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Local Criteria Used by Farmers to Evaluate the Agronomic Performance and the Fertilizing Capacity of Cowpea Varieties: Diversity, Variability and Proximal Relation with Agronomic Measurements in Contrasted Sahelian Locations

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Abstract

When contributing to participatory research, farmers usually appreciate the performance of cowpea varieties using qualitative scores. The score they attribute to each variety are based on local knowledge. The specific criteria they individually use to attribute a score are not well described. The objectives of this work were to: 1) identify and describe exhaustively the local criteria used by farmers to measure the agronomic performance of cowpea; 2) assess the variability and statistical structure of these farmer criteria across local contexts; 3) and analyze the association between these farmer criteria and the classical agronomic measurement. To achieve these objectives, an augmented block design was implemented across fifteen locations in the regions of Maradi, Dosso and Tillabéri, representing a diversity of local contexts. From a set of 36 cowpea varieties, fifteen varieties were sown per location, including five varieties (controls) common to all locations. In each location, two replicates were sown in randomized Fisher's blocks. After agronomic measurement and participatory evaluation (scoring of varieties by farmers), a group survey (focus group) was conducted in each location to identify the criteria considered by farmers to found their discretional scoring of varieties during the participatory evaluation. The analysis of the data identified, across locations, thirteen criteria defined by farmers to characterize the agronomic performance of cowpea. Some of these criteria were different according to location. Farmers ranked the three varieties with the best performance for each agronomical trait (Top 3 varieties). A comparison of the farmer ranking with the ranking based on agronomic measurements revealed similarity and complementary between both methods. This study highlighted the importance of considering both local and scientific knowledge in local varietal evaluations.

Keywords

Agronomic Performance, Participatory Research, Cowpea, Farmers' Criteria

1. Introduction

The agronomic performance of a crop is influenced by natural, socio-economic, and agronomic factors [1] [2]. It is also characterized through several measurement criteria. Numerous studies presented a diversity of measurement criteria in sorghum [*Sorghum bicolor* (L.) Moench] [3] [4], cassava (*Manihot esculenta* Crantz) [5] and cowpea [*Vigna unguiculata* (L.) Walp] [6]. Cowpea is a legume crop with particular role in soil management by natural nitrogen fixation. Its contribution to soil fertility, weed control and resistance to water stress is generally considered to appreciate variety performance [7] [8] [9]. Coulibaly [6], measured the agronomic performance of cowpea focusing on grain and fodder yields.

As part of the participatory research approach, several researchers are implementing concept of experiments implying farmers [6]. Experiments conducted in farmers' conditions can introduce bias due to the heterogeneity and diversity of contexts, especially in multi-location settings. There is a need to define new tools, particularly those that align with local perceptions.

Most of the studies carried out so far generally conduct farmers evaluation based on criteria defined by researchers [6]. In some situations, farmer rankings are correlated with agronomic measurements [4]. Even though these studies reported qualitative information explaining part of the criteria founding farmers scoring [4], it is interesting to conduct a formal investigating of the exhaustive criteria considered by farmers to appreciate the varieties and found their scoring. So, our approach was to explore the complexity of farmers' knowledge underlying how farmers assess varieties to attribute scores. This will help understanding how farmer assess and evaluate the performance of cowpea varieties. We also analyzed the correlation of farmer evaluation with agronomic measurements, to assess in which extend farmer criteria could serve as proxies for classic agronomic parameters.

The objectives of this work were to: 1) identify and describe exhaustively the local criteria used by farmers to measure the agronomic performance of cowpea; 2) assess the variability and statistical structure of these farmer criteria across local contexts; 3) and analyze the association between these farmer criteria and the classical agronomic measurement.

2. Material and Method

2.1. Study Locations

The study was carried out in the cereal and leguminous cropping area of Niger Republic, located between 0˚15'0" and 7˚15'0" East and between 13˚15'0" and 16˚45'0" North (Figure 1). It comprised seven locations in the region of Maradi (Central south zone of Niger), six in the region of Dosso, and two in the region of Tillabéri (West Zone of Niger). The climate is Sahelian, characterized by two seasons. There is a long dry season from October to May, featuring a cool, dry wind from November to mid-February, followed by a hot wind for the remainder of the period. Additionally, there is a short rainy season from June to September, during which the rainfall ranges from 350 to 650 mm, with an average of approximately 400 - 500 mm per year. Three geomorphological units characterized the study area, namely, lateritic plateaus, sandy hillslopes, and valley bottoms [10]. These landscape sections are primarily associated with farming and animal husbandry, relying predominantly on rainfed crops [11], such as pearl

