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Finger Millet (*Eleusine corocona*) Production in Lower Eastern, Kenya: Status, Constraints and Opportunities

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Authors' contributions

This work was carried out in collaboration between all authors. Authors SIS, YMM and RNO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors YMM and RNO managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Due to its drought resistant nature, high nutritional content and ability to produce with few inputs, finger millet is one of the crops that can combat food insecurity in arid and semi-arid lands like eastern Kenya. Against this backdrop, a survey was carried out in Kalama and Katangi divisions of Machakos and Kitui counties, to assess status, constraints and opportunities for finger millet production. Logit model was used to determine effect of education, land size, age and gender on finger millet production. Finger millet production was reported by 93% of respondents in Machakos and 92% in Kitui, to be on the decline in the past 20 years due to; lack of seeds (47%, 50%), pests and diseases (33%, 20.8%), overdependence on maize (97.8%, 95.9%) and climate change (20%, 29.2%) in Machakos and Kitui, respectively. Constraints in production were; blast disease (43.8%, 37.2%), bird predation (39.9%, 39.6%), weed infestation (57.1%, 55.8%), climate change (30%,

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39.2%) and lack of seeds (63%, 77.4%) in Machakos and Kitui, correspondingly. Opportunities in production lay in the cereals capacity to withstand climate change (76%, 76%), high nutrient content (74%, 85%), market availability (63%, 74%) and extension services (87%, 88%) in Machakos and Kitui counties, respectively. Education and land size had a positive effect on millet production (0.807, 1.095) while gender had a negative effect (-3.684, -1.170) in Machakos and Kitui counties, respectively. Based on the results, finger millet production in both regions has been on a downward trend but there is a lot of potential for increased production, as evidenced by opportunities identified by farmers. It's only through addressing constraints in production by relevant stake holders that opportunities can be realized and consequently status of finger millet production improved in eastern Kenya.

Keywords: Arid and semi-arid lands; climate change; finger millet; food security.

1. INTRODUCTION

Eastern Kenya is characterized by arid and semi-arid climate. These regions are prone to low, unpredictable rainfall, high temperatures and low yield production, exacerbated by dependence on rain fed agriculture [1]. Arid and semi-arid lands (ASALs) are considered most vulnerable to effects of climate change due to delicate nature of their environment, high rates of poverty that limit adaptation to changing climate, high evapotranspiration and low soil fertility resulting in food insecurity [2].

A possible solution to food insecurity in ASALs may be production of indigenous crops like finger millet. Finger millet is considered one of the most important small cereals in eastern and southern Africa [3]. This can be attributed to characteristics alluded to the cereal that advocate for its use as a crop to combat food insecurity, particularly in the face of changing climate [4]. These characteristics include drought resistance, resistance to pests and diseases, high nutrition and high yielding with very little inputs. The cereal is thus considered a solution to chronic food shortages for rural communities who reside in semi-arid regions especially in Sub Saharan Africa [5]. However, production of finger millet has been declining over the years. One of the main reasons for this decline is the crop being abandoned in favor of 'introduced' crops like maize [6]. Unfortunately, recurring droughts due to climate change have led to increased occurrence of maize crop failure, causing households who rely on maize production food insecure [7]. The current study aims to bring focus on production of finger millet in eastern Kenya, where its cultivation has the potential to alleviate food insecurity [8].

The purpose of the current study was therefore to assess the status, constraints and opportunities in finger millet production in Machakos and Kitui counties, to find basis for its promotion as a trajectory to enhanced food security.

