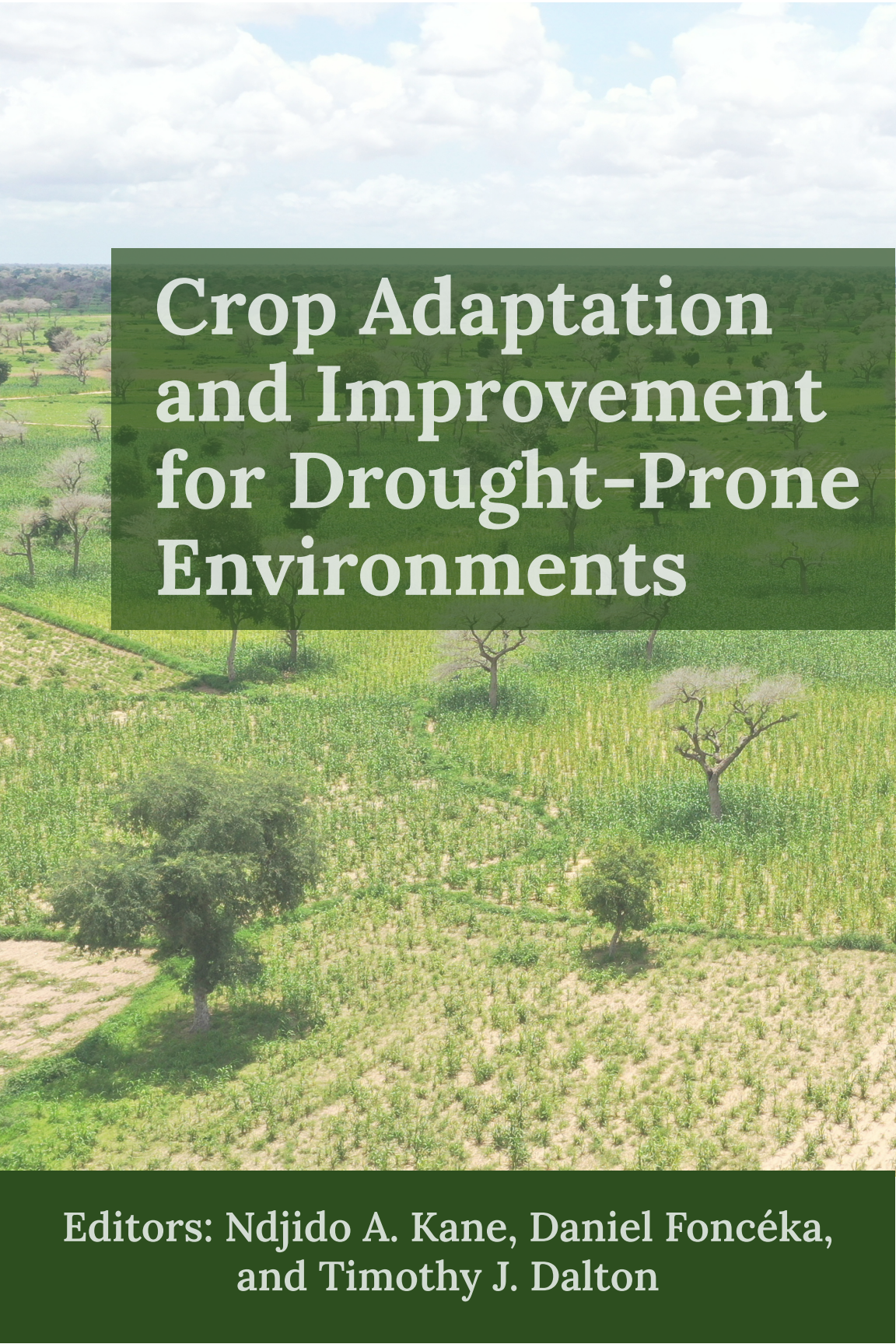

Crop Adaptation and Improvement for Drought-Prone Environments

Editors: Ndjido A. Kane, Daniel Foncéka, and Timothy J. Dalton

Cover image courtesy of: Alain Audebert (CIRAD), August 2021.

Farmers fields with millet and groundnut grown in rotation in a *Faidherbia albida* park located in the Groundnut Basin (Niakhar, Senegal).

