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Farmers' Varietal Preferences, Implications in Improvement of Sorghum (*Sorghum bicolor* (L) Moench) and Productivity in Mali

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ABSTRACT

Sorghum is the second most important cereal crop after pearl millet in terms of area planted, production, and per capita consumption in Mali. Production of sorghum is declining due to several reasons including biotic and abiotic stresses. A Participatory Rural Appraisal consisting of focus group discussions followed by individual interviews was conducted in different communities where sorghum is among the main starchy staples. The focus group discussions were conducted among a total of 74 small-scale farmers, in three sites, whilst 265 households were involved in the interviews. The results indicated that, in Mali, sorghum is grown for food, feed, building and for organic manure production. The adoption and access to improved sorghum varieties and hybrids are still poor. The two major sorghum production constraints identified were drought and *Striga* infestation. The main farmers' varietal preferences are high yield potential, earliness, grain quality, and tolerance to drought and *Striga* infestation.
KEYWORDS: farmers, sorghum, households, hybrids, drought

INTRODUCTION

Sorghum is among the major cereal crops in Mali. It occupies about 30% of total harvested agricultural area [1]. Sorghum productivity is constrained by numerous biotic and abiotic stresses. Agronomic practices applied by most farmers do not maintain soil fertility. Farmers manage their crops to produce annual harvests, relying mostly on farmer varieties in contrast to modern varieties developed by professional plant breeders [2]. Professional plant breeders have not developed varieties for marginal environments, partly because of an incomplete understanding of why farmers grow their own varieties. [3, 4, 5, 6]. One reason for this misunderstanding is the common assumption by breeders that modern varieties selected in optimal environments will also out yield farmer varieties in farmers' marginal environments [4, 7]. Understanding farmer varietal choices should help breeder and extension programs to better serve the needs of resource poor farmers. This understanding can also strengthen collaboration between farmers and plant breeders in meeting these goals [4, 7]. Participatory rural appraisals (PRAs) have been used worldwide to solicit farmers' views on various agricultural resource management options necessary to ensure household food security and improvement in their welfare [8]. These have resulted in community based action plans being implemented for the farmers' benefit.

A participatory rural appraisal was used to assess farmers' varietal preferences and their implications in the sorghum improvement and productivity in Mali.

The objectives of this study were to:

- Rank and show the importance of sorghum in selected localities.
- Determine sorghum production constraints in semi-arid regions of Mali.
- Identify the criteria used by farmers in choosing which variety to grow.

MATERIALS AND METHODS

Study area

The focus group (FG) discussions and questionnaire (surveys) were conducted in districts of: Diedougou (12°47′80″N and 6°40′75″W), Wacoro (12°36′03″N and 6°41′36″W), Kenioroba (13°07′22″N and 9°48′41″W) and M'Pessoba (12°66'93″N and 5°72′15″W).

Methodology

The FG discussions were conducted with a total of 74 small-scale farmers identified through local agricultural extension workers and randomly selected without any bias towards age, gender, experience in farming, or status. The number of farmers interviewed was 30 in Diedougou, 27 in Kenioroba and 17 in Wacoro. The study was conducted between December 2012 and May 2013 when most smallholder farmers were less busy.

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The opening of PRA meetings in all three communities followed a standard procedure starting with formal discussions with the leaders of farmers' association or the village chief about the reason for the study and introduction of the PRA team by the Agricultural extension Officers of each district.
Local language was the mean of communication during the meetings, for clarity of understanding.

A combination of various PRA methods was used including focus group discussions, pairwise rankings, preference rankings and scoring [8]. Identification and ranking of constraints related to sorghum production and use were done using pair wise ranking and scoring techniques. This is a tool that facilitates priority setting. Rankings were done by key informants or groups that represented a mixture of interests [9]. Farmers were also asked to give their criteria for choosing which variety to grow using preference ranking. This method of ranking involves participants assessing different items or options using criteria they have identified [10].

Farmers' perceptions on sorghum production collected from the focus group discussion were used to develop an individual interview questionnaire. The survey questionnaire was composed of 20 questions, administered to 265 households in 25 villages or communities of three districts: seven villages in Diedougou area, eleven villages in Kenioroba area and seven villages in M'Pessoba area. Survey areas were selected on the basis of sorghum importance, agro-ecological and socio-economic conditions as well as ethnic and cultural diversity.

Households were selected in each village on voluntary basis and experience on sorghum production. Individual interviews were conducted in these households with a farmer respondent who is household head or others members in the household. This study was conducted in 2013 and 2014.

Data collection and analysis

Different PRA techniques were used to obtain information about the farming problems, varietal selection criteria, research priorities and opportunities. A combination of data collection techniques was employed: structured questionnaires, semi structured interviews and unstructured interviews.

The PRA questionnaire was filled and completed during individual interviews (survey) period, data were recorded in Microsoft Excel, and then imported into IBM SPSS (Statistical Package for Social Science) version 20. Data were analyzed using nonparametric statistics and summarized into averages, frequencies or percentages as shown in the forms of tables and graphs.