2. MATERIALS AND METHODS

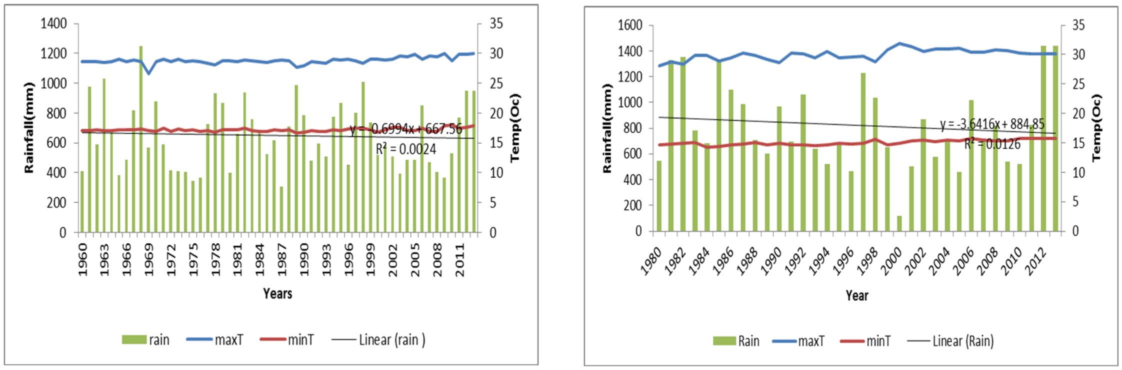
2.1 Site Description

The survey was carried out in Kalama and Katangi divisions of Machakos and Kitui counties respectively, in the lower parts of Eastern Province of Kenya. Machakos county is located between latitudes 0º45´S to 1º31´S from North to South and longitudes 36º45´E and 37º45´E from East to West with a mean altitude of 1714 meters above mean sea level. Long rains fall between March and May and short rains between October and December. Annual rainfall ranges between 500mm and 800 mm (Fig. 1). Maximum and minimum temperatures experienced are 24.3ºC and 11.1ºC respectively [9]. Main agricultural activities include subsistence crop (maize, beans, green grams, cowpea, pigeon pea, mangoes) and small-scale livestock (cattle, sheep and goats) farming.

Kitui County is located between latitude of 0º 3.7' and 3º 0 South and longitude 37º 45' and 39º 0' East with an altitude of 1151 meters above mean sea level [10]. The region receives average rainfall of about 900 mm (Fig. 1). Long rains fall between April and May, while short rain between October and December [10]. Agricultural activities include subsistence crop (maize, beans, cowpea, pigeon pea, cassava, cotton) and livestock (cattle, sheep and goats) farming.

2.2 Farmer Selection and Data Collection

The field survey was carried out on a total of 120 farmers; 60 in Kalama and 60 in Katangi, in Machakos and Kitui counties, respectively.



Kalama, Machakos **Katangi, Kitui**

Fig. 1. Rainfall and temperature trends in Machakos and Kitui counties

A stratified random sampling procedure, with location as a stratum was used to select respondent's households. Four locations, each with 15 households were surveyed in each county. Questionnaires were administered at the locations Mbevo, Katanga, Kola and Kitonyini in Kalama and at Naivass, Utumoini, Kiimani and Kathungili in Katangi. A computer random number generator was used to select households in each location.

Data was collected on various parameters including;

(i) The status of finger millet production over the last 20 years.
(ii) The reasons for decline of finger millet production over the last 20 years.
(iii) The possible reasons of production of finger millet including drought resistance, market availability and nutrient content.
(iv) Possible constraints to finger millet production including challenges due to climate change, pest attack and lack of seeds.
(v) Opportunities for finger millet production including combating climate change, presence of extension services, finger millet nutritional content and high marketability.
(vi) The likelihood of an individual to engage in finger millet production as influenced by location, age, gender and education.

2.3 Data Analysis

Data were analyzed for descriptive statistics using Statistical Packages for Social Sciences (SPSS) version 16. Factors determining the likelihood of finger millet production were analyzed using the logit regression model. Logit model parameters were estimated using maximum likelihood method where the coefficients most likely to be observed were selected [11]. The probability of growing finger millet was estimated using the following formulae;

$$p_i = F(\propto + \beta x_i) = {}^{1}/_{1 + e^{-(\alpha + \beta_{x1})}}$$

Where P_i is the probability that a farmer will grow finger millet given that x_i where x is a vector of explanatory variable and e is the natural logarithm, α is the constant of the equation and β is the intercept term.

3. RESULTS AND DISCUSSION

3.1 Status of Finger Millet Production

3.1.1 Production trends

Finger millet production was reported by 92% of respondents in Kitui and 93% in Machakos to be on a downward trend over the last 20 years (Fig. 2). Reasons for the decline were identified as overdependence on maize, lack of improved seed varieties, climate change, pests and diseases (Fig. 3).

