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Research Paper

Smallholder farmers' perceptions of maize ear rot disease and opportunities for tolerant maize varieties in the bimodal humid forest zone and western highlands of Cameroon

Foncha Felix[1,2]* • Mafouasson Apala Hortense Noelle[3] • Kouam Eric Bertrand[1] • Christopher Suh[3] • Walter Ajambang Nchu[2] • Kenfack Fongang Patrick[4]

[1]Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang, P.O Box 222, Dschang, Cameroon.
[2]Institute of Agricultural Research for Development (IRAD), Bambui, P.O Box 51 Bamenda, Cameroon.
[3]Institute of Agricultural Research for Development (IRAD), P.O Box 2123 Yaoundé, Cameroon.
[4]Institute of Agricultural Research for Development (IRAD) Mbalmayo, P.O Box 2067 Yaoundé, Cameroon.

*Corresponding author. E-mail: fonlix@yahoo.com.

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Abstract. Disease and pests are among the major constraints limiting maize productivity by smallholder farmers in Cameroon. The objective of this study was to investigate Cameroonian smallholder farmers' preferred maize qualities and their implications on breeding. A participatory rural appraisal was carried out across four sites in Cameroon. Focus group discussions and interviews were held with 205 randomly selected farmers on issues regarding major maize production constraints, e.g., ear rots, associated mycotoxins, coping mechanisms, and existing cropping systems. Maize ear rots, production constraints and farmers' preferences were scored and ranked. Maize ear rot disease was ranked as the deadliest disease in maize next to maize streak virus and stalk rot disease. Based on the descriptions given by the majority of farmers about maize ear rot cases in their farms, the occurrence of *Aspergillus* ear rot was the most abundant (93.5%) which was caused by too much rainfall during the physiological maturity of the maize ear. Across all study sites and by gender, there were no significant differences ($p > 0.05$) in the factors responsible for maize ear rot disease. Late harvesting (65.6% male and 59.8% female) and lack of disease-resistant varieties were also perceived as some of the most important factors contributing to the high maize ear rot disease. Less than 10% of farmers were aware of mycotoxins. In order to increase the adoption rate of improved maize varieties, breeders should aim at developing varieties that are not only ear-rot resistant but also meet farmers' preferred traits.

Keywords: Disease resistance, maize, ear rots, mycotoxins, production constraint, variety preference.

INTRODUCTION

In recent years, more and more maize (*Zea mays* L.) has been produced across the world and according to the recent statistics published by the Food and Agriculture Organization (FAO), maize has become the second most produced crop after sugar cane (Anonymous, 2019). Maize globally accounts for 19% of the average calorie intake per capita and the demand for the crop as food will only be increasing due to global population growth (FAOSTAT, 2019; Nolte *et al.*, 2016). Maize is one of the most important cereal crops in the world serving as human food, feed for animals, raw materials for industries and bio-energy (Ranum *et al*., 2014). Maize can be grown in many parts of Sub-Saharan Africa (SSA) where a large proportion of the population depends on maize as a primary source of staple food (FAOSTAT, 2020). There has been a rising preference for maize grains as raw materials for the emerging growing livestock and brewery industries (Badu-Apraku and Fakorede, 2017). However, maize productivity in Cameroon is still low varying from 1.5 to 1.8 t/ha (FAOSTAT 2017). This is due to various production constraints like biotic and abiotic stress and limited access to essential inputs since maize production in Cameroon is mostly carried out by small-scale farmers at the subsistence level (Godwin *et al.*, 2011). Evidently, the farmers grow maize under variable and high-stress-prone environments. One of the reasons that result in low maize yield in Cameroon is the low adoption rate of improved maize varieties by the farmers. The level and adoption rate of improved maize varieties were estimated in some villages in the humid forest zone of Cameroon and found to be low as compared to the use of local varieties (Ngonkeu *et al*., 2017). This is due to the fact that improved varieties are not always available to farmers or the ones available do not meet the end-users preferences (Wotia and Omukunda, 2021). For a breeding programme to be effective, farmers' preferences for varieties must be identified by a breeder-farmer interaction and collaboration (Fedrick Wotia and Elizabeth Omukunda, 2021; Sibiya *et al.*, 2013). Plant breeders should involve farmers in their breeding programmes to learn more about the most important selection criteria for male and female farmers for cultivar preferences in their localities (Ngonkeu *et al.*, 2017; Mukanga, 2009). This will promote the use of locally adapted improved varieties. Such a strategy has led to the selection and development of new crop varieties, including maize in other parts of the world (Sibiya *et al*., 2013; Danial *et al*., 2007). This is a clear evidence that plant breeders need to be well familiar with farmers' preferences like the requirements for specific agronomic criteria, storage, processing and marketing traits if the adopted rate needs to be higher (Danial *et al.*, 2007).

Maize, being a staple for millions across Sub-Saharan Africa (SSA), faces major biotic constraints affecting the production and safety of the crop. These include the northern corn leaf blight (NCLB), southern corn leaf blight (SCLB), Curvularia leaf spot (CLS), and aflatoxin contamination by *Exserohilum turcicum*, *Bipolaris maydis*, *Curvularia lunata*, and *Aspergillus flavus*, respectively (Bankole *et al*., 2022). Maize diseases have been reported to cause huge yield losses of up to 36% in Cameroon (Cardwell *et al.*, 1997). Mycotoxin contamination in maize grain is a global threat to both the safety of human food and animal feed. Contamination of maize with aflatoxins usually starts at the pre-harvest stage and can continue during storage. Thus, identifying sources of resistance to multiple plant pathogens attacking leaves and grains is important for developing crops with broad resistance for improved yield and quality of maize (Bankole *et al.*, 2022). Contaminated grains also affect international economic regulatory and trade policies (Brien *et al.*, 2009). Most often, huge losses occur as a result of ear rot diseases, especially *Aspergillus* ear rot which is also a major threat to public health due to the aflatoxin accumulation. Previous works have been done elsewhere to develop lines resistant to aflatoxin accumulation in the maize grain (Brown *et al.*, 2016; Abebe *et al.*, 2006).