RESULTS

FOCUS GROUP DISCUSSIONS

Importance of sorghum

Farmers listed six main uses of sorghum in Diedougou: First, sorghum is produced as cash cropas feed (fodder), and human consumption (Table 1). Farmers in this area, consume e s relatively more maize for human consumption than sorghum. The driving force for sorghum production as cash is supported by the firm contract farmer association signs each year with the World Food Program (WFP).
Farmers in Wacoro listed five main reasons to grow sorghum (Table 1). Food, fodder, cash, sacrifice and construction (roofing, fencing etc.). Farmers in Wacoro found that sorghum is important for home consumption because of its high yield in cooking compared to Maize, millet.
In Kenioroba, four main reasons are listed for growing sorghum: food, fodder, cash and sacrifices by priority (Table 1). In Kenioroba, like in Wacoro farmers found that sorghum is very important for home consumption because of it higher yield in cooking. Meals from sorghum grains have better taste and sorghum grains can be used to cook many local dishes such as sorghum-rice, djouka, and couscous.

Table 1: Ranking of sorghum utilization in Diedougou, Wacoro and Kenioroba during focus group discussions in 2013, in Mali

Usages	Rank in Diedougou	Rank in Wacoro	Rank in Kenioroba
Consumption	3rd	1st	1st
Cash	1st	3rd	3rd
Fodder	2nd	2nd	2nd
Dowry (wedding)	4th	*	*
Beer	6th	*	*
Therapeutic	5th	*	*
Sacrifices (Religion)	*	4th	4th
Construction	*	5th	*

* = Usage not listed in surveyed villages in 2013.

Results (Table 1) showed that, except at Diedougou, sorghum is an important food and feed (stover) crop for farmers. According to farmers, sorghum grain is used primarily at home local foods such as "to" (thick porridge), couscous, porridge, sorghum-rice and many other dishes. Sorghum stover after harvest is used for animal feeding. In addition, sorghum plays an important role in the socio-cultural and religious aspects of farmers' lives.

It revenue is used for dowry payment and supporting weddings ceremonies and funeral sacrifices, and as beverage (local beer) in rituals. Leaves and grain are also used as medicine (therapeutic) to heal several illnesses in the areas.

Constraints to sorghum production

In Diedougou, nine constraints with gender interests were identified and ranked (Table 2). Men's top three constraints were high cost of inputs, lack of equipment and lack of training. These constraints were equally ranked. Women ranked lack of land as the top constraint, followed by lack of equipment and high cost of inputs. Both men and women agreed on lack of equipment and high cost of inputs but men did not have land problem due to their land tenure.

Drought was ranked fourth by men but women ranked equally drought, low soil fertility and lack of training of farmer as equal (fourth position) followed by *Striga* damage and lack of markets. Lack of improved seeds is not a major problem for women (ranked 9th) whereas men ranked it at the fifth position. Women explained that all improved seeds they grow are obtained from a Non-governmental organization (NGO) as part of "food security pack". Low soil fertility, *Striga,* lack of market to sell grains and lack of land were ranked by men as sixth, seventh, eighth and ninth position, respectively.

There were no women participants at Wacoro and Kenioroba because there were not enough for forming two groups. During FG discussion at these two sites, ten constraints were identified and ranked (Table 2).

At Wacoro, high cost of inputs was ranked first. Low soil fertility, lack of equipment and lack of training were ranked second. Drought and *Striga* were ranked fifth and lack of improved seed, bird damage, diseases (charcoal rot) and lack of markets for payment were ranked seventh, eighth, ninth and tenth.

At Keniroba, the top constraints were lack of training (first), high cost of inputs (second), while lack of improved seed and drought were ranked third. Farmers ranked lack of equipment as fifth followed by low soil fertility. *Striga* and charcoal rot disease were ranked seventh. Lack of markets and bird damage were ranked ninth and tenth, respectively.

Table 2. Ranking of sorghum production constraints in Diedougo, Wacoro and Kenioroba during focus group discussion in 2013.

Constraints	Diedougou		Wacoro	Kenioroba
	Men	Women		
Low soil fertility	6th	4th	2nd	6th
Drought	4th	4th	5th	3rd
***Striga* infestation**	7th	7th	5th	7th
High cost of inputs/fertilizer	1st	3rd	1st	2nd
Lack of equipment	1st	2nd	2nd	5th
Lack of markets for payment	8th	8th	10th	9th
Lack of field	9th	1st	*	*
Lack of improved seed	5th	9th	7th	3rd
Lack of training	1st	4th	2nd	1st
Charcoal disease	*	*	9th	7th
Birds	*	*	8th	10th

* = Constraint not listed in villages.

The first set of main important constraints of sorghum production identified during the FG discussion were lack of training, high cost of inputs, and lack of equipment in all three communities. In Diedougou women reported that lack of land was more important than lack of training. Men argued that, in their tradition, women do not have the right to own land. It is men who hand over to women part of their land, usually the part with low fertility. Men own land because they support household expenses. Lack of improved seeds was replaced by lack of equipment in third position at Kenioroba. After training, cost of inputs, and lack of equipment, drought, *Striga*, low soil fertility and lack of improved seeds were the most important constraints. Lack of markets, charcoal rot disease and bird damage were listed as third minor constraints.

