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Evaluation of the Indigenous Use of the Weed *Sida cordifolia* L. in the Sahelian Zone of West Africa

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Abstract

Most farmers in Niger live below the poverty line and require low-capital intensification to improve agricultural production. The purpose of this study was to evaluate local knowledge on less beneficial weed for future use in managing the soil fertility of the Sahel region. *Sida cordifolia* was utilized in a scientific procedure to verify how local farmers utilize this species and the nature of the important roles behind this wild plant in terms of soil fertility management. The results of a questionnaire showed that *S. cordifolia* was less frequently used than other wild plants found in the same area, but that local farmers recognized this plant as one of the indicators of soil fertility in millet fields. The results of soil analysis also revealed a significant coefficient of variance in certain parameters such as total acidity and aluminum saturation of the soil, while multiple regression analysis showed the high influence of total acidity and soil pH on plant height and dry matter weight, respectively. These results indicate that the significant difference in plant growth of *S. cordifolia* was mainly due to soil acidity rather than soil fertility. The application of organic matter is one effective approach to resolve this problem and it was shown that the poor growth of *S. cordifolia* is a particularly useful marker to identify patches where organic matter should be applied. Despite its simplicity, this technique is considered particularly beneficial to allocate limited resources efficiently for sustainable, improved production.

Discipline: Soils, fertilizer and plant nutrition
Additional key words: local knowledge, Niger, sandy soil, soil fertility management

Introduction

The utilization of wild plants plays an important role in the everyday life of people in rural areas of Africa. Wild plants are used to treat common diseases[2, 3] as food supplements[8, 15] and as forage for livestock[11]. However, some wild plants appear less beneficial. *Sida cordifolia* is a plant that is considered a nuisance for crop production and on pastureland[25] and feared by local people due to its rapid expansion[9]. It is less frequently used by people as food or forage for livestock because of its prickly structure, meaning it often thrives in colonies on fallow land. Despite this, local farmers' recognition of this plant was reported in Niger in relation to soil fertility management[7].

In Niger, various wild plant species are used by local farmers for different purposes; many studies have been performed to obtain information on the same. Hiernaux *et al.*[19] and Schlecht *et al.*[28] undertook intensive studies on grazing in Western Niger and identified different plant species utilized for livestock production in fallow and rangeland. Cook *et al.*[8] studied 13 wild plants and identified that *Tapinanthus globiferus* had the greatest antioxidant content. Glew *et al.*[14, 15] performed a typical study on *Sclerocarya birrea*, *Sesbania pachycarpa* and *Crataeva religiosa*, revealing the magnesium, copper, zinc, protein, amino acid and fatty acid contents of these wild plants. Gerard *et al.*[13]characterized the dynamics of species of fallow vegetation along with changes in soil fertility.

Despite these many studies, empirical information on wild plants and their relationship to soil fertility management remains limited. The soil in Niger is nutrient-poor, making soil fertility a major concern among local farmers.

The purpose of this study was to evaluate empirical information among local farmers in Niger with a special focus on wild plants used as an indicator of soil fertility. *S.*

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cordifolia is one of the plant species that proliferates in Niger and people see this change through transhumance with neighboring countries like Mali[24]. However, given the scarcity of written information, we subjected this plant to a scientific procedure to verify how local farmers recognized this species and the important roles behind this wild plant in terms of soil fertility.

Materials and methods

1. Description of the study site

This study was conducted in Western Niger (Fig. 1), where two ethnic groups, the agriculturalist Zarma and the pastoralist Fulani, practice a crop-livestock mixed production system of millet (*Pennisetum glaucum*) with cowpea (*Vigna unguiculata*) in a rain-fed ecosystem. Two villages were chosen for the study: Tchigo Tégui as a typical agro-pastoral area in the Sahel and Sadoré as an area typical of those dominated by Fulani rather than Zarma. Both are in a region classified as the Sudano-Sahelian agro-ecological zone, having a mono-modal rainfall pattern with annual rainfall of around 550 mm[10]. The soils in the study area are sandy, siliceous, isohyperthermic and Psammentic Paleustalf[21,34]. The soil chemical properties such as pH(H_2O), total nitrogen, organic carbon, available phosphorous, effective cation exchange capacity and ammonium saturation are 5.3, 0.15g kg^{-1}, 0.19%, 3.54mg kg^{-1}, 0.92 $cmol_c$ kg^{-1}, 34.2% in average, respectively[16,33]. In this region, leaving fields fallow is still the dominant practice for restoring soil fertility.