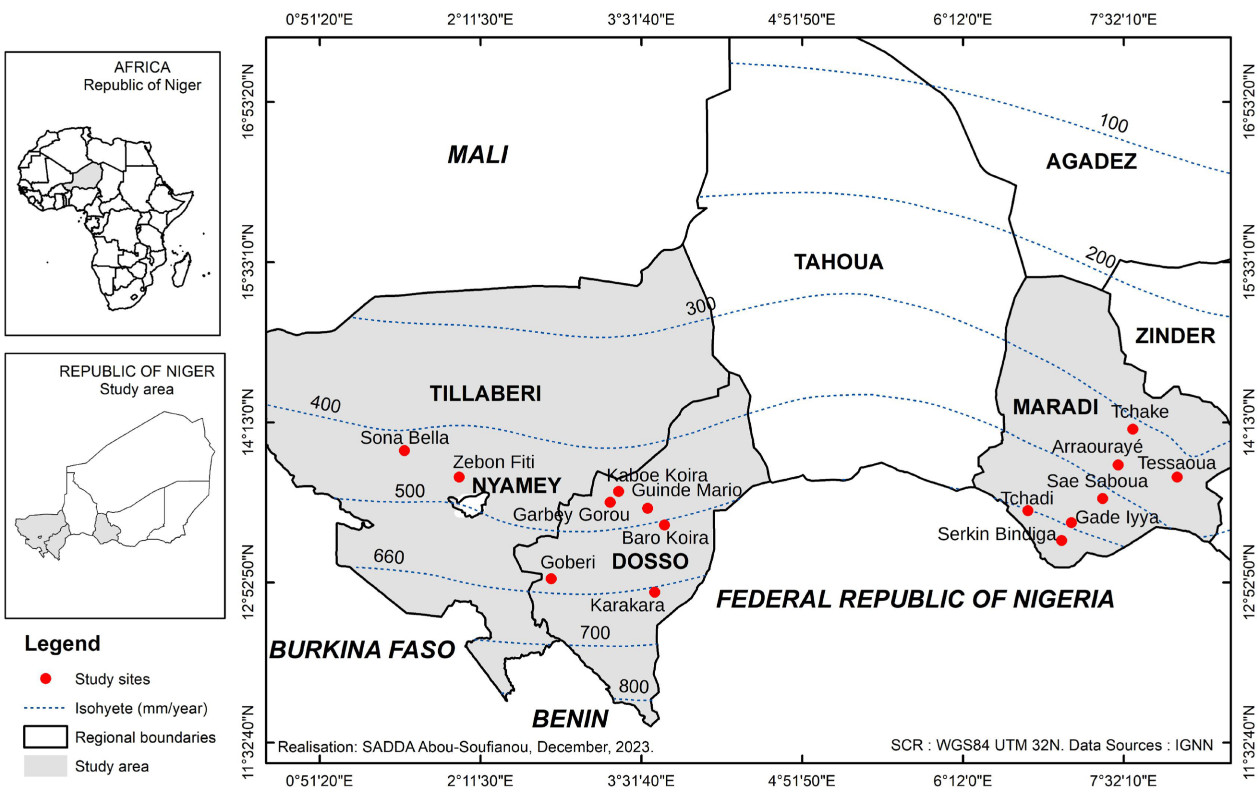

Figure 1. Locations of the study sites in three regions of Niger, Maradi (central zone), Dosso and Tillabery (western zone).

millet [Pennisetum glaucum (L.) R Br.] and sorghum [Sorghum bicolor (L.) Moench.], as well as cowpea [*Vigna unguiculata subsp. unguiculata* (*L.*) *Walp.] and groundnut* (*Arachis hypogaea L.*). The soil of Maradi region is mostly sandy as located in a sedimentary basin but we found clay soil in valley along the Goulbi, ponds and lacs. Whereas in the two western regions, the soil is a calcareous plateau and some clay along the rivers and dallols. In Maradi, based on our observation, Cowpea is mostly cultivated in association with other cereals like millet and Sorghum whereas in the west it is cultivated in pure. Due to the proximity of western region to Niamey (headquarter of Niger), the cowpea is generally cultivated for fodder production intended for animal breeder in the city of Niamey whereas in Maradi cowpea is cultivated for grain and generally exported in Nigeria.

2.2. Experimental Design

From a set of 36 cowpea varieties, fifteen varieties were sown per location, including five varieties (controls) common to all locations. In each location, a field of approximately a quarter of hectare area (66 m × 53 m) was used to randomly assign the varieties into two Fisher's complete blocks (A and B). We used two Fisher's bloc to minimize the variability and make results more statistically robust. However, considering the soil heterogeneity, setting up such a trial without replications can affect the results. Each block contained 15 plots (one plot per variety), separated from each other by a distance of 2 m (**Figure 2**). The plots consisted of 10 rows × 10 hills. Both distances between rows and between hills were set to 1 m. The two blocks were sown during rainfed season. Trials were replicated in 2016 and 2017 to eliminate the interannual variability which can influence the performance of cowpea varieties.

