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On-farm participatory evaluation and selection of crop varieties at climate changes in Southern Niger

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Participatory varietal selection (PVS) is one of the most rapid and cost-effective ways for breeders, farmers, and agronomists to identify high-yielding and well adapted varieties to current climate threats and to obtain feedback from the potential end users in the early phases of the breeding cycle (s). On the other hand, a participatory evaluation of improved and local varieties of pearl millet, sorghum, cowpea, and groundnut was conducted in Southern Niger during the growing seasons of 2020 and 2021. The farmers' varietal and trait preferences were identified through on-farm participatory variety testing and focus group discussions. The findings showed that farmers' preferred varieties match most often with scientists, and the farmers' most preferred traits in the study area were yield, yield components, and earliness. The highest average grain yields across environments were recorded from pearl millet variety ICRI-TABI, sorghum variety SSD35, cowpea variety Dan Hajia, and groundnut variety 55-437. In the study area, farmers' strategies for tackling climate change and variability included selecting early maturing varieties with high yields and tolerant to drought, pests, and diseases. These findings could be critical for increasing farmers' farming systems productivity and thereby contributing to poverty alleviation and food security in the Sahel.

Key words: Participatory varietal selection (PVS); pearl millet; sorghum; cowpea; groundnut; climate change and variability; food security.

INTRODUCTION

The recurrent drought or erratic rainfall and famine in Sub-Saharan Africa (SSA) since the late 1960s have rendered resource-poor communities vulnerable to cope with socioeconomic changes (Sendzimir et al., 2011; Glantz, 2019; Ball, 2020). As a result, the agricultural production and living standards of resource-poor people in SSA have dramatically decreased in the past decades compared to the rest of the world (Traore et al., 2015; Bjornlund et al., 2020). Thus, smallholder farmers in the Zinder region of Niger that depends on subsistence farming have become more threatened by climate variability and change. According to Jayne et al. (2021), since 2000 the agricultural production in SSA depended more on the expansion of cropped areas rather than

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productivity growth. With the limited amount of available new arable land, the food demand will have to be met through higher cropping intensification and yields. This intensification will require the use of improved agronomic management practices (fertilizers, intercropping, raised bed planting, tie-ridging, etc.) and the use of improved varieties that are high-yielding and well adapted to climate threats, for instance, more frequent droughts, heatwaves, and floods.

Minor cereals as pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) along with legume crops such as cowpea (*Vigna unguiculata*) and groundnut (*Arachis hypogaea*) are the most important crops grown in Niger. In 2019, the productions of pearl millet and sorghum (respectively 3.3 and 1.9 million tons), cowpea, and groundnut (respectively 2.4 and 0.5 million tons), accounted for 95% of the total cereal crop production and 63% of the total legume production in Niger (INS, 2020). However, the available landraces give poor field yield. The low yield is often associated with the use of unimproved local varieties/local races, low soil fertility, drought, and other biotic and abiotic stresses.

Despite the high productivity of newly improved varieties, their level of adoption is low, and the seed system is dominated by traditional varieties with low yielding potential (Singh et al., 2019). Regardless of the importance of the innovation, if the new varieties developed are not disseminated and adopted, the process of varietal innovation is considered ineffective (Bazile, 2006; Sissoko et al., 2019). For instance in Niger, according to the 2019 annual yearbook of available certified pearl millet varieties in Niger, only eight improved varieties were available for the rainy season of 2019 (MAG/EL, 2019). Among them, the variety HKP developed in 1978 by the National Institute of Agricultural Research in Niger (INRAN), accounted for 90% of the improved seeds available. The limited diversity of improved pearl millet certified seeds could be explained by the low adoption level by farmers. Farmers in SSA have their own specific preferences for crop varieties. Many studies have revealed that crops released in most developing countries have been adopted by only a few farmers, with the majority of farmers growing old landraces (Witcombe et al., 1996; Joshi and Witcombe, 1998). Understanding farmers' requirements and trait preferences is essential for wide adoption of newly developed crop varieties and production technologies (Rusinamhodzi and Delve, 2011). Farmer participation in the breeding of crop varieties for low-resource farmers is necessary to ensure acceptance and eventual adoption (Belay and Wale, 2021). Farmers' preferences can be determined through participatory plant breeding approaches (Ndiso et al., 2015; Horn and Shimelis, 2020). The PVS is a simple way for breeders and agronomists to learn which varieties perform well on-station and on-farm and to obtain feedback from the potential end users (farmers) in the early phases of the breeding cycle (Ndiso et al., 2015). It is a means for social scientists to identify the varieties that most men and women farmers prefer, including the reasons for their preference and constraints to adoption (Paris, 2011). It has shown success in identifying an increased number of preferred varieties by farmers in a shorter time than the conventional system, in accelerating their dissemination and increasing cultivar diversity (Weltzien et al., 2003; Belay and Wale, 2021). Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Witcombe et al., 2003). Various researchers (Hoffmann et al., 2007; Vom Brocke et al., 2010; Rusinamhodzi and Delve, 2011) have reported the importance of the PVS approach. Therefore, to improve the adoption level of new improved varieties, there is a need to engage stakeholders, particularly farmers in order to explore farmers' acceptance and valuation of improved crops in developing countries.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with the Catholic Relief Services (CRS), as part of the implementation of the GIRMA project, funded by USAID conducted several demonstration trials in the Zinder region of Niger in 2020 and 2021 growing seasons. This study aimed to identify farmers' preferred pearl millet, sorghum, cowpea, and groundnut varieties that fit the needs of their local communities; to increase farmers' awareness and resilience; and to enhance farmers' access to improved varieties in Niger.