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PART I

SOCIO-ECONOMIC ANALYSIS OF DRYLAND CROPS PRODUCTION

2. Assessment of Farmers' Groundnut Varietal Trait Preferences and Production Constraints in the Groundnut Basin of Senegal

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Abstract

Groundnut is a cash crop that generates income and improves the livelihoods of smallholder farmers in several developing countries. Although Senegal is one of the major producing countries, the national average grain yield remains low. A participatory rural appraisal was conducted in the Groundnut Basin of Senegal in 2015 and aimed to assess farmer perceptions of production constraints and varietal trait preferences. Ninety farmers were randomly selected in nine villages distributed across three regions of the Groundnut Basin. Data was collected through Focus Group Discussions (FGDs) and Semi-Structured Interviews (SSI). The results of the study indicated that seed availability was the most limiting factor in groundnut production across villages. Low soil fertility and storage insect pests were the second and third most important constraints respectively. Other constraints included limited access to land, drought, and commercialization. Among varietal traits, farmers unanimously considered pod and haulm yields as the most important. Other important traits mentioned were adaptation to drought, high pod weight, and earliness. These production constraints and varietal trait preferences should be taken into consideration when defining

the groundnut product profiles of the national breeding program in order to improve productivity and increase the adoption of newly bred cultivars.

Keywords: groundnut, production constraints, farmers, trait preferences

Introduction

Groundnut is one of the most important oilseed legumes grown worldwide. Asia and Africa account for more than 90% of global groundnut area and it is cultivated mostly under rainfed conditions by small-scale farmers. The African continent accounts for 31.1% of total global production (FAOSTAT, 2018). In Senegal, groundnut occupies a central role in the agricultural economy since its introduction by explorers in 1836. Historically, the Senegalese economy has relied on groundnuts, which accounts for up to 60% of GDP, 80% of export earnings, and more than half of the planted area from 1961 to 2020 (FAOSTAT, 2020). The crop was grown throughout the country, and particularly in the central area called the Groundnut Basin.

Over recent decades, the contribution of groundnut to GDP has declined. Groundnut production has been reduced due to numerous factors. These include a long drought period starting in the 1970s and continuing to the present. Added to this is poor soil fertility, climate change, a disorganized value chain, inconsistency of the various governmental and donor policies, and the low adoption of newly developed agricultural technologies. A study conducted by Faye et al. (2019) on the adoption rate of improved varieties of main crops grown in Senegal showed evidence that improved groundnut varieties are not widely adopted by farmers; the reported rate is 55%. In the same report, results also showed that the varieties that are cultivated have an average age of more than 10 years. This shows a low penetration of new varieties in the farming environment. Some authors explain this situation by an inadequate awareness, omission of farmers during the process of cultivar development, and farmers' fear of taking risks in testing varieties that are not yet well known by the majority (Ceccarelli & Grando, 2007; Omanya et al., 2007).

Technology transfer to farmers is one of the major bottlenecks of many agricultural projects in Africa. Efforts should concentrate on improving the access to the developed innovations because technological change in

agriculture is essential for reducing poverty and stimulating economic growth, particularly in low-income countries (Dhirifi, 2014). It is also important that the technologies developed and proposed consider the needs of the target users. This shortcoming has opened the way to alternative approaches for increasing the rate of technological adoption by farmers (Chambers, 1994; Duraiappah et al., 2005).

Participatory rural appraisal (PRA) is one of the most popular strategies. PRA enables local farmers to mobilize and participate in the early stages of technology development. In the particular case of plant breeding, the involvement of farmers as an integral part of the process ensures the participation of the most important stakeholders in the definition of breeding objectives and therefore influences the direction of the research. Plant breeders cannot respond to every quirk of farmers' circumstances but the relevance of breeding research in poor nations can be improved (Haugerud & Collinson, 1990; Sattar et al., 2017). The main objective of most PRA approaches is for a better incorporation of farmers' technical knowledge and identification of research priorities into the breeding programs to develop varieties that meet their needs (Morris & Bellon, 2004). PRA results guide the breeder to focus on farmers preferred traits while addressing the constraints prevailing in the production areas. Many studies, such as Ceccarelli and Grando (2009), reported that PRA approaches enhance the adoption of newly bred cultivars.