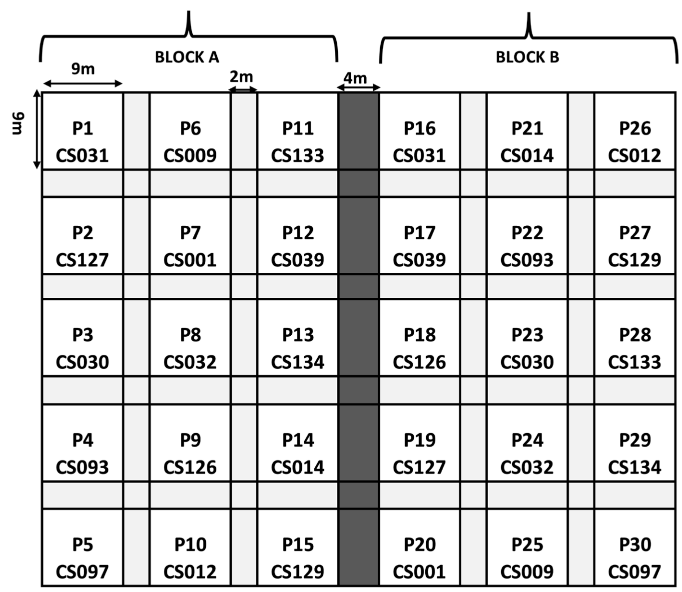

Figure 2. Experimental design of trials implemented in each of 15 locations (the randomization is an example from the site of Tchake).

2.3. Determining an a Priori List of Criteria Used to Evaluate Agronomic Performance of Cowpea Varieties

Based on literature review and research expertise, a list of traits linked to cowpea traits was developed and proposed for discussion with farmers in group surveys. These include traits for cycle duration and maturity, particularly in drought situation, grain and fodder production, resistance to pests, and drought and waterlogging tolerance. As a legume crop, cowpea contribution to soil fertility improvement was also considered. Furthermore, grain quality for food processing and economic value were also included. These traits were submitted to farmers during focus groups to confirm the importance of the traits in local contexts and to define how farmers appreciate cowpea performance with regard to each trait.

2.4. Identification and Description of Parameters According to the Criteria of Measuring Agronomic Performance of Cowpea Varieties

The data were collected during participatory evaluation conducted with farmers at the end of each cropping cycle. A group of five to ten farmers was selected among the producers gathered at each surveyed site.

Roughly the groups were composed of 20% women and 80% men (with variation between locations and years); farmers were generally between 35 to 55 years old. During the interview, farmers list and describe the criteria they use in their location to appreciate and measure each of the traits of interest. The parameter were selected during literature review but validated by farmer organizations (Fuma and Mooriben). The list was presented to farmers during the participative evaluation. We first ask farmers if a parameter is relevant (makes sense) to their practice and which criteria they used to measure it if yes. The different criteria are mentioned when a consensus is found among farmers. One or more criteria could be used to measure a parameter according to the farmers participating in the focus group but each criteria must be confirmed by other farmers. During survey data analysis, we evaluated, among local contexts, the variability of criteria cited by farmers.

2.5. Analysis of the Association between Farmer Criteria and Agronomic Measurement

Thirteen agronomic performance criteria for cowpea were identified during the participatory evaluation. Among these criteria, we selected four criteria which were measured using agronomic method in each study location. The first is the duration of the cycle, measured through the dates of 50% flowering of cowpea (plot). The second is grain yield, which involves measuring the weight of grains obtained by surface unit. The third is the haulm yield, which involves weighing the haulm of each cowpea variety per surface unit. The fourth, is the resistance to Striga, determined by counting the number of cowpea plants attacked by Striga in each plot.

At the end of each participatory evaluation, farmers systematically examined all trial plots to discern and rank the top three most efficient varieties based on their own predetermined criteria. These criteria were used to classify the first three varieties exhibiting the highest agronomic performance as per the farmers' perception. At the same time, researchers identified the top three most efficient varieties using measured agronomic traits. Subsequently, a Principal Component Analysis (PCA) was carried out integrating all studied traits, using the R programming language. The purpose of this analysis was to discern patterns and relationships among the various parameters. A comparative analysis was then undertaken to assess the correlation between the classification methods employed by farmers and the conventional scientific parameters used by researchers to evaluate agronomic performance.

3. Results

3.1. Traits Linked to Phenology and Multiple Purpose Production

A total of four parameters measuring the cowpea growth cycle were identified across all locations (Table 1). The first is "flowering", corresponding to the date on which the first flower appears on the cowpea variety. When sown at the same

Table 1. Traits linked to phenology and multiple purpose production of a cowpea variety identified by farmers.

Main agronomic trait		Cycle length				Grain yield				Leaf yield				Haulm yield			
Farmer criteria (Proxy)		Flowering	Branching	fruiting	Flower insect	Size of pods	Quantity of pods	Grain diameter	Leaves density	Branching	Leaves persistence	leaf width	Cycle length	Pods quantity	Haulm thickness	Grain-pods ratio	Pods quantity
West Zone	Karakara	1	1		1	1		1				1			1	1	
	DjindeMario	1	1			1	1		1	1	1	1				1	1
	KaboyeKwara	1	1			1		1	1	1	1				1	1	1
	Goberi	1	1			1	1	1		1						1	1
	GarbeyGoru	1	1			1	1	1		1						1	1
	BaroKwara		1	1						1		1				1	1
	Dembo		1			1	1	1		1		1					1
	ZebonFiti		1			1	1		1	1	1				1	1	1
Central South Zone	Majeni	1				1			1		1					1	
	GadeIya	1		1			1		1		1		1				1
	Arawraye	1		1		1				1			1				
	SayeSaboua	1					1		1		1			1			1
	SarkinBindiga	1					1		1	1	1				1	1	
	Tchake	1					1		1		1						1
	Tchadi			1					1		1					1	

date, the variety that starts flowering first is considered early. The second parameter is "branching", denoting the date on which the first branches emerge on the cowpea variety. Similarly, when sown on the same date, the variety that begins branching first is considered early. The third parameter is "fruiting", representing the date on which the first pod appears on the cowpea variety. Again, when sown on the same date, the variety that starts fruiting first is deemed early. The fourth parameter is "flower insect" indicating the date on which the first insects appear on the flower of the cowpea variety. When sown on the same date, the variety on which flower insects are first observed is perceived by farmers as early. The "flowering" parameter was identified in all locations, with the exception of three located in the western part of the country. The "branching" parameter was exclusively determined in the western locations. The "fruiting" parameter was mentioned in one western site versus three central locations. The "flower insect" parameter only appeared in the site of Karakara.