2. Local information gathering in relation to soil fertility management

Two types of surveys were conducted in the study area. The first involved identifying locally available wild plants used as indicators of the soil fertility of farmland. This survey was performed by interview in the two villages: in 19 of 21 households in Sadoré and in 35 of 135 households in Tchigo Tégui. The second survey was done by applying a questionnaire focusing on farmers' recognition of *S. cordifolia* in relation to soil fertility. The concept of soil fertility in this study was based on the local recognition by indigenous knowledge[17]. Scientific names of wild plants were identified by locally available nomenclature[23].

3. Quantification of the growth of *S. cordifolia*

S. cordifolia is a well-known plant of the Malvaceae family; it is called *kongoria* among the Zarma, *yargnankoji* among the Fulani and *hatchi'n maka* in the Hausa language. It is an annual plant that germinates after two days of effective rain in June and becomes senescent in October[7]. *S. cordifolia* is usually considered detrimental to crops and pasture land[25] and is thus feared by local people due to its rapid expansion[9]. It is less used by people as food or as forage for livestock because of its prickly feature and some toxicity[6].

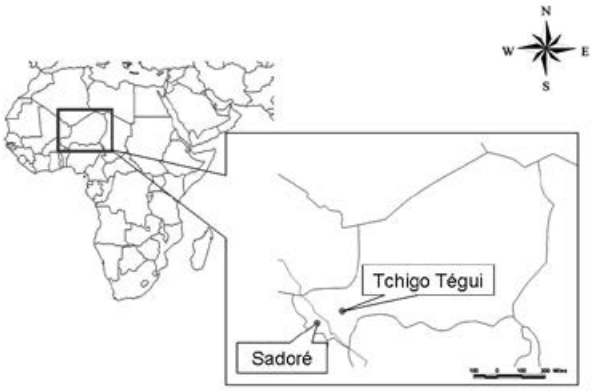

Fig. 1. Niger in West Africa and the study sites

S. cordifolia is usually found in the form of a colony (Fig. 2). To measure the plant growth of *S. cordifolia*, the plant density, plant height and dry matter weight (DMW) were measured by plant sampling with twenty replications. The sampling sites were within 4 km^2 in Sadoré and the plant sampling was performed in October 2002, just prior to the annual senescence stage of *S. cordifolia*. A 1 ×1 m iron frame was used to demarcate the sampling area. The plant density and height were measured just after the sampling and DMW was measured after two weeks of air-drying. Subsequently, the measured DMW was revised with the moisture content of the plant sample by mechanical oven-drying at 105 °C for 24 hours.

4. Soil characteristics in the colony of *S. cordifolia*

Soil sampling was performed in the same areas where plant sampling was conducted. Surface soil at a depth of 0–15 cm was taken from five points in an area to make a composite sample. Samples were air-dried for more than a week and sieved using a 2-mm mesh prior to the analysis. Mechanical oven-drying of the soil was performed at 105 °C for 24 hours to determine its moisture content. The parameters and methods for the analysis were as follows; pH by pH meter with 1:2.5 of soil and distilled water (pH), available phosphorus by the Bray-II method (BrayII-P), organic carbon content by the Walkley and Black method (Corg), total nitrogen by the Kjeldahl method (T-N), total acidity by the titration method (TA) as a sum of exchangeable Al^{3+} and H^+, exchangeable bases (Na^+, K^+, Mg^{2+} and Ca^{2+}) by 1N ammonium acetate extraction method, which were used to calculate the effective cation exchangeable capacity (eCEC) as a sum of exchangeable bases with TA.