The increasing demand for training was due to the introduction of new agronomic practices (fertilizers, pesticide, field managements etc.) and new improved varieties by research institutions that were not known by most farmers in rural areas which require higher input than local varieties.

Varieties of sorghum grown in each of the three sites

Farmers grow local cultivars, improved varieties and hybrids. The choice of a variety depends mainly on the morphological, agronomic and organoleptic characteristics as well as the ecological and socio-economic conditions where a variety is grown base on farmer opinions. During FG discussion, 28 sorghum varieties names were reported across all areas (Table 3).

Table 3. Repartition of sorghum varieties and hybrids resulting from the PRA conducted in 2013 at Diedougou, Kenioroba and Wakoro communities in Mali.

Site	Number of local varieties	Number of improved varieties	Number of Hybrids
Diedougou	5	5	-
Wacoro	6	3	3
Kenioroba	4	2	-
Total	**15**	**10**	**3**

Local landraces have been cultivated by many farmers for 30 – 60 years, and most of these varieties belong to the Guinea race of *Sorghum bicolor (L.) Moench*. Preference for local varieties is based on food quality (taste), grain quality (longer storage), adaptation to low soil fertility and photoperiod sensitivity responses. The major limitation of the local landraces are their relatively low yield, susceptibility to *Striga* and lodging.

Improved varieties were introduced from research institutions and have been grown by farmers for the last 10 years. These introduced varieties have good yield and forage quality but have poor grain quality, low adaptation to local environments, susceptibility to diseases, storage problems (insects) and are prone to bird damage.

Sorghum hybrids were grown only in Wacoro. These hybrids were introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) recently. The hybrids have very good yield, but are sensitive to photoperiod, susceptible to grain mold and have small grains.

QUESTIONNAIRE

Households Characterization

Mean total area of surveyed households was nine hectares while average planted area to sorghum was 2.73 ha, or 29% of total area. All surveyed households grow sorghum (31%) which is the major crop. Maize, pearl millet, rice, cotton, groundnut and cowpea are also grown. Sorghum, maize, pearl millet, rice and cowpea are grown mainly for household consumption while cotton and groundnuts are main cash crops.

Households are poorly equipped in terms of farm equipment (plows, Seeders, draught animals, donkey carts, etc.). On average, each farm has at least one piece of farm equipment (plows, seeder plows, and donkey or horse carts), two draught bulls and less than ten cattle.

Household incomes

Main sources of incomes among of surveyed households varied. Forty-one per cent of households get most of their income from selling cash crops such as cotton, peanut and sesame, 28% get most from selling sorghum and 19% from selling other food crops (maize, millet, root and tuber crops). In addition, 10% get most of their incomes from selling livestock and two per cent (2%) from others sources such as fishing, trading, monthly salary, and farm labor (Figure 4.1).

Overall, sorghum occupied second place in economic status of farmers in the study areas.

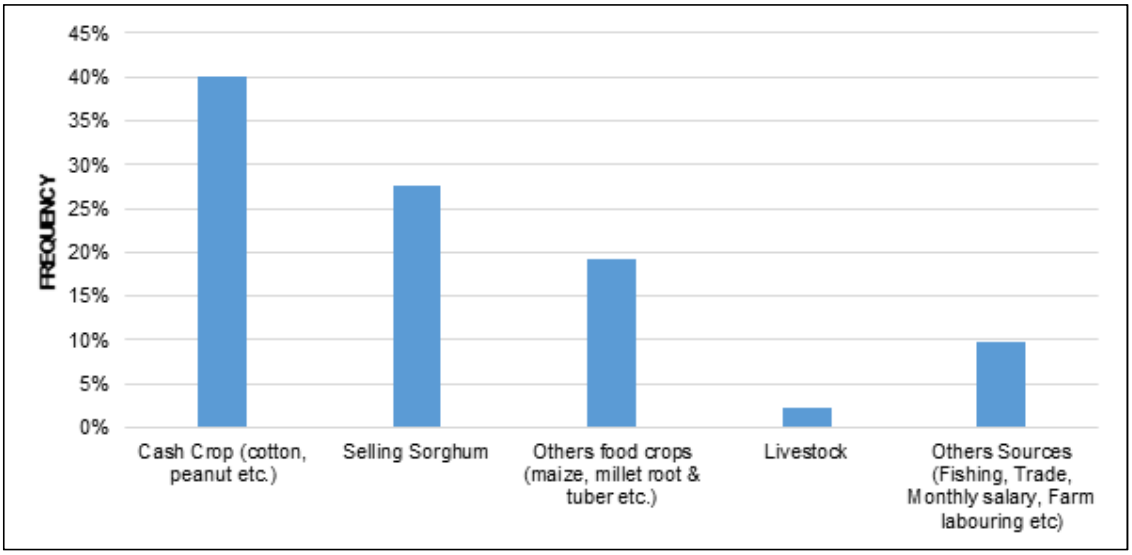

Figure 4.1. Sources of household's incomes from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Main reasons for growing sorghum

Sorghum is primarily grown by 68.7% of the households for consumption, 28.3% for cash and 2.6% for others reasons such as dowry payment, therapeutic, sacrifices and beverage (Figure 4.2).