MATERIALS AND METHODS

Study area

The study was conducted from June 2020 to October 2021 within the target zones of the GIRMA/CRS project in the Zinder region of Niger. The trials were conducted in the departments of Magaria and Dungass. Zinder region covers a large area of climatic and environmental zones. The rainy season lasts from May to October with rainfall peak in August. The dry season comprises a relatively cold period from November to February and a hot period lasting from March to May. In the northeast part of the region, the average rainfall is less than 100 mm / year and the vegetation is sparse of the Saharan type, while at the southern limit, it exceeds 600 mm / year. Magaria and Dungass are located on the isohyet 400–600 mm. The vegetation is of the Sahelian type, characterized by agroforestry parks, generally dominated by species belonging to Combretaceae and Fabaceae families. The study sites' soils are mainly sandy with low fertility. Soil property average values were 5.57 for pH, 1.23 g kg^{-1} for organic C, 0.08 g kg^{-1} for total N, 10.7 mg kg^{-1} for P, 0.10 $cmol^{+}kg^{-1}$ for exchangeable K, 887 g kg^{-1} for sand and 63 g kg^{-1} for clay (Maman et al., 2017). The pH level relates a very high acidity of the soil while the other parameters are very low compared to standards (Fairhurst, 2015; Traore et al., 2022).

Sites sampling

The GIRMA/CRS project in the Zinder region covers 11 municipalities viz. Magaria, Bandé, Dantchio, Wacha, Gouchi,

SBroum, Yekoua, Kwaya, Dungass, and Malawa. The villages were randomly selected from a list of villages made with the assistance of the local agricultural extension agents. Priority was given to villages easily accessible, where the community is responsive to the innovations, and where there were reports of a prevalence of undernourishment. Willing farmers (men and women) were selected based on their experience in cultivating crops and their willingness to test the varieties and share experiences. Overall, 2323 farmers were randomly selected from the 32 villages in 2020 while 688 farmers from 13 villages participated in the PVS in 2021.

Experimental details

The PVS trials were laid out on farmers' fields during the growing seasons of 2020 and 2021. A total of 44 and 39 trials were performed in 32 and 13 villages from 10 and 11 municipalities of Zinder in 2020 and 2021, respectively. Trials were conducted using a randomized complete block design. Each variety was grown in a 20 m x 20 m plot with a spacing of 2 m between plots. The plant spacings were 1 m x 1 m with two seeds per hill for pearl millet and sorghum, 1 m x 0.5 m with two seeds per hill for cowpea, and 0.5 m x 0.2 m with one seed per hill for groundnut. Each site (village) was considered as an experimental replicate for data analysis.

Crops varieties

The crops varieties evaluated included pearl millet (Nakowa ; Doubani ; SOSAT-C88 ; Chakti ; Mil de Siaka ; ICRI-Tabi, and the local variety), sorghum (Mota Maradi ; SSD35 ; IRAT 204 ; Soubatoumi ; SEPON84, and the local variety), cowpea (TN-5-78 ; IT90K-372-1-2 ; IT97K499-38, KVX; Dan Adja, and the local variety), and groundnut (55-437, Sumnut, JL24, RRB, and the local variety). However, in 2021, sorghum, pearl millet (Doubani and SOSAT-C88), and cowpea (IT97K499-38) were not included in the trials due to seeds and/or arable land shortage. NPK (15-15-15) fertilizer at a rate of 6 g/hill was applied in microdoses at the tillering stage for each experimental plot. To ensure better plant growth, weeds and insects were also controlled until harvest. Other cropping operations were managed as for farmers' practices. Data on yield was recorded for each experimental plot at harvest.

Voting system

For the on-farm farmers' participatory variety evaluation, the card system was used to assess farmers' preferences and acceptance for the tested varieties for yield and quality attributes. The card system consisted of three types of cards (Green, Yellow, and Red). Green card means they accept the variety; yellow card means that they accept the variety as an alternative and the variety is worth being tested again; and red card means they reject the variety, as it did not meet their requirements.

Procedure for participatory variety evaluation

The participatory variety evaluation procedure of the International Rice Research Institute (IRRI) with slight modifications was adopted. Women and men were grouped separately to avoid biases, as they may not feel free in their decision when the whole community is present. Farmer's groups were briefed by the researcher on what was involved in varietal selection exercise. In both 2020 and 2021, all the selected farmers participated in the participatory variety selection.

Firstly, the voting procedure was explained to each target group and farmers were allowed to ask questions for more clarifications (Figure 1a). Secondly, prior to the evaluation, farmers visited the plots along with the trial farmer who gave some information on the crops (Figure 1: b1 and b2). Thirdly, for each group (women and men), participants were given voting cards to select their preferred varieties based on their own criteria. Farmers were sent one by one into the plots to evaluate the varieties, a short time delay between the departure of each person was observed to avoid one participant influencing other participants (Figure 1: c1 and c2). After the vote, the counting was performed in public according to gender group. The relative card numbers permitted the calculation of the preference indices (Figure 1: d1 and d2).

Finally, a Focus Group Discussion (FGD) method was used to collect qualitative data about the crops evaluated (Figure 1: e1 and e2). Men and women were interviewed separately and restitution sessions were arranged to discuss with each target group/individuals the reasons for accepting or rejecting a certain variety and document the results (Figure 1: f).

Data analysis

The preference index (PI) was determined using the following formula:

PI (%) = 100*(Number of green cards + 1/2* Number of yellow cards) / total number of participants in the target group (IRRI, 2006).

Farmers' preferences for pearl millet, sorghum, cowpea, and groundnut varieties and constraints for their adoption were tabulated using Excel. Significant differences among varieties for grain yield were analyzed via the analysis of variance using the statistical software GENSTAT 15th edition.

RESULTS

Pearl millet (*Pennisetum glaucum*)

Pearl millet variety ICRI-TABI was tested in all villages. The varieties Doubani and SOSAT-C88 were missing in the village of Sawaya while Chakti was missing in the village of Mazanya. The variety Nakowa and the variety Mil de Siaka were missing in two and six villages, respectively. Traits preferred by farmers were identified and prioritized for both men and women. The PVS evaluation showed that women ranked SOSAT-C88 as the most preferred variety (highest preference index) except in six villages, where SOSAT-C88 was ranked second to fifth among the tested varieties. The local varieties were the most preferred in Angoal ari (Wacha) and Idon bissa (Sbroum). The varieties Mil de Siaka, ICRI-TABI, and Nakowa were ranked first in Dungass, Zanan Zaboua, and Sawaya, respectively (Table 1). The most preferred traits for farmers in the study area were seed settingting, earliness, long panicle, fodder yield, and grain yield (Table 2). The variety Chakti was one of the most preferred varieties by men and women in Wacha.

