, in the RF, delay PPD was also significant. For the culinary traits, 3 out of the 5 traits were significant in the forest zones. While in the savanna zones, 2 out of 5 traits (drying ability and good taste) were also significant. Regarding secondary traits, 1 out of 5 traits (large root size) was significant in the FST, while 2 traits (regular root shape and long underground storage root in the field) were also significant in the savanna zones. Across the country, Kendall's test showed that 94.7% of the farmers agreed with the rankings of preferred traits (Table 8). Across the country, 6 agronomic and 4 culinary traits were significant (Table 8).

The rank correlations among agroecologies were generally high (greater than 0.6), positive, and significant for agronomic traits such as high yield, pests and diseases resistance, suitability for intercropping, early maturity, delayed PPD and drought tolerance. Culinary traits such as poundability, good taste, suitability for multipurpose uses, and drying ability, also scored high, positive and significant rank correlations. However, the rank correlations on late maturity, long underground storage root in the field, weed suppression ability, and color of fresh root were negative and non-significant (Table 8).

Cassava cultivars grown and associated characteristics

In total, 55 cultivars are grown across the survey area (Table 9). The most common cultivars mentioned by farmers were Gbazékouté, Gabon, Cameroon, Fétonégbodzi and Lagos. However, the most widespread cultivars across agroecologies were Gbazékouté and Fétonégbodzi. These cultivars with good cooking quality (poundability, sweetness) were most adapted, high yielding, early maturing, and had good market demand. In addition, minor cultivars in the forest zones were Ahokpo, Yaokouté, Kalicotou, Kanigbéli, Aboram, Tchoukouno, Etrodji and Ewuidi. For the savanna

Table 7 Farmers' preferred traits in cassava cultivars across four agroecologies in Togo

Preferred cassava traits	FST ($N=200$)		RF ($N=180$)		WS ($N=120$)		DS ($N=100$)		Overall	
	Mean rank	Perc. & Rank	Mean rank	[a]Perc. & Rank	Mean rank	[a]Perc. & Rank	Mean rank	[a]Perc. & Rank	Mean rank	[a]Perc. & Rank
Agronomic traits										
High yield	1.74	90 (1)	1.85	92.5 (1)	1.92	96.2 (1)	1.95	95 (1)	1.86	93.42 (1)
Early maturity	1.84	85 (2)	2.65	47.1 (5)	2.00	88.4 (3)	2.14	90.1 (2)	2.15	77.65 (2)
Diseases resistance	2.30	80 (3)	2.18	70.1 (4)	2.37	64 (4)	2.23	89.4 (3)	2.27	75.87 (3)
High root dry matter content	2.42	75 (4)	2.10	74 (3)	3.3	52 (7)	3.35	47 (6)	2.79	62 (5)
Delayed PPD	–	–	1.93	86.4 (2)	2.85	55 (6)	2.85	63.9 (5)	2.54	68.43 (4)
Suitability for intercropping	2.67	64.5 (5)	3.1	26 (7)	2.46	61 (5)	3.80	41 (7)	3.00	48.12 (7)
Drought tolerance	4.1	34.65 (6)	–	–	1.95	91.7 (2)	2.32	80.7 (4)	2.80	69.01 (6)
Weed suppression hability	4.3	30.57 (7)	2.45	55.4 (6)	–	–	4.76	2 (8)	3.83	28.99 (8)
Culinary traits										
High dry immediately	–	–	–	–	3.35	35 (2)	2.95	60 (1)	3.15	47.5 (4)
Good taste (sweet)	3.10	50.45 (2)	2.37	60.2 (2)	2.21	76 (1)	3.30	51.7 (2)	2.74	59.58 (2)
Non-fibrous roots	5	6.5 (4)	4.3	7 (4)	–	–	3.95	9 (3)	4.41	7.5 (5)
Poundability	2.71	55.9 (1)	1.97	85 (1)	–	–	–	–	2.34	70.45 (1)
Suitability for multipurpose uses	3.35	41.5 (3)	2.87	37 (3)	–	–	–	–	3.11	39.45 (3)
Secondary traits										
Large root size	4.52	20 (2)	3.36	11 (3)	3.95	11 (3)	–	–	5.91	14 (5)
Root flesh color	4.35	27.4 (1)	3.23	17(2)	–	–	–	–	3.79	22.2 (2)
Late bulking	–	–	–	–	4.35	3 (4)	4.65	3 (3)	4.50	3 (4)
Regular root shape	4.67	12.7 (3)	–	–	3.51	15 (2)	3.84	21 (2)	4.00	16.23 (3)
Long underground storage root in field	5.1	5.96 (4)	3.15	20 (1)	2.13	81.2 (1)	2.75	70.1 (1)	3.28	44.31 (1)
W ($p<0.001$)	0.934		0.978		0.949		0.928		0.947	