Analysis of Table 1 showed that three farmer criteria were consistently used to assess cowpea grain yield across all surveyed locations. These parameters include: 1) the size (length and width) of the pods; 2) the quantity of pods; 3) and the grain diameter. Farmers believe that a variety producing larger and wider pods, a substantial quantity of pods, and larger grains is likely to yield better results in terms of grain production.

Six parameters were used to measure leaf yield, encompassing: leaf density, bearing types (erected of creeping), leaf persistence, leaf width, cycle length, and pods quantity. According to farmers, a variety demonstrating high leaf density, a creeping bearing, persistent leaves, broader leaves, a late growth cycle, and low grain yield is supposed to exhibit superior leaf yield. In the other hand, varieties characterized by sparce leaves, an erected bearing, an early growth cycle, leaf lose before harvesting, and robust grain yield are considered weak in terms of leaf yield.

The "leaf density" parameter was assessed in three western locations, while it was recognized in all central locations except one. The parameter "type of bearing" was considered by all western locations except one, whereas it was mentioned in two central locations. The "leaf resistance" parameter appeared in nine locations out of the fifteen surveyed locations. The "leaf width" parameter was determined exclusively by four western locations. The "cycle length" parameter was identified in only two central locations. The parameter "quantity of pods" appeared as a consideration only in the site of Sae Saboua. These findings indicate significant variation in parameters across locations. It is evident that farmers, depending on their geographic location, employ different criteria for measuring the agronomic performance of cowpea varieties.

Three parameters were identified by farmers to assess the haulm yield of a cowpea variety (Table 1). Haulm thickness indicates the cowpea variety that produces pods with thick haulms, resulting in a better haulm yield compared to other varieties. Another parameter is the grain per pod ratio, indicating that a cowpea variety producing long pods with fewer grains per pod yields a better haulm yield. The haulm yield is also proportional to the quantity of pods. Additionally, haulm yield is directly proportional to the quantity of pods; the greater the pod yield, the higher the haulm yield. All these parameters were identified in the locations of Kaboye Koira and Zebon Fiti, however, in other locations, only one or two parameters were identified.

3.2. Traits Linked to Resistance to Biotic and Abiotic Stress

Farmers used six parameters to evaluate the resistance of cowpea varieties to insect attacks. The first parameter is the length of the cycle; indeed, a cowpea variety with a short or long cycle may either avoid or face insect attacks. The second is hardiness, representing the capacity of a cowpea variety to develop normally after biotic stress. Essentially, it is less susceptible to insects compared to other cowpea varieties. The third parameter is the haulm thickness; varieties with thicker haulms are less vulnerable to insect attacks, as the density of the haulm prevents insects from infecting the pods. The fourth parameter is leaf width; a variety withe larger leaves is less susceptible to insect attacks. The fifth is the presence of repellent substance; varieties that secrete repellent substances are less sensitive to insect attacks. Another parameter is leaf density which protects pods against insect attacks. In the majority of the surveyed locations, at least one parameter was identified, whereas in the site of Djinde Mario, four parameters were identified.

A total of five parameters were used by farmers to assess the resistance of a cowpea variety to Striga gesneriodes. These parameters are leaf density, leaf color, hardiness, growth cycle, and the abundance of Striga in the field. A cowpea variety which high leaf density is less susceptible to Striga, as the intense competition impedes the survival of Striga plants. A variety that maintains green leaves despite Striga attacks indicates resistance. Early maturing varieties complete their cycle before the emergence of Striga, thus avoiding attacks. In a cowpea cultivation plot, a higher number of Striga plants indicates greater susceptibility of the cowpea variety, especially if it lacks tolerance.

The parameter "leaf density" was observed in three western locations and one central site. However, "hardiness" is specific to central locations. The parameter "leaf color" and "cycle length" were identified in both central and western locations. The "Striga abundance" parameter was determined only at the Tchake site.

The analysis of **Table 2** shows that six parameters were used to measure the resistance of a cowpea variety to drought. These parameters include leaf color, cycle duration, leaf density, flower density, root length, and bearing type. A cowpea variety with green leaves during drought is less sensitive to drought than other varieties. Regarding the cycle duration, a late maturing variety is less sensitive to drought than early varieties. A cowpea variety with large leaves and a lot of flowers is more sensitive to drought because it needs a substantial amount of water to maintain its biomass. A cowpea variety with long roots that extend

Table 2. Traits linked to resistance to biotic and abiotic stress of a cowpea variety idenfied by farmers.