5. Statistics

Statistical analysis was performed to test the normality of plant samples and multiple regression analysis by Excel Toukei 2010, add-in software for Microsoft Excel. The fre-

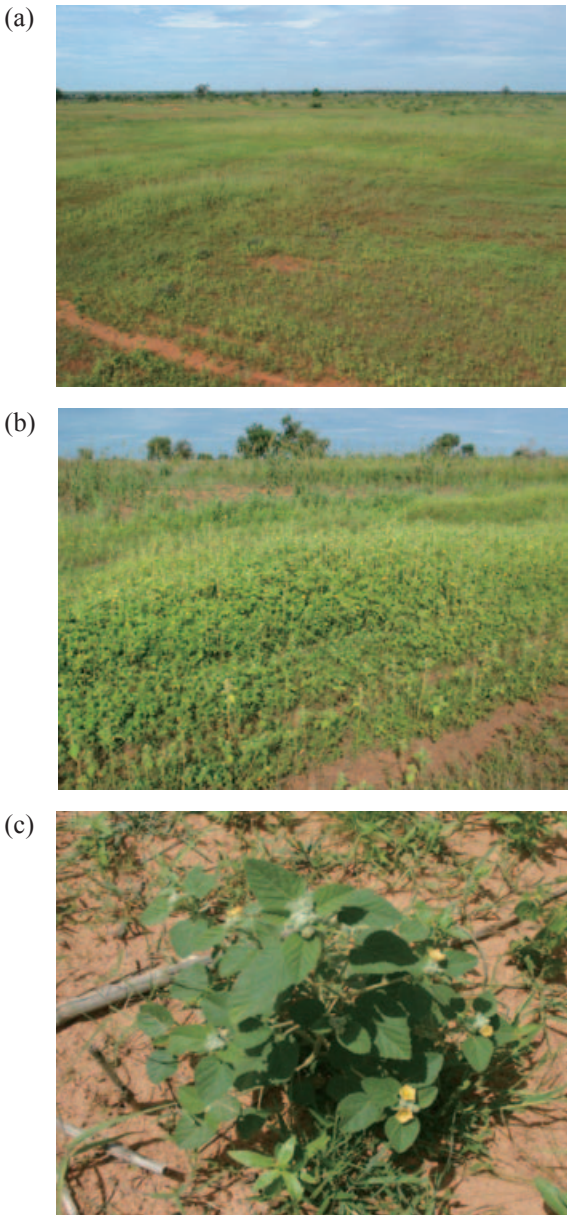

Fig. 2. Natural vegetation of *S. cordifolia* in fallow land
(a) poor growth spots, (b) good growth spots and (c) full portrait

quency distribution was calculated and its distribution was examined by testing the goodness of fit.

Stepwise multiple regression analysis was performed with quantitative data on plant growth as an explanatory variable and soil chemical property as an independent variable. Correlation coefficients for all parameters were examined and parameters of no significance with explanatory variables were excluded prior to the regression analysis. The degree of influence or DI was determined to identify an independent variable with more influence than others. DI was calculated as follows:

$$DI = C \times R$$

where C is the coefficient and R is the range, namely the value obtained through the maximum value subtracted by the minimum value[30].

Table 1-1. Identified herbaceous species in Tchigo Tégui through the questionnaire survey on locally available wild plants, which are used as indicators of the soil fertility of farmland

Local name	Scientific name	Family
Arkusu bonkwarei	*Polycarpaea linerarifolia*	Caryophyllaceae
Andro	*Chrozophora brocchiana*	Gramineae
Bata	*Aristida longiflora*	Gramineae
Bari gawshi	*Panicum anabaptistum*	Gramineae
Balasa	*Commelina forskalaei*	Commelinaeae
Borboto	*Pennisetum pedicellatum*	Gramineae
Dani	*Cenchrus biflorus*	Gramineae
Dara dara	*Vigna unguiculata*	Papilonaceae
Dorey	*Chrozophora brocchiana*	Euphorbiaceae
Faku	*Corchorus plitorius*	Tiliaceae
Fhataska	*Heliotropium indicum*	Boraginaceae
Ganda bani	*Cassia mimosoides*	Caesalpiniaceae
Gadigy	*Alysicarpus ovalifolius*	Papilonaceae
Gagi	*Digitaria gayana*	Poaceae
Garza	*Brachiaria Lata*	Gramineae
Garaji	*Brachiaria distichophylla*	Gramineae
Haramdam	*Diheteropogon hagerupii*	Gramineae
Kassawura	*Aristida pallida*	Gramineae
Kongoria	*Sida cordifolia*	Malvaceae
Kouloume	*Eragrostis tremula*	Gramineae
Koro tamu	*Ipomoea vagans*	Convolvulaceae
Marak	*Zorina glochidiata*	Papilonaceae
Nine basey	*Waltheria indica*	Sterculiaceae
Subu kirey	*Schizachyrium exile*	Gramineae
Soubou kuware	*Aristida mutabilis*	Gramineae
Sudafiti	*Evolvulus alsinoides*	Convolvulaceae
Thien kabe	*Cyperus conglomeratus*	Cyperaceae
Gansi	*Panicum laetum*	Gramineae
Yodo	*Ceratotheca sesamoides*	Pedaliaceae
Total number of species		29
% of Garmineae		45
% of Papilionaceae		14
% of Malvaceae and others		41