The ANOVA results showed highly significant differences ($P< 0.01$) among pearl millet varieties and across sites for grain yield (Table 3). The lowest yield of 126.1 kg/ha was obtained with Nakowa in Gouchi while the highest yield of 850 kg/ha was recorded with the local variety in Sbroum (Table 4). Farmers reported birds

Figure 1. Procedure for the participatory variety evaluation: (a) Explanation of the evaluation procedure to farmers (separated by gender) in Ali Isbori. (b1) Women visiting cowpea plots before voting in Gourgouzou. (b2) Men visiting pearl millet plots before voting in Guindo. (c1) Women voting cowpea varieties in Gourgouzou. (c2) Men voting pearl millet varieties in Angoual Gamji. (d1) Women vote counting of cowpea varieties in Gourgouzou. (d2) Men vote counting of pearl millet varieties in Guindo. Focus group discussion with women (e1) and men (e2) after voting in Maimaje. (f) Restitution at Maigoyba in Dungass.
Source: Author

attack as a major hindrance for the Chakti variety since it is an early maturing variety. Grain filling starts before the other varieties, which exposes it to birds' attacks. Women ranked ICRI-Tabi variety second in most villages, whereas men listed this variety among the least preferred varieties. Farmers in Wacha claimed that this variety was late maturing and resembled the wild species Shibra due to the smaller girth of the panicles. ICRI-Tabi grain yield ranged from 233 kg/ha in Dantchiao to 828 kg/ha in Mallaoua. Farmers ranked Doubani and Nakowa among the least preferred pearl millet varieties except in Sawaya, Mai Rakoumi, and Angoal Gamdji. Nevertheless, farmers appreciated these varieties owing to their long panicles, good seed settings, and high fodder yields. However, they claimed these varieties to be very late maturing compared to the other varieties. Doubani and Nakowa highest grain yields were 723 and 728 kg/ha, respectively. Similarly, the variety Mil de Siaka was not appreciated by farmers in Wacha due to its long maturing cycle.

Sorghum (*Sorghum bicolor*)

In this study, six sorghum varieties were evaluated in collaboration with farmers. The sorghum variety SSD35 followed by the local variety and Mota Maradi was the most preferred variety in the study area (Table 5). Farmers prefer it for its big panicle, high fodder yield, and earliness (Table 6). In addition, farmers claimed that this variety doesn't shed grains at maturity even when panicle fell down. The analysis of variance's results showed highly significant differences ($P< 0.01$) among sorghum varieties and across study sites for grain yield (Table 3). With 751 kg/ha, SSD35 achieved the highest average grain yield across environments (Table 4). The varieties Mota Maradi and IRAT 204 are appreciated for their earliness, which is advantageous for short rainy seasons or to avoid late drought. Farmers, on contrary, dislike Mota Maradi and IRAT 204's short panicles, which are unfavorable for grain threshing. Farmers listed Soubatoumi as the least preferred variety because of its late maturing cycle. They claimed that this variety was still at the grain filling stage when cattle herders returned at the end of the season. However, they still appreciated its high fodder yield and big panicles.

Cowpea (*Vigna unguiculata*)

The cowpea variety Dan Hajia was the most preferred variety, except in Wacha where it was ranked fifth, and in

Table 1. Preference index (%) per village and gender for pearl millet PVS.

			Chakti	Doubani	ICRI-Tabi	Local variety	Mil de Siaka	Nakowa	SOSAT-C88
WACHA	Djambirdji	Men	65.9	50	59.1	36.4	22.7	-	97.7
		Women	78.2	57.3	79.1	54.5	62.7	-	88.2
	Wacha	Men	90.5	83.3	15.5	46.4	-	45.2	77.4
		Women	91.7	83.3	33.3	87.5	-	70.8	100
	Angoal ari (Gayi)	Men	61.1	83.3	88.9	94.4	-	80.6	38.9
		Women	25.9	69	87.9	89.7	-	51.7	79.3
	Kaki Baré	Men	35.5	41.9	71	43.5	-	14.5	100
		Women	76.9	48.1	48.1	86.5	-	26.9	100
DUNGASS	Geri	Men	58.3	54.2	66.7	-	95.8	12.5	79.2
		Women	19.2	46.2	61.5	-	61.5	15.4	92.3
	Mai Rakoumi	Men	4.8	95.2	21.4	-	50	61.9	33.3
		Women	35.7	50	32.1	-	67.9	53.6	67.9
	Doumdjia kri	Men	0	37.5	81.3	-	100	0	25
		Women	34.6	38.5	73.1	-	100	34.6	76.9
SBROUM	Idon Bissa	Men	44.4	50	22.2	100	-	61.1	61.1
		Women	77.1	60.4	81.3	83.3	-	62.5	62.5
	Maimaje	Men	15.8	73.7	57.9	97.4	-	52.6	89.5
		Women	66.1	80.6	82.3	88.7	-	61.3	96.8
	Mazanya	Men	-	56.3	68.8	93.8	31.3	-	37.5
		Women	-	65.7	82.9	87.1	55.7	-	62.9
MAGARIA	Zanan zaboua	Men	69	35.7	28.6	83.3	-	35.7	71.4
		Women	75	46.4	89.3	82.1	-	64.3	78.6
	Angoual Gamdji	Men	30.4	87.5	35.7	89.3	76.8	94.6	64.3
		Women	71.2	76.9	72.1	50	57.7	66.3	76.9
	Sawaya	Men	15	-	60	-	30	90	-
		Women	28.6	-	64.3	-	54.8	92.9	-
		Total average (%)	48.8	61.3	60.2	77.4	61.9	52.2	73.2

Source: Author

Ali Isbori and Barima where women ranked it fourth (Table 7). This variety was appreciated for its high grain yield, earliness, and big seeds. Farmers were eager to grow this variety and even inquired about how they could purchase the seeds. However, farmers complained about its low fodder yield. The ANOVA results did not show significant differences ($P > 0.05$) among cowpea varieties for grain yield (Table 3). However, highly

Table 2. Pearl millet traits ranked by importance and gender (number of occurrence).