Failure by Plant breeding programmes to achieve high adoption rates of improved varieties by farmers has been reported (Mukanga *et al.*, 2011; Singh and Moris, 1997). The acceptability of new agricultural technologies in improved varieties by farmers depends on how well farmers' constraints and preferred traits have been identified and addressed (Mafouasson *et al.*, 2020; Soleri *et al.*, 2000; Kamara *et al.*, 1996). Participatory rural appraisal (PRA) has been used globally to get farmers' views on various agricultural resource management options necessary to ensure household food security and improvement of their livelihood (Wotia and Omukunda, 2021; Sibiya *et al.*, 2013; Mukanga *et al.*, 2011). Through PRA, community-based action plans are drawn up and implemented for the farmers' interest. Therefore, PRA is essential in getting farmers' knowledge and investigating the production constraints and the farmers' preferences in the varieties they grow. It is important to consider farmers' preferences for maize varieties during varietal development. This will increase the level of adoption of the released variety by the farmers (Mafouasson *et al.*, 2020). Mukanga, 2009 used the PRA methodology to investigate smallholder farmers' perceptions of maize ear rot diseases. They recommended that breeders should develop varieties that are not only ear rot resistant but combine farmers' preferred traits. The present study was carried out to determine the position and rank of *Aspergillus* maize ear rot disease in relation to other maize production constraints and to set up a base for breeding ear rot-resistant maize germplasm. The specific objectives of the study were to: (i) assess farmers' perceptions of maize ear rot disease in maize production and (ii) establish baseline information about maize varieties grown by farmers and in the study sites.

MATERIALS AND METHODS

Study sites

The participatory rural appraisal was carried out at four villages selected from the Western highlands and Bimodal rain forest zone of Cameroon (Njimom and Kouoptamo from the Noun Division of the Western Region and Mbalmayo and Ozom 1 from the Nyong-et So'o and Lekié Divisions of the Centre Region) during the 2019/2020 cropping season. The characteristics of the study sites are shown in Table 1. Through the help of local Ministry of Agriculture and Rural Development field extension officers who knew the villages very well, these villages were

Table 1. Characteristics of the study sites.

Agroecological Zone (AEZ)	Site	Geographic Coordinates	Altitude (m)
AEZ III	Njimom	5.8385˚N 10.9637˚E	925
	Kouoptamo	5.6488˚N 10.6042˚E	1,141
	Mbalmayo	3.5144˚N 11.5078˚E	335
AEZ IV	Ozom 1	3.8830˚N 11.4113˚E	703

Table 2. Number of farmer participants by gender and age in the PRA sites.

AEZ	Sites	Number of participants				
		Male	Female	Adults	Youths	Total
AEZ III	Njimom	46	15	55	6	61
	Kouoptamo	35	10	42	3	45
AEZ IV	Mbalmayo	24	39	58	5	63
	Ozom 1	10	26	34	2	36
Total		115	90	189	16	205

chosen according to the following criteria amongst others: accessibility by all-weather roads, the predominance of maize as a main cultivated crop, and the diversity of the communities, that is, what precipitated the establishment of those communities.

Sampling procedure

PRA was restricted to farmers above 18 years old since they are the ones actively engaged in maize production. A field extension officer (Staff from the Ministry of Agriculture and Rural Development) who is a resident in the local area acted as the facilitator and assisted in data collection. The research team comprised researchers and facilitators, with knowledge of the area and local language while the farmers served as respondents for data collection. Two hundred and five small-scale farmer participants were involved in the PRA study (Table 2). The farmers were identified with the help of local agricultural officials. The choice was based on the number of households per study site and the ability to grow maize. The participants were randomly selected without any bias towards age, gender, experience in farming, or status in the community. In all study sites, the key informants considered were persons who are familiar with the place and had some experience in maize production to be able to get information on community history, organisation, and general welfare.

Each PRA session involved a minimum of 36 farmers.

Study methods

The qualitative participatory research methods and tools explored to get information are those used by Mukanga 2009, which was adapted from the PRA Programme at Egerton University in Kenya (PRA Programme, 1999). The methods used comprised a series of exercises in which the farmers-respondents played an important role. An introductory visit was made to each of the four study sites. During the exploratory phase, secondary data were obtained about each area from the local Ministry of Agriculture officials and heads of maize production cooperatives. Semi-structured interview (SSI) and focus group discussion (FGD) techniques with key informants (KIs) were used to get all the information related to maize production, with more attention on ear rots and mycotoxins. In addition, preferences were obtained using matrix scoring and pairwise ranking. Before each PRA exercise, the objectives and procedures of the exercise were explained to the farmers by the facilitators and the principal investigator, after which the farmers were allowed to ask any questions for clarification. Farmers were not told that the focus of the study was on maize ear rots in order to avoid any bias in their responses. However, if maize ear rot was not mentioned as a major disease in the area, they were then asked about it. During the FGD, farmers who did not know how to speak English or French used their local languages and the facilitators who understood the languages did the interpretations.

