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Plant species richness and diversity in urban and peri-urban gardens of Niamey, Niger

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Abstract Urban and peri-urban agriculture (UPA) significantly contributes to food and nutritional security of urban dwellers in many African countries. Economic and demographic pressures often lead to transformation of subsistence-oriented traditional homegardens into commercial production units. Such transformation is claimed to result in decreasing plant diversity, particularly of local species. A study was therefore undertaken in 51 gardens of Niamey, Niger, to assess the factors determining plant diversity and the suitability of UPA for in situ conservation of plant genetic resources. In each garden, the number and abundance of all human-used plant species were determined, and species density, Shannon index and Shannon evenness were calculated. In the 51 surveyed gardens, a total of 116 plant species were cultivated, most of them for the production of fruits or vegetables. Annual vegetables dominated, particularly exotic species grown for sale. In the cold season, an average of 14 species were cultivated per garden, the Shannon index was 0.96 and evenness was 0.39. Commercial gardens had a species richness similar to that of subsistence gardens, but a lower evenness ($P < 0.005$), caused by the dominance of a few vegetable species. Gardens of immigrants had a lower Shannon index than those of members of the local Djerma ethnic group. Stepwise multiple regression analysis showed significant influence of various variables on plant species richness and diversity parameters: garden size (richness and Shannon index), ethnicity of the gardener (richness and evenness), gender of the gardener and cash-oriented production (evenness), household size (richness) and garden possession status (Shannon index). Cluster analysis revealed the existence of five garden types. The highest species richness and diversity, particularly of perennial and local species, was found in large, peri-urban, commercial gardens managed by relatively wealthy, elderly gardeners with large families and a regular non-agricultural income.

Keywords Cluster analysis · Commercialisation · In situ conservation · Plant genetic resources · Urban agriculture

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Introduction

Niger, whose agricultural area is largely limited to the semi-arid southern Sahelian zone, is the world's poorest country and recurrently affected by periods of famine (USAID 2002). With its approximately 900,000 inhabitants, the country's capital Niamey provides an ideal example to study the intensive use of open space by urban and peri-urban agriculture (UPA). Due to the high birthrate and the arrival of migrants from rural areas triggered by low soil fertility, erratic rainfall and poor infrastructure, the city has experienced, over recent years, a high population growth rate (5.3% per year; USAID 2002), leading to a continuous increase in food demand. It is in such a context that, all over Africa, UPA has become an increasingly important activity for improving the quality and quantity of food intake (Maxwell et al. 1998; Bryld 2003). Worldwide, UPA is estimated to produce as much as one-seventh of the total food supply (Drescher 1998). African cities such as Bamako (Mali) or Lubumbashi (Democratic Republic of Congo) are reportedly self-supporting in the supply of vegetables through UPA (Tambwe 2006).

A 'homegarden' is generally described as an agroforestry system nearby the gardener's house, comprising a mixture of annual and perennial crops in several strata and often largely directed towards fulfilling subsistence needs (Nair and Kumar 2006). Nevertheless, some authors refer to mixed species gardens as homegardens even if they are not around the homestead, which is particularly the case in urban areas, due to land scarcity, and in semi-arid regions, where their vicinity to water sources is very important for irrigation (Niñez 1985; Linares 2004; Drescher et al. 2006). In addition, the presence of perennials may be limited under arid and semi-arid conditions (Ceccolini 2002; Gebauer et al. 2007) and urban settings due to land scarcity (Wiersum 2006), water shortages (Thaman et al. 2006) and insecure land tenure (Linares 2004). Thus, urban homegardens in semi-arid regions may not fit the 'classical' definition of homegardens, although they could have a similar function as household-based small production units (Drescher et al. 2006). While gardens in an urban setting may also fulfill subsistence needs, they are often heavily market oriented. To avoid confusion in terminology, we use the more general term 'garden' instead of 'homegarden' in our study. However, given their importance in the literature, we often refer to 'classical' homegardens for comparison.

In rural settings, homegardens typically offer a diverse range of products, such as fruits, vegetables, spices, medicine, forage and fuel. The often very high diversity of species in such gardens reportedly reduces the risk of infestation by pests or diseases, offers long-term stability of yields and efficient use of resources and makes year-round availability of crops possible, even under semi-arid conditions (Soemarwoto and Conway 1992; Torquebiau 1992). However, species diversity in homegardens is often very dynamic and largely influenced by different socio-economic and agroecological factors (Wiersum 2006; Kehlenbeck et al. 2007). Homegardens are often described as sustainable, although quantitative support for this ill-defined statement is rare (Kehlenbeck and Maass 2006). This argument is partly based on the claim that the sustainability of man-made agro-ecosystems increases with their plant diversity (Soemarwoto and Conway 1992; Torquebiau 1992), which also leads to an improved nutritional status of households managing species-rich systems as compared with species-poor ones (Davis et al. 1994). Homegardens are also regarded as an important land use system for in situ conservation of plant genetic resources (Trinh et al. 2003; Eyzaguirre and Linares 2004), particularly of local species such as indigenous leafy vegetables, which are better adapted to local agroecological conditions (Drescher 1998) and said to have a higher nutritional value than exotic leafy vegetables. Leaves of *Gynandropsis gynandra*, for example, contain about 80 times more iron than those of spinach (*Spinacia oleracea*) (Smith et al. 1996). However, in most urban areas, constant economic and demographic pressure as well as high market demand lead to transformation of traditional homegardens towards ornamentalisation or commercialisation (Abdoellah et al. 2006; Wiersum 2006; Kehlenbeck et al. 2007). The related cultural and socioeconomic changes may result in decreasing plant diversity (especially of local species) in the gardens, dominance of a few exotic species/improved varieties for cash crop production, impoverishment of dietary diversity of gardeners' households or loss of tribal culture and indigenous knowledge (Soemarwoto and Conway 1992; Fundora Mayor et al. 2004; Tesfaye Abebe et al. 2006).

Most available studies of homegardens are from humid areas of tropical Asia and Mesoamerica (Karyono 1990; Soemarwoto and Conway 1992; Trinh et al. 2003; Blanckaert et al. 2004; Kehlenbeck and Maass 2004; Albuquerque et al. 2005; Abdoellah et al. 2006; Peyre et al. 2006), whereas reports from Africa, particularly from urban areas or arid/semi-arid regions, are very limited (Drescher 1998; Linares 2004; Gebauer 2005). Additionally the large majority of the available studies remain rather descriptive, and quantitative methods including multivariate statistics to unravel causes of biodiversity patterns are rarely used (Blanckaert et al. 2004; Kehlenbeck et al. 2007). For urban and rural gardens in the sub-Saharan country of Niger, such information is lacking. The main objectives of this study were therefore to quantify plant diversity in urban and peri-urban gardens of Niamey (Niger) and to analyse the effects of garden and household size, market orientation, ethnic affiliation and gender of the gardener on plant diversity in these gardens. In addition, the study aimed to classify gardens according to species abundance and to assess their suitability for in situ conservation of plant genetic resources.