Main agronomic trait		Resistance to insects						Resistance to striga					Resistance to drought						Resistance to flooding		
Farmer criteria (Proxy)		Cycle length	hardiness	Haulm thikness	leaf width	repellent substance	Leaves density	Leaves density	Leaves colour	hardiness	Cycle length	Striga abondace	Leaf colour	Cycle length	Leaves width	Flower density	Roots length	Erected bearing	Leaves density	Leves colour	Pods quantity
West Zone	Karakara	1		1			1						1						1	1	
	DjindeMario	1	1		1	1				1			1		1		1		1		1
	KaboyeKwara	1						1	1	1				1	1			1	1		1
	Goberi	1									1		1						1		1
	GarbeyGoru	1	1			1		1			1		1				1		1		1
	BaroKwara						1	1					1			1			1	1	1
	Dembo	1											1			1		1	1	1	
	ZebonFiti												1		1		1			1	1
Central South Zone	Majeni		1							1											
	GadeIya		1					1	1												
	Arawraye	1								1											
	SayeSaboua		1							1											
	SarkinBindiga			1						1		1									
	Tchake										1										
	Tchadi		1								1										

deeper is less sensitive to drought. A cowpea variety with an erect bearing is less sensitive to drought because its leaf area is very small, limiting its water requirements. All these parameters were exclusively identified in the western locations.

3.3. Parameters Related to Soil Fertility and Value Chain

A total of three parameters were identified to measure the capacity of a cowpea variety to fertilize soil. These parameters include leaf density, leaf persistence and the "back effect". A cowpea variety with high leaf density improves soil fertility by reducing wind and water erosion, providing minerals after the decomposition of this important biomass. The less persistent are the cowpea leaves, the great is the capacity of this variety to improve soil fertility. A variety of cowpea that loses its leaves before the end of the harvest improves soil fertility because the leaves are immediately decomposed by micro-organisms under the action of humidity. Another parameter indirectly measuring the fertilizing capacity of a cowpea variety consists of assessing the back effect of cowpea growing in a field. According to farmers, cultivating a cereal in a field where cowpea was grown the previous year and obtaining a good yield compared to other fields indicates that the variety improved soil fertility. This is a posteriori and indirect evaluation.

The parameter "leaf density" is used in three central locations and two western locations. "Leaf persistence" was determined in six western locations versus one central site. Varieties with the capacity of fertilize soil have low requirements for mineral fertilization (**Table 3**). However, a variety with high leaf density and green leaves is less demanding in mineral fertilization. "Leaf density" was identified in all the central locations except Saé Saboua. "Leaf color" appears exclusively in the site of Goberi.

The analysis of **Table 4** shows that precocity, grain color, taste, cooking time, storage time, and processing aptitude are parameters used to evaluate the economic value of cowpea in all the surveyed locations. An early variety is more purchased by producers because it produces quickly, and the grains are quickly consumed and sold in local markets before the end of the rainy season. Varieties with brightly colored grains have a higher economic value. A variety with good taste after processed is more purchased by farmers. This is an indirect parameter, as farmers may have this information before going to the market. The same situation applies to cooking time. A farmer can consider this parameter only if

Table 3. Traits linked to the capacity of a cowpea variety to fertilize soil identified by farmers.

Main agronomic trait		Fertilizing capacity			Exigence to fertilization	
Farmer criteria (Proxy)		Leaves density	Leaves persistence	Rotation	Leaves density	Leaves colour
West Zone	Karakara		1		1	
	DjindeMario		1			
	KaboyeKwara		1			
	Goberi		1	1		1
	GarbeyGoru	1	1			
	BaroKwara	1				
	Dembo			1		
	ZebonFiti		1			
Central South Zone	Majeni			1	1	
	GadeIya				1	
	Arawraye			1	1	
	SayeSaboua	1				
	SarkinBindiga		1		1	
	Tchake	1			1	
	Tchadi	1			1	

Table 4. Traits linked to the economic value of a cowpea variety identified by farmers.

Main agronomic trait		Grain quality						Grain filling			Economic value				
Farmer criteria (Proxy)		Grain diameter	Taste	Grain weight	Cooking time	Storage time	Processing aptitude	Grain diameter	Grain weight	Precocity	Grain colour	Taste	Cooking time	Storage time	Processing aptitude
West Zone	Karakara	1	1	1		1	1	1	1		1	1			
	DjindeMario	1	1		1	1		1		1	1			1	
	KaboyeKwara	1		1		1	1	1		1	1			1	
	Goberi	1	1	1	1	1	1	1	1		1	1			
	GarbeyGoru	1		1	1		1	1	1	1	1	1		1	
	BaroKwara					1				1	1	1			
	Dembo	1	1	1	1	1	1	1	1		1	1	1		1
	ZebonFiti	1			1	1		1	1	1	1				
Central South Zone	Majeni	1				1									
	GadeIya	1			1										
	Arawraye					1									
	SayeSaboua	1			1										
	SarkinBindiga	1			1										
	Tchake	1			1										
	Tchadi	1													

they have the information a priori. More grains can be stored longer, more they gain economic value. A variety with a large spectrum of processing options has good market value (beans, wake da shinkafa, wake ruwa-ruwa, Beroua, etc.). These parameters were determined exclusively in western locations.