The checklist of the topics for discussion and SSI were discussed with the facilitators in each study site prior to the exercise. The topics for group discussions included community/village organisation, the importance of different crops, including maize, insect pests and diseases, and control practices for these pests and diseases. Other issues discussed were maize crop hectarage, constraints on maize production, current coping strategies, farmer recommendations for overcoming the constraints and criteria used in selecting maize varieties.

For the structured survey, a questionnaire was administered to the farmers by the facilitators. (The questionnaire was initially pre-tested on a small population sample and adjusted). This was followed by Transect walk (walk with farmers to the field). During the PRA, farmers used matrices to list, rank and score the different desired characteristics of maize varieties, the socio-economic production constraints affecting maize production and the factors responsible for ear rot infection. Preference ranking exercises comprised of two parts: pair-wise ranking and matrix ranking. Pair-wise ranking demonstrated why a particular subject was preferred, and each preferred subject listed minor reasons and one major reason for preference, meanwhile matrix ranking provided the relative preferences without showing why these were preferred. The pests and diseases affecting their maize crop were used to rank and score by counting the number of participants that were in agreement that a particular biotic constraint was important. The proportion of those who agreed was determined and the percentage score was used to rank the pest or disease. Later, in a plenary session with farmers, corresponding plant-breeding interventions were listed against a list of selected biotic and abiotic constraints.

Data collection and treatment

In order to easily get information, farmers were grouped by gender and age group for each PRA activity. The participants in Njimom and Kouoptamo belonged to high maize production cooperatives and were mostly Muslims in religion. The participants in Mbalmayo comprised mixed communities from various villages involved in maize production. The participants at Ozom 1 comprised a village setting involving local farmers that have some experience in maize production. Primary data were collected through a structured survey and participatory methods obtained from farmers' characteristics of the study areas. Secondary data were obtained from local agricultural extension officers and the Ministry of Agriculture and Rural Development's annual reports on maize production, areas under maize production, and marketing. A checklist of topics was drafted and used to guide discussions with farmer groups and individual key informants. These discussions exploited all the issues concerning maize production which included constraints to production, varieties grown, farmers' criteria used in selecting maize varieties to be grown, maize insect pests and diseases with specific emphasis on ear rots, the degree of awareness about ear rots, mycotoxins, and disease resistant varieties, farmer's age, gender, farming experience on maize cultivation, labour availability, and farmers' coping mechanisms and maize disease management strategies. Data on the effects of aflatoxin maize contamination were obtained from local animal feed producers from the study locations. The technique used in the FGD consisted of problem listing, analysis and ranking by different participants. Discussion groups were constituted in each study area for activities such as the ranking of disease and pest scoring.

RESULTS

Secondary data

Social and economic issues

There were 42726, 38456, 78237 and 450 households in Njimom, Kouoptamo, Mbalmayo and Ozom1 respectively (Source: Divisional Delegations of Agriculture and Rural Development). Rain-fed crop production was the main form of agriculture in all the study sites. The average farm size varied considerably from 0.5 to 3 ha. Family members were the main source of labour from all four study sites. Farmers in all study sites mostly employed manpower to plough their farms due to a lack of money to hire tractors. The road network to the farms was poor during the rainy season in all the study sites and this makes it difficult for the farmers to transport their produce to the markets or homes. No irrigation facilities were available in all the study sites and farmers relied on rain-fed agriculture. Very little off-season green maize production was done.

Farming systems and crop production

Farmers in all four communities mostly practiced mixed cropping and rain-fed maize production was common. Mono-cropping was the main maize cropping system and occasionally intercropping maize with legumes. Maize production was mainly carried out during the first season (March to August) in Njimom and Kouoptamo while Mbalmayo and Ozom 1 cultivated maize during the first and second (August to December) seasons. Very little organic manure was used, and farmers in all study sites mostly relied on chemical fertilizers. Crop rotation and fallowing methods were used to enhance soil fertility. Some farmers indicated that they used poultry manure

Table 3. Major crops grown by location in the PRA sites.

Njimom	Kouoptamo	Mbalmayo	Ozom1
Maize	Maize	Maize	Maize
Beans	Beans	Beans	Beans
Groundnut	Groundnut	Groundnut	Groundnut
Cowpea	Cowpea	-	-
Bambara groundnut	Bambara groundnut	-	-
Soybeans	Soybeans	-	-
Pumpkins	Pumpkins	-	-
Cassava	Cassava	Cassava	Cassava
Sweet potato	Sweet potato	Sweet potato	Sweet potato
Banana	Banana	Banana	Banana
Plantain	Plantain	Plantain	Plantain
-	-	-	Yams
Tomato	Tomato	-	-
-	Cabbage	-	-
Other vegetables	Other vegetables	Other vegetables	Other vegetables
Coffee	Coffee	-	-
Oil palms	Oil palms	-	-
-	-	Cocoa	Cocoa

Source: Divisional Delegations of Agriculture and Rural Development of Noun, Nyong-Esso and Lekie

Table 4. Maize production by location in the PRA sites.

Sites	Average yield (tons ha^{-1})	Maize production (metric tons)
Njimom	1.6	7740
Kouoptamo	2.2	9250
Mbalmayo	1.5	8872
Ozom 1	1.2	1346

Source: Divisional Delegations for Agriculture and Rural Development, Noun, Nyong-Esso Lekie and local maize cooperatives of the study sites.

when they could not afford chemical fertilizers.