Materials and methods

Study area

The study was conducted in urban and peri-urban gardens of Niamey (13°31′17" N, 2°6′19" E), the capital of Niger. The typical Sahelian climate at this location can be divided into three distinct periods: the cold season (October to February, no precipitation), the hot season (March to May, no precipitation) and the rainy season (June to September). Mean temperatures are 27°C during the cold, 33°C during the hot and 29°C during the rainy season; the mean annual rainfall amounts to 540 mm (WMO 2007). The rural agriculture in Niger is mainly dominated by fields sown to pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) sparsely relay-cropped with cowpea (*Vigna unguiculata*), complemented by extensive livestock husbandry. In and around Niamey, intensive horticulture mixed with millet cropping and meat, milk and egg production destined to satisfy the local markets is an important activity (Graefe et al. 2008). The Niger River crosses Niamey and constitutes the most important water source for irrigated horticulture. The native and largest ethnic group in Niamey are the Djerma, but Haussa, Tuareg, Peul and Kanouri are also common (INS 2008).

Data collection

Fieldwork was conducted from January to August 2007 in ten districts of Niamey, including urban and peri-urban ones (Fig. 1), which were chosen based on an earlier study of UPA by Graefe et al. (2008). In these districts, 13 gardens briefly described by Graefe et al. (2008) were selected, to which 38 gardens were added using a 'snowball' sampling method for selection. These 51 gardens, comprising 29 urban and 22 peri-urban ones, and covering a total area of 4.4 ha, were surveyed in the three different seasons of the year, except in August (rainy season) where only 45 gardens were available because six gardeners

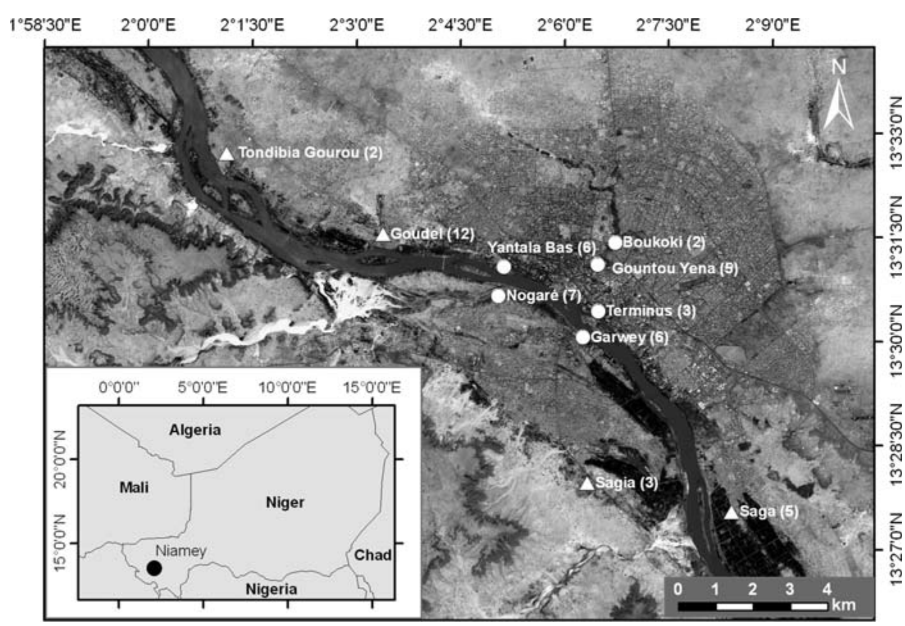

Fig. 1 Quickbird satellite image (Google Earth Pro, Google Inc., Mountain View, CA, USA) of Niamey (Niger). The *white dots* indicate the locations of 29 gardens surveyed in six urban districts in 2007, the *white triangles* those of 22 gardens in four peri-urban districts. *Numbers in brackets* show the number of gardens per district

withdrew their participation. Garden sizes were determined using a differential GPS receiver (Global Positioning System; Trimble Pathfinder Pro XR; Westminster, CO, USA). Gardeners were individually interviewed to gather basic socioeconomic data (origin, ethnic affiliation, profession and income sources of the gardener, household size, number and size of land holdings) and garden-related information (plant uses, portion of sold products, use of fertilisers, pesticides and wage laborers, among others). According to Abdoellah et al. (2006), a garden was defined as commercial if more than 50% of its produce was sold and as non-commercial otherwise.

In all gardens, the useful plant species (including ornamentals) and their abundances were determined, whereby weeds were excluded. All species were recorded with their local and scientific names. Species were identified according to Peyre de Fabregues (1979) and Arbonnier (2000) following the nomenclature of Hanelt and the Institute of Plant Genetics and Crop Plant Research (2001) and of Zander et al. (2002) or, if not available there, of the Missouri Botanical Garden (2007). According to the mentioned literature, species originating from sub-Saharan Africa were regarded as 'local', and those from other regions as 'exotic'. As suggested by Kehlenbeck and Maass (2004) and Tesfaye Abebe et al. (2006), all recorded plant species were assigned to the different main use categories fruit, vegetable, stimulant, spice, medicine, staple, wood and multipurpose use (MPU), ornamental or other uses, according to gardeners' information and the literature used for species identification. For analysis of the vertical vegetation structure, all species were assigned to the ground layer (<1 m), the intermediate layer (1–5 m) or the top layer (>5 m).

Data analysis

Species density was determined as the estimated number of species in a 1,000 m^2 garden, in order to remove some of the size effects when comparing gardens of different types. Following Evans et al. (1955), we assumed that species number was proportional to log(area + 1). While this species-area curve is only an empirical relationship found in some natural systems, it provides a first approximation to allow for comparisons despite the large differences in garden sizes encountered in this study. In addition, the Shannon index (H') and the Shannon evenness index (E) were calculated to assess species diversity of the gardens (McCune et al. 2002). To describe and compare the importance of different plant use categories per garden, the summed dominance ratio (SDR) was computed (McCune et al. 2002). First, the relative densities and relative frequencies were used to calculate the SDR for each species, followed by summing up the single SDR values of all species within each of the use categories.

For statistical analysis, SPSS (version 12.0) and MVSP (Multi-Variate Statistical Package, version 13.3p, Kovach Computing Services; Anglesey, Wales, UK) were used. *T*-tests were used to compare means of two groups; for more than two groups, one-way analysis of variance (ANOVA) followed by post hoc Tukey tests were performed. To analyse temporal changes of diversity between the seasons, paired-samples *T*-tests were applied. Linear bivariate relations between variables were analysed using Pearson's correlation coefficients for metric variables and Spearman's correlation coefficients r_S for ordinal variables. Multiple linear regression analysis was performed to identify factors determining plant species richness and diversity using the stepwise method (Backhaus et al. 2006). For these analyses, dependent variables were overall plant species richness, richness of local species, overall diversity expressed by the Shannon index and Shannon evenness index. The independent variables included garden size, characteristics of the gardener and his/her household, and socio-economic features.