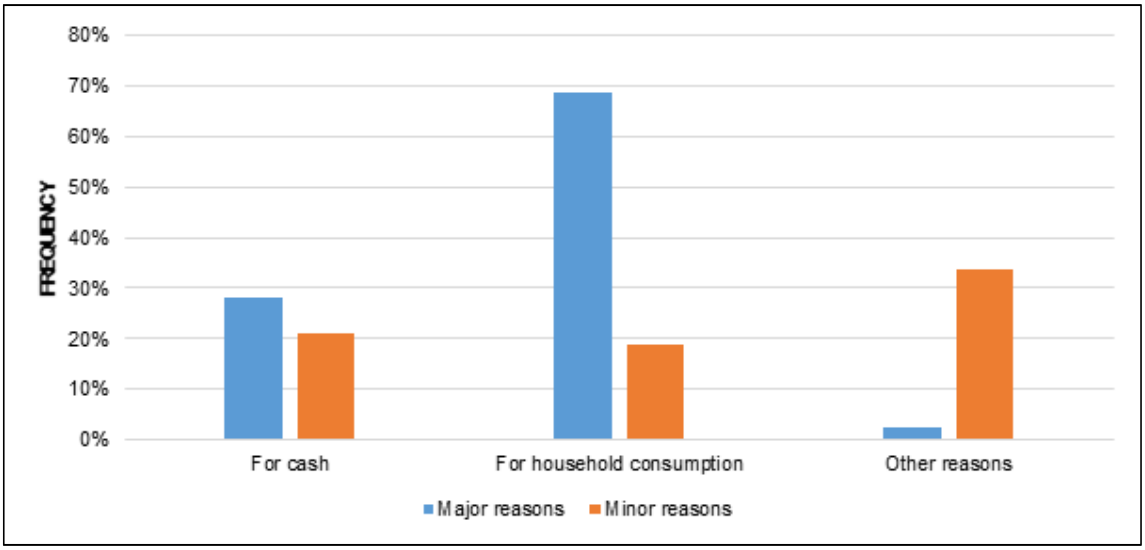

Figure 4.2. Main reasons for growing sorghum in households from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Main sources of seed for planting

The majority of households grow one variety of sorghum but some households grow two to three varieties. They plant a combination of improved and local varieties with medium to early maturing varieties to secure and optimize yield, for grain qualities and drought managing.

Seventy percent (70%) of surveyed households use seed from their previous crops for the next cropping (Figure 4.3). The second most important source of seeds is exchanges among farmers (between neighbors, relatives, and friends). Other sources of seeds are Non-Governmental Organizations (NGOs). NGOs provide improved seed to farmers as part of a food security package and for diffusion of information about the new technologies generated by research.

Access and adoption of seeds from seed companies or research institutes is poor. About 70 to 80% of farmers have never bought seed from the seed companies or research institutes.

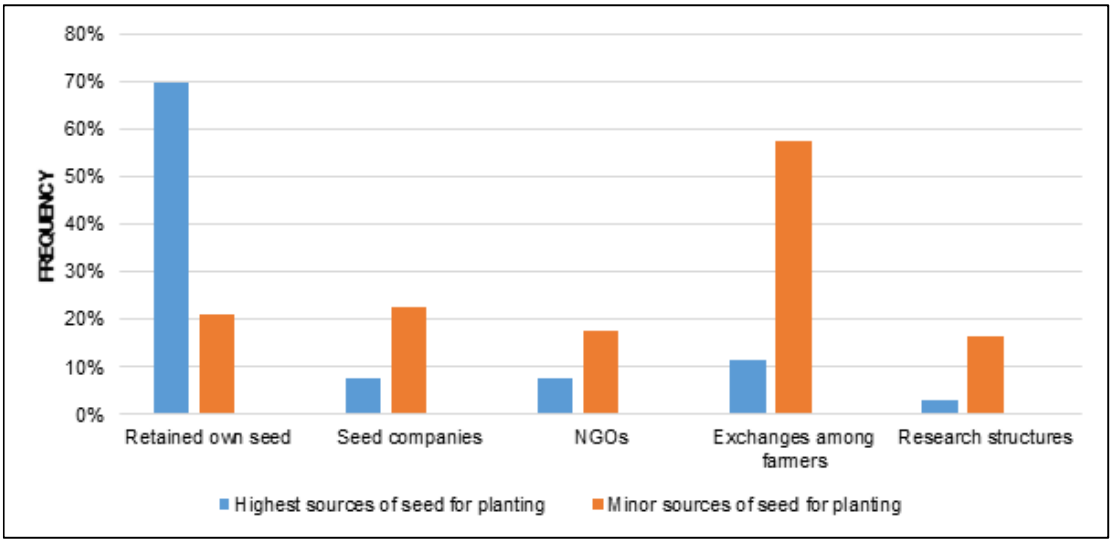

Figure 4.3. Main sources of seed for planting in households from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Crop management practices

Sorghum cultivation relies mainly on traditional methods. Many households have little farm equipment and little income to buy inputs. Most farmer use family labor for production (planting, weeding and harvesting).