The most important food crops grown were maize, beans, groundnut, cowpea, soybean, bambara groundnut, cassava, banana, plantain, sweet potato, yam, pumpkins and tomato. Cash crops like coffee and oil palms were seen in Njimom and Kouoptamo while Mbalmayo and Ozom1 mostly relied on cocoa as a cash crop (Table 3). Tomato production was common in Njimom and Kouoptamo. A variety of vegetables was produced there during the off seasons using local irrigation facilities to supply to the urban centres around.

Maize production

The size of maize farms ranged from 0.5 to 10 ha in all four sites. The smallest farm size was recorded in Ozom 1 and the largest was recorded in Njimom. Averagely, maize yields were highest in Kouoptamo (2.2 tons ha^{-1}) and lowest in Ozom 1 (1.2 ton ha^{-1}) (Table 4). The sizes of farms in the study sites were determined by the family size and ability to pay for man labour.

Primary data

Maize ear rots and mycotoxins

Maize ear rots was ranked as the most important disease across all the study sites. This was followed by the stalk rot disease and the common rust (Table 5). Based on visual symptoms and pictorial description of maize ear rots, farmers in Ozom1reported *Fusarium* ear rot to be the most prominent while all the farmers from the other three communities reported *Aspergillus* ear rot to be the most severe. Several colours linked to rotten ears and grains were pointed out during the focus group discussions (FGDs). The most common colours and descriptions revealed by the farmers were greenish, brown, pink, red, shrunken grain, yellow-green grain, black powdery kernels, white brown ears and grey black head, whitish mass occurring from the bottom to top of the ear and

Table 5. Ranking of major diseases affecting maize at the four study sites.

Disease	Njimom n = 61 %	*Rank	Kouoptamo n = 45 %	Rank	Mbalmayo n = 63 %	Rank	Ozom 1 n = 36 %	Rank	Total n = 205 Mean%	Rank
Ear rots	98.3	1	93.3	1	90.5	1	91.7	1	93.5	1
Maize streak virus	86.9	2	77.8	3	17. 5	7	38.8	6	55.3	4
Stalk rot	75.4	3	82.2	2	49.2	4	77.7	3	71.1	2
Common rust	44.3	5	48.9	4	77.8	3	83.3	2	63.6	3
Black smut	29.5	6	26.7	6	36.5	6	55.6	4	37.1	5
Greyleaf spot	-		-		85.7	2	41.7	5	31.9	6
Downy mildew	67.2	4	15.6	7	33.3	5	-		29.0	7

*Classified as major if two or more sites ranked them 1-5 and minor if a site ranked 6 or more.

Table 6. Maize ear rot colours and descriptions of damages revealed by farmers at the four PRA sites.

Colour of maize ear rot	Damage observed	Likely disease name
Yellow-green grain	Rotten grain with insect between grain	*Aspergillus* ear rot (*Aspergillus flavus*)
Kernels with black powder	Rotting beginning from ear shrank upwards	*Aspergillus* ear rot (*Aspergillus niger*)
Red	Rotten grains all the ear	*Fusarium* ear rot
Pink	Rotting from ear tip downwards	*Fusarium* ear rot
Powderly-blue green	Growth on and between grains	*Penicillium* ear rot
Grey-whitish	Black spots on the upper part of the ear	Common smut (Not an ear rot)

discoloured grain. During the survey, each farmer group provided more than three different colours. Most of the farmers from all the study sites described the yellow-green grain and black powdery kernels (Table 6). The farmers also reported that the maize ear rot disease was more prominent during the first planting season (March to August) than during the second season (August to December) due to too much rainfall during the harvesting period of the former. They further revealed that late harvesting often leads to greater yield loss as a result of ear rot diseases.

Farmers' awareness of maize ear rot diseases, mycotoxins, disease-resistant and drought-tolerant varieties

Some of the farmers (19.6%) also reported that damages caused by insects and birds to maize resulted in ear rots in their farms with a loss of 1 bag (50 kg) to 4 bags (200 kg) per hectare. Despite that, most of them (7.3% and 3.3% awareness for females and males respectively) were not aware of mycotoxins and the related public health hazards they could cause. Some slight gender differences existed in the degree of awareness of ear rots and the related mycotoxins they cause (Figure 1). The proportion of females (61.3%) that considered maize ear rots as a danger was more than the proportion of males (44.7%). Most of the farmers (10.7% and 9.6% awareness for females and males respectively) from all study sites were not aware of drought-tolerant maize varieties.

Factors influencing the occurrence of maize ear rot disease in the farmers' field

Across all study sites and by gender, there were no significant differences ($p > 0.05$) in the factors responsible for the occurrence of the maize ear rot disease. Too much rain during the physiological maturity and late harvesting of maize were attributed to be the main cause of ear rots (Table 7) as reported by a majority of the farmers (74.8%). reported too much rainfall during physiological maturity to be the main cause of maize ear rots. This was closely followed by late harvesting.

Other maize production constraints

Apart from the maize ear rots that affected maize production in the study sites, farmers also listed many other constraints to maize production in their farms (Table 8). Despite the fact that group interviews were separately held for men and women, there were no remarkable differences in the ranking of production constraints. Therefore, only the overall score for each production constraint was used in the final ranking for each study site.