To classify the gardens according to their plant species composition, a hierarchical cluster analysis was carried out based on ln-transformed species abundance data (McCune et al. 2002). For cluster analysis, squared Euclidean distances and the 'minimum variance' method in MVSP were applied (Backhaus et al. 2006). To define the correct number of different clusters, the 'elbow' criterion was used (Backhaus et al. 2006). Stepwise discriminant analysis was carried out to analyse whether the clusters differed significantly from each other and to determine the species mainly responsible for the separation (McCune et al. 2002).

Results

The 51 surveyed gardens harbored a relatively high but very variable richness and diversity of useful plants. Garden sizes ranged from 37 to 10,355 m^2 with a mean of 860 m^2 (Table 1). Almost 70% of the gardeners owned the piece of land they cultivated, but only one lived within his garden. More than 80% of the respondents reported cultivating their gardens mainly for commercial production. Rented gardens were all commercial. Nearly half of the gardens surveyed were managed by the native Djerma ethnic group, whose market orientation was less pronounced than that of other ethnic groups (Table 1). The gardens managed by migrants such as Guarmanché and Mossi from Burkina Faso were highly commercial.

Of all gardeners, 43% reported to have in addition to gardening a supplementary income within their family, such as trade or a retirement pension. One-quarter of those gardeners managing commercial gardens reported to have employees for gardening, often including child labor. The 11 gardens managed by women, all of them Djerma, were smaller than those managed by men, with mean sizes of 312 and 1,010 m^2, respectively. While 64% of the gardens managed by women were subsistence gardens, 95% of those managed by men were commercial ones.

For irrigation, mainly water from the Niger River, but also from small brooklets and wells, partly equipped with pumps, was used. Nearly all gardeners reported to regularly apply commercial pesticides for plant protection as well as mineral fertilisers, but organic fertilisers were also frequently used. The latter was mostly farmyard manure from their own livestock that was kept by 51% of the respondents.

Species composition, richness and diversity

In total, 116 different plant species from 50 families were cultivated in the 51 surveyed gardens, 71% of which were exotic and 47% were woody perennials (Appendix, Table 7). Most of the cultivated species were used as fruits (33 spp.) and vegetables (31 spp.). For about 30% of the plants with a non-medicinal main use, gardeners mentioned medicine as a secondary use (Appendix, Table 7). However, not all respondents, especially from the younger generations, had retained the traditional knowledge about medicinal plants and their uses. Ornamentals were only rarely planted (Appendix, Table 7).

In the cold season, a total of 115 species were found (Table 2); the most frequently cultivated annual species were the exotic vegetables *Lactuca sativa* (94% of the gardens) (see Appendix, Table 7 for the common names of all species), *Brassica oleracea* (80%) and *Lycopersicon esculentum* (78%), while frequent local annuals were the vegetables *Hibiscus sabdariffa* (28%) and *Abelmoschus esculentus* (26%). Among perennials, the most frequently cultivated species were the vegetables *Moringa oleifera* (55% of gardens) and *Adansonia digitata* (45%). However, 18% of the gardens had no single perennial species and 43% of the gardeners did not cultivate any fruit trees. In urban locations, perennials were significantly more abundant than in the peri-urban area, with means of 445 and 135 individuals

Table 1 Profile of 50 gardens and gardeners' households surveyed in Niamey (Niger), 2007 according to ethnic affiliation of the gardener

Characteristic	Djerma ($n = 24$)	Gourmanché ($n = 8$)	Mossi ($n = 7$)	Peul ($n = 5$)	Tuareg ($n = 6$)
Mean no. of household members	7	6	7	6	8
Gardeners born in Niamey (%)	100	38	14	100	67
Gardeners with external income (%)	29	63	86	40	83
Gardeners owning the garden (%)	86	50	29	60	67
Commercial gardens (%)	67	100	100	80	100
Employees for gardening (%)	20	38	43	20	0
Mean garden size (m^2)	593	2,076	677	709	696
Range of garden size (m^2)	37–3,752	404–10,355	192–1,991	62–1,508	308–1,203

Data of a single commercial garden, sized 539 m^2 and managed by a gardener of the Jarouba ethnic group, are not shown

Table 2 Total number of plant species per use category in the cold, hot and rainy season in gardens of Niamey (Niger), 2007

Use category	Cold season ($n = 51$)	Hot season ($n = 51$)	Rainy season ($n = 45$)
Fruit	33	31	28
Vegetable	30	26	18
Stimulant	4	3	1
Spice	11	9	4
Medicine	6	5	3
Staple	8	5	4
Wood and MPU	18	17	16
Ornamental	3	2	1
Other	2	2	2
Total	115	100	77

MPU multipurpose use

per garden, respectively ($P = 0.047$). Abundance of fruit trees, however, was slightly higher in peri-urban than in urban areas (34 versus 7 individuals per garden, $P = 0.260$) and in owned as compared with rented gardens (24 versus 5 tree individuals per garden, $P = 0.201$). In gardens operated by women, numbers of species and of individuals of perennials were significantly much lower compared with in those operated by men (species number 1.4 versus 7.2; $P < 0.001$; individual number 33 versus 388; $P = 0.001$), whereas richness of local species was only slightly lower (1.2 versus 3.2; $P = 0.092$). The use of market orientation as a categorisation criterion was confirmed by marked differences in species composition and abundances between gardens rated as either commercial or subsistence. In gardens categorised as commercial, a significantly higher proportion of individuals of the most important cash species (*Allium porrum*, *Amaranthus caudatus*, *Beta vulgaris*, *B. oleracea*, *Fragaria × ananassa*, *H. sabdariffa*, *L. sativa*, *Mentha* sp., *Petroselinum crispum*, *Pisum sativum*, *Solanum gilo*, *Solanum melongena*) was found as compared with in subsistence gardens (80% of total individuals versus 37%, $P < 0.001$).

Forty-four species, including *Cola nitida* and *Theobroma cacao* cultivated for experimental reasons, were only recorded from one of the surveyed gardens. Thirty of the 34 species of local origin were cultivated in less than 20% of the gardens (Appendix, Table 7), and 21 were represented by fewer than ten individuals each. One of these rather rare local species, *Gossypium arboreum*, may be regarded as a relict crop as gardeners mentioned that it was cultivated more frequently in the past for cotton production, while nowadays only its leaves are rarely used as medicine for infants. Several other rare species such as the indigenous fruit tree species *Annona senegalensis*, *Dialium guineense* and *Grewia tenax* were exclusively found in gardens managed by Peul.