More than 20% of households do not plow before sowing, 41% don't use seed treatment, 70% don't use herbicides, 60% don't apply mineral fertilizer and 75.8% apply organic fertilizer (Figure 4.4). Those households who apply fertilizer, the dose of fertilizer (mineral and organic) per unit area is low.

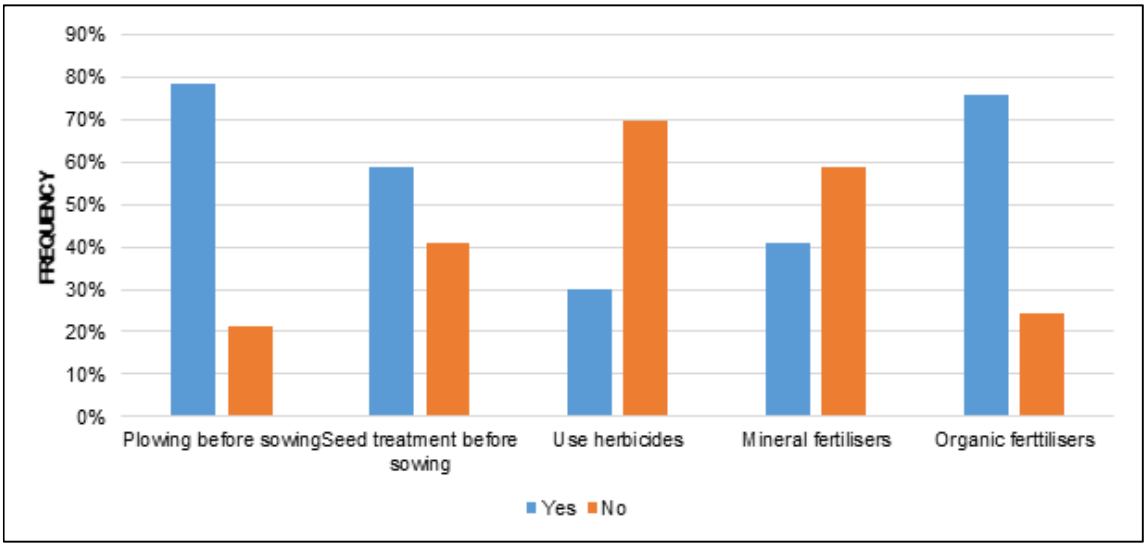

Figure 4.4. Crop management practices in households from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Farmer variety selection criteria

The farmers were asked to give two to three main criteria for selecting a variety and to rank them.

Seven main criteria were cited by farmers for selecting a variety. Thirty four percent (34%) use yield potential as their major criteria for selecting a variety, 25.7% for earliness, 14.7% for grain color (white), 7.9% for drought tolerance, 6.4% for *Striga* tolerance, 5.7% for grain size and 5.4 % for adaptation to the environment (Figure 4.5).

Differences in preferences among traits reflected different uses of varieties (food, cash, etc.) and the agro-ecological conditions in which varieties are grown (poor soil, drought prone area, unpredictable rainy season, etc.). A large number of farmers are interested in early maturing varieties because they consider earliness enables crop to escape late season drought at the same time mitigates hunger.

Another twenty three percent of farmers list yield potential as the second most important criteria for selecting a variety. Other traits listed as the second most important were white grain color (15.1%), drought tolerance (12.5%), earliness (11.7%) and grain taste (9.1%) (Figure 4.5). White color and good taste of grain are generally preferred by farmers for food. Vitreous grain (hard grain) is preferred for good food quality, floury grain for couscous and grain size is important for sorghum-rice and porridge.