Overdependence on maize may be attributed to the cereal being considered a staple crop in both regions. Maize in eastern Kenya is consumed daily in various forms such as ugali (a dish of maize flour cooked with water to a hard consistency) and porridge (a dish of maize and water cooked to a thick paste consistency). In addition, farmers mix maize grain with other foods like beans, pigeon pea, cowpea and potatoes which are consumed regularly. Kibaara [12] reported that maize was the main staple food in Kenya accounting for 40% of calories consumed daily. Moreover, maize production receives more government support than other cereals in form of subsidies. Eicher [13] and [14] found that maize production was high in Kenya due to increased government support on maize prices, access to credit, and marketing subsidies.

Majority of respondents grew local varieties of finger millet in Machakos (47%) and Kitui (50%). Farmers attributed this trend to lack of access to improved seeds caused by neglect of finger millet by the research community and extension service providers. Handschuch [15] and [16] found that millets in Africa had been greatly underresearched, resulting in farmers' limited exposure and knowledge of improved varieties.

Climate change had led to increased drought and reduced rainfall resulting in low finger millet yields. Farmers noted that although finger millet produced higher yields than other cereals during periods of drought, the effect of changing climate had caused yields to be on the decline. This view is shared with [17] and [18] who found that yields of the cereal were below their potential due to increasing effects of climate change.

Pest and disease attacks were ranked as a low priority constraint (33% and 20.8% of respondents in Machakos and Kitui, respectively) attributable to finger millet being highly resistant to majority of pest and disease attacks both in the field and during storage. However, quelea birds (*Quelea quelea*) and blast disease were identified as the main pest and disease that affected production of the crop. FAO [19] and [20] reported that bird predation was one of the main constraints to cultivation of finger millet. Mgonja et al. [3] and [21] reported blast disease as one of the main reasons for low finger millet production in East Africa.

3.1.2 Reasons for finger millet cultivation

Reasons farmers cited for cultivation of finger millet were drought resistance, high availability of markets and high nutrient content (Fig. 4).