Variety	Year	/Gender	Desirable features									
			Seed setting	Earliness	Long panicle	Fodder yield	Grain yield	Compact panicle	Tillering	Big grain	Thick panicle	Good adaptation
Chakti	2020	Male	7	11		1	1		1	11	1	
		Female	3	14		1	5	1	2	12	4	
	2021	Male	1	3			2					
		Female		3			1			1		
Doubani	2020	Male	7	2	11	5		2				
		Female	4		10	3	3	2	2	1		
ICRI-TABI	2020	Male	9	2	1	5	2	7	7			
		Female	4	6	1	5	8	7	5	1		
	2021	Male	4	1		2			1			
		Female	3				2	1	1			
Local variety	2020	Male	4	3	3	4	3		6	4	2	5
		Female	1	2	5	5	3		3		2	4
	2021	Male	1			3	2		1			1
		Female	1		3	1	2		1			1
Mil de Siaka	2020	Male	2		2	4	1	2	2	2		1
		Female	2	2	3	1	1	3	1			
	2021	Male	4						2			
		Female	1			1	2	2	1			
Nakowa	2020	Male	2	4	11	5	2	2	3	3		
		Female	4	2	11	3	3	2	4	2	1	
	2021	Male		2	4	3	2					
		Female	2		4	2	2	1				
SOSAT-C88	2020	Male	8	6		3	1	6	2		7	1
		Female	6	8	1	3	7	5	1	1	7	
Total			80	71	70	60	55	43	46	38	24	13

Source: Author

significant differences were observed across township. The highest grain yield (941 kg/ha) was recorded for Dan Hajia in Mallaoua (Table 4). The local variety and TN-5-78 were the second most appreciated cowpea varieties in the study area, particularly in Wacha and Magaria Kantalo.

Table 3. Analysis of variance for grain yield for the different crops evaluated.

Crops	Source of variation	Df[a]	MS[b]	F-value	P-value
Pearl millet	Varieties	6	40326	3.91	0.003
	Township	8	154147	14.95	0.000
	Error	46	10309		
Sorghum	Varieties	5	153549	5.52	0.001
	Township	6	218933	7.87	0.000
	Error	30	27824		
Cowpea	Varieties	5	40149	2.32	0.062
	Township	8	231552	13.35	0.000
	Error	38	17341		
Groundnut	Varieties	4	82013	3.61	0.013
	Township	10	182354	8.04	0.000
	Error	40	22691		

Df: degree of freedom; MS: Mean square.
Source: Author

TN-5-78 variety was appreciated for its high fodder yield, high grain yield, and earliness. Nevertheless, farmers claimed poor storage quality for this variety. Furthermore, women in Ali Isbori and Kakibare claimed that seeds of the TN-5-78 variety are very soft, making threshing very challenging. Farmers ranked the variety KVX as the second most preferred variety in Ali Isbori, Kakibare, and Wacha. Conversely, in Dungass, Sbroum, and Magaria KVX was among the least preferred varieties due to pests attacks. The most preferred traits for farmers were fodder yield, grain yield, and earliness (Table 8). The IT97K499-38 variety was the least preferred variety for most of the farmers in the study area. Farmers complained about the duration of its maturing cycle. Due to its late maturing, this variety was harvested before the end of its cycle in most of the villages, resulting in the lowest yield. However, in Ali Isbori, men listed IT97K499-38 as the third most preferred variety.

Groundnut (*Arachis hypogaea*)

Groundnut varieties Sumnut was the most preferred variety in Dungass and Magaria while RRB was the most preferred variety in Sbroum (Table 9). These varieties were appreciated for their high seed yield and earliness. However, women in Dungass, Wacha, and Magaria claimed that the seeds of the RRB variety are too small and not very favorable for processing. Men, on the other hand, reported that this variety was sensitive to pod borer. 55-437 and JL24 varieties were particularly appreciated by farmers in the study area for their high fodder yield. Groundnut variety 55-437 most preferred traits were fodder yield, grain yield, big pods, and earliness. The analysis of variance's results showed highly significant differences ($P< 0.01$) among groundnut varieties and across study sites for grain yield (Table 3). The 55-437 variety had the highest average grain yield (606 kg/ha) across locations (Table 4). Many farmers claimed that the variety 55-437 was similar to the local variety El Dakar. It is suspected that the local variety El Dakar was the improved variety 55-437, which farmers have been cultivating for many years.

JL24 variety was appreciated for its large pods and high ramification. However, farmers in Mazanya (SBroum) reported that JL24 sheds its pods in the soil during harvest. Farmers in Djambirji (Wacha) noted also a low germination rate for JL24. The highest grain yields were recorded for Sumnut (1251 kg/ha), JL24 (1014 kg/ha), and RRB (952 kg/ha) in Dungass. The most preferred traits by farmers for these varieties were seed yield, fodder yield, and earliness (Table 10). The local variety was among the least preferred groundnut varieties. Nonetheless, in Wacha farmers reported that the local variety was resistant to aphids' attacks and had a high germination rate. Furthermore, despite its low grain yield compared to other varieties, many farmers appreciated this variety for its high oil content and fodder yield.

DISCUSSION

Varieties and traits preferred by farmers

For high adoption of the cultivars to be developed, it is

Table 4. Crop varieties' grain yields (kg/ha) in the selected townships of the PVS.