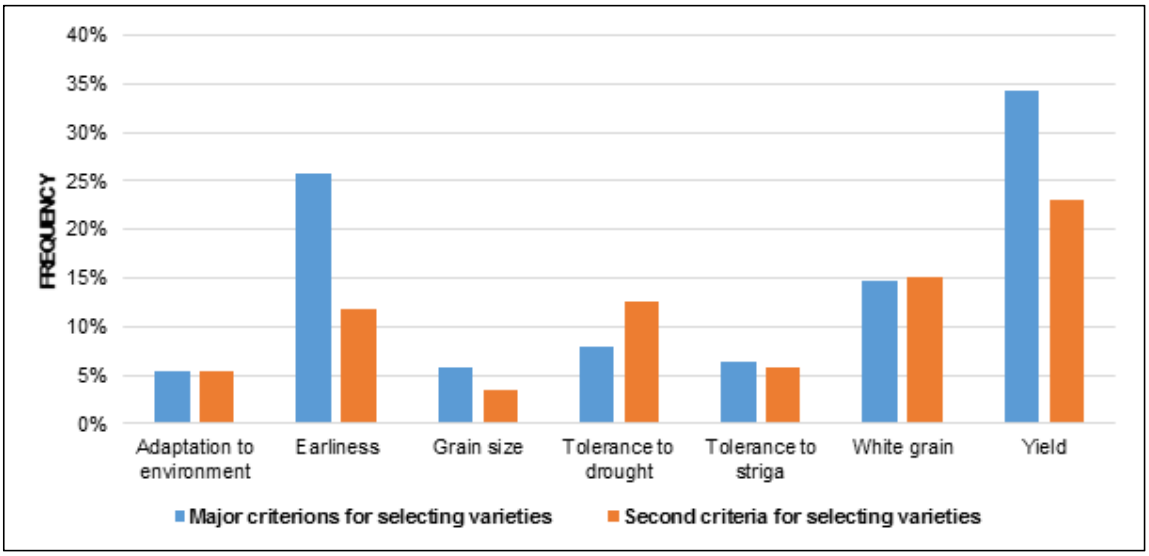

Figure 4.5. The criteria for selecting which varieties to grow from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Do the varieties that farmers grow satisfy the preferences cited?

Farmers were asked if the varieties they grow fit their above own cited preferences. The survey results showed that 7% of farmers largely satisfied with the varieties they grow whereas 73% of are not (Figure 4.6). These farmers hope to find other varieties.

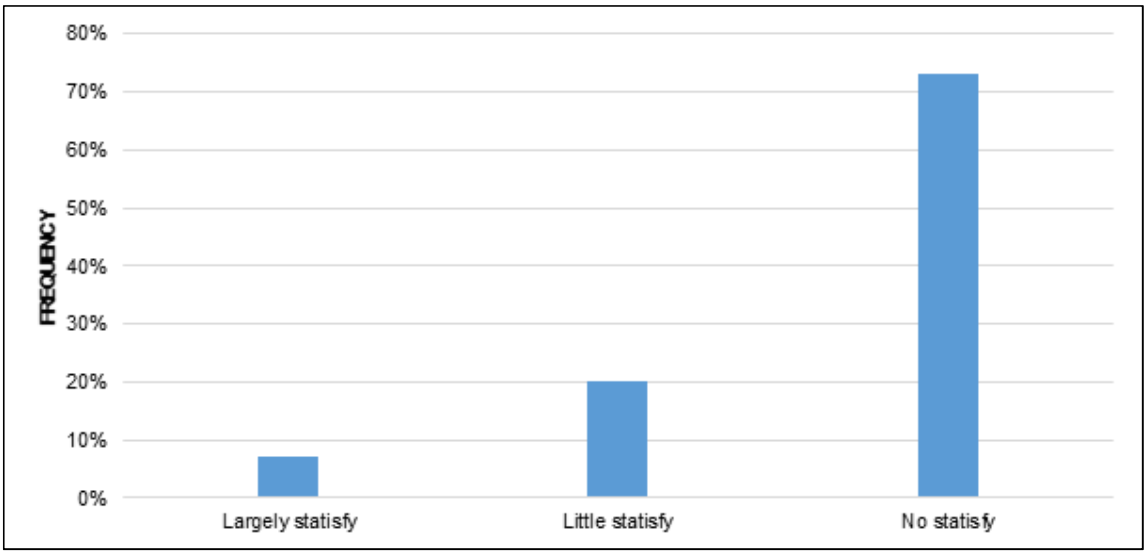

Figure 4.6. The varieties that farmers grow satisfy the preferences cited? from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Framer opinions on Sorghum low yield

Farmers cited 11 reasons for sorghum low yield (Figure 4.7). Twenty six percent (26%) of farmers indicated that sorghum low yield is mainly due to low soil fertility while 21% think it is due to lack of equipment. These two factors are socio-economic rather than breeding problems. Drought (13.2%) and poor rainfall (11.7%) were among the main reasons for low yield. Poor rainfall is defined by the majority of respondents as insufficient rain not meeting crop maturity or drought but some farmers consider it as unpredictable rains. These two factors could be combined and ranked as the major constraint followed by *Striga* infestation. Farmers also felt that soil type (sandy), late sowing and lack of improved seed are reasons for low yield.