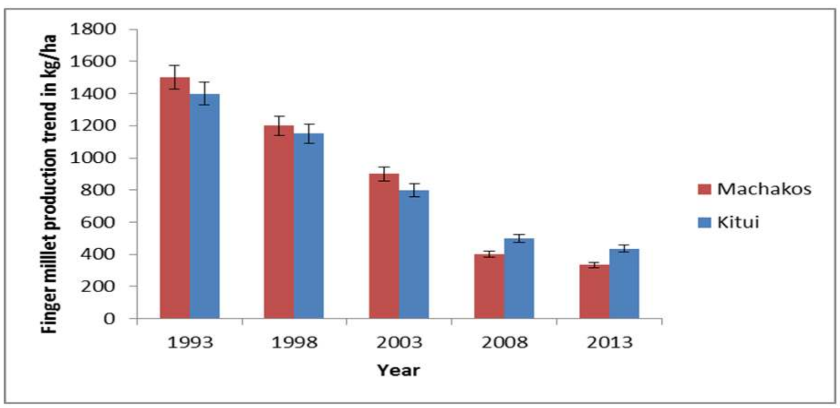


Fig. 2. Finger millet production trends in Machakos and Kitui counties

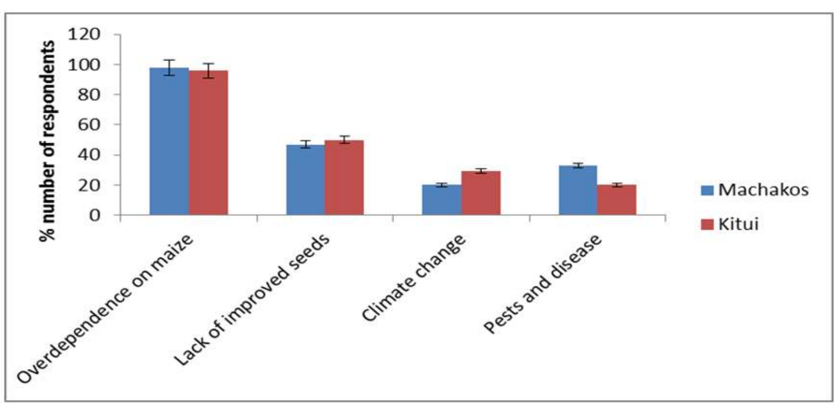


Fig. 3. Reasons for decline in finger millet production

Drought resistance was identified as one of the reasons for finger millet production in both regions. Farmers noted that with increasing effects of changing climate, certain crops were more severely affected than others. Respondents had observed that in the same season, finger millet was able to produce yields while other cereals like maize experienced total crop failure. This may be due to the crop being indigenous to the continent and thus better adapted to the harsh (irregular rainfall, drought and high temperatures) ASAL environment than other cereals. Fakrudin et al. [22] reported that finger millet cultivation in tropical and sub-tropical regions of Africa was able to save poor farmers from starvation due to its ability to produce yields even during periods of drought.

High market availability was identified as one of the reasons for finger millet cultivation. The main sale point for most farmers was the local market. There was a market day twice a week that provided an opportunity for farmers to sell the crop frequently. This observation is in line with [16] who found that millets had a large market due to being sold mainly in local markets. Finger millet sold at about double the price of other cereals attributable to the small size of the grain and high nutritional content, enabling farmers to make high profits. Oduori [23] reported that high nutritional content of the crop was one of the main reasons for the favorable demand and high sale price of finger millet in the county compared to other cereals.

In addition, farmers had observed that finger millet consumption had more health benefits than other popular cereals like maize. They recommended it to the elderly to improve their physical health, the sick to hasten recovery process and women after giving birth to replenish their blood. The finding corroborates a report by [24] where finger millet was identified as one of the most nutritious crops providing proteins, carbohydrates, minerals and amino acids, especially methionine which is lacking in the diets of numerous poor people who live on starchy foods.

3.2 Constraints in Finger Millet Production

Respondents identified blast disease, bird predation, weed infestation, climate change and lack of seeds as the main constraints in production of the cereal (Fig. 5).

Finger millet is known to be highly susceptible to blast disease infestation, especially during the long rain season, causing great yield losses. This agrees with suggestions of [25,21] who found that the crop was highly susceptible to blast disease with infestation of the fungus causing to as much as 50% loss in yields.

Respondents reported that quelea birds were the main pest affecting finger millet in the field as identified by 39.9%, 39.6% of respondents in Machakos and Kitui, respectively. The results mirror those of [20,26] who reported that bird predation was one of the main constraints to cultivation of the crop.

Most of those who grew finger millet relied on seeds from their own farms or their neighbors. This may be attributed to extension work being focused on more popular crops like maize and beans, and opposed to traditional crops like finger millet that are better adapted to the ASAL regions. Jayne et al., [7], had also cited problems of farmers accessing seeds as one of the main reasons for decline of finger millet production.

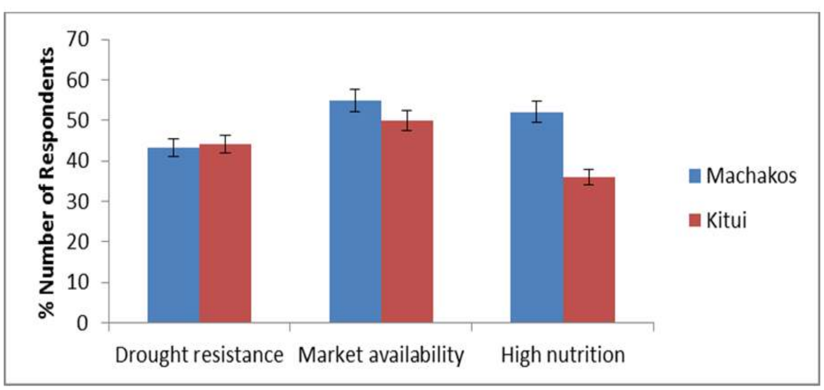


Fig. 4. Reasons for finger millet cultivation

High weed infestation was identified as a major constraint as finger millet looks like certain weeds (*Eleusine indicia*) that are close relatives to the crop. Farmers complained that due to the close similarity of the cereal to weeds, weeding became a difficult and expensive task as the crop required to be weeded more times than other crops to remove weeds that were missed during first weeding. Oduor [27] had also identified high weed infestation as one of the reasons for declining finger millet production in the country.

3.3 Opportunities for Finger Millet Production

Opportunities for finger millet production were cited as; climate change, extension services, high nutritional content and high market availability (Fig. 6).