Results

1. Local farmers' recognition of wild plants as an indicator of soil fertility diagnosis

The results of the first questionnaire are shown in Tables 1-1 and 1-2. Local farmers in Sadoré considered 17 species of wild plant to be indicators of soil fertility, while the total was 29 species for farmers in Tchigo Tégui. In general, local farmers recognized an average of 37 herba-

ceous species in this region[18] and thus these figures represented 46 and 79% of total herbaceous species, respectively. Most wild plants identified by local farmers in this questionnaire were from the Garmineae family, which was a main component in the identified species of both sites. Other plants were from various families, such as Papilionaceae (14% in Tchigo Tégui, 18% in Sadoré) and Malvaceae (41% in Tchigo Tégui, 29% in Sadoré) as well as Commelinaceae, Caesalpiniaceae, Tiliaceae and Sterculiaceae in Sadoré, and Caryophyllaceae, Commelinaceae, Convolvulaceae, Euphorbiaceae, Tiliaceae, Boraginaceae Caesalpiniaceae, Cyperaceae, Rosaseae, Pedaliaceae and Sterculiaceae in Tchigo Tégui.

Table 1-2. Identified herbaceous species in Sadoré through the questionnaire survey on locally available wild plants, which are used as indicators of the soil fertility of farmland

Local name	Scientific name	Family
Kumbi	*Ricinus communis*	Euphorbiaceae
Balasa	*Commelina forskalaei*	Commelinaceae
Kongoria	*Sida cordifolia*	Malvaceae
Ganda bani	*Cassia mimosoides*	Caesalpiniaceae
Dani	*Cenchrus biflorus*	Gramineae
Haramdam	*Diheteropogon hagerupii*	Gramineae
Goso	*Sesbania leptocarpa*	Papilionaceae
Karsan	*Cymbopogon schoenathus*	Gramineae
Kassawura	*Aristida pallida*	Gramineae
Gadigy	*Alysicarpus ovalifolius*	Papilonaceae
Kouloume	*Eragrostis tremula*	Gramineae
Faku	*Corchorus plitorius*	Tiliaceae
Nine basey	*Waltheria indica*	Sterculiaceae
Soubou kuware	*Aristida mutabilis*	Gramineae
Gansi	*Panicum laetum*	Gramineae
Borboto	*Pennisetum pedicellatum*	Gramineae
Garaji	*Brachiaria distichophylla*	Gramineae
Total number of species		17
% of Garmineae		53
% of Papilionaceae		18
% of Malvaceae and others		29

Table 2 shows the five most common wild plant species in both sites, which were used not only to diagnose soil fertility but also for other purposes, such as forage, traditional medicine and construction materials. According to the results, the wild plants were from various families, and most species were common to both villages, with the exceptions of *Cymbopogon giganteus* and *Eragrostis tremula*. *S. cordifolia* was found on the lists for both sites, with 37% of local farmers recognizing it in Tchigo Tégui and 100% of farmers in Sadoré. It was also shown that *S. cordifolia* was only used as construction material, and not for forage, medicine or food. According to the local farmers, *S. cordifolia* was their last resort when all other available sources of forage from fallow areas had been used up during the dry season. Goats and sheep take calyces and grain when there is no forage available.

2. Perception of *S. cordifolia* among the local people

Questions and responses in relation to the second questionnaire are shown in Table 3. According to the results, all surveyed farmers responded that they had seen good growth of millet where *S. cordifolia* growth was good. Moreover, 89.5% of the surveyed farmers considered that the growth of *S. cordifolia* had some relationship to soil fertility, and all responded that the application of farmyard manure or household waste was an approach to improve soil productivity

Table 2. Top five wild plants for soil fertility diagnosis and their utilization for other purposes according to local farmers in Sadoré and Tchigo Tégui