To date, there is scant formal documentation on the main groundnut constraints and the traits preferred by farmers in Senegal. Existing documents refer to commercialization aspects and to the diagnosis of the problems related to the whole value chain (Dia et al., 2003; Georges et al., 2016; Ndiaye, 2018; Noba et al., 2014). Agricultural extension agencies have often reported low soil fertility and drought as the major constraints to groundnut production in Senegal. However, the scientific method has not been used to ascertain groundnut production constraints and farmers' preferred traits.

Such studies have been conducted and published in most groundnut growing countries of West Africa. In the study conducted by Coulibaly et al. (2017) concerning two main groundnut production zones in Niger, drought appeared as the major constraint affecting production, followed by low soil fertility. In Burkina Faso, besides organizational difficulties (i.e., access to

credit and access to material, among others), pest attacks and drought were identified as important constraints followed by diseases (Boubacar et al., 2020). As a starting point for the breeding program in Togo, a PRA was conducted in three regions, identifying leaf spot diseases, rosette, groundnut bud necrosis, and insects, such as pod sucking bug and bruchid, as the most important constraints limiting the production (Banla et al., 2018). High pod yield is the most preferred trait in almost all reported studies. However, pod size and oil content were the second and third preferred traits in the Savanes region in Togo, and early maturing in Niger (Banla et al., 2018; Coulibaly et al., 2017).

The PRA approach has been widely used across Africa for other crops including potato, maize, cowpea, cassava, sweet potato, and pearl millet (Abakemal et al., 2013; Baafi et al., 2015; Egbadzor et al., 2013; Kanfany et al., 2020; Muhinyuza et al., 2012; Njoku et al., 2014). Those studies clearly established that constraints and the trait preferences of farmers for a given crop are location specific. Hence, plant breeders should consider both local adaptation and, when possible, adaptation to a wide range of environments when developing a new cultivar (Omanya et al., 2007). This study applies PRA to gather information and farmers' knowledge to identify groundnut production constraints and to assess traits preferred by farmers in the Groundnut Basin of Senegal. This will serve as important background information to the breeding program and will enable the development of more popular varieties that meet farmers' needs for wide adoption.

Materials and Methods

1. Study Areas and Sampling

The study was conducted between March and April 2015 in the Groundnut Basin located in central Senegal, where groundnut and pearl millet are the predominant crops (FAOSTAT, 2015). Three representative groundnut-growing regions of Senegal, Kaolack, Kaffrine, and Tambacounda, were purposefully selected based on the importance of groundnut in terms of production and area (Table 1). During the 2014 cropping season, these three regions accounted for 39% of the national groundnut area and over 42%

of total groundnut production (FAOSTAT, 2015). With the help of the local extension officers, one department was selected in each region based on the number of farmers and farmers' organizations in the department. Three villages were then selected in each department according to their accessibility and the importance of groundnut production.

Table 1
Characteristics of Selected Groundnut Production Regions in Senegal

Regions	Cultivated area (ha)	Production (mt)	Precipitation (mm)	Selected communities
Kaffrine	209,100	272,570	655	Kathiot, Kahi
Kaolack	169,843	223,001	655	Guinth Kaye, Kaymor, Porokhane
Tambacounda	104,210	161,941	741	Koussanar, Makacolibatang
Senegal	1,134,330	1,432,086		

Nine study sites were considered in the study (Figure 1). The villages were located in seven rural communes: three in Kaolack, two in Kaffrine, and two in Tambacounda. A focus group discussion was held in each of the selected villages to develop a general idea of groundnut cultivation in the corresponding area. In addition, within each village, 10 farmers were randomly selected for semi-structured interviews, creating a sample of 90 producers.