In the cold season, mean species richness per garden was 14.06 and mean Shannon index was 0.96, however highly variable (Table 3). The lowest Shannon index was observed in an urban commercial garden, which was largely dominated by *L. sativa*. The highest Shannon index was found in a very large commercial garden, where many rare species were cultivated.

In the surveyed gardens, the ground layer (<1 m) was dominated by different annual vegetables and spices, particularly *L. sativa*. In the intermediate layer (1–5 m), small trees such as *Citrus* spp., *Gymnanthemum amygdalinum* and *M. oleifera* were frequent. The dominating species in the top layer (>5 m) were *A. digitata*, *Azadirachta indica* and *Mangifera indica*. In 55% of the gardens, all three

Table 3 Mean values (ranges in brackets) of plant species diversity parameters in the cold, hot and rainy season of gardens in Niamey (Niger), 2007

Characteristic	Cold season (CS) ($n = 51$)	Hot season (HS) ($n = 51$)	Rainy season (RS) ($n = 45$)	Significance level		
				CS-HS	HS-RS	RS-CS
Species richness	14.06 (2–53)	9.80 (0–50)	6.69 (1–46)	<0.001	<0.001	<0.001
Individual no.	9,325 (217–84,432)	9,467 (0–192,156)	3,905 (0–22,356)	0.972	0.958	0.013
Species density	15.04 (2.59–46.02)	10.18 (0–37.99)	6.80 (0–34.37)	<0.001	<0.001	<0.001
Shannon index	0.96 (0.01–2.18)	0.77 (0–2.54)	0.53 (0–2.13)	0.021	0.021	0.021
Evenness	0.39 (0.01–0.82)	0.39 (0–0.998)	0.26 (0–0.95)	0.875	0.037	0.019

Significance level according to paired samples *T*-test, combining the different seasons strata were observed; 16% of the gardens had the ground and the intermediate layers only; and in 29% of the gardens only the ground layer existed. Several gardeners declared their desire for cultivating more trees, but mentioned the lack of water as a constraint.

Temporal changes of plant species richness and diversity

Total species richness continuously decreased from 115 species in the cold, to 100 in the hot, to 77 in the rainy season (Table 2). This was mainly due to the decrease in the number of annual species such as vegetables, spices and staples. Consequently, species composition was also different from one season to another.

Exotic species of temperate origin such as the vegetables *B. oleracea*, *L. sativa* and *P. sativum* were mainly cultivated in the cold season; other temperate species such as *Allium cepa* and *Anethum graveolens* were even exclusively grown in the cold season (Appendix, Table 7). In contrast, in the hot season, vegetables of local origin such as *Corchorus olitorius* and *H. sabdariffa* were relatively abundant in the gardens, while the exotic *A. caudatus* and *L. sativa* were also widely cultivated. The latter was said to achieve a high price despite its bitter taste during the hot season. Eleven gardeners stopped cultivation of annual species in the hot season. In several gardens, weeds appeared during this season and many plants dried up. Lack of water sources and labor force for irrigating the plots were said to be the limiting resources for gardening during the hot season.

In the rainy season, 21 of the 45 gardeners surveyed halted the cultivation of annual crops. Thirteen of them even stopped all cultivation. Gardeners mentioned that annual crops were difficult to cultivate during the rainy season due to intense rain, temporal flooding or soil silting. In the remaining gardens, mainly *A. caudatus* and *L. sativa* were planted, but only in relatively small numbers. Instead staple crops such as *S. bicolor* and *Zea mays* were widely cultivated, as well as *V. unguiculata* that was exclusively cultivated during the rainy season (Appendix, Table 7).

Similarly to the decrease in the total plant species richness from the cold to the hot and the rainy season, a substantial decrease in species diversity parameters was also noted (Table 3). A comparison between the cold and the hot season showed a significant decrease of species richness ($P < 0.001$), species density ($P < 0.001$) as well as Shannon index ($P = 0.021$). From the hot season to the rainy season, species richness ($P < 0.001$), species density ($P < 0.001$), Shannon index ($P = 0.021$) and evenness ($P = 0.037$) decreased significantly in the 45 surveyed gardens.

Effects of garden and household characteristics on plant species richness and diversity

While total species richness was only slightly correlated with garden size ($r = 0.646$; $P < 0.001$; Fig. 2), larger gardens had a higher number of perennial ($r = 0.788$; $P < 0.001$) and local plant species ($r = 0.797$; $P < 0.001$). The number of vegetation layers increased with garden size ($r_S = 0.500$; $P < 0.001$). Species richness was also positively correlated with the number of household members per m^2 of garden area ($r = 0.509$, $P < 0.001$).

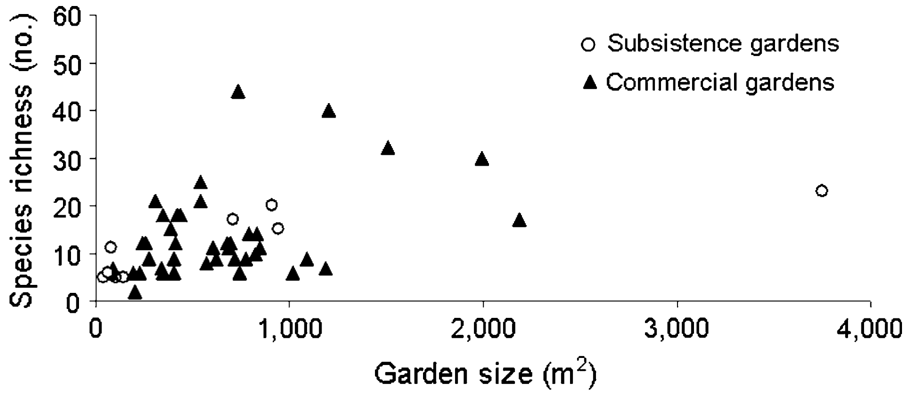

Fig. 2 Relation between species richness in the cold season and garden size of 9 subsistence gardens (*dots*) and 41 commercial gardens (*triangles*) in Niamey (Niger), 2007. Data of one very large commercial garden with size of 10,355 m^2 and species richness of 52 are not shown

Compared with commercial gardens non-commercial ones had only a slightly higher Shannon index (1.23 versus 0.90; $P = 0.082$) and a significantly higher evenness (0.56 versus 0.36; $P = 0.005$), while species richness was not different (12 versus 15, $P = 0.495$). Species diversity was also affected by the ethnic affiliation of the gardener. The gardens operated by migrants from Burkina Faso (Gourmanché and Mossi), who mostly rented the land, showed significantly lower Shannon index than gardens managed by the native Djerma, and lower evenness than those of the Peul (Table 4). Species richness was lower in gardens managed by women compared with those managed by men (10 versus 15; $P = 0.024$), but Shannon index and evenness were higher (H': 1.24 versus 0.89; $P = 0.043$; E: 0.56 versus 0.35; $P = 0.001$).