3.4. Correlation between Farmer and Agronomic Methods of Cowpea Varieties Evaluation Based on Four Agronomic Traits

Farmers initially identified the top three performing varieties based on their own criteria. Independently, researchers identified the top three varieties based on agronomic measurement. In total, thirty-two, twenty-six and twenty-one varieties were respectively ranked first, second, and third out of the thirty-six varieties listed. Notably, some of the varieties classified by the farmers' method align with the same ranks according to the agronomic method (Table 5).

The results reveal that five varieties are consistently classified as the most efficient in fodder yield by both farmers and based on agronomic data. However, these findings are applicable only to the locations of Djinde Mario, Araurayé, Sarkin Bindiga, and Tchadi. Notably, the CS009 variety demonstrated superior performance in fodder yield, but the classification differed between the two methods.

Table 5. Classification of the most efficient varieties in leaf yield and grain yield and comparison between the ranks of farmers and those resulting from quantitative data from the trials. The varieties marked in green are those classified as the most efficient by both methods.

Villages	Ranking	Leaf yield						Grain yield					
		Farmers			Scientists			Farmers			scientists		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
West Zone	Karakara	CS 032	CS 114	CS 111				CS 052	CS 001	CS 012			
	Djinde Mario	CS 030	CS 032	V14	CS 030	CS 032	CS 031	CS 009	CS 129	CS 031	CS 009	CS 030	CS 012
	Kaboye Koira	CS 040	CS 014	CS 009				CS 127	CS 126	CS 129			
	Goberi	CS 013	CS 009	CS 129	CS 014	CS 129	CS 032	CS 009	CS 008	CS 013	CS 008	CS 031	CS 127
	Garbey Gorou	CS 014	CS 032	CS 097				CS 094	CS 129	CS 044			
	Baro Koira	CS 054	CS 033	CS 028	CS 052	CS 028	CS 009	CS 052	CS 129	CS 127	CS 052	CS 008	CS 126
	Dembo	CS 008	CS 127	CS 013									
	Zebon fiti	CS 126	CS 031	CS 052									
Central South Zone	Tessaoua	CS 014	CS 009	CS 012	CS 133	CS 014	CS 009	CS 001	CS 127	CS 012	CS 093	CS 097	CS 127
	Gade Iya	CS 133	CS 099	CS 009				CS 110	CS 125	CS 039	CS 099	CS 097	CS 001
	Araurayé	CS 095	CS 133	CS 014	CS 009	CS 133	CS 012	CS 129	CS 127	CS 097	CS 097	CS 001	CS 127
	Saé Saboua	CS 111	CS 097	CS 032	CS 039	CS 099	CS 127	CS 099	CS 009	CS 039	CS 111	CS 133	CS 031
	Sarkin Bindiga	CS 131	CS 001	CS 101	CS 009	CS 001	CS 014	CS 130	CS 001	CS 134	CS 001	CS 099	CS 032
	Tchaké	CS 032	CS 031	CS 133	CS 127	CS 048	CS 032	CS 129	CS 048	CS 012	CS 099	CS 001	CS 129
	Tchadi	CS 133	CS 116	CS 014	CS 133	CS 116	CS 052	CS 110	CS 129	CS 052	CS 001	CS 129	CS 127

Green Colour: dual purpose according to agronomic ranking; Pink Colour: dual purpose according to farmer ranking; Yellow Colour: dual purpose according to both rankings.

Furthermore, the varieties CS009, CS052, and CS129 are the only cowpea varieties consistently classified as having the best grain yield by both farmers and based on agronomic data (Table 5). However, these results are specific to the locations of Djinde Mario, Baro Koira, and Tchadi. Other varieties (CS129, CS001, and C127) exhibited good performance in grain yield, but the ranking differed between the two methods.

Regarding the life cycle criteria, the results demonstrate convergence in the classification of agronomically earliest varieties. Specifically, varieties CS093, CS097, CS125, CS099, and CS 110 were consistently classified as the earliest by both methods (Table 6). These findings are applicable only to the locations of Tessaoua, Gade Iyya, Saé Saboua, and Sarkin Bindiga. However, other varieties, such as CS111, CS093, CS044, CS110, and CS129, showed good performances in precocity but were differently ranked by farmers and researchers.

For resistance to Striga, only one variety, CS048, was consistently classified as the most resistant by both farmers and researchers, a result valid exclusively for the site of Chadi. However, other varieties (CS093, CS095, CS039 and CS125) showed good resistance to Striga but were differently classified by the two methods.

Table 6. Classification of the most efficient varieties in precocity and striga resistance and comparison between the ranks of farmers and those resulting from quantitative data from the trials. The varieties marked in green are those classified as the most efficient by both methods according to the villages.