Scientific name	Family	Recognition (%)	Other utilization			
			Food	Forage [a]	Medicine	Materials [b]
in Sadoré						
Sida cordifolia	Malvaceae	100.0	0	0	0	89.5
Cassia mimosoides	Caesalpiniaceae	47.4	0	47.4	21.1	36.8
Cenchrus biflorus	Gramineae	26.3	0	26.3	10.5	0
Cymbopogon giganteus	Gramineae	15.8	0	15.8	0	15.8
Alysicarpus ovalifolius	Papilionaceae	10.5	0	10.5	10.5	0
in Tchigo Tégui						
Cenchrus biflorus	Gramineae	94.3	0	91.7	2.8	0
Cassia mimosoides	Caesalpiniaceae	57.1	0	52.8	44.4	47.2
Eragrostis tremula	Gramineae	48.6	0	47.2	47.2	47.2
Alysicarpus ovalifolius	Papilionaceae	45.7	0	44.4	33.3	2.8
Sida cordifolia	Malvaceae	37.1	0	0	19.4	30.6

[a] in rainy season only, [b] for mats, ropes and skewers

Table 3.

Questionnaire	Responded "Yes" (%)
Number of households in Sadoré = 21	
Number of households completing questionnaire = 19	
Sampling scale = 90.5%	
I know *S. cordifolia.*	100.0
I think that millet growth is good where *S. cordifolia* grows well.	100.0
I think that the change mentioned above is due to the difference in soil fertility.	89.5
I apply organic matter* to places where *S. cordifolia* doesn't grow well.	100.0
I observe improved millet growth after the abovementioned practice.	100.0
I think that you can obtain same change by the application of inorganic fertilizer.	10.5

* Farmyard manure or household waste

where the growth of *S. cordifolia* was poor. Only 10.5% of the surveyed farmers responded that they used inorganic fertilizer for the same purpose.

3. Growth of *S. cordifolia* in the study area

Fig. 3 showed the frequency distribution for plant density, plant height and DMW of *S. cordifolia* in the study area. Distribution was high in 8-58 plant m^{-2}, 5-25cm, 100-400g m^{-2}. The testing probabilities for goodness of fit were 0.06, 0.60 and 0.09 for plant density, plant height and DMW, respectively, hence the sample population engaged for this analysis was considered to have normal distribution.

4. Soil chemical characteristics in *S. cordifolia* grown spots

Table 4 shows the result of soil analysis for the sampling area. Compared to the average soil characteristics in the same area, pH (H_2O), T-N, Corg were almost in the same range while other parameters such as BrayII-P, eCEC and Al saturation were lower than average.

Table 5 shows the results of multiple regression analysis. The obtained formulas showed no multicolinearity because the signs of coefficient and correlation coefficient coincided. Plant height was assigned as the objective variable with the explanatory variables of T-N and TA. This regression obtained a modified R^2 of 0.813 with significance at the level of <1%; hence this regression was considered sufficiently precise. In an additional analysis, DMW as the objective variable with the explanatory variables of pH and exchangeable Na^+ obtained a modified R^2 of 0.569 with significance at the level of <1%. Data on the degree of influence shown in the table indicate that TA had significantly more influence on plant height and pH had significantly more influence on DMW than the other parameters, which means that the higher the soil acidity or the lower the pH, the lower the plant growth or DMW. To evaluate obtained regression models, measured and simulated data were plotted in a scattered diagram and the root mean square error (RMSE) was calculated as an indicator for goodness of fit (Fig. 4). RMSE for plant height and DMW were 0.7 and 10.5, respectively, meaning the obtained regression models were considered precise.