Among insect pests, the Fall armyworm was considered to be the most destructive pest followed by the stem borers and grain weevils (Table 9). The grasshopper was the

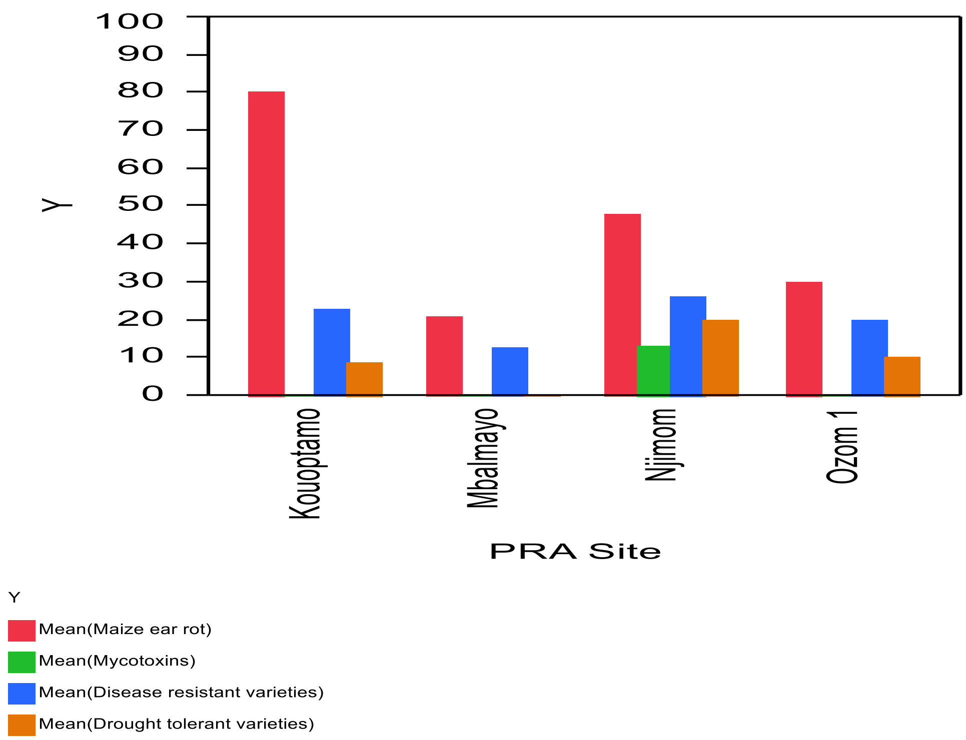

Figure 1. Proportion of farmers aware of maize ear rot diseases, mycotoxins, disease resistant and drought tolerant varieties in the four study sites.

Table 7. Factors influencing the occurrence of maize ear rots in farmers' fields, proportion (%) of participants that agreed in all the four PRA sites by gender.

	Lack of resistant varieties	Too much rainfall	Lack of crop rotation	Weeds	Drought	Late harvesting	Prolonged stress
Site							
Njimom	33.8A	73.4A	40.8A	82.6A	20.9A	69.2A	47.1A
Kouoptamo	34.3A	82.6A	26.5A	44.3A	20.7A	75A	56.5A
Mbalmayo	15.5A	69.5A	10.1A	44.1A	13.5A	52.8A	37.2A
Ozom 1	36.9A	73.5A	30.4A	62.7A	21.6A	53.9A	38.1A
p-value	0.76	0.91	0.12	0.34	0.73	0.11	0.46
Rsquare	0.23	0.11	0.74	0.53	0.25	0.75	0.44
Gender							
Male	32.7a	79.4a	30.5a	62.8a	22.5a	65.6a	46.6a
Female	27.6a	58.6a	23.4a	54.1a	15.9a	59.8a	42.6a
p-value	0.73	0.20	0.51	0.64	0.20	0.53	0.69
Rsquare	0.02	0.25	0.07	0.04	0.25	0.07	0.03

In a column, means followed by the same letter are not significantly different (Turkey's HSD test at 5% probability level).

least important. Monkeys were also listed and ranked at Kouoptamo.

Maize varieties grown by farmers

Across all study sites, the farmers cultivated two hybrids, five open-pollinated varieties (OPVs) and five landraces (local varieties) (Table 10). Most of the farmers grew PAN 16, a hybrid from South Africa, followed by CHC 201 (Kasai), an OPV from the Institute of Agricultural Research for Development (IRAD). The farmers in the Western highlands (Njimom and Kouptamo) produced white maize varieties that were mostly used to prepare their favourite

Table 8. Constraints influencing maize production in the four PRA sites: a summary of the scoring matrix and rank.

Constraint	Rank[a]				
	Njimom	Kouoptamo	Mbalmayo	Ozom 1	Mean rank
Insect pests and diseases	2	3	2	4	2.8
Unreliable rain	1	2	2	1	1.5
High cost of farm inputs	3	2	4	2	2.8
Weeds	4	1	2	4	2.8
No information on pests, disease and drought-tolerant varieties	-	-	10	11	5.3
Lack of improved seeds	-	11	7	5	5.8
High labour cost	9	7	5	4	6.3
Low producer prices	6	8	-	3	4.3
Birds	7	6	4	3	5
Insect pests and diseases	2	3	2	2	2.3
Low soil fertility	5	4	7	6	5.5
Poor markets	6	5	4	3	4.5
Poor roads	-	10	-	-	2.5
Drought	2	4	6	3	3.8
Lack of storage facilities	10	8	5	6	7.3
Monkeys	6	3	-	-	3

[a]Constraint classified as major if two or more sites rank it 1-5, important if ranked 6-9 in more than two sites and minor when a site ranks it 10 or more.