– denotes trait not reported, traits with lowest mean rank is the most important; *N*: number of respondents; FST: forest–savanna transition, RF: rain forest, WS: wet savanna, DS: dry savanna; [a]Mean rank obtained from FGDs sessions (constraint with lowest mean rank is the most important), [b]Perc. & Rank: Percentage of times the trait was mentioned by farmers followed by it rank number in parentheses

Table 8 Concordance of farmers' rankings of their preferred traits across four agroecologies in Togo

Preferred cassava traits	FST ($N=200$)	RF ($N=180$)	WS ($N=120$)	DS ($N=200$)	Correlation among the four agroecologies
	W	*W*	*W*	*W*	r_s
Agronomic traits					
High yield	0.98**	0.91**	0.89**	0.94**	0.85**
Early maturing	0.84*	0.68*	0.84**	0.92**	0.69*
Resistance to pests and disease	0.87*	0.72*	0.81*	0.78*	0.84**
High root dry matter content	0.65*	0.67*	0.59*	0.64*	0.26
Delayed PPD	–	0.96**	0.55	0.56	0.64*
Suitability for intercropping	0.69*	0.69*	0.61*	0.64*	0.73*
Drought tolerance	0.34	–	0.89**	0.90**	0.65*
Weed suppression hability	0.22	0.45	–	0.27	−0.28
Culinary traits					
Poundability	0.95**	0.97**	–	–	0.91**
High dry immediately	–	–	0.75*	0.93**	0.63*
Good taste (sweet)	0.86*	0.87*	–	0.68*	0.89**
Non-fibrous root	0.45	0.51	–	0.35	0.43
Multipurpose uses (fufu and gari)	0.79*	0.64*	–	–	0.75*
Secondary traits					
Large root size	0.63*			–	0.36
Root flesh color	0.45		–	–	−0.27
Late bulking	–	–	0.21	0.43	−0.45
Regular root shape	0.41	–	0.67*	0.73*	0.16
Long underground storage of root in field	0.24	0.36	0.47	0.64*	

– denotes trait not reported, *N*: number of respondents; PPD: post-harvest physiological deterioration, *W* Kendall's coefficient of concordance, r_s: coefficient of correlation among agroecologies, asterisks represents a significant percentage of rankings according to Chi-square test, ** significant at $p=0.01$, * significant at $p=0.05$, NS = non-significant

Table 9 Cassava cultivars grown and their attributes in four agroecologies of Togo

Agroecologies	Cultivars	Attributes
FST ($N=200$)	Gbazekouté, **Lagos**, **Fétonégbodzi, Gabon Yovovi**, **Cameroon**, Béninvi, Ankra, Bazoka, Tuaka, Apkahé, Assome, Atidjin, Domeyibo, Gavonakoute, Kataoli, Woma, Wouti, Kanigbeli, TMS 96_0409, TMS 92_0379, Sika bankye, Ampong bankye	Good yield, sweet taste, early maturity, suitability to intercropping
RF ($N=180$)	**Gbazékoute**, **Lagos**, **Fetonegbodzi**, **Yovovi**, **Beninvi**, **Cameroon**, **Gabon**, **Bob**, Ahokpo, Nana, Yaokoute, Kalicotou, Kanigbeli, Aboram, Tchoukouno, Etrodji, Ewuidi, Yaokoute, TMS 96_0409, TMS 92_0379, Sika bankye, Ampong bankye	Good yield, sweet taste, early maturity, suitability to intercropping
WS ($N=120$)	**Gbazékoute**, **Bob**, **alkalio**, Degaule, **Cameroon, Gabon**, Sassakawa, Kalaba, Soso, Samzou, Sabe, Basidayo, Kekeou, Adika, Zamzambri, TMS 96_0409, TMS 92_0379, Sika bankye, Ampong bankye	Good yield, sweet taste, early maturity, suitability to intercropping
DS ($N=100$)	**Gbazékouté, alkalio**, Degaule, **Cameroon**, **Gabon**, Sassakawa, Kalaba, Kambom bantchi, Kisseimou koutowou, Djobala, Takata, Ogoulo, Soso, Samzou, Sabé, Basidayo, Kékéou, Adika, Zamzambri, Tchoukouno	Good yield, sweet taste, early maturity, suitability to intercropping