3.3.1 Climate change

Respondents (76% in both Machakos and Kitui counties) considered finger millet to have a lot of potential in dealing with effects of climate change due to its drought resistant nature. Rukuni et al. [28] had also pointed out that finger millet grain has a high potential for improvement of food security, especially in the arid and semi-arid areas due to its ability to provide good yield with little rainfall.

3.3.2 Extension services

Of the farmers interviewed, 87% in Machakos and 88% in Kitui identified potential of finger millet in extension services. Extension work in both regions was focused on crops that were considered popular like maize and beans, consequently reducing popularity of finger millet. Farmers predicted that an increased focus on the cereal by extension workers would improve popularity of the crop. Kaliba et al. [29] and [30] had similarly observed that farmers produced crops based on their knowledge. They further noted that extension service providers played a great role in determination of crops grown by farmers. The decision to produce finger millet was thus expected to be positively influenced by focus of extension service providers on the cereal.

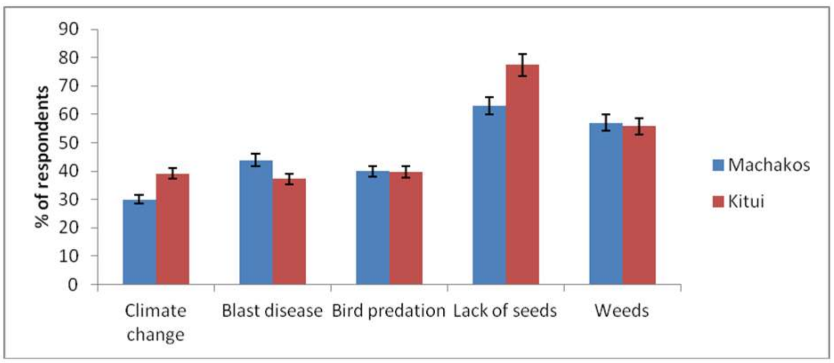


Fig. 5. Constraints in finger millet production

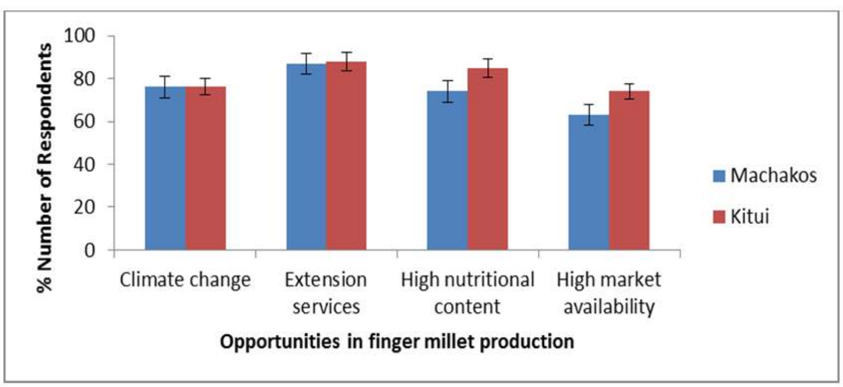


Fig. 6. Opportunities in finger millet production

3.3.3 High nutritional content

Respondents in Machakos (74%) and Kitui (85%) viewed finger millet as a crop with great potential due to its high nutrient content. Farmers considered the grain nutritionally superior to other cereals. This agrees with [31] and [32] who had observed that finger millet was nutritionally superior to other cereals due to its high calcium, minerals, fiber, starch, carbohydrate and protein content.

3.4 Evaluation of Factors Affecting Production of Finger Millet Using the Logit Model

In Kitui, education had a positive effect on finger millet production (Table 1). The exp β showed that for a unit increase in education level probability for finger millet production increased by a factor of 2.989. Land size had a positive effect on finger millet production with exp β showing that with each unit increase in land size the probability of production increased by a factor of 2.644. Age had a positive effect on the cereals production with exp β showing that a unit increase in age would result in an increase in production by a factor of 1.002. Gender had a negative effect on finger millet production as shown by the negative β value of -1.170. The exp β showed that probability of finger millet production increased by a factor of 0.310 with a female farmer and decreased by the same factor with a male farmer.