Table 9. Major pests affecting maize production at the four study sites.

Pests	Study sites							
	Njimom n = 61		Kouoptamo n = 45		Mbalmayo n = 63		Ozom 1 n = 36	
	%	*Rank	%	*Rank	%	*Rank	%	*Rank
Fall armyworm	95.1	1	88.8	1	93.7	1	86.1	1
Stem borers	73.8	2	66.7	2	71.4	2	75	2
Grain weevils	60.7	3	60	3	63.5	3	63.9	3
Termites	25	7	-	-	-	-	-	-
Birds	21.3	8	46.7	6	23.8	7	50	5
Rats and mice	46.7	5	53.3	5	43.1	6	52.8	4
Grasshoppers	-	-	-	-	-	-	41.3	6
Monkeys	-	-	-	-	55.7	4	-	-
Earth worms	9.8	9	-	-	-	-	-	-
Leaf aphids	34.2	4	51.1	5	-	-	-	-
'Cutting grass'	-	-	-	-	47.6	5	-	-

*Classified as major if two more sites indicate 1-5; minor if a site indicated 6 or more.

dish locally called 'fufu corn' meanwhile those from the Bimodal Humid Forest Zone (Mbalmayo and Ozom 1) mostly grew yellow maize varieties which is mostly harvested fresh and sold to traders who roast or boil and sell by the roadsides. The farmers from the Western highlands had some number of landraces they grew among which 'Megbiefu' was grown by most (75.4%) of them. This local variety is said to have high commercial value and is disease resistant. Those from the Bimodal Humid Forest Zone had a prominent landrace called' Sanga' which most of them preferred since it gave them higher yields and is disease resistant. Most of the farmers preferred their local varieties since they could easily recycle their seeds and avoid more expenditure for the hybrids or OPV varieties. The farmers indicated that they often select the healthiest and biggest ears and keep them for seeds for the next planting season.

Farmers' criteria in choosing maize varieties

Despite the fact that farmers' criteria in choosing maize

Table 10. Proportion of farmers (%) in the four study sites who planted different maize varieties.

Varieties	Nature	Maturity	*Percentage of farmers per site					Reasons provided
			Njimom	Kouoptamo	Mbalmayo	Ozom 1	*Overall	
CHH 101	Hybrid	Late	11.5	26.7	11.1	16.7	12.2	High yields, disease resistant
CHC 201	OPV	Late	52.5	88.9	8.2	-	43.3	High yields
CHC 202	OPV	Late	32.8	55.6	16.4	10	45.9	High yields, disease resistant
8704	OPV	Intermediate	-	-	47.6	83.3	31.7	High yields, sweet and big cobs
8501	OPV	Intermediate	-	-	27	47.2	20.5	High yields, big cobs
PAN 16	Hybrid	Intermediate	34.2	37.8	20.6	36.1	38.5	High yields, high commercial value
Mecho	Landrace	Intermediate	49.2	42.2	-	-	23.9	High yields, disease resistant
Megbiefu	Landrace	Late	75.4	35.6	-	-	30.2	High yields, high commercial value
Fufu	Landrace	Intermediate	24.6	22.2	-	-	12.2	High yield, disease resistant
Gerald	Landrace	Late	27.9	44.4	-	-	18	High yields, big grains
Sanga	Landrace	Intermediate	-	-	63.5	-	19.5	High yields, disease resistant, big cobs

*Percentage of the total number of farmers growing certain varieties across all sites, some farmers grew more than one variety.

varieties were similar across the four study sites, some differences in variety characteristics existed. These differences varied from one study site to the other. A detail of the varietal preferences and the reasons given are presented in Table 11. High yield, ear rot resistance, stem rot resistance, husk cover, early maturity, drought tolerance, Fall armyworm resistance and resistance to grain weevils were the most important criteria in choosing maize varieties with rank scores of 1-5. The second group of criteria with rank scores of 6-10 were ear size, double ear, resistance to field diseases and pests and grain colour and larger grain size. The third group of criteria ranked 11-14 were soft gain texture and white corn flour. The last group of criteria with rank scores of 15-20 included grain type, grain colour and sweet taste. The majority of traits preferred were those related to yield, followed by those that enabled the plant to escape drought (earliness) and disease and pest resistance.

Farmers' coping strategies for maize ear rot disease

For ear rot management**,** farmers revealed some local methods they use to avoid maize ear rots. These included early harvesting, drying of maize ears on rooftops before shelling, sorting and discarding of maize rotten ears and grains before storing. It was reported at Njimom that beached palm oil when mixed with maize grains (at the rate of two teaspoons per 12.5 kg) and stored prevented the grains from any grain rot or weevils attack.

The farmers also revealed that they practice seed selection by selecting the healthiest and biggest cobs (OPVs or landraces) for the next planting season. Also, to be able to produce healthy and productive maize, farmers applied soil fertility management such as the use of poultry manure, fallowing, crop rotation and intercropping maize with legumes.

Breeding opportunities

Many maize breeding opportunities were identified during the plenary discussions with the farmers (Table 12). These included breeding for disease-resistant varieties, Fall armyworm-resistant varieties, drought-tolerant varieties, grain weevils-resistant varieties and low soil nitrogen-tolerant varieties.

DISCUSSION

Maize ear rots

Getting the farmers' perceptions and knowledge on maize ear rot disease, and including them in the plant breeding programme can enhance the rate of adoption of the newly released varieties. A good understanding of the farmers' perceptions about the cause of the disease is essential in the building

Table 11. Summary of the farmers' preference scores and derived ranks from the four study sites.