Most of these results were confirmed by those of the multiple regression analysis. The fit of the model was best for richness of local species (69%) and of overall species (55%; Table 5). Both were positively correlated with garden size and gardener ethnic affiliation (traditionally nomadic groups such as Tuareg or Peul versus sedentary ones). Overall species number was also positively correlated with household size. Only 19% and 32% of the overall Shannon diversity and evenness was explained by the respective regression models (Table 5). Shannon index increased with garden size and property status (rented versus owned). The degree of market orientation had

Table 4 Mean species richness and diversity parameters of 50 gardens surveyed in Niamey (Niger) in the cold season, 2007, according to ethnic affiliation of the gardener

Characteristic	Djerma ($n = 24$)	Gourmanché ($n = 8$)	Mossi ($n = 7$)	Peul ($n = 5$)	Tuareg ($n = 6$)
Species richness	11.83^{a}	14.25^{a}	12.14^{a}	18.80^{a}	19.17^{a}
Species density	13.54^{a}	12.77^{a}	12.69^{a}	19.98^{a}	20.61^{a}
Shannon index	1.13^{a}	0.57^{b}	0.53^{b}	1.09^{ab}	1.11^{ab}
Evenness	0.48^{ab}	0.20^{b}	0.23^{b}	0.49^{a}	0.40^{ab}

Data of one garden managed by a Jarouba are not shown

Means in a row followed by different letters are significantly different at $P < 0.05$ (one-way ANOVA followed by a Tukey test)

Table 5 Results of stepwise multiple regression analyses for different parameters of plant species diversity in 45 gardens of Niamey (Niger), 2007

	Overall species richness	Local species richness	Shannon index	Evenness
Adjusted R^2	0.55***	0.69***	0.19**	0.32***
Independent variables				
Garden size (×1,000) (0.037–10.355 m^2)	4.66***	1.88***	0.09*	0.15
Gardener age (0 = <40 years; 1 = ≥40 years)	0.12	0.02	0.11	-0.09
Ethnicity of gardener (0 = non-nomad; 1 = nomad)	7.45**	2.13**	0.23	0.15*
Gender of gardener (0 = female; 1 = male)	−0.05	−0.02	−0.27	−0.24**
Household size (1–16 members)	0.68*	0.13	0.20	0.08
Production cash-oriented (0 = <50% of products sold; 1 = ≥50% of products sold)	0.05	0.02	−0.15	−0.18*
Garden possession status (0 = rented; 1 = owned)	0.08	−0.01	0.37*	0.13
Additional income (0 = not available; 1 = available)	−0.05	0.03	0.02	0.07
Employees for gardening (0 = not available; 1 = available)	−0.04	−0.02	−0.07	0.12

For each independent variable, the non-standardised regression coefficient (β-coefficient) and the significance level are presented. Six gardens were not included in the analysis because of missing values for some independent variables

*, **, *** F-test (for the model) or T-test (for independent variables) significant at $P \leq 0.05$, ≤ 0.01, ≤ 0.001, respectively

negative effects on evenness that was further determined by gardener ethnic affiliation and gender.

Classification of gardens

Cluster analysis based on crop species abundance data resulted in five distinct clusters (Fig. 3). The discriminant analysis detected the following species (in order of their importance) to be mainly responsible for cluster separation: *A. porrum*, *Talinum triangulare*, *Tamarindus indica*, *Dyospyros mespiliformis*, *S. bicolor*, *Anethum graveolens*, *A. caudatus*, *Musa* × *paradisiaca*, *L. esculentum*, *Borassus aethiopum*, *Cymbopogon citratus* and *C. olitorius*. The analysis showed that 96% of the original grouped cases were correctly classified. Although the cluster analysis was performed on the basis of species abundances, large differences among clusters were also found with respect to garden size, species richness and diversity and socioeconomic parameters such as ethnic affiliation, gender of gardener or level of market orientation.

Cluster 1 comprised rather small subsistence gardens, mostly from peri-urban areas. About 75% of these gardens were managed by native Djerma gardeners and nearly all women-managed gardens were found in this cluster. The Shannon index and evenness of gardens grouped in cluster 1 were relatively high but species richness and density quite low, particularly for local and perennial species (Table 6). No garden of cluster 1 harbored the otherwise common *C. olitorius* or *C. citratus*, but *L. esculentum* and *M.* × *paradisiaca* as well as *Solanum tuberosum* were abundant. Only 35% of these gardens had all three vegetation strata. The three gardens of cluster 2 were large, commercial ones, managed by male, non-Djerma gardeners, who reported to have an additional income besides gardening. These gardens not only showed, together with those of cluster 5, the highest species richness and density as well as number of individuals (especially of fruits and vegetables), but also high Shannon index and high evenness (Table 6). In addition, the number of local and perennial species, as well as fruit tree density, were the highest, resulting in a species-rich top layer. In these gardens, no *A. caudatus* was cultivated, but *Anethum graveolens*, *B. aethiopum*