N = number of interviewed farmers; FST: forest–savanna transition, RF: rain forest, WS: wet savanna, DS: dry savanna; most widespread cultivars are in bold

zones, Soso, Samzou, Sabé, Basidayo, Kékéou, Adika, and Zamzambri were reported as minor cultivars.

Farmers' perception of cassava mosaic disease (CMD)

Nearly 100% of farmers surveyed were aware of CMD (Table 10). Consequently, all farmers were able to

Table 10 Farmers' perception of CMD across four agroecologies in Togo

Agroecology	% of farmers aware of CMD	% of farmers aware of causes of CMD	% of farmers aware of available control measures	Farmers' name for the disease
FST (*N* = 200)	100	10.50	5.4	"*Akute dolele*" (cassava disease)
RF (*N* = 180)	99.41	8.54	3.5	"*Akute dolele*" (cassava disease)
WS (*N* = 120)	98.26	5.65	1.15	*"Leleka"* (cassava leprosy)
DS (*N* = 100)	98.95	3.56	1.26	*"Leleka"* (cassava leprosy)
Overall (%)	99.15	7.06	2.82	

N: number of respondents, FST: forest–savanna transition, RF: rain forest, WS: wet savanna, DS: dry savanna

Table 11 Association between farmers' perception of CMD and socio-demographic factors

Socio-demographic factors	χ^2	df	*p*
Gender	1.56	1	0.32^{NS}
Age	0.95	2	0.54^{NS}
Education level	0.21	3	0.79^{NS}
Experience in cassava cultivation	4.34	3	0.86^{NS}

df: degree of freedom, *p* is the probability, NS: not significant at 5% threshold

recognize CMD on diseased plants in the field. A Chi-square test revealed that recognition of CMD symptoms was not associated with socio-demographic characteristics of respondents (Table 11).

CMD was given two different names in Ewe (forest zones) and Kotokoli (savanna zones) communities. In Ewe communities, the disease was called "Akute dolele" meaning cassava disease while Kotokoli communities linked it to human leprosy ("leleka") in the savanna zones. However, there was no name given to CMD in Kabye and Bassar communities.

From the survey, the causes and vectors of CMD were unknown by most of the farmers (nearly 93%) (Table 10). Some farmers (10%) reported insects, harvesting of cassava leaves (8%), cold weather (4%), water logging (2%), weeds (2%), and sunbeams as possible causes of CMD (Fig. 2e). Between agroecologies, however, the Chi-square test revealed that farmers' perceptions of the causes of CMD differed significantly ($\chi^2 = 10.53$, df = 3, $p = 0.001$).

In the FST, 25% and 10% of farmers associated CMD with low soil fertility and insects, respectively (Fig. 2a); whereas farmers in the rain forest stated insects (20%), cold weather (16%) and waterlogging (10%) as the probable causes of the disease (Fig. 2b). In contrast, farmers in wet savanna zone suggested that CMD occurs as a result of drought (45%), low soil fertility (20%), and harvesting of the leaves (20%) (Fig. 2c). Drought (30%), low soil fertility (35%), and harvesting of the leaves (16%) were mentioned as the main causes of CMD in the DS (Fig. 2d). Witchcraft was strikingly reported as a possible cause of CMD in the DS (in Kabye communities), indicating that the causes of CMD were unknown by farmers.