Figure 1

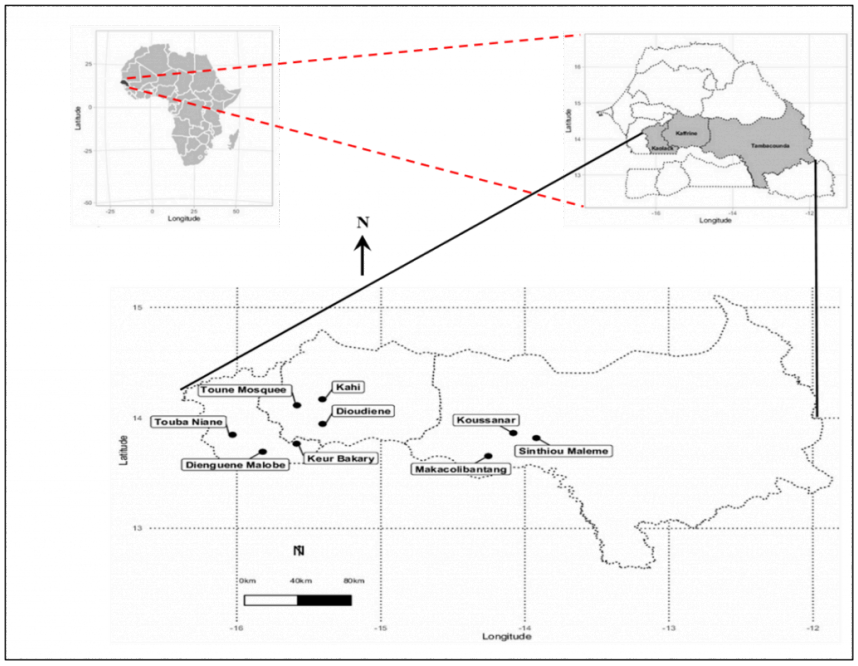

Figure 1 – Map Showing Sampling Locations in the Groundnut Basin

2. Data Collection and Analysis

Local extension staff at the respective localities facilitated the PRA process by mobilizing farmers to participate in the focused group discussions. Both formal and informal approaches were employed to collect data for the study. The informal approach was used to generate information on farmer perceptions at the community level. The discussions involved nine focus group discussions (FGDs) with one at each village. Each focus group comprised of 10 to 17 farmers. The FGDs were standardized using a checklist of topics to be covered. The topics discussed included farm characteristics and farmers' agronomic practices, farmers' trait preferences for groundnut varieties, marketing of their products, and the perceived constraints affecting production.

The group discussions were followed by formal interviews using semi-structured questionnaires to explore issues that were more specific.

Individual farmers were surveyed using a semi-structured questionnaire to collect information on production constraints and farmer's preferences for varieties. This enabled each individual farmer to express their opinion independently.

Scoring and ranking techniques were used to assess farmers' varietal trait preferences and constraints to groundnut production. Data was coded and entered in Microsoft Excel. Analysis was conducted using Statistical Package for the Social Scientists (SPSS version 19) and summarized into percentages and means. Variables were subjected to descriptive statistics, cross-tabulation, one-sample t (two-sided), and Fisher tests. R was used to draw the map showing the PRA sites.

Results

1. Demographic and Socio-economic Characters

In the studied sites, mostly men produce groundnut. The sex ratio is 88.9% males to 11.1% females (Table 2). In our sample, 72.22% of the respondents were farmers by occupation while 27.78% had additional income-generating activities. Most of the interviewed farmers (82.23%) were uneducated. A few (8.89%) possessed a primary school certificate and 5.56% a secondary certificate. The age of respondents ranged between 35 and 60 years. The proportion of the active population that were groundnut producers was 71.11%. Most of the farmers (63%) did not have any form of support or training and only 36% of the farmers belonged to a farmers' association.

Figure 2

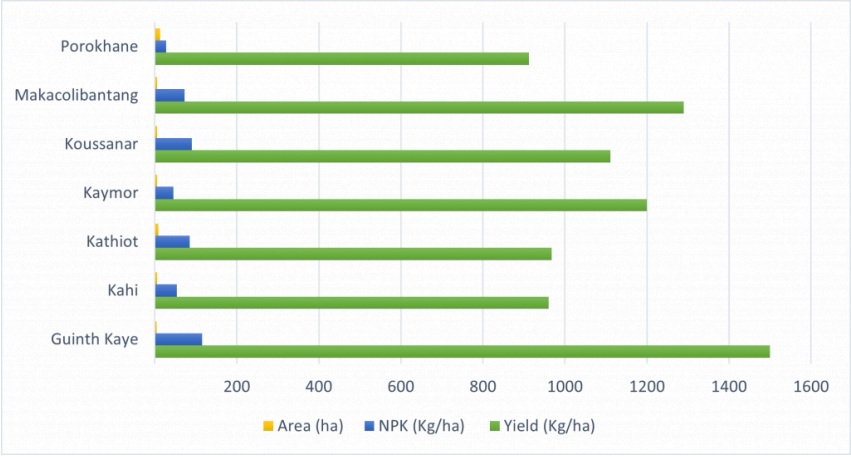

Figure 2 – Average Pod Yield Obtained as a Function of the Area and Application Rate of Mineral Fertilizer