Preferred traits	Total score	*Rank	Reasons for the preference
Higher yields	195	1	Grain yield
Ear rot resistance	191	2	Minimal loss to fungal attacks
Stem rot resistance	186	3	Minimal loss to attack the disease
Good husk cover	150	4	Less bird attack and field rotting
Early maturity	146	5	Drought escape, unreliable rain fall
Drought tolerance	143	6	Unreliable rain fall
FAW resistance	140	7	Minimal loss to FAW
Weevil resistance	136	8	Lack of storage facilities
Big ear size	130	9	More grain yield
Double ear	123	10	More grain yield, less farm sizes
Resistance to field pests and diseases	115	11	Minimal loss to insects and pests
Grain colour	108	12	Boiling and roasting (attracting)
Large grain size	104	13	More yield
Soft grain texture	100	14	Easy flour extraction
White corn flour	96	15	Use for meal (fufu corn)
Grain type	93	16	Taste, weevil resistance
Sweet taste	89	17	Sweetness when roasted or boiled

*Rank score 1-5 = highly preferred; 6-10 = important; 11-14 = less important and 15-20 = rarely.

Table 12. Constraints to maize production and maize breeding opportunities identified during the PRA at the four study sites.

Problem	*Constraints	Coping strategies	Maize breeding opportunities
Low maize yields	Unreliable rain fall	Early planting	Drought tolerant varieties
	Ear rots	Feeds to poultry	Improved varieties with ear rot resistance
Low maize yields	Pests and diseases	Crop rotation, intercropping	Improved varieties with pests and disease resistance
Low maize yields	Grain weevils	Use of traditional stores, store grains with bleached palm oil	Better storing characteristics to be included to improved varieties
Low maize yields	Poor soil fertility	Fallowing, poultry manure, intercropping maize with legumes	Low nitrogen and acid tolerant varieties
Low maize yields	High costs of improved seeds	Recycle their local seeds	Release of more improved OPVs
Low maize yields	Low farm inputs	Intercropping	Improved varieties tolerant to low soil nitrogen
Low maize yields	Weeds	Manual weeding	Improved varieties with weed tolerance

*Identified during plenary sessions with the farmers.

up of an appropriate approach to combat the disease. Too much rainfall during the physiological maturity of the maize was reported as one of the major causes of ear rot disease. These data reveal that the farmers are aware of the fact that moisture results in ear rot disease. These results agree with those of an earlier work (Alakonya *et al*., 2008) which reported that increased exposure of mature maize ears to water or rainfall in the field increases the chances of ear rot disease incidence and severity if the pathogen is present. Early harvesting after physiological maturity could reduce the incidence of ear rots but complications associated with postharvest storage pose a challenge (Weinberg *et al.*, 2008). More to that, early maturing and drought-tolerant varieties were some of the desirable traits mentioned by the farmers. Such varieties mature before the end of the rains and therefore escape ear rot disease. This further emphasizes the importance of maize ear rot resistance breeding.

Breeding for varieties that should be adoptable by farmers is essential. In this situation, the evaluation of possible ear rot-resistant varieties must take into consideration, traits for yield and earliness. Therefore, there may be a need to strike a balance between selection for other desirable traits and ear rot resistance. Despite the fact that most of the farmers were aware of the maize ear rot disease, very few of them were aware of mycotoxins. This lack of awareness often leads them to keep the rotten ears for animal feed rather than discard them. These results are similar to those of earlier findings carried out (Wotia and Omukunda, 2021; Mukanga *et al.*, 2011). The poor understanding of the associated mycotoxins by the farmers implies that farmers and their households were being exposed to high levels of mycotoxins. Most of the farmers (70.7%) often use rotten maize grains to feed their animals. It was reported in Njimom that the rotten maize grains were often used to produce a local alcoholic drink called “afofo”. The feeding of poultry and using rotten maize for beer brewing are aimed at minimising the economic losses associated with the ear rot disease, but this has had the negative effect of increasing the incidence of mycotoxin-related illness in poultry and humans (Mukanga *et al.*, 2011; Sydenham *et al.*, 1990). More work needs to be done to educate the farmers on the dangers of consuming rotten maize and feeding it to livestock.

The fact that most farmers are still not aware of the effects of mycotoxins reveals that there is a need to intensify health awareness about mycotoxins produced by maize ear rot diseases. Little or no regulation policies exist in Cameroonian markets to reduce the level of mycotoxin food poisoning. This makes farmers put less importance on ear rots than they should. It has been reported elsewhere that a poor maize market system probably led maize farmers to have less consideration of marketability as an important characteristic to consider when selecting a variety to grow (Robbins and Ferris, 1999).

Maize varieties grown

The farmers showed a lot of concern for new maize varieties that will match their selection criteria and adapt to their farming systems and conditions. These findings are in accordance with Mukanga *et al.* (2011) who realized that varieties that meet farmers' preferred traits were highly adopted in Zambia. Similar results were obtained in other studies in other parts of Cameroon (Mfouasson *et al.*, 2020; Tandzi *et al.*, 2018; Ngonkeu *et al.*, 2017). The farmers’ personal experiences influenced the choice of varieties to grow. Despite the fact that some improved varieties are available at the Institute of Agricultural Research for Development (IRAD), farmers were sometimes reluctant to use them because they were more familiar with their local varieties. The farmers also preferred their landraces since they could easily recycle their seeds and avoid any expenditure. These findings are also similar to those of some previous findings in Cameroon (Mfouasson *et al*., 2020; Tandzi *et al.*, 2018; Ngonkeu *et al*., 2017). More to that, their local maize varieties were believed to be more disease resistant than the improved varieties.