Villages	Ranking	**Precocity**						**Resistance to striga**					
		Farmers			**Scientists**			**Farmers**			**Scientists**		
		1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
West	Karakara	CS 114	CS 111	CS 001									
	Djinde Mario	V14	V15	CS 009	CS 044	CS 030	CS 127	V15	CS 030	CS 001			
	Kaboye Koira	CS 127	CS 044	CS 014				CS 040	CS 014				
	Goberi	CS 009	CS 111	CS 001	CS 111	CS 032	CS 129						
	Garbey Gorou	CS 094	V14	CS 127				CS 014					
	Baro Koira	CS 093	CS 126	CS 009	CS 127	CS 093	CS 031	CS 052					
	Dembo	CS 092											
	Zebon fiti	CS 101	CS 023	CS 110									
Center	Tessaoua	**CS 093**	**CS 097**	CS 012	**CS 093**	**CS 097**	CS 127	CS 032	CS 093	CS 012	CS 093	CS 097	CS 127
	Gade Iya	**CS 125**	CS 126	CS 044	**CS 125**	CS 044	CS 110	CS 133	CS 099	CS 009			
	Araurayé	CS 110	CS 129	CS 127	CS 095	CS 110	CS 014	CS 133	CS 095	CS 097	CS 095	CS 110	CS 134
	Saé Saboua	**CS 099**	CS 059	CS 009	**CS 099**	CS 032	CS 111	CS 099	CS 012	CS 039	CS 039	CS 044	CS 001
	Sarkin Bindiga	CS 127	**CS 125**	**CS 110**	CS 009	**CS 125**	**CS 110**	CS 001	CS 133	CS 130			
	Tchaké	CS 099	CS 129	CS 001	CS 044	CS 048	CS 129	CS 133	**CS 048**	CS 129	CS 127	**CS 048**	CS 126
	Tchadi	CS 110	CS 129	CS 012	CS 125	CS 095	CS 127	CS 095	CS 125	CS 110	CS 125	CS 095	CS 129

3.5. Identification of Dual-Purpose Varieties

The classification results emphasize varieties capable of achieving a better grain-fodder trade-off, revealing three groups of dual-purpose varieties based on the classification methods across all surveyed locations. The first group comprises CS013, CS009, and CS012, and these varieties were only classified by farmers in the same context. The second group consists of CS030 and CS052, identified exclusively by researchers in the locations of Djinde Mario and Baro Koira respectively. Lastly, only the CS001 variety was classified as dual purpose by both farmers and researchers.

3.6. Structure of Local Criteria According to Geographical Zone

This study across fifteen locations in the Sahelian zones of Niger identified 55 local criteria used by farmers to appreciate and evaluate the performance of cowpea varieties. The specific number and set of criteria used by farmers varied among locations. This structured the local criteria according to geographical zone, locations of west having similar sets of criteria and, respectively, locations of center south having similar sets of criteria (Figure 3). However, residual variation is observed between locations inside each zone, particularly in the west.

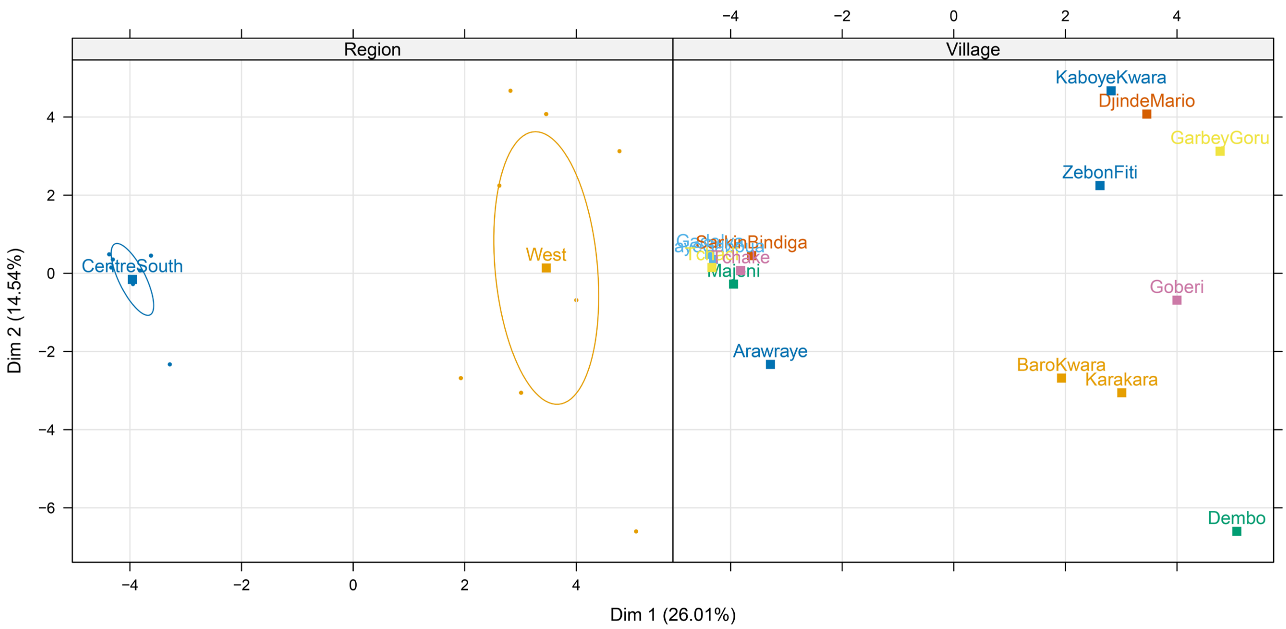

Figure 3. Local criteria used to evaluate cowpea performance structured according to geographical zone.