2. Groundnut Importance and Production Level

The selected rural communes were predominantly groundnut producing areas, but other crops, like cereals, played a key role in the agricultural system. The average landholding varied from 1 to 30 ha and there was a significant difference in the importance of the crops grown in each location. A ranking of the importance of groundnut compared to other crops was completed based on the cultivated area allocated to groundnut and the production level. As expected, in almost all rural communes, groundnut occupied the largest share of land and was ranked first with an average mean rank of 1.3. In the central part of the peanut basin (Kaolack, Kaffrine) groundnut was the most important crop followed by pearl millet. Elsewhere in the eastern part of the country (Tambacounda), corn or sorghum were ranked as the second most important crop. Mean comparison of yields reveals significant differences between localities ($p = 0.042$). The average estimated grain yield in 2014 was 1,112 Kg ha-1. The highest estimated grain yield (1,500 Kg ha-1) was recorded in Guinth Kaye, while the lowest value 0.9 Kg ha-1 was recorded in Porokhane. Both localities are in the same region (Kaolack). A similar trend was observed for the application of fertilizer

(Figure 2). On average, 116 Kg ha-1 of NPK fertilizer (6-20-10) was recorded at Guinth Kaye while 28 Kg ha-1 was recorded at Porokhane.

Table 2
Average Socio-demographic Profile of Interviewed Farmers by Region

Variables					
	Kaolack	**Kaffrine**	**Tambacounda**	**Total**	**%**
Gender					
Female	3	3	4	10	11
Male	27	27	26	80	89
Age					
<15	0	0	1	1	1
15-35	3	5	5	13	14
35-60	18	15	18	51	57
60"}">>60	9	10	6	25	28
Education					
Koranic school	27	20	12	59	66
Local language	1	8	6	15	17
none	1	1	1	3	3
Primary	0	1	7	8	9
Secondary	1	0	4	5	6
Member of a Farmer Organization					
No	26	17	11	54	60
Yes	4	13	19	36	40
Occupation Other than Farming					
No	10	7	8	25	28
Yes	20	23	22	65	72
Subsidy from the Government					
No	25	19	19	63	70
Yes	5	11	11	27	30
Received Training in Groundnut Cultivation					
No	30	24	20	74	82
Yes	0	6	10	16	18

3. Varieties Grown and Their Provenances

Five known and named varieties were cultivated in the surveyed zones: GH119-20, 73-33, 28-206, Fleur 11, and 55-437 (Table 3). There were differences in the most commonly planted varieties by location (Figure 3). Out of the five varieties, 73-33 was the most cultivated and was ranked first in almost all rural communes except in Guinth Kaye, Porokhane, and to some extend Kaymor, where either 28-206 or GH119-20 were more commonly cultivated.

Table 3
Attributes of the Cultivated Varieties

	Attributes						
Varieties	**Released Year**	**Pod Yield (t/ha)**	**Haulm Yield (t/ha)**	**Cycle (Days)**	**100 Seed Weight (g)**	**Seed Size**	**Main Use**
GH119-20	1960	1.5-2	2-2.5	110	85-90	large	confectionery
73-33	1973	2-2.5	1.5-2	110	50-52	medium	oil
Fleur11	1995	2.5-3	2	90	50-55	medium	oil-confectionery
55-437	1994	1.5-2	1	90	35-38	small	oil
28-206	1928	1.5-2	1.5	120	45-49	small	oil