Generally, concerning CMD control methods, nearly 3% of respondents across the country were aware of available control measures; by collaborating with the national cassava breeding program (Table 10). Across the four agroecologies, 20% of farmers did not know management practices for CMD; 27% of farmers mentioned intercropping while 22% stated cultivar mixing as the disease management practice. In addition, farmers also mentioned early planting (10%), use of fertilizers (6%), crop rotation (4%), planting CMD-free cuttings (4%), and planting cassava on fertile soil as control measures to combat the disease (Fig. 3e). However, the Chi-square test revealed that farmers' perceptions on the control measures of CMD differed significantly ($\chi^2 = 10.23$, df = 3, $p = 0.001$) between agroecologies. In the forest zones, the most common CMD control practices suggested by farmers were intercropping (30%), cultivars mixing (17%), early planting (13%), and use of fertilizers (12%); whereas farmers in the rain forest mentioned intercropping (35%), early planting (10%) and use of fertilizers (10%) (Fig. 3b). Farmers in the WS suggested CMD control practices such as cultivar mixing (25%), early planting (25%), intercropping (15%), and crop rotation (10%). Like in other agroecologies, cultivars mixing (41%), intercropping (30%), and early planting (19%) were mostly proposed as CMD control measures in the DS (Fig. 3d).

Discussion

Practices in cassava cultivation

Cassava was mostly intercropped in the survey area, and this assured the farmers of food security at different times of the year. In the forest zones, farmers intercropped cassava with maize, bean, groundnut, and legumes, unlike in

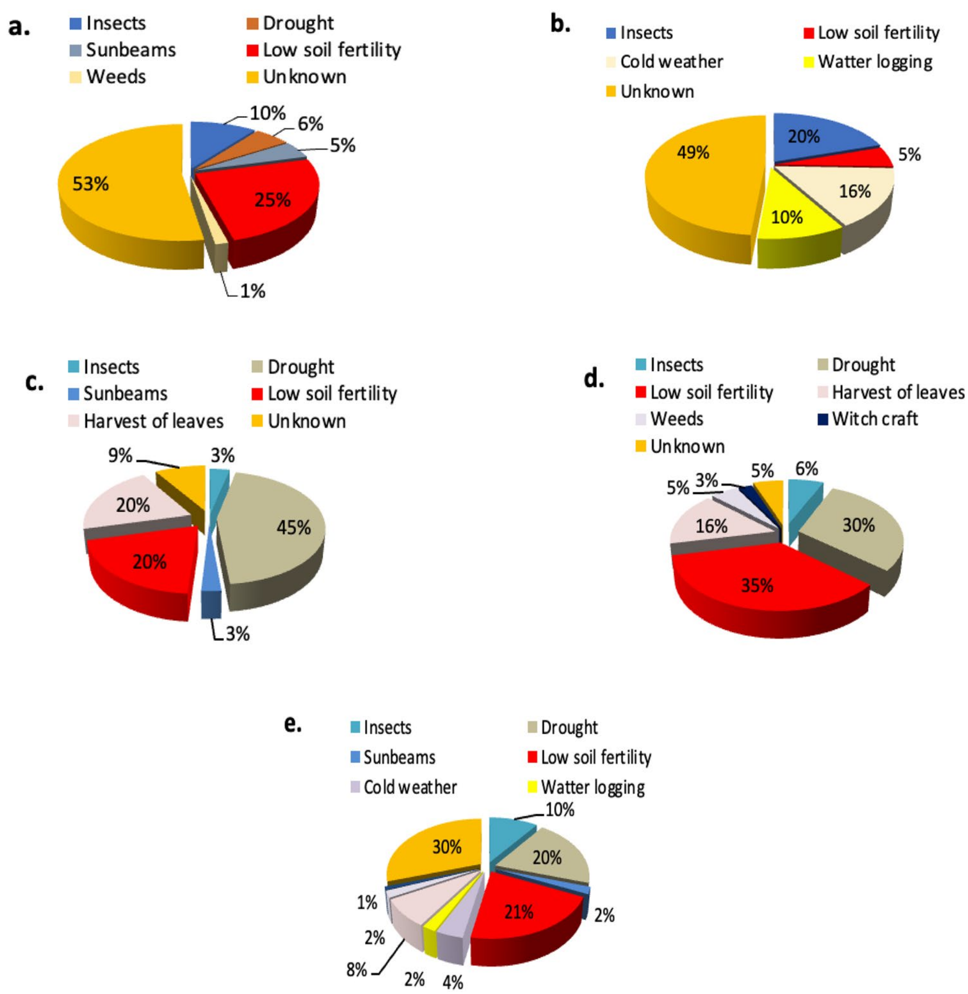

Fig. 2 Farmers' perception of the causes of CMD across four agroecologies in Togo. **a** Forest transition; **b** rain forest; **c** wet savanna; **d** dry savanna; **e** across the four agroecologies