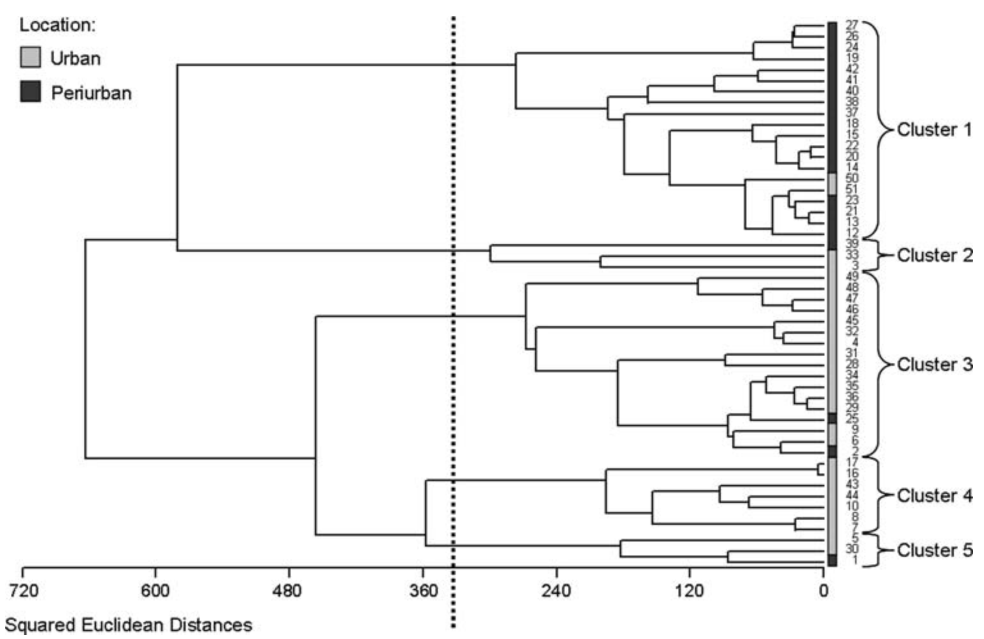

Fig. 3 Dendrogram resulting from a hierarchical cluster analysis (minimum variance method, squared Euclidean distances) on the basis of ln-transformed abundances of 115 plant species cultivated in 28 urban and 22 peri-urban gardens in Niamey (Niger) in the cold season of 2007. The *dotted line* marks the cut-off point to define the correct number of clusters according to the 'elbow' criterion. *The numbers in the clusters* refer to the garden number. One urban garden (no. 11) was identified as an outlier before and was, therefore, excluded from this analysis

Table 6 Mean garden size and plant diversity parameters of 50 gardens grouped into five clusters, surveyed in Niamey (Niger) in the cold season, 2007

Characteristic	Cluster 1 ($n = 20$)	Cluster 2 ($n = 3$)	Cluster 3 ($n = 17$)	Cluster 4 ($n = 7$)	Cluster 5 ($n = 3$)
Garden size (m^2)	737^{b}	$4,355^{a}$	438^{b}	591^{b}	$1,089^{b}$
Species richness	11.4^{b}	41.7^{a}	9.9^{b}	13.6^{b}	31.7^{a}
Number of individuals	$3,730^{c}$	$24,375^{a}$	$6,887^{c}$	$9,510^{bc}$	$19,924^{ab}$
Species density	12.8^{b}	36.3^{a}	11.5^{b}	14.8^{b}	32.1^{a}
Shannon index	1.21^{ab}	1.77^{a}	0.58^{b}	1.00^{b}	0.88^{b}
Evenness	0.53^{a}	0.47^{ab}	0.25^{b}	0.39^{ab}	0.26^{b}
No. of local species	1.6^{c}	13.0^{a}	1.9^{c}	2.4^{c}	6.3^{b}
No. of perennial species	2.8^{c}	26.0^{a}	4.0^{c}	6.9^{c}	16.3^{b}
No. of fruit tree individuals per 100 m^2 garden area	0.7^{b}	4.1^{a}	0.5^{b}	0.6^{b}	2.0^{b}

Means in a row followed by different letters are significantly different at $P < 0.05$ (one-way ANOVA followed by a Tukey test)

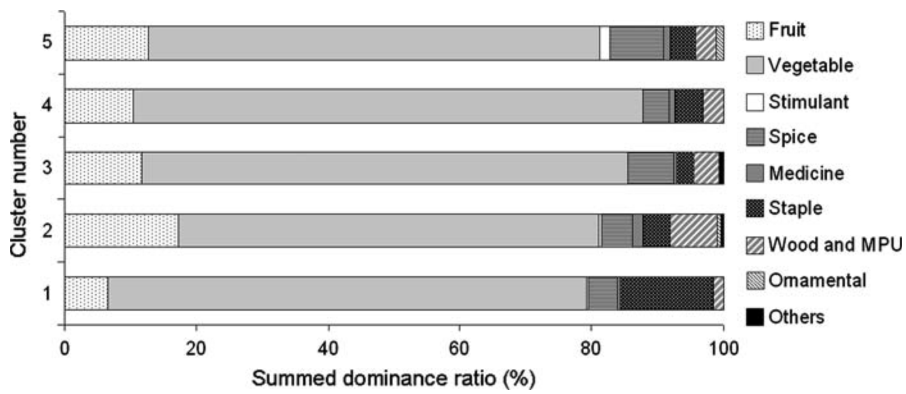

Fig. 4 Summed dominance ratios (SDR) of plant species classified in different use categories and cultivated in 50 gardens that were grouped into five clusters (Niamey, Niger, cold season of 2007)

and *C. olitorius* were abundant. *T. indica* was found only in gardens of this cluster. Contrary to cluster 2, gardens grouped in cluster 3 were rather small and species poor, including for local and perennial species (Table 6), about 50% of them lacking the top vegetation layer. About half of them were managed by gardeners from Burkina Faso. They were mainly located in the urban area (Fig. 3), rented by the respondents and used for commercial production. Gardens of this cluster showed among the lowest species density, Shannon index and evenness. Only a few *A. caudatus* were cultivated, but numbers of individuals of *S. bicolor* was very high in these gardens that also harbored large numbers of *F.* × *ananassa*.

Gardens of cluster 4 were all located in the urban area, commercially oriented and owned by gardeners of different ethnic affiliations. This cluster grouped gardens with rather small sizes and intermediate diversity parameters (Table 6). In about 70% of these gardens a complex vegetation stratification existed. No *M.* × *paradisiaca* or *S. bicolor* were grown in gardens of this cluster, but the abundance of *A. caudatus* was very high. Cluster 5 grouped commercial gardens of intermediate sizes that were mostly rented and managed with the help of several hired workers by retired male, non-Djerma gardeners with rather large families. These gardens had high species richness and density, but relatively low Shannon index and evenness (Table 6) due to the dominance of *L. sativa*. Gardens of this cluster also showed large quantities of *C. citratus* and the local vegetable *S. gilo* and were the only ones where *A. porrum* and *T. triangulare* were cultivated. In all these gardens three vegetation strata existed.

Some differences among clusters were also found concerning the summed dominance ratios (SDR) per use category (Fig. 4). Vegetables were the most important use category, particularly in gardens of clusters 1, 3 and 4. In gardens of cluster 1, staple crops were also important. Fruit species as well as wood and MPU species were prevalent only in gardens of cluster 2. Gardens of clusters 3 and 4 lacked stimulant species; ornamental species occurred only in gardens of clusters 2 and 5.

Discussion

The surveyed gardens were highly variable concerning size, plant species composition, richness and diversity, vertical vegetation structure and level of commercialisation. Some gardens resembled species-rich complex agroforestry systems, whereas others were almost managed as a monoculture of annual cash crops in one single vegetation layer. Compared with similar studies, species richness of the 51 surveyed gardens in Niamey (with a total of 116 species and a mean of 14 species per garden in the cold season) (Table 3) seemed relatively high. A recent study of 120 very large commercial urban gardens in Khartoum (Sudan) by Thompson (2007) reported a total species richness of 79 spp. and a mean species richness of only 3 species per garden. In 81 urban homegardens of semi-arid El Obeid (Sudan), the same low mean of 3 species per garden, but an even lower total species richness (32 spp.) were found, probably caused by the lack of irrigation (Gebauer 2005). In Zambia, mean species richness of 31 urban and 21 peri-urban homegardens was 10 and 5 species, respectively (Drescher 1998). Under humid conditions, however, plant species richness in homegardens is often much higher. A total of 602 species and a mean of 7 to 24 species per garden was found in small homegardens on Java, Indonesia (Karyono 1990) and a total of 338 species in homegardens of humid Mexico (Alvarez-Buylla Roces et al. 1989).