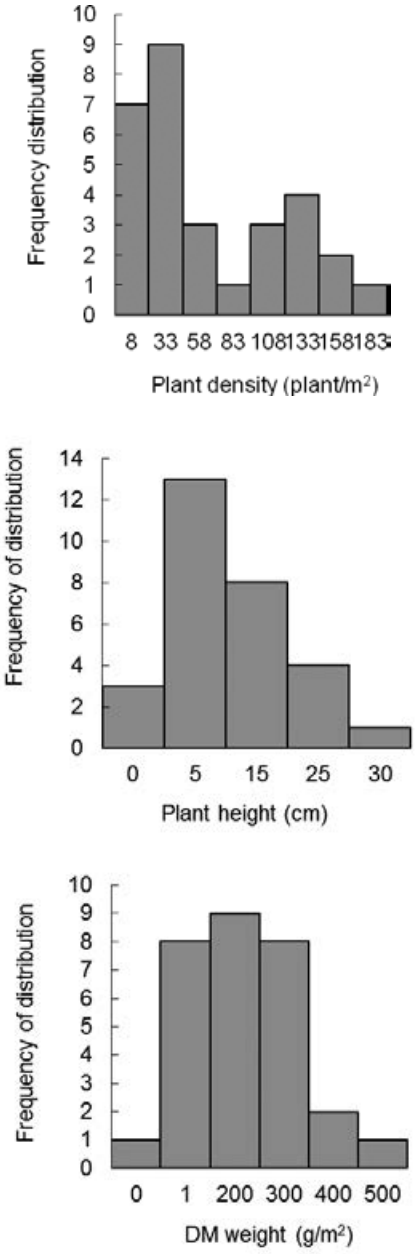

Fig. 3. Frequency distribution of (a) plant density, (b) height and (c) dry matter weight of *S. cordifolia* grown in fallow land of the study area

Table 4. Soil chemical parameters of various spots in farmlands where the growth of *S. cordifolia* showed wide growth variation from poor to good growth

Depth (cm)	n=20	pH (H_20)	eCEC	Total acidity	Al saturation	C org	BrayII-P	Total N
			$cmol_c\ kg^{-1}$		%		$mg\ kg^{-1}$	
0-15	Mean	5.68	0.96	0.19	16.76	0.22	2.71	171.88
	min	4.93	0.60	0.02	0.00	0.14	1.90	119.78
	max	6.42	1.93	0.58	65.57	0.34	5.48	259.13
	SD	0.47	0.28	0.17	19.62	0.05	0.75	42.79
	c.v	8.23	28.91	88.00	117.10	24.55	27.70	24.90

[a] Al saturation = Exchangeable $Al^{3+}/\Sigma(Na^{+}+K^{+}+Mg^{2+}+Ca^{2+})$

Table 5. Degree of influence on the growth of *S. cordifolia* identified by multiple regression analysis

Objective variable	Explanatory variable	Coefficient	Correlation coefficient	*P*	Range	Modified R^2	Degree of influence
Plant height	Total acidity	-37.06	-0.65	<0.000	0.57	0.813**	-21.05
	Total nitrogen	0.12	0.29	0.0001	137.00		15.97
	constant	3.51					
DMW	pH (H_2O)	104.09	0.61	0.0016	2.20	0.569**	228.99
	Exchangeable Na^{+}	3932.38	0.59	0.0027	0.04		155.93
	constant	-484.21					

** significant level at 1%

Discussion

1. Perception of *S. cordifolia* among local farmers in relation to millet production

According to the results of our survey, local farmers at the study sites were aware of an association between the growth of *S. cordifolia* and the soil fertility of millet fields. To improve the spots where *S. cordifolia* did not grow well, most local farmers stated that they applied farmyard manure or household waste during the dry season. Their responses sounded rational and this was confirmed through a recent survey by Hayashi *et al*[17]. Despite limited organic resources, local farmers prioritized the allocation of household waste and farmyard manure to restore low-productive areas of farmland where plant growth including *S. cordifolia* was inadequate. Although the use of urea, compound NPK fertilizer, or diammonium phosphate (DAP) was recommended practice in the area, most farmers responded that they did not apply chemical fertilizer. They may have empirically been aware of the fact that soil acidity may be aggravated by applying these chemical fertilizers because of their discharge of protons, which reduce soil pH.

The results of soil characteristic analysis of *S. cordifolia* showed a similarity with the average data referred to in the previous study. However, the coefficients of variance for TA and Al saturation far exceeded the other parameters, which implies the heterogeneity of the soil where *S. cordifolia* grew. This is consistent with the findings of previous studies concerning the variation in soil and millet yield in the same region[26,29,33]. Ikpe and Powell[22] reported that soil acidity was significantly reduced by the application of organic matter, such as cow dung, to the surface soil and that this boosted the millet yield. This is also consistent with what local farmers recognized empirically at the study sites as the main cause of variation in plant growth in the field.