savanna zones, where the majority of the farmers intercropped cassava with root and tuber crops (yam and sweet potatoes). Similar results have been reported by ITRA (2008), Sogbedji et al. [31] and Kombate et al. [19]. Intercropping cassava either with yam or sweet potato affects negatively its yield potential [25] since both are root crops and will compete for the soil nutrients and root space.

Constraints to cassava production

The four agroecologies shared similar production constraints. However, the most important constraints within the rain forest zone were not necessarily important in the dry savanna zone. For example, in the rain forest, post-harvest physiological deterioration of roots (PPD) was the key constraint, whereas in the dry savanna zone, wild animals and livestock were reported to be the most severe cassava production constraints. The colder and moister conditions in the rain forest probably favored deterioration of roots after harvest and root rot diseases [6, 15].

Origins of planting material

Cassava planting materials were mainly sourced from farmers own fields and neighbors fields, indicating that the exchange of planting materials between farmers was widespread. This result is consistent with previous reports that farmers' materials and those from neighbors constitute the main sources of cassava planting materials [14, 19, 22] in Ghana and Togo. This practice can facilitate the spread of varieties, particularly in regions where farmers are beginning to cultivate new cassava varieties. However, if infected cuttings are exchanged, it can exacerbate the spread of CMD. This situation likely contributed to the widespread occurrence and high prevalence of CMD in farmers' fields, given the limited availability