Figure 3

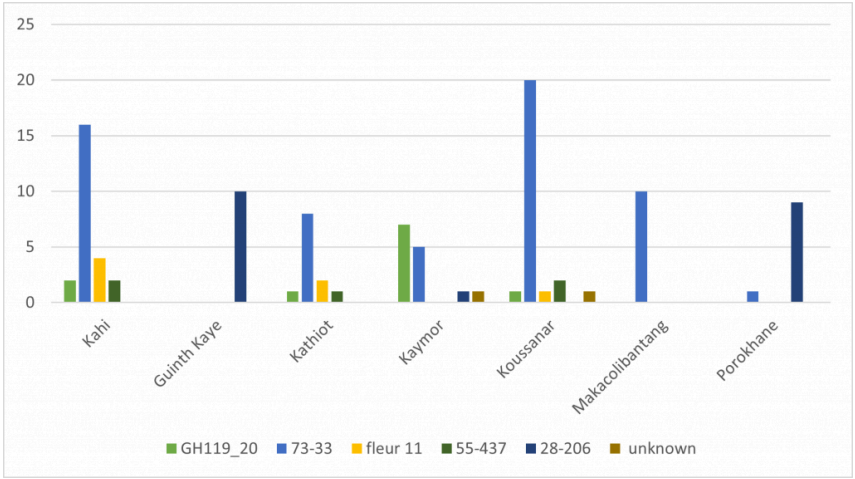

Figure 3 – Popular Varieties Cultivated in the Studied Sites

The variety 73-33 was the most grown across all the studied sites. The 28-206 was specific in Guinth Kaye and Porokhane and the variety GH119-20 was present in Kaymor. Fleur 11 was not very popular in Kaffrine (Kahi and Kathiot). A small portion of respondents (2%) did not have any idea about the type of variety they grew. Most farmers (83%) recycled seed by keeping a portion of the previous harvest. Only 20% obtained government-subsidized seeds or procured them from the local market. It was only in Koussanar, a rural commune of Tambacounda, where farmers were organized in a cooperative and multiplied their seed for the next coming growing season.

4. Trait Preferences

The mean rankings of farmer-preferred traits for groundnut varieties are presented in Figure 4. Characteristics with the smallest mean rank (1) are perceived to be the most important and the highest value (5) is considered as less important. Except for tolerance to biotic stresses (P = 0.007), where a significant difference was observed between rural communes, traits were ranked similarly by farmers interviewed in the study zones. Most of the farmers identified haulm yield as the second most important characteristic after pod yield, except in Koussanar where good pod filling was ranked

highest. The same locality identified erect plant stature as an important groundnut characteristic for variety adoption. High seed weight is also a preferred feature for groundnut growers in Kahi, Kathio, Kaymor, and Makacolibatang. Other important traits mentioned were adaptation to abiotic stresses such as short cycle and tolerance to drought. Tolerance to biotic constraints like resistance to leaf diseases is desired in groundnut variety. In general, farmers from the different sites did not consider good taste as an important trait for groundnut variety.

Figure 4

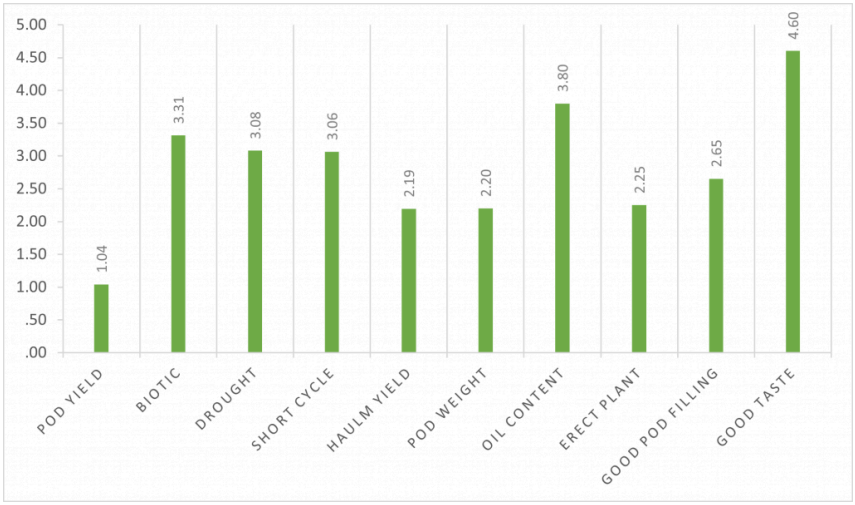

Figure 4 – Farmers Preferences for Groundnut Variety Traits Across Rural Communes

5. Production Constraints

Prioritization of the constraints was based on the mean ranking given by farmers. These constraints were identified and listed during the focus group discussions. Each interviewed farmer further ranked them (Table 4). Characteristics with the lowest mean rank are classified as the most important. The most important constraints mentioned by farmers across sites were seed availability, land degradation, insects at storage, and land availability. Drought was ranked fifth, with a significant difference between sites. Marketing and leaf diseases were ranked sixth and seventh respectively with substantial differences in farmers' responses in ranking marketing.