4. Discussion

The evaluation of cowpea performance in a local environment aims to identify and describe the farmer criteria employed to measure thirteen agronomic performance criteria. Four local criteria are utilized to assess the cycle, with flowering being the most frequently cited among farmers, indicating its association with cowpea earliness. The appearance of open flowers is known as associated with cowpea precocity [12]. Wilms production is assessed using six criteria, with ramification being emphasized more by farmers in the western zone, where expertise in cultivating creeping cowpea for leaf sales in Niamey prevails. Leaf density and leaf persistence are logical parameters for measuring haulm yield, as the top yield primarily consists of leaves. Additionally, farmers believe that the quantity of pods can influence haulm yield by leading to the loss of leaves when the pods mature [13].

The repellent substance is one of the criteria farmers use to measure cowpea sensitivity to insects. Certain cowpea varieties remain uninfected despite insect attacks due to their secretion of a protective substance, as observed in a study on corn by Huignard [14]. Sensitivity to Striga is measured based on five farmer criteria, with Striga abundance being the only criteria identified in a single site, where farmers observe the number of Striga plants per pocket to deduce the level of infestation.

After identifying local criteria for measuring biotic resistance, farmers determine the criteria linked to the resistance to abiotic constraints. Root length is one criteria farmer used to measure cowpea resistance to drought, as long roots penetrate deep into the soil to harness more water [15]. Additionally, varieties with an erect habit use less water than those with a semi-erect or creeping habit, as the erect variety has a reduced leaf surface, limiting its water requirement. Unlike the parameters used for drought resistance, biomass is used by farmers to measure cowpea resistance to waterlogging [16].

Three parameters are used by farmers to assess the ability of cowpea varieties to improve soil fertility. Varieties that lose leaves during the development cycle facilitate soil fertility improvement by accelerating decomposition. Farmers indirectly recognize the capacity of cowpea to improve fertility through rotation, observing improved yields in subsequent crops [17].

Agronomic performance is not limited to variety traits in the fields. Farmers also use other criteria to assess grain quality and economic value. For consumers, a quality grain is defined by varieties with a short cooking time, while processors prioritize varieties with brightly colored grains and good taste. Traders focus on parameters measuring the economic value of cowpea, such as early varieties, which are more commonly purchased because they produce quickly and are quickly consumed and sold in local markets before the end of the rainy season. The length of storage also increases the economic value of cowpea [18] [19].

Analysis reveals variations in farmer criteria across contexts and underscores certain parameters used to simultaneously measure multiple agronomic criteria. However, additional work is needed to prioritize these parameters and explore relationships between leaf density and resistance to Striga, as well as to verify the relationship between cycle length and agronomic efficiency.

Moreover, certain local varieties from the west zone demonstrate agronomic efficiency in the south-central zone, such as the CS009 variety. Local varieties, such as CS133 (Lakkadé) and CS030 (Doungouri koirey), perform comparably to improved varieties. Varietal performance is influenced by factors such as soil type, climate, and precipitation, resulting in variations in farmer criteria to assess the same criterion, such as seed yield.

There is a great variability in the criteria used by farmers to evaluate a cowpea variety performance. This includes a variability among villages and a variability between regional zones. However, farmers in a same village have not the same criteria for measuring a parameter, which explain the diversity of criteria for a same parameter in a village. But the integration of all these criteria makes the approach exhaustive considering that a consensus is found for each criteria. According to the production purpose and the production system, which could vary according to region, another variability in criteria for measuring agronomic performance is introduced. This explains why some criteria are exclusively present in a zone. For example, the criteria used to measure the parameter of economic value of a cowpea variety, except three, all the remaining a excluvely identified in the western zone. It means that these criteria and the parameter associated, are not relevant for farmers of central zone. This means that in the framework of participatory research in a "farmers research network" (FRN), it is absolutely mandatory to take into account the right criteria used by farmers when evaluating the agronomic performance of cultivated crops.

The study highlights the complexity of agronomic performance evaluation and emphasizes the need for additional research to enhance understanding.

5. Conclusion

The participatory evaluation provided insights into local criteria used by farmers to assess the thirteen agronomic performance traits describing the performance of cowpea varieties. Based on these criteria, farmers identified the top three performing varieties performing better among the fifteen varieties tested in their location. Notably, landraces like CS133 (Lakkadé) and CS030 (Doungouri koirey) demonstrated good efficiency comparable to improved varieties like CS127 (IT90K372-1-2) in terms of top yields in farmers conditions. The performance of cowpea varieties appeared to be local context-dependent. Beside bioclimatic variability, we showed that farmers from different locations use different measurement criteria based on their perceptions and preferences. Based on observed correlation between farmer and agronomic evaluations on four focal agronomic criteria (cycle length, grain production, haulm production and Striga resistance), we identified farmer criteria that could be used as proxies for classic agronomic measures. In perspective, a comprehensive study of the variation scales for each farmer criteria is essential to refine the search for local proxies and enhance integration of local and scientific knowledges through participatory research.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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