Crop	Varieties	Township										
		Bande	**Dantchiao**	**Dogo-Dogo**	**Dungass**	**Gouchi**	**Magaria**	**Malawa**	**S'Broum**	**Wacha**	**Yekoua**	**Kwaya**
Pearl millet	Chakti	-	291.7	360.5	406.1	202.1	171.1	384.2	388.4	186.5	227.4	-
	Doubani	-	291.7	573.9	723.2	213.7	420.6	395.3	599.8	398.6	378.8	-
	ICRI-Tabi	-	233.3	475.5	776.9	332.6	360.1	828.6	712.7	363.6	430.8	-
	Local variety	-	-	440.7	524.6	218.7	419.7	390.2	850	202	349.2	-
	Mil de Siaka	-	191.7	587	690.3	268.6	335.6	656.4	509.5	-	292.1	-
	Nakowa	-	350	599.7	586.9	126.1	591.1	381.4	728.2	271.4	328.3	-
	SOSAT-C88	-	408.3	566.4	620.5	339.6	330.4	673	675.3	323	309.2	-
	mean	-	294.4	514.8	618.4	243.1	375.5	529.9	637.7	290.9	330.8	-
	s.e.d.	-	24.3	74.8	135.8	68.7	116.1	325.8	128.2	44.6	96.2	-
Sorghum	IRAT 204	-	64.3	650	394.3	550	-	836.7	-	316.9	181.7	-
	local variety	-	295.5	561.3	824.8	706.25	-	656.7	-	640	371.3	-
	Mota Maradi	-	342.1	787.5	520.4	525	-	1263.3	-	239.4	581.4	-
	SEPON84	-	97.7	650	427.8	400	-	816.7	-	190.4	469.1	-
	Soubatoumi	-	61.6	706.3	487.9	393.75	-	433.3	-	276.6	81.8	-
	SSD35	-	528.2	727.5	882.4	869	-	750	-	913.5	589.8	-
	mean	-	231.6	680.4	589.6	574	-	792.8	-	429.5	379.2	-
	s.e.d.	-	93.73	101	219.7	196	-	552.2	-	134.1	103.9	-
Cowpea	Dan hajia	145	-	600	701.1	127.1	142.6	941.7	464.1	259.8	-	242.5
	IT90K-372-1-2	33.3	-	458.3	550	172.9	6.3	733.3	48.1	56.3	-	105
	IT97K499-38	30	-	525	402.2	104.2	0	566.7	69.8	25	-	0
	KVX	166.7	-	525	366.2	204.2	50	600	64.6	102.1	-	120
	Local variety	141.7	-	416.7	502.7	141.7	378.6	200	578.5	106.3	-	80
	TN-5-78	101.7	-	583.3	429.3	208.3	250	600	100.6	243.8	-	210
	mean	103.1	-	518.1	491.9	159.7	137.9	606.9	221	132.2	-	126.3
	s.e.d.	129.4	-	126	166.9	56.4	160.8	238.6	156.5	45.4	-	123.6
Groundnut	55-437	487.3	262.2	719.1	792.5	449.4	460.7	650.3	960	509.2	733.3	641.6
	JL24	539.2	260.5	818.5	1014.9	383.8	414.5	583.6	620.3	325.8	555.7	668.8
	Local variety	313.1	153.4	517.9	107.2	397.4	445.4	219.8	734.4	230.8	583.3	590.9
	RRB	468.8	225	668.2	952.6	246.6	462.3	744.8	785.6	383.3	678.9	731.9
	Sumnut	346.1	232.8	838.1	1251.8	356.9	436.3	700.3	815.6	356.7	450	539.3
	mean	430.9	226.8	712.4	823.8	366.8	443.8	579.8	783.2	361.2	600.3	634.5
	s.e.d.	172.9	58.31	136.4	306.8	104.6	119.4	356	126.8	61.2	205.3	115.9

s.e.d: Standard error of difference.
Source: Author

Table 5. Preference index (%) per village and per gender for sorghum PVS.

			IRAT 204	local variety	Mota Maradi	SEPON84	Soubatoumi	SSD35
WACHA	Wacha	Men	88	88.2	58.8	17.6	55.9	97.1
		Women	44.1	91.2	52.9	17.6	47.1	100
	Doumbaoua	Men	84.2	89.5	21.1	52.6	26.3	86.8
		Women	79.2	75	79.2	45.8	37.5	95.8
	Djambirji	Men	73.9	69.6	78.3	84.8	30.4	100
		Women	92.1	84.2	86.8	100	44.7	89.5
DUNGASS	Geri	Men	87.5	50	93.8	43.8	3.1	75
		Women	86.4	31.8	81.8	54.5	9.1	45.5
	Takay	Men	58.8	50	26.5	14.7	17.6	82.4
		Women	50	60	16.7	50	10	86.7
	Tanti	Men	38.1	85.7	90.5	59.5	35.7	92.9
		Women	12.5	97.5	90	65	57.5	92.5
	Mai Goyba	Men	72.4	91.4	98.3	15.5	36.2	84.5
		Women	79.7	98.6	91.9	31.1	5.4	62.2
	Doumdjia kri	Men	45	50	82.5	60	52.5	70
		Women	42	40	76	56	46	52
SBROUM	Bido	Men	19.6	51.8	80.4	71.4	28.6	35.7
		Women	39	65	80	66	44	56
	Magaria Kantalao	Men	45	55	70	67.5	-	-
		Women	88	76	68	70	-	-
MAGARIA	Angoal Manda	Men	69	100	61.9	14.3	23.8	90.5
		Women	55	98.3	70	30	16.7	81.7
	Hayania	Men	41.1	71.4	92.9	46.4	3.6	91.1
		Women	78.6	87.1	65.7	52.9	34.3	88.6
	Mailallé	Men	69.2	84.6	46.2	34.6	21.2	88.5
		Women	100	62.5	31.3	93.8	56.3	93.8
	Dan Dourway	Men	16.7	63.9	50	61.1	41.7	100
		Women	18.8	81.3	51.3	77.5	62.5	92.5
		Total average (%)	59.8	73.2	67.6	51.9	32.6	82.0

Source: Author

Table 6. Sorghum traits ranked by importance and gender (number of occurrence).