Farmers’ criteria in choosing maize varieties

The top seven criteria used in choosing maize varieties were higher yields, ear rot resistance, stem rot resistance, good husk cover, early maturity, drought tolerance and fall armyworm resistance. Previous works carried out in Zambia (Mukanga *et al*., 2011) and Kenya (Odendo *et al*., 2002) revealed similar results despite the fact that earliness featured among their best three traits. The farmers in the study sites preferred high-yielding varieties irrespective of the level of disease resistance. This result is similar to the findings of Mafouasson *et al.* (2020) who found that higher-yielding varieties were the most preferred trait to farmers in the Bimodal humid forest zone of Cameroon. High-yielding varieties will be beneficial to farmers economically, reduce food insecurity and use less hectarage to achieve their desired productivity. The farmers also preferred early and drought-tolerant varieties since unreliable rainfall is becoming a major threat to maize production in Cameroon. Similar results were obtained in a previous work in Zambia (Mukanga *et al.*, 2011) which realized that early and drought-tolerant varieties were preferred by farmers since they provided food timely to avoid hunger and escaped the problems of unreliable rainfall.

Other maize production constraints

The maize production constraints listed in this study are similar to those of other studies in Cameroon (Mafouasson *et al.*, 2020; Ngonkeu *et al*., 2017) and Sub-Sahara Africa (Mukanga *et al.*, 2011; Odendo *et al*., 2002). However, the ranking of these constraints varies from one farming group to the other. Abiotic and biotic constraints such as soil fertility, drought tolerance and disease and pest resistance are long-term research works mean while socio-economic constraints like lack of tractors, lack of irrigation facilities, and poor farm-to-market roads require adjustments to specific community coping strategies (Mukanga, 2009).

Farmers’ coping strategies for maize ear rot diseases

Mixing bleached palm oil with maize grains before storing, sorting rotten grains or ears and drying unshelled maize ears on rooftops heated with fire were some of the local techniques used by the farmers to reduce the maize ear rot infection. The physical removal of visible disease ears and kernels during or after harvesting has been reported elsewhere (Mukanga *et al*., 2011; Munkvold and Desjarins, 1997). The physical removal is done in order to reduce the contamination of maize grains by mycotoxins (Mukanga *et al*., 2011), using rotten grains to formulate animal feeds is a major threat to public health as human beings end up consuming the animal or animal products, thereby exposing them to the related mycotoxin illnesses (Sydenham *et al*., 1990).

Maize breeding opportunities

A good number of opportunities are there for the development of many maize varieties including ear rot resistance in Cameroon among other valuable traits. The occurrence of ear rots in pre-harvest and post-harvest maize requires the need to develop ear rot-resistant maize varieties. It was discovered in a previous study in Zambia (Mukanga *et al.*, 2011*)* that most of the traditional methods used by farmers to reduce ear or grain rots such as drying maize on rooftops or smoking it over a fire and sorting maize ears or grains were not effective, hence, high need to develop ear rot resistant varieties. This study has revealed other maize-preferred traits other than ear rot resistance that can be combined to come out with improved maize varieties that the farmers will easily adapt. Grain yield was seen to be the most important trait by the farmers since it ensures household food security. A previous study by Sibiya *et al*., 2013 revealed that local varieties exhibited high yield potential and genetic variability for disease resistance that can be exploited in breeding programmes. Abiotic stresses (drought, heavy rains, storms and soil fertility) were among the constraints faced by the farmers. Breeding opportunities, therefore, exist for breeding varieties resistant or tolerant to these abiotic stresses and to raise yields of the local varieties.

Conclusion and implementation in maize breeding

Maize production was dominant in all PRA sites. This study identified the maize varieties farmers grew, the criteria used in selecting the varieties and the major constraints to maize production in the Western Highlands and Bimodal Humid Forest Zone of Cameroon. Farmers grew their local maize varieties and some improved maize varieties which did not possess adequate resistance to ear rots. Due to that, they were exposed to high levels of mycotoxins since they often use the rotten maize grains for animal feeds or produce local alcohols (‘‘afofo’’). Apart from higher yields and ear rot resistance, stem rot resistance, good husk cover, early maturing, drought tolerance and Fall armyworm resistance were the most important farmer-preferred traits that must be taken into account when developing an ear rot-resistant maize variety. Furthermore, breeders must adopt stress and market needs when developing ear rot-resistant maize varieties. All the traits of high yield, good taste, flint texture, large cobs, and large grain size should be processed by any improved maize variety. The study also suggests that increased farmer-breeder interaction must be encouraged as it allows for the identification of other farmer-preferred traits besides ear rots and the prioritising of these during the selection process. Farmers’ perceptions are not often included in the planning phase of most maize breeding programmes. Breeders often design their maize breeding programmes to suit the government policies for ensuring household food security, hence, paying more attention to higher yields. This has often resulted in the non-adoption of new maize varieties. It is therefore required that the maize breeders should consider farmers’ desired traits before developing any maize variety. This would increase the chances of adoption of the newly released maize varieties. From the breeder’s point of view, if a particular trait is desired, it will be necessary to combine it with farmers’ preferred traits to add more value to it. Much work still needs to be done to alert farmers about disease-resistant varieties.

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The authors declare that they have no conflict of interest.

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