Table 1. Logistical regression results for Kitui

Variable	β	S.E.	Wald	Exp β
Gender	-1.170	0.656	3.186	0.310
Education	1.095	0.400	7.500	2.989
Age	0.002	0.023	.010	1.002
Land size	0.972	0.815	1.424	2.644

In Machakos education had a positive relationship to finger millet production (Table 2). The exp β showed that for an increase unit in education probability of production increased by a factor of 2.241. Land size had a positive effect as well with exp β showing that with each unit increase in land size the probability of finger millet production increased by a factor of 5.478. Age had a negative effect on the cereals production with exp β showing that a unit increase in age would result in a decrease in finger millet production by a factor of 0.969. Gender had a negative effect on finger millet production as shown by the negative β value of -3.684. The exp β showed that probability of finger millet production increased by a factor of 0.025 with a female farmer and decreased by the same factor with a male.

Table 2. Logistical regression results for Machakos

Variable	β	S.E.	Wald	Exp (β)
Gender	-3.684	1.163	10.038	0.025
Education	0.807	0.382	4.457	2.241
Age	-0.032	0.031	1.021	0.969
Land size	1.701	0.992	2.941	5.478

The positive effect of education on the cereals production in both regions can be explained in terms of increased exposure to many agricultural crop choices through agricultural related courses in schools. This may have increased exposure of farmers to drought resistant crops like finger millet, leading to their cultivation. Enete and Onyekuru [33] found that higher education was expected to have a positive influence on farmer's decision to produce small grains like finger millet. Both regions showed that increase in land size increased probability of finger millet cultivation. This may have been a result of the fact that increase in land would give farmers more options in crop diversification as insurance against total crop failure. The increased diversification may have played a role in increased production of drought resistant crops like finger millet. Mukarambwa and Mushunje [20] saw that farmers with larger land sizes were expected not to be constrained by land shortages on the number of crops they produced, thus increasing probability of cultivation of drought resistant crops like finger millet crop.

In both Machakos and Kitui counties female led households were more likely to cultivate finger millet than male led households. This can be explained by women making up a majority of those involved in agricultural production. This places them in a better position to be exposed to finger millet crop and its potential benefits, through interaction with extension service providers. Given that the effects of changing climate are on the rise, farmers who are knowledgeable on drought resistant crops are more likely to advocate for their production. A study carried out in Ethiopia found that women were more interested in dry land crops like millets which required less water and inputs, while men were more geared towards cash crops like bananas and sugarcane. The views are shared by [34] who reported that traditional crops like finger millet were mainly attached to women.

The effect of age on finger millet production varied in both regions. In Kitui the increase in age increased probability of finger millet cultivation while the opposite was true in Machakos. In Kitui, older farmers advocating for production of finger millet is largely a factor of their long term knowledge on production and potential benefits of the cereal. These farmers are knowledgeable on the ability of millet to produce with very little input especially during periods of drought than the younger farmers, who may not have ample knowledge on the cereal and hence more interested in production of cash crops like maize. Enete and Onyekuru [35] opinioned that age of farmers could be used as a proxy for farmers experience and knowledge and thus played a role in differences in agricultural crop production among farmers. A study carried out by [36] found that younger farmers in Zimbabwe favored cultivation of cash crops like maize while older farmers advocated for drought resistant crops like finger millet. In Machakos more younger farmers advocating for production of finger millet than older farmers may be as a consequence of the close proximity to Nairobi. Most of these young people became part time farmers and undertook other income ventures in the capital city. The older generation in Machakos tended to be more focused on production of cash crops like maize and beans, as farming is their main source of income.

4. CONCLUSION

Finger millet production has been decreasing over the past 20 years. Main reasons for cultivation were drought resistance, high nutritional value and availability of markets. Main constraints in production were lack of seeds, lack of pesticides and climate change. Potential for production was seen in aspects of climate change, extension services, nutritional content and marketability. Education and Land size had a positive effect on finger millet production while gender had a negative effect. Based on the logit model results, extension service providers should take into consideration farmer's age, education, land size and gender when determining a target group for finger millet dissemination. Determination of status, challenges and opportunities in finger millet production will enable all those involved in production of the cereal with a way forward for attainment of sustainable finger millet production, and subsequently improved status of food security in the region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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