Desirable feature	IRAT 204		local variety		Mota Maradi		SEPON84		Soubatoumi		SSD35		Total
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Big panicle	7	2	11	10	1	2	8	10	7	13	11	6	88
Fodder yield	7	9	7	5	2	11	8	2	14	0	7	9	81
Earliness	9	4	4	8	14	1	5	5	0	5	8	8	71
Compact panicle	5	6	4	1	0	2	3	3	0	0	4	4	32
Grain yield	1	4	3	2	2	0	3	4	0	1	3	4	27
Big grain	3	1	3	5	0	0	1	0	0	1	4	1	19
Long panicle	2	0	1	2	1	1	3	1	0	0	1	3	15
Tillering	2	1	1	0	3	2	0	1	0	0	0	2	12
Good adaptation	0	0	4	2	0	0	0	0	0	0	1	3	10
Easy to thresh	2	0	1	2	0	1	1	0	0	0	0	2	9
Total	38	27	39	37	23	20	32	26	21	20	39	42	

Source: Author

important to take into account the farmers' cultivar preference or selection criteria (Frison et al., 2011; Mulumba et al., 2012). Through participatory varietal selection, farmers can grow new improved varieties that perform better than their local varieties (Walker, 2006; Dansi et al., 2013). The farmers' participatory approach helps also in the rapid dissemination of new varieties and was found to be very effective in scaling-up seed transfer and adoption of the new varieties by farmers (Rahman et al., 2015). Hence, improved and released crop varieties are used for PVS in farmers' fields to improve the resilience of their farming systems. In the present study, released varieties of pearl millet, sorghum, cowpea, and groundnut were used for the PVS in the Zinder region of the Niger republic. Farmers' selection of varieties and most important traits were assessed through voting and focus group discussions. In Niger, the society is patriarchal and women most often struggle to voice their opinion. Thus, to offset biases, men and women were interviewed separately as suggested by Narayanasamy (2009). Differential farmers' varietal and trait preferences were observed according to gender for the different crops evaluated.

Pearl millet (*Pennisetum glaucum*)

In this study, women predominantly preferred the SOSAT-C88 pearl millet variety while men relatively preferred the local variety. However, both men and women explained that the improved variety SOSAT-C88 panicle characteristics (width, grain color, seed setting, etc.) are similar to their local variety and meet their preference criteria. Despite its earliness, the Chakti variety was not well appreciated by farmers because it was prone to bird damage due to being the first to set seeds in the fields and its shorter panicles. Nonetheless, Chakti was among the most preferred varieties in Wacha township where low rainfall was registered during the 2020 rainy season. The yield components seed setting and long panicle along with earliness were the most preferred traits for the pearl millet crop. These findings are in line with those of Drabo et al. (2019) who reported that very long panicle and earliness were more preferred for pearl millet varieties in the Sahel zone of Burkina Faso. Furthermore, long panicles provide an important advantage for Sahelian farmers whose mode of transportation (on camel or donkey backs) and commerce rely on millet bundles made up of approximately 200 panicles tied together. However, farmers claimed that Chakti would still be advantageous in case there is a need to replant when the rainy season has advanced. Therefore, depending on the sowing date Chakti can be grown to mitigate early drought or the effect of terminal drought. Early maturity and grain yield were earlier indicated as the most important selection criterion for pearl millet varieties in the Sahel and Sudan zones of four West African countries, including Niger (Omanya et al., 2007). Besides, early maturity is associated with low water requirements (Dancette, 1983) and provides relative drought escape, especially at the end of the cropping season (Drabo et al., 2019).

Sorghum* (*Sorghum bicolor)

Farmers predominantly preferred the SSD35 variety due to its earliness, big panicles, and high fodder yield. The late maturing variety Soubatimi was the least preferred sorghum variety in the study area. This clearly shows that farmers' major selection criterion is earliness and yield to boost sorghum production. Recently, Belay and Wale (2021) reported similar findings in the Northern Gondar areas of Ethiopia, where farmers select sorghum varieties

Table 7. Preference index (%) per village and per gender for cowpea PVS.

			Dan Hajia	IT90K-372-1-2	IT97K499-38	KVX	Local variety	TN-5-78
WACHA	Ali Isbori	Men	78.3	25	43.3	76.7	10	43.3
		Women	54.8	57.1	50	73.8	81	52.4
	Kakibare	Men	100	36.8	2.6	92.1	63.2	50
		Women	96.7	43.3	13.3	76.7	40	56.7
	Wacha	Men	48.8	66.3	15.1	89.5	68.6	94.2
		Women	55.6	72.2	55.6	61.1	83.3	88.9
DUNGASS	Barima	Men	87.9	24.1	75.9	-	48.3	32.8
		Women	72.2	77.8	83.3	-	98.1	64.8
	Geri	Men	65.4	75	30.8	100	30.8	40.4
		Women	69.4	72.6	51.6	93.5	54.8	45.2
	Mai Gwaibo	Men	100	43.2	20.3	10.8	82.4	81.1
		Women	95.8	8.3	14.6	35.4	64.6	54.2
	Tanti	Men	94.4	75	80.6	77.8	83.3	75
		Women	76.7	53.3	60	60	43.3	26.7
	Doumdjia kri	Men	67.5	75	65	55	26	50
		Women	90	88	82	78	26	54
SBROUM	Idon Bissa	Men	73.5	26.5	41.2	23.5	88.2	32.4
		Women	80	36	28	60	72	72
	Maimaje	Men	100	41.7	58.3	61.1	63.9	75
		Women	100	83.3	69.7	84.8	53	87.9
	Mazanya	Men	77.1	35.4	41.7	58.3	85.4	43.8
		Women	89	47.6	32.9	47.6	84.1	45.1
	Saboua-Sassoubroum	Men	66.1	29	45.2	35.5	46.8	85.5
		Women	78	72	89	67	56	72
	Magaria Kantalo	Men	57.7	57.7	61.5	46.2	51.9	73.1
		Women	71.9	53.1	40.6	53.1	50	93.8
	Dan Kada	Men	85	80	82.5	60	77.5	55
		Women	57.7	65.4	73.1	57.7	65.4	80.8
MAGARIA	Dantchiao	Men	87.5	28.1	25	50	62.5	84.4
		Women	96.9	6.3	18.8	46.9	53.1	56.3
	Gaounaoua	Men	100	6.8	11.4	13.6	6.8	61.4
		Women	100	18.8	28.1	25	28.1	68.8
	Angoual Gamdji	Men	72.5	65	27.5	37.5	85	77.5
		Women	68.1	47.9	30.9	38.3	83	50
		Total average (%)	79.8	49.8	45.6	57.7	59.3	62.5