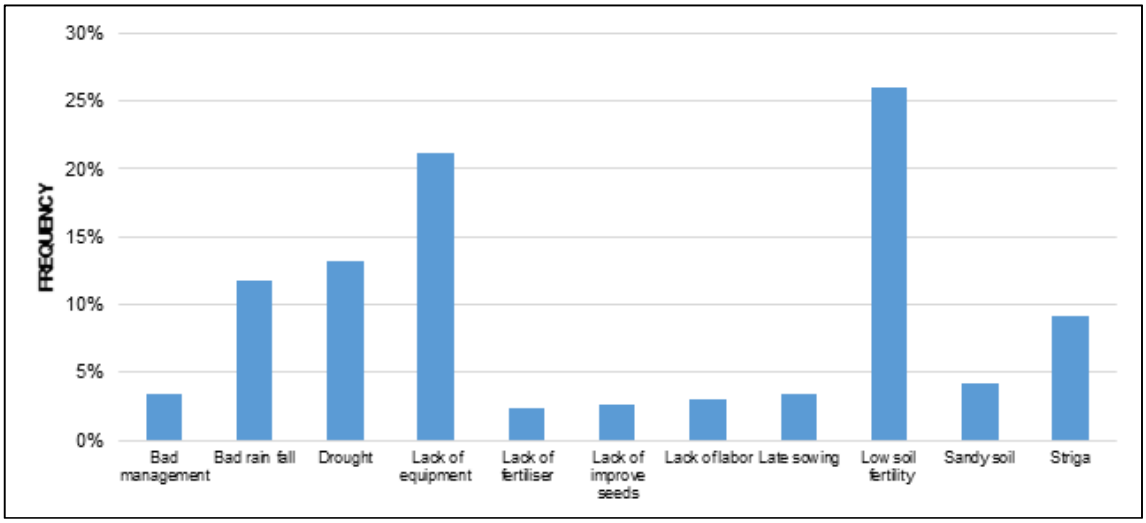

Figure 4.7. Main reasons of the low yield of the sorghum in the households from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

Suggestion by farmers to improve sorghum yield

Farmers suggested 10 solutions for improving sorghum yield (Figure 4.8). The three top solutions for improving sorghum yield were providing them with inorganic and organic fertilizers (18.5%), farm equipment (18.1%) and adapted varieties (17%).

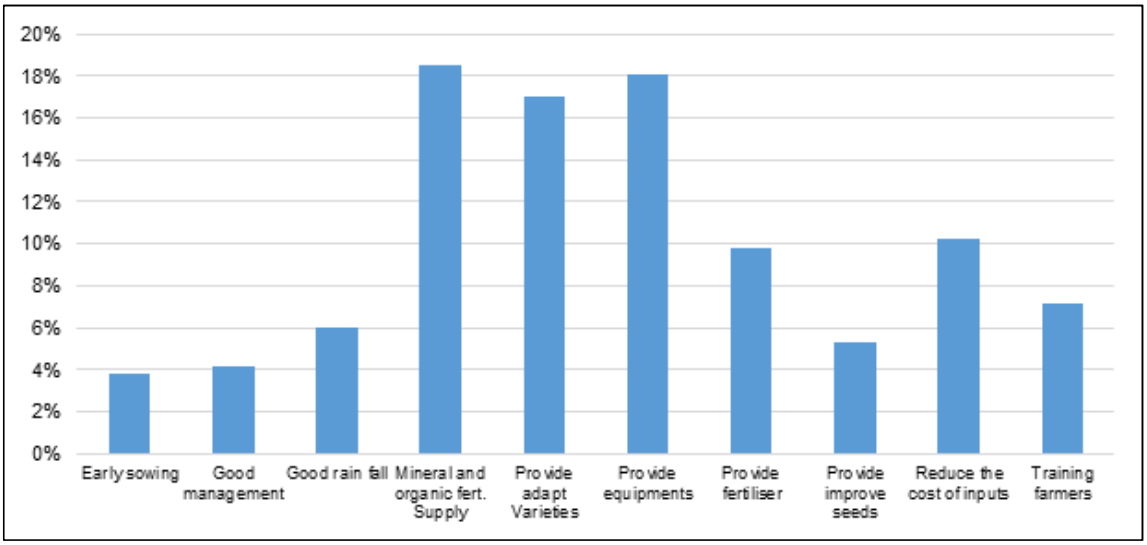

Figure 4.8. Proposed solutions to improve sorghum yield from survey conducted in 2014 in three villages (Diedougou, Kenioroba and M'Pessoba) of Mali.

DISCUSSION

The main reasons for growing sorghum in the surveyed area are grain for human consumption, crop residues for feeding animals, fencing, thatching, firewood and compost (organic fertilizer). Similar finding were reported by Mathieu [11] in Mali. Also Ketema [12] reported that sorghum is a high priority staple crop ranked as 1st, 2nd and 3rd in Ethiopia, Sudan and Uganda, respectively.

Major sorghum production constraints are low soil fertility, high cost of inputs, lack of farm equipment, drought, poor rainfall and lack of training of farmers. Soil fertility problems (decreasing of fertility and cost of inputs) and lack of farm equipment are among the main constraints of sorghum production in Mali and sub-Saharan Africa [13]. The report of the Ministry of Rural Development (MDR) of Mali [14] indicates that climatic risks,

human and animal demographic growth, entail an overexploitation of farmland. This demographic growth is manifested by an increase in farmlands leading to the cultivation of marginal lands for agricultural, causing reductions of forest and pastoral lands, There are also reductions on fallow times threatening the renewal of soil fertility due to nutrient depletion Mali [14].