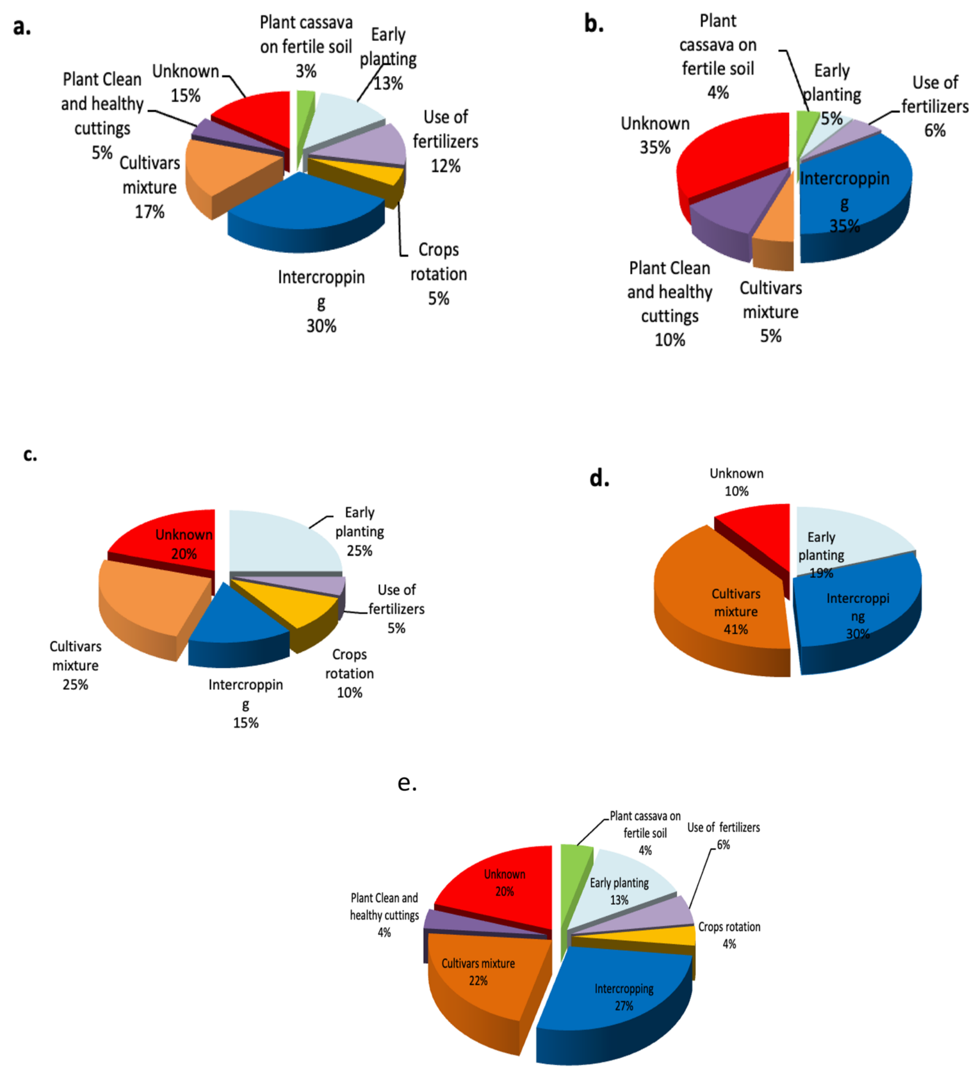

Fig. 3 Farmers' perception of the control methods of CMD across four agroecologies in Togo. **a** Forest transition; **b** rain forest; **c** wet savanna; **d** dry savanna; **e** across the four agroecologies

of disease-free planting materials from the Togolese Research Institute of Agriculture.

Disease-free planting materials were not available across the country. This is because there was no formal cassava seed system for the multiplication and distribution of newly resistant varieties released by the cassava breeding unit. In the survey area, planting materials were mostly provided free of charge thus there was no incentive for production of commercial seed. These are the underlying reasons why farmers used to replant cuttings sourced from their previous fields and neighbors. Furthermore, planting materials are taken usually without any proper quality control, and this may promote the spread of pests and diseases. However, this informal seed distribution system may be advantageous in that farmers can select stable cultivars with the desired traits for their locality [22].

Cassava varieties grown and criteria for selection

In Togo, both local and improved varieties of cassava are cultivated. However, the local cassava varieties are the most prevalent. It was observed that only 15 out of 32 released improved varieties are produced by farmers. Our study identified cultivars that are preferred by farmers, which provides an opportunity for these preferred cultivars to be screened for agronomic performances and CMD resistance across CMD prone areas in Togo. The farmers generally preferred cultivars with good taste, high yields, good gari, and foufou production. These findings are in agreement with those made by Houngue et al.

[16] who evaluated the farmers' preferred characteristics of cassava in Benin.

About one to four different cultivars were grown by farmers across the country, which is consistent with the results reported by Kombate et al. [19]. Oluwole et al. [27] reported that the average number of cassava cultivars in farmers' fields in Nigeria and Tanzania was three and two, respectively. This situation can pose challenges, particularly during a pandemic outbreak that could potentially decimate existing landraces. To enhance genetic variability, one strategy involves developing new varieties by cross-breeding locally adapted landraces with introduced varieties possessing complementary traits. The majority of cultivars reported by farmers were specific to each zone in response to use and preferences.

While high storage root yield and early maturity were the most desirable traits to farmers in forest–savanna transition, delayed PPD was the most important in the rain forest. This result revealed the variation in farmers' preferences. Roots quality traits desired by farmers were high dry matter content, poundability, sweet taste, and white flesh color. Studies by Manu-Aduening et al. [22, 23] reported similar findings in Ghana. Across the agroecologies, high yield was the most desirable agronomic trait to be incorporated into a cassava breeding program. This trait was followed by early maturity, resistance to pests and diseases, delayed PPD, high dry matter, drought tolerance, and suitability for intercropping. However, there were a few exceptions among agroecologies, and this called for breeding varieties with multiple complementary traits. These results partially confirm those obtained by Kombate et al. [19] where, among 20 preference criteria considered by farmers, high yield, early maturity, good quality of fufu, resistance to diseases, and good quality of gari were the most valued traits. Among 20 preference criteria listed by farmers in Bouenza (Congo), high yield, early maturity, and taste were the most valued traits [20]. Manu-Aduening et al. [22] and Agre et al. [4] reported similar attributes influencing farmers' adoption of cassava cultivars in some West African countries (Ghana, Benin, Nigeria). According to these authors, the most undesirable traits of abandoned landraces were late maturity, followed by high fiber content, bitter root taste, inadequate planting materials, and excessive vegetative growth. The continuous cultivation system of cassava did not favor crops maturing after 12 months, which likely contributed to farmers abandoning late-maturing cultivars.