These constraints were common to groundnut growing areas but the order varied from site to site. Insects, mainly pod-sucking bugs (Pentatomidae and Lygaeidae) and groundnut bruchid (Bruchidae), were considered the most common constraint to groundnut storage and were ranked as the most important in Kathiot alongside leaf diseases. Lack of tools was ranked in Koussanar, Kaymor, and Kathiot as an important constraint. Regarding drought, there was a noteworthy difference between respondents in their respective studied areas. More than half of the respondents (58%) did not classify drought as a major constraint to groundnut cultivation, while the remaining participants (42%) said the opposite. The damages were not so important and drought at the vegetative stage of the life cycle was more frequent. However, terminal drought caused more damage when it happened.

Table 4
Relative Ranking of Major Groundnut Production Constraints by Location

Constraints								Total		
	Guinth Kaye	Kahi	Kathiot	Kaymor	Koussanar	Maka	Porokhane	Mean	F	Rank
Land degradation	2.31	2.33	2.2	2.06	1	1	4.66	2	0.47	2
Storage insects	4.01	2	1	3	2.4	1.56	4	2.04	0.063	3
Leaf diseases	3.89	2.78	1	1	2	3.2	3.41	2.56	0.406	7
Drought	4	2.67	3	3.67	1.75	1.75	4	2.36	0.023*	5
Land availability	2.17	1	3	2	3.71	4.1	3	2.13	0.597	4
Seed availability	2.8	1.63	2	1.6	1.67	2.2	2	1.91	0.145	1
Commercialization	3.44	2	2.5	3	1.75	2	2.4	2.5	0.018*	6
Lack of tools	5	3	2	2.4	1.67	2.5	2	2.58	0.047*	8
Cattle damage	5.07	4.22	4.34	3	3.5	4	5	3.33	0.667	9

Note. Characteristic with the smallest mean value is perceived to be the most important. *Significant at 0.05

Discussion

The presence of women farmers (11.1%) in this study was very low and reflects their limited access to land. One major consideration of this situation is socio-cultural. In Senegal, land acquisition is through inheritance from father to son. Another aspect that contributes strongly to this imbalance is the status of the family chief, typically conferred to the man who theoretically is in charge of the family's daily expenses. The limited involvement of women in groundnut cultivation has also been reported in other countries of West Africa (Banla et al., 2018; Oppong-Sekyere et al., 2015). Women do not own land, but they are involved in the cultivation. Arable land access is a real problem for women in West Africa, particularly in Senegal. PRA conducted on sorghum and pearl millet reported limited access to land by women, justifying their low involvement in the production (Kanfany et al., 2020). Conversely, in Burkina Faso, Sinare et al. (2021) highlighted the large involvement of women (more than 50%) in groundnut cultivation despite their limited and unequitable access to production resources. A similar situation was reported in Tanzania where men and women were equally involved in groundnut production (Daudi et al., 2018). Women's engagement in groundnut cultivation is socio-culturally specific.

Because the constraints listed by the farmers in the studied sites involve different actors of the value chain, we classified them into two categories. The first group included seeds availability, land availability, and commercialization. The second group encompassed low soil fertility, insects at storage, drought, and leaf diseases. The consistency of ranking the first group of constraints over the communities suggests that these are major constraints affecting groundnut production in the Groundnut Basin. These difficulties are similar in that the government and the private sector plays a greater role than research in helping farmers solve these problems. However, it is important to underscore the efforts made by the government to reorganize and make the groundnut sector more efficient. The most recent is the Program for Accelerated Pace of Agriculture (PRACAS) with a seed capital reconstitution program of 3.5 billion CFA. This program aims to

provide producers with a quantity of quality seeds. These efforts are beneficial, but it is more than important to put in place a system or tool to estimate the needs and consequently establish a production plan of the first generations in terms of seed multiplication (G1, G2, and G3). The traceability of the subsequent levels (G4, R1, and R2) allows one to know in real-time who has which variety, what level, where, and when the product will be available. The answers to these different questions will help resolve in part the availability of seeds, one of the major constraints.