The mean Shannon index of $H' = 0.72$ to 0.96 observed throughout the year in the surveyed gardens of Niamey (Table 3) was rather low and similar to that of the peri-urban, mostly commercial gardens of Zambia ($H' = 0.81$), but lower than in urban gardens of the same country ($H' = 1.35$; Drescher 1998). Homegardens in humid Indonesia, on the other hand, had a mean Shannon index of almost 3.0 (Karyono 1990; Kehlenbeck and Maass 2004). It is well known that the Shannon index will decrease if a single species dominates, even if the overall species richness might be high (Drescher 1998). Such a trend was observed in several gardens surveyed in Niamey, where a dominance of a few annual species such as *H. sabdariffa* or *L. sativa*, combined with the low abundance of many perennial species (*A. digitata* or *M. oleifera*) led to low diversity indices despite the high species richness (Table 6, gardens of cluster 5).

Species seasonality and contribution of gardens to household food supply and income

The large differences of plant species composition, richness and diversity among the three seasons studied were clearly related to the change in climatic conditions throughout the year. The cold season, with its moderate temperature and lower potential evapotranspiration, seemed to be most suitable for horticulture, particularly for the cultivation of annuals. Consequently, the highest species richness and diversity were observed during this period, whereas these parameters were rather low during both the rainy and the hot seasons (Table 3). Thus, the role of sample gardens for income generation and for supplying households with fresh products such as vegetables seemed to decline from the cold to the hot and the rainy season, although some gardens retained a high number of annual vegetable individuals even in the less favourable seasons. The possibility of maintaining a garden during the hot season in Niamey would largely depend on the ability of a household to invest in time (for frequent irrigation), knowledge and cash-demanding infrastructure such as pipes and water pumps, as also reported for homegardens in arid Yemen (Ceccolini 2002). During the rainy season, cultivation of annuals (apart from staple cereals for subsistence) was rare in the studied gardens. Similar findings were also mentioned by Drescher (1998), Linares (2004) and Graefe et al. (2008), and were partly explained by frequent occurrence of fungal diseases on vegetables and high labor demand for cultivating staple crop fields during this season.

Frequent and often indiscriminate use of pesticides was reported to be common in the surveyed gardens and may have consequences for the quality and safety of the food produced. In Niamey, for some short-duration vegetables, residues of pesticides might be high, as well as contamination with pathogens where wastewater was used for irrigation. This, together with the frequent (and sometimes excessive) use of mineral fertilisers, raises concerns about negative externalities of intensive UPA in some of the surveyed gardens.

Contribution of the gardens towards in situ conservation of local plant species

The overall contribution of the surveyed gardens towards in situ conservation of indigenous species may be questioned. More than 70% of all plant species cultivated in the these gardens were of exotic origin; local species were mostly represented by only a few individuals. With increasing market orientation of a garden, local species with low market value are often the first ones to be removed (Soemarwoto and Conway 1992). In Niamey, interviewed gardeners highly appreciated the cultivation of marketable exotic crops, using improved planting material offered by local traders and an outreach program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sahelian Centre, located about 25 km south of Niamey. Whether the introduction of exotic, mostly marketable species and improved varieties will indeed enhance the loss of local species and varieties over time as was reported from other case studies in developing countries (Fundora Mayor et al. 2004; Sunwar et al. 2006) can hardly be predicted from a one-time study such as ours. Similarly, no conclusions about the future transformation trends of gardens can be drawn, although a general increase of their degree of market orientation may be assumed (Wiersum 2006).

Some of the surveyed gardens seemed to be more suitable for in situ conservation than others based on differences in plant species richness and diversity, which are reported in the literature to largely depend on a combination of agroecological and socioeconomic factors (Abdoellah et al. 2002; Kehlenbeck and Maass 2004; Sunwar et al. 2006; Kehlenbeck et al. 2007). A positive effect of garden size on species richness such as in our study (Table 5) has been described previously (Abdoellah et al. 2002; Albuquerque et al. 2005; Kehlenbeck et al. 2007). Conversely, ease of access to markets and urbanisation were often reported to have a negative effect (Karyono 1990; Shrestha et al. 2002; Abdoellah et al. 2006; Tesfaye Abebe et al. 2006). The supply of diverse food and the demand for certain crops at the markets seem key forces driving gardeners from subsistence to semi-commercial or commercial production (Peyre et al. 2006). This may lead to a decrease in the number of perennials and the dominance of fast-growing, mostly exotic vegetables, resulting in a simplified vegetation structure in these gardens (Shrestha et al. 2002; Peyre et al. 2006; Thaman et al. 2006). Drescher (1998) reported lower plant species richness and diversity in peri-urban as compared with urban gardens, which he explained by the high level of market orientation observed in the peri-urban gardens. In Niamey, however, even commercial peri-urban gardens such as those classified in clusters 2 and 5 (Table 6) may harbor high plant species richness and diversity, including for local and perennial species. Some other studies reported that garden species diversity may in fact be positively influenced by market proximity and/or 'semi-commercialisation' (Trinh et al. 2003; Wezel and Ohl 2005; Kehlenbeck et al. 2007), particularly if there is demand for traditional crops in urban centers (Sunwar et al. 2006).

Gardener's ethnic affiliation and origin may influence plant species composition and diversity indices (Kusumaningtyas et al. 2006; Kehlenbeck 2007). The higher richness and evenness in gardens of nomads as compared with non-nomads, revealed by the multiple regression analysis (Table 5), may be explained by their rather high mobility and their comprehensive knowledge of the plant species and their uses in different agroecological environments. Regarding gender, only few studies showed effects of this variable on plant species richness and diversity. Women are often reported to play an important role for in situ conservation of plant genetic resources in homegardens by cultivating local species for subsistence, whereas men are often more interested in introduction and cultivation of exotic cash crops (Niñez 1985; Drescher 1998; Del Angel-Pérez and Mendoza 2004; Eyzaguirre and Linares 2004). However, the women gardeners in our study grew fewer species than men, including local ones.