Across the country, most of the cultivars grown were of sweet type. Cassava is eaten raw or after boiling across the country. This would explain why farmers surveyed preferred sweet landraces. Bitter landraces have been associated with health hazards such as diabetes, cancer, and iodine deficiency [13, 22, 29]. Therefore, bitter landraces with high hydrogen cyanide would be abandoned for fear of poisoning [22].

Farmers' perceptions and action against CMD

CMD causes and its control measures were unknown, despite its prevalence in farmers' fields. Similar results were reported by Chikoti et al. [8], while Manu-Aduening et al. [22] reported that farmers in Ghana were not fully aware of major cassava diseases on their farms. Usually, farmers tend to view damage to pathogens and insect pests as a whole and not separately in the survey area [8]. Majority of farmers in Togo cannot identify CMD symptoms in their fields. Generally, Togo farmers lack critical knowledge about CMD, its transmitting vectors, and how it can be controlled. This lack of knowledge constitutes the major obstacle for CMD control in Togo. These results suggests that farmers could be trained by researchers and extension agents on the symptoms of CMD, thus giving them the ability to take proper action to control the disease in their own fields and minimize its spread to neighboring fields. Few farmers who were familiar with CMD reported that they were sensitized to it by researchers and extension agents. These results were in accordance with those reported by Chikoti et al. [8] and by Houngue et al. [16], who also found that the lack of CMD knowledge by farmers requires researchers and extension agents to sensitize and train farmers.

CMD control measures were not well known by farmers in Togo. Most farmers thought drought caused CMD, and consequently proposed that irrigation of their farms could control CMD. Farmers proposed CMD control measures are related to the best agronomic practices aiming to increase cassava productivity in the field. Even when mentioning relevant practices, for example planting CMD-free cuttings (forest zones) observations in their fields revealed that control was not achieved. Our findings are similar to those reported by Chikoti et al. [8], Manu-Aduening et al. [22]. CMD may be controlled by the use of disease-free planting materials, resistant varieties, and rouging [5, 30]. In addition to clean planting materials, cultural management strategies employed to tackle the menace of CMD include disease and /or vector avoidance through the adjustment of planting dates and intercropping [2, 12]. There is therefore an urgent need for farmer education regarding the identification and control of CMD. Simultaneously, a lasting solution necessitates the breeding of CMD-resistant clones possessing traits valued by farmers, such as early maturity, high yield, sweet taste, high dry matter content, and resistance to other pests and diseases.

Conclusions

The study revealed that inadequate capital, cassava mosaic disease (CMD), post-harvest physiological deterioration (PPD), and the non-availability of clean cassava planting materials are the main constraints limiting cassava production in Togo. Despite the awareness of CMD among farmers, the causes, spread mechanisms, and control strategies of the disease are largely unknown. We recommend that farmers receive training by researchers and extension agent on the disease so that farmers can implement adequate control measures when CMD is identified. Farmers expressed a preference for high-yielding cassava varieties with traits such as early maturity, pest and disease resistance, delayed PPD, high root dry matter content, poundability, and sweet taste. The lack of clean cassava planting materials underscore the necessity of establishing a sustainable cassava seed system linked to a robust breeding program. The participatory approach to cassava breeding in Togo is essential for developing varieties that align with farmers' preferences and address the identified production constraints.

Abbreviations

ITRA Institut Togolais de Recherche Agronomique
CMD Cassava mosaic disease
PRA Participatory rural appraisal

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Author contributions

TG carried out the survey, analyzed and interpreted the data, and drafted the manuscript. DKD, SK, PT, and IA participated in the study design and were contributors to writing and correcting the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Data are within the paper and its supporting information files. The datasets are fully available without restriction on reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate

All participants involved in the study provided informed consent prior to their participation. Additionally, permission was sought and obtained from local community leaders, including extension agents, local lead farmers, and village chiefs, before conducting field investigations. The authors have all copyrights.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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