Despite numerous efforts in recent years to curb land degradation, the phenomenon persists and becomes more and more disturbing in Mali. Today, soil degradation, characterized by decrease in fertility and crop productivity is a major constraint in all eco-systems and a great concern both for producers and authorities of Mali [14].

Very little mineral fertilizers are used in sorghum production. Indeed, without subsidies, the prices of inputs (fertilizers) compared to the income from crops such as pearl millet, maize, and sorghum are out of farmer reach (fertilizers are not cost-effective). The use of the organic manure is limited because most farmers are without sufficient farm equipment especially cart and draught animals. Few farmers have donkey carts for farm work. Lack of farm equipment in Mali was also reported by Mathias [15]. Farms in African agriculture, especially sub-Saharan Africa, rely on human muscle power and is based on operations that depend on the hoe and other hand tools. For farmers to earn a living from agriculture, they need improved technologies. One of the major constraints to the augmentation and modernization of production is poor farming equipment and low level of engineering technology inputs into agriculture. In Mali Mathias [15], the provision of required agricultural technology to farmers is still low with only 35 percent of farmers having some form of mechanization technology.

Drought and unpredictable rains are important factors limiting sorghum production in Mali. According to the Intergovernmental Panel on Climate Change IPCC [16] and Siart et *al.* [17] claimed that the length of the rainy season has decreased since the severe droughts of the early 1970s in Mali and mean rainfall has decreased by 20-49% between the periods 1931-1960 and 1968-1997. Climate change is expected to have drastic consequences in Mali leading to cereal yield decrease from drought and declining soil fertility, expansion of cultivated areas to compensate for low yields, reduction of livestock due to shrinking grazing areas and reduction of fauna and fishing resources Kandji et al [18]. Boyer and Westgate [19] reported that drought is the most important cause of crop yield loss, especially in water-limited areas where most of the world's poorest farmers live.

Limited training of farmers is also a serious problem. To combat the effects of climate change, many varieties and new production and management skills have been suggested by Malian research institutes and ICRISAT to improve productivity but farmers have very limited information on these new varieties and management skills. Juma [20] reported that Africa's productivity is also constrained by lack of diffusion of improved technology for agricultural production.

An important finding of this study was that the majority of sorghum varieties grown by farmers are local early maturing landraces. This is due to their adaptation, grain qualities and pest resistance. This is consistent with the results of Toure *et al.* [21]. The adoption and access to improved sorghum varieties is still poor in the study areas. The main seed sources in households are farmers' own production, as also reported by Siart *et al.* [17] in "Mandé" in southern Mali.

Criteria for selecting varieties are highly variable, which is due to the size of the production area of sorghum in Mali. It spreads across all the agricultural humid regions to Sahelian (semis arid) regions and sorghum is grown by several ethnic groups with very diverse socio-economic and agro-ecological characteristics. The top criteria for selecting a variety were high yield potential, earliness, grain quality (color, taste and size), tolerance to drought and *Striga.* Studies conducted in southern Mali (Dissan/Bougouni) by Lacy *et al.* [22] showed similar findings.

Goita *et al* [23] on conducted survey on rice: they reported that fertilizer cost, water management, lack of agricultural materials and declining soil fertility were identified as the main constraints of rice production. Farmer preferences for varieties were yield, taste, swelling ability, grain color and size. Similar constraints and preferences in sorghum production (excluding swelling) were identify in current study.

To improve sorghum yield, farmers propose the use of mineral fertilizers and organic manure, access to farm equipment and inputs costs reduction. These constraints have also been reported MDR of Mali [14]. Farmers also recommend improved and adapted varieties utilization and better training in farm management.

The need for the involvement of farmers in the development of new crop varieties was highlighted DeVries and Toenniessen, [24]. They advocated that farmers should be involved in all aspects of variety development including priority setting, early generation selection, variety testing and selection so that breeders obtain regular input from farmers that enables them to structure their selection indices accurately.

BREEDING OPPORTUNITIES

Survey results identified several breeding opportunities for improving sorghum yield requested by farmers. Drought and *Striga* are considered the most important factors limiting sorghum production in Mali. Farmers link *Striga* with poor soil fertility and manage it by providing fertilizers and weeding. For drought management, farmers use early maturing varieties, early sowing and planting in low lands. These methods cannot always overcome drought because early maturing varieties are not always drought tolerant, and drought can occur at any stage of

the growing season. In addition, yield potential of some early maturing varieties are low compared with late maturing varieties.
Farmers' major criteria for selecting varieties are high yield, grain quality (color, taste, size etc.), and drought tolerance. Further improvement of sorghum must take these selection criteria into consideration.

CONCLUSIONS

The PRA activities showed the importance of sorghum and identified production constraints in the study areas. It also provided information on the types of sorghum varieties grown by farmers and their agronomic practices (management). The study identified farmer sorghum variety selection criteria for their varieties and gave suggestions on how to improve sorghum yield. Understanding farmers' preferences will help plant breeders to know farmer needs. PRA findings are the starting point for improved variety development and easy adoption by farmer.

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