Source: Author

based on yield and earliness. Farmers' choice can be explained by the length of the cropping rainy season, which can be critical for adaptation and preventing farmers-herdsmen conflicts very common in the study area. This is in line with the findings of Shinjo (2017) who reported in Southwestern Niger that transhumance is essential for households residing in an area with a high rate of cropping because they had to remove their herds from cropped fields to a drier region in the rainy season.

Cowpea (*Vigna unguiculata*)

Cowpea is a multipurpose crop grown by resource-poor farmers in Sub-Saharan Africa for its green pods, tender leaves (used as vegetables), dry seeds (used as pulses), and green fodder (used as livestock feed) (Sisay et al., 2019; Kebede and Bekeko, 2020; Kriesemer et al., 2021). The study revealed that the most preferred traits by farmers for cowpea varieties were grain yield, fodder

Table 8. Cowpea traits ranked by importance and gender (number of occurrence).

Desirable features	Dan Hajia		IT90K-372-1-2		IT97K499-38		KVX		Local variety		TN-5-78		Total
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Fodder yield	0	0	5	8	14	14	13	7	6	4	7	8	86
Yield	7	12	5	8	3	2	4	4	10	10	11	5	81
Earliness	18	16	1	2	1	1	3	2	7	9	7	5	72
Multiple harvest	3	2	0	1	0	1	2	1	8	6	2	4	30
Big seeds	7	4	0	0	2	0	3	4	1	0	0	0	21
Good taste	6	0	1	0	0	0	2	0	1	1	0	6	17
Seed color	0	0	1	2	2	0	1	0	0	2	3	1	12
Good for consumption	2	0	2	0	0	0	0	1	0	1	1	2	9
Stay green	2	0	1	0	0	3	0	1	1	0	0	0	8
Cash crop	0	0	0	0	0	0	0	0	1	0	3	3	7
Total	45	34	16	21	22	21	28	20	35	33	34	34	

Source: Author

yield, and earliness. The most preferred varieties were Dan Hajia and TN-5-78. These varieties were preferred for their earliness and high grain yield. Farmers, however, complained about Dan Hajia's low fodder yield, which was caused by the variety's erected stand. Although high grain yield was more important than fodder yield, high fodder yield remains an important consideration for cowpea variety adoption in southeast Niger (Saidou et al., 2011). Our results corroborate the findings of Kamara et al. (2010) in a participatory evaluation of cowpea cultivars in the Guinea and Sudan savanna zones of northeast Nigeria who showed that improved varieties were favored by farmers because of their high grain and fodder yields. Early maturity was an important consideration in the selection of varieties and the majority of the farmers reported the tested varieties to be earlier in flowering and maturing than their traditional varieties. Saidou et al. (2011) reported consistent results in the Maradi and Zinder regions of Niger in a participatory on-farm evaluation of improved cowpea lines.

Groundnut (*Arachis hypogaea*)

For groundnut, farmers' most preferred traits were grain yield and fodder yield followed by earliness. However, the evaluated varieties were ranked differently depending on gender and location. In Niger, women are mostly involved in the processing of groundnut seeds, which may explain the divergence of their preferences from men. Gender effects on production systems and opinions of men and women on traits preferences were earlier reported as important factors in agriculture in many countries (Kevane and Gray, 1999; Tyroler, 2018; Sinare et al., 2021). The differential preferences of varieties according to the village suggest that it is necessary to recommend varieties adapted to each site. These findings are consistent with those of Ndjeunga et al. (2010) who drew similar conclusions in Mali, Niger, and Nigeria. Similar results were also obtained recently by Sinare et al. (2021) in Burkina Faso.

Agronomic performance of improved and local varieties

The agronomic performance of improved and local varieties of the four crops used in the present study was assessed under farmers' field management, and every interviewed farmer including women and men expressed their opinion on the variety during the focus group discussion. The overall observed mean performances of each crop allowed the determination of the best performing varieties. For instance, for pearl millet, the variety ICRI-TABI was the best performing variety across locations. This variety was found to have a high tillering capability, allowing the plants to withstand drought stress. Many authors have reported that high tillering capacity of pearl millet varieties increases their plasticity under severe drought since the secondary tillers can compensate for main tillers' losses (Haussmann et al., 2012; Vadez et al., 2012). The improved sorghum variety SSD-35 was the best performing variety among the six varieties evaluated. This variety was recently reported as resistant to midge biotic stresses and to have high-yielding potential (Abdou, 2019). Besides, the SSD-35 variety was previously revealed as tolerant to *Striga hermonthica* in North Cameroon (Kosma et al., 2014). The best performing cowpea and groundnut varieties were respectively the improved varieties Dan Hajia and 55-437. These varieties achieved the highest average yield across locations. Dan Hajia variety is an early semi-erected variety created in 2015 with a maturity cycle of 50 to 55 days and a yielding potential of 1.5 to 1.9 t/ha.

Table 9. Preference index (%) per village and per gender for groundnut PVS.