In the second group, low soil fertility, insects at storage, and drought were identified as major constraints limiting the production, followed by leaf diseases. This finding confirms the deteriorating state of soil fertility in Senegal reported earlier by previous studies conducted in the same regions (Kanfany et al., 2020). Senegal falls in the Sahelian zone and is subjected to different scenarios of drought characterized by unequal distribution of rainfall in both time and space. Consequently, the production of many crops is threatened yearly by the interannual and across location rainfall variability. Almost all West African countries identified drought as a major constraint to groundnut production (Banla et al., 2018; Coulibaly et al., 2017; Oppong-Sekyere et al., 2015 ; Ntare et al., 2008). In the present study, drought is perceived to be more important in the eastern part of the Groundnut Basin in the Tambacounda region (annual average rainfall 800 mm) than in the central zone (average annual rainfall between 500–600 mm). This paradoxical situation could results from the rainfall distribution and the type of cultivated varieties. In fact, 73-33, a long cycle variety (110 days), was the most cultivated in the eastern zone; in the central areas a mix of medium and short cycle varieties was grown (55-437 and Fleur 11, 90 days). The most drastic years in groundnut cultivation in Senegal were 2002 and 2011, due to low and erratic rainfall patterns. The impact of such events is not only extremely damaging, but also lasting. Farmers revealed that the rainy seasons become shorter from year to year. Therefore, short cycle varieties are wanted. However, it is important to report that during FGD, farmers in the studied areas did not want extra-early maturing varieties because such varieties might be the first to mature in an area and therefore might suffer from too much rainfall and from livestock damage. They need groundnut varieties that can mature early and escape the drought before it sets in. Drought tolerance was unevenly ranked for any given site, showing that they depended greatly on specific localities. Therefore, the development

of varieties better adapted to drought becomes an important breeding objective for each specific location.

In Kathiot and Kaymor (Nioro zone), leaf diseases were the major constraint that affected groundnut production; in other localities, leaf diseases were not perceived by farmers as important. The traditional measure taken by farmers to deal with leaf diseases and soil borne diseases in the study areas was crop rotation. Primarily, groundnut is cultivated in rotation with pearl millet in most of the studied zones or with other cereal species such as sorghum, maize, rice, and fonio. Crop rotation plays an important role in groundnut management. It is known that crop rotation is beneficial to restore soil fertility, as well as to prevent crop pests and soil borne diseases. According to farmers, crop rotation is a good strategy that can restore soil fertility and avoid severe leaf diseases. These results indicated that breeding for improved drought tolerance and leaf disease resistance should constitute major breeding objectives to ensure high yield and varietal acceptance by farmers in specific zones.

High pod yield is the most preferred trait reported in most studies conducted on groundnut across Africa (Banla et al., 2018; Coulibaly et al., 2017; Ntare et al., 2008; Oppong-Sekyere et al., 2015). Contrary to the findings reported by Banla et al. (2018) in Togo, where pod size and oil content followed high pod yield as the most important traits, in the present study, high biomass yield was ranked as the second preferred trait in all study areas. This is attributed to the high feeding values of groundnut haulm to animals and the Sahelian context of Senegal. Hence, breeding for dual purposes, high pod and biomass become essential for variety adoption. Farmers gave much importance to seed and pod size in the study and correlated big pod size to high pod yield. However, scientific studies have shown that there is no correlation between pod yield and morphometric characteristics in the Sahel (Foncéka et al., 2012). Another important consideration for farmers is the attractiveness and the marketability side of large pods and seeds. The fact that groundnut is a cash crop could justify why farmers paid much attention to pod and seed size. These findings corroborate the importance of large pods and seeds reported in West African countries, especially in Togo, Burkina, and Ghana (Banla et al., 2018; Sinare et al., 2021. In the past, groundnut was initially cultivated for its oil correlated to maturity. Oil content and good taste received little attention at the farmers'

level in the present study. This result could differ if the survey had considered the perspectives of industrial processors and end-users. These suggest that in the selection process for new improved varieties, yield and yield-related traits must constitute the primary selection criteria for a new improved variety to be accepted by farmers. The agreement between farmers and breeders in some of the criteria used for selecting groundnut varieties suggests the need for collaborative work to improve the efficiency of selection.

Conclusion

In view of the results, it appears that breeding efforts should focus on developing high yielding (pod and biomass) and early-maturing varieties that will minimize crop loss through drought escape. To increase adoption and meet farmers' needs in the Groundnut Basin of Senegal, groundnut breeders should take into consideration the varietal preferences identified. The soil degradation identified by farmers as a major constraint lays down a multidisciplinary research approach based on innovative practices to limit and prevent soil degradation. The findings also call out the government and the private sector on land issues, access to equipment, seed availability, and commercialization, all identified as major constraints to increasing groundnut productivity.

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