2. Validation of indigenous knowledge to manage soil fertility

As local farmers in Niger have limited access to outsourcing for soil fertility management[4,32], judicious utilization of their finite resources is crucial. Precision agriculture is one way to use limited resources efficiently through minimal inputs for maximal outputs from crop production[11,29]. Gandah *et al.*[13] applied low-tech precision agriculture to improve fertility management by observing individual plant hills. However, the average amount of land cultivated by individual households in Niger is considerable, reaching 13.2 ha in less densely populated areas and around 5 ha in densely populated areas[20]. Therefore, the availability of manual labor as well as organic resources could be an inherent constraint on the management of farmland. Our study showed that local farmers in Niger used some specific wild plant species to indicate the soil fertility in farmland. Most of these species were also used for other purposes, such as forage for livestock, ingredients in traditional medicine and

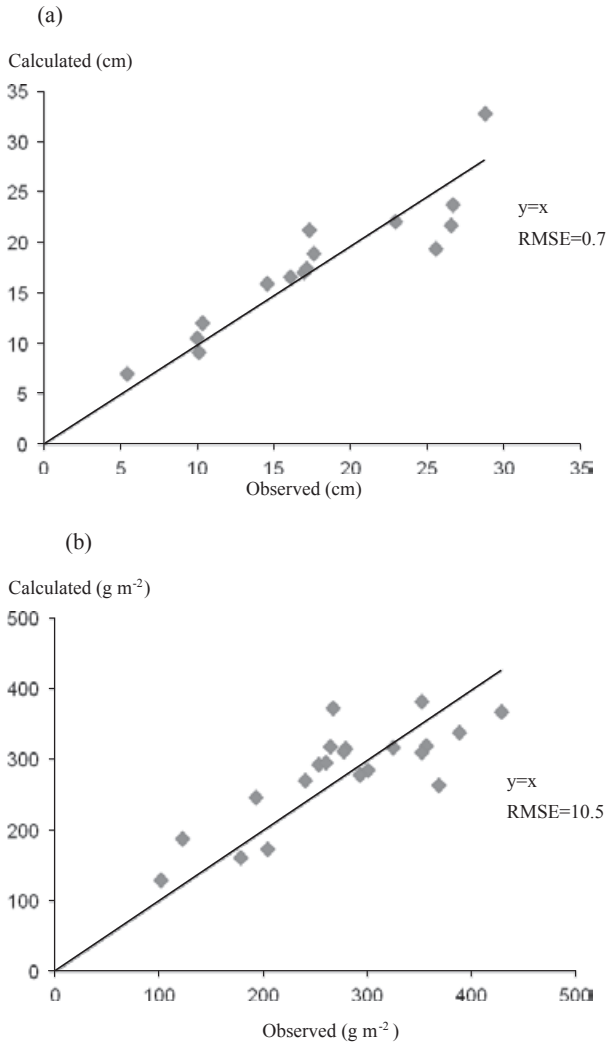

Fig. 4. Observed and calculated (a) plant height, (b) dry matter weight of *S. cordifolia*

Equation for the simulation of (a) and (b) are y=0.8396 x +2.8455 and y=0.6575 x+101.2, respectively.

construction. However, the survey also found that local farmers did not recognize *S. cordifolia* as a multi-purpose wild plant, as it was used only for a few purposes like construction and to indicate soil fertility. This implies that there would only be minimal sacrifice involved in using *S. cordifolia* exclusively for a single purpose, namely, as an indicator of soil fertility. In general, soil has low fertility in Niger, owing to the highly weathered sandy soils; however, soil in farmlands shows heterogeneous fertility owing to the micromorphological feature of the farmland surface[33]. Since *S. cordifolia* existed in the form of colonies in fallow areas, it can be directly used to identify spots where finite resources should be allocated.

Since local farmers in Niger live below the poverty line, costly technologies to improve their livelihood are unfeasible[1]. Targeting improved production through minimal inputs of organic or inorganic amendment is ideal, and utilizing existing local knowledge is particularly beneficial to resolve persistent problems in this region.

Conclusion

The study identified local farmers' recognition of wild plants as an indicator of soil fertility and this plant was not used as an extra source of food, fodder or medicine. Soil analysis revealed that the growth of *S. cordifolia* was significantly associated with soil acidity. The application of organic matter is one of the most effective ways to resolve this problem and utilizing *S. cordifolia* was found to be particularly effective in identifying spots at which to apply organic matter. A systematic approach to use this wild plant needs to be developed to achieve low-capital intensification for agricultural production in the Sahelian region.

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