			55-437	JL24	Local variety	RRB	Sumnut
WACHA	Djambirdji	Men	95.8	50	100	4.2	97.9
		Women	85.2	61.1	98.1	41.7	91.7
	Ali Isbori	Men	61.1	91.7	66.7	25	52.8
		Women	77.6	100	53.4	34.5	44.8
	Doumbaoua	Men	60	46	76	88	80
		Women	65.4	30.8	88.5	80.8	69.2
DUNGASS	Geri	Men	56.5	41.3	97.8	52.2	60.9
		Women	65.7	75.7	88.6	84.3	92.9
	Mai Gwaibo	Men	77.4	83.9	-	33.9	85.5
		Women	55.3	76.3	-	23.7	76.3
	Tanti	Men	55.9	61.8	-	76.5	55.9
		Women	58.3	63.9	-	58.3	61.1
	Doumdjia Kri	Men	60.7	82.1	-	64.3	46.4
		Women	49.1	35.5	-	85.5	49.1
SBROUM	Idon Bissa	Men	93.3	3.3	43.3	70	63.3
		Women	87	75.9	55.6	63	44.4
	Maimaje	Men	97.2	72.2	77.8	100	66.7
		Women	88.9	90.3	86.1	87.5	84.7
	Mazanya	Men	68.8	81.3	65.6	34.4	62.5
		Women	53.7	64.6	54.9	72	67.1
	Saboua-Sbroum	Men	43.3	33.3	58.3	90	63.3
		Women	94.4	83.3	88.9	72.2	77.8
	Bido	Men	74.1	58.6	19	93.1	24.1
		Women	65.4	71.8	43.6	88.5	73.1
	Magaria Kantalo	Men	50	50	41.7	75	47.9
		Women	56.7	63.3	63.3	80	36.7
	Dan Kada	Men	42.1	100	89.5	76.3	55.3
		Women	34.6	84.6	65.4	76.9	34.6
MAGARIA	Angoual Manda	Men	78.6	88.1	52.4	59.5	90.5
		Women	93.8	95.8	68.8	37.5	70.8
	Lakiré	Men	72.9	35.4	76	58.3	100
		Women	96	82	98	76	100
	Hayania	Men	78.8	65.2	62.1	81.8	72.7
		Women	95.2	100	100	100	95.2
	Mailallé	Men	63.5	57.7	78.8	94.2	92.3
		Women	87.5	81.3	81.3	43.8	93.8
	Dan Dourway	Men	73.3	70	66.7	70	40
		Women	88.6	80.7	71.6	83	84.1
	Sawaya	Men	40	65	-	40	75
		Women	66.7	71.4	-	26.2	83.3
		Total average (%)	70.2	68.1	71.2	65.1	69.1

Source: Author

However, in this study, the Dan Hajia variety yielded only one-third of its potential yield, while the 5-437 variety, a medium maturing variety with an erected stand yielded only half of its potential yield. This could be attributed to the low fertility status of the study area soil and/or the poor rainfall distribution over time and space. Soil fertility

Table 10. Groundnut traits ranked by importance and gender (number of occurrence).

Desirable feature	55-437		JL24		Local variety		RRB		Sumnut		Total
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Yield	13	9	10	11	9	10	15	13	10	12	112
Fodder yield	13	12	15	11	5	5	9	10	13	15	108
Earliness	8	4	1	3	0	6	6	6	3	3	40
Good adaptation	4	2	2	2	4	2	3	5	1	3	28
Big pods	6	7	4	3	2	0	1	3	1	0	27
Pod seed setting	3	2	1	4	0	2	7	0	2	1	22
High seed oil content	1	5	2	0	5	1	3	1	1	1	20
Good ramification	4	2	3	1	1	0	1	1	1	1	15
Good germination	4	1	2	0	2	1	0	1	1	1	13
Drought tolerant	0	0	0	0	3	2	2	0	3	0	10
Total	56	44	40	35	31	29	47	40	36	37	

Source: Author

and rainfall are the most limiting factors for agricultural production in Niger (Issoufa, 2015; Moussa et al., 2018). Crops are grown on predominantly sandy soils, which are deficient in primary nutrients, particularly phosphorus and nitrogen (Bationo et al., 1998). The JL 24 variety performed well in most of the villages. This variety was previously described as drought tolerant and non-dormant in the West African Catalogue of Plant Species and Varieties (FAO, 2008).

Hindrances affecting the adoption of improved varieties

The low adoption of agricultural technology and specifically of improved varieties is among the main causes that lead to low farming systems productivity and also increase the risks of poverty and food insecurity in the sub-Saharan region of Africa (de Graaff et al., 2011; Muzari et al., 2012; Majola et al., 2021). Understanding farmers' requirements and trait preferences, as well as their farming systems, is essential for wide adoption of newly developed crop varieties and production technologies (Rusinamhodzi and Delve, 2011). In this study, Farmers cited the scarcity of improved seeds at the beginning of the rainy season as one of the most significant constraints to crop production. Therefore, for pearl millet and sorghum, farmers used to perform a form of mass selection where they select the best-looking panicles in their field that they conserve and use as seeds for the following growing season. However, for pearl millet which is a high outcrossing (75%) allogamous crop, this form of selection mostly leads to the mixture of the improved variety with the local variety that is cultivated in the area, which causes the loss of the improved variety without a renewal of the improved variety seeds. Another major hindrance that limits the adoption of improved varieties is the lack of using varietal packages (appropriate crop management practices such as the use of fertilizers, the use of pesticides, optimal density, etc.) for improved seeds. This leads to reduced yield, and therefore, the poor performance of improved varieties compared to local varieties.

Conclusions

In this study, using focus group discussion and on-farm participatory variety testing, qualitative and quantitative data were collected to assess farmers' most preferred traits and varieties in southern Niger. The improved varieties ICRI-TABI (pearl millet), SSD35 (sorghum), Dan Hajia (cowpea), and 55-437 (groundnut) were found to be the most performing varieties across locations. Farmers' most preferred traits were predominantly grain yield, yield attributes, and earliness. Improved seeds of these staple and cash crops of pearl millet, sorghum, cowpea, and groundnut will help farmers in Southern Niger increase the productivity of their farming systems, food availability, incomes and food security to cope with the negative impact of climate change and variability. However, the adoption of these varieties by farmers depends on a thorough knowledge of their preference criteria that were found of agronomic, culinary, technological, and economical nature. The findings of this study will allow national extension services and non-governmental organizations to better guide their varietal exchange programs.

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CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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