Wealthy households may maintain more perennials (Thaman et al. 2006) and an overall higher plant species richness and diversity in their gardens than poor households because wealthy people in general have a larger compound, greater mobility and better access to new genetic material (Drescher 1998, Shrestha et al. 2002). Although the wealth status of respondents in our study was not assessed in detail, gardeners who rented their plots seemed to be rather poor. The lower Shannon diversity in rented as compared with owned gardens (Table 5) may have been caused by economic pressures on gardeners to generate enough income from their rented plots, thus focussing on cultivation of a very small number of profitable cash crops. Apart from garden size, all factors identified as influencing plant species richness and diversity in our study were also mentioned as important in the summary table published by Wiersum (2006) for Indonesian homegardens.

Cluster analysis may help to better identify those types of gardens generally suitable for in situ conservation of plant genetic resources or containing certain key species targeted for conservation. However, this classification approach is not yet very common (Leiva et al. 2002; Kehlenbeck and Maass 2004; Peyre et al. 2006). Our cluster analysis showed that the garden types most suitable for in situ conservation of plant genetic resources are those managed by wealthier, highly educated people, who were not completely dependent on the generation of cash income through their garden (which is the case for the three gardeners of cluster 2) or those managed by elderly, retired gardeners with large families (the three gardeners of cluster 5). In these gardens not only the highest total species richness, but also the highest amount of local species was found (Table 6), though the latter were often only present in low abundances. These low abundances may limit the general suitability of these urban and peri-urban gardens for in situ conservation, as also mentioned by Alvarez-Buylla Roces et al. (1989) and Kehlenbeck (2007). However, the absolute value of the surveyed gardens for in situ conservation of wild and domesticated indigenous plant species could not be assessed because no list of threatened and endangered species of Niger is available. Sunwar et al. (2006) recommended to prevent the loss of indigenous species by emphasising their traditional prestige, increasing and maintaining the related knowledge, and improving seed supply and the quality of traditional varieties. Diversity studies as such may also promote species conservation because they may raise awareness among consumers and decision-makers and may cause gardeners to be more proud of maintaining a species-rich garden (Kehlenbeck and Maass 2004; Kehlenbeck 2007).

Conclusions

Niamey's urban and peri-urban gardens seem to play an important role for family nutrition and cash income of the households involved. The relatively high plant species richness and diversity of the studied gardens was mainly dependent on garden size, the gardener's ethnic affiliation and gender, and on socioeconomic factors. Some gardeners who were not dependent on generating their main cash income from their garden maintained species-rich gardens, including many local species. This type of gardens resembled homegarden-like systems and may be suitable for in situ conservation of plant genetic resources. For an effective promotion of in situ conservation of local plant species in such gardens, suitable threatened key species should be identified and promoted, awareness of gardeners and consumers about the nutritional and cultural value of these species should be increased and their cultivation and marketing be supported.

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Appendix

See Table 7.

Table 7 Plant species cultivated in 51 gardens of Niamey (Niger), 2007, sorted by their main use category

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
Fruits											
1	*Ananas comosus* (L.) Merr.	Bromeliaceae	Pineapple	Ananas	Abarba	Abarba	–	E	4	0	0
2	*Annona senegalensis* Pers.	Annonaceae	Wild custard apple	Annone	Gwanda	Muffa	5	L	2	2	2
3	*Annona squamosa* L.	Annonaceae	Sugar apple	Pomme de cannelle	–	Mufa	–	E	4	4	2
4	*Borassus aethiopum* Mart.	Arecaceae	African fan palm	Rônier	Gijinia	Sabize	7;5	L	4	4	2
5	*Carica papaya* L.	Caricaceae	Papaya	Papaye	–	–	5	E	20	20	16
6	*Citrus aurantiifolia* (Christm. and Panz.) Swingle	Rutaceae	Lime	Limette	–	–	–	E	6	6	4
7	*Citrus limon* (L.) Burm. f.	Rutaceae	Lemon	Citronnier	–	Lemu	–	E	35	35	31
8	*Citrus reticulata* Blanco.	Rutaceae	Mandarin	Mandarine	–	–	–	E	2	2	2
9	*Citrus sinensis* (L.) Osbeck	Rutaceae	Orange	Orange	–	–	–	E	14	14	13
10	*Cucumis melo* L.	Cucurbitaceae	Melon	Melon	Gurji	Muna	–	L	6	8	0
11	*Dialium guineense* Willd.	Caesalpiniaceae	Velvet tamarind	Tamarinier noir	–	–	5;7	L	2	2	2
12	*Diospyros mespiliformis* Hochst. ex A. DC.	Ebenaceae	Monkey guava	Néflier africain	Kangna	Tokaey nya	5;7;9	L	6	6	4
13	*Ficus carica* L.	Moraceae	Fig	Figue	–	–	–	E	6	6	7
14	*Ficus ingens* (Miq.) Miq.	Moraceae	Red-leaved fig	–	Bingi	Durmi nya	5;7	L	2	2	2
15	*Ficus sycomoris* L.	Moraceae	Sycomore fig	Figuier d'Adam	Bawri	Géygéy	–	L	2	2	2
16	*Fragaria* × *ananassa* (Duchesne) Guedès	Rosaceae	Strawberry	Fraise	–	–	–	E	10	6	4
17	*Grewia tenax* (Forssk.) Fiori*	Tiliaceae	White cross berry	–	Kamanmua	Sari	9;12	L	2	2	0
18	*Hyphaene thebaica* (L.) Mart.	Arecaceae	Ginger bread palm	Palmier doum	Goriba	Kongwu	5;7;13	L	16	16	16
19	*Lannea microcarpa* Engl. et K. Krause	Anacardiaceae	Wild grape	Raisinier	Malga	Tamarza	2;5	L	2	2	2
20	*Mangifera indica* L.	Anacardiaceae	Mango	Mango	Mangoro	Mongoro	5	E	41	41	44
21	*Morus alba* L.	Moraceae	White mulberry	Mûrier	–	–	–	E	2	2	2
22	*Musa* × *paradisiaca* L.	Musaceae	Banana	Banana	Abarba	Banana	–	E	16	16	16

Table 7 continued

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
23	*Passiflora edulis* Sims	Passifloraceae	Passion fruit	Maracuja	–	–	–	E	2	2	0
24	*Phoenix dactylifera* L.	Arecaceae	Date palm	Palmier dattier	Dabino	Dabino nya	–	E	22	22	18
25	*Physalis angulata* L.	Solanaceae	Cutleaf ground-cherry	Amour en cage	Koran hanwaynia	–	–	E	2	0	0
26	*Psidium guajava* L.	Myrtaceae	Guava	Goyavier	Goybe	Goyav nya	5	E	18	18	20
27	*Punica granatum* L.	Punicaceae	Pomegranate	Grenadier	–	–	–	E	4	4	4
28	*Tamarindus indica* L.	Caesalpiniaceae	Tamarind	Tamarinier	Tsamia	Bosey	4;5;7;11	L	4	4	4
29	*Terminalia catappa* L.	Combretaceae	Indian almond	Badamier	–	–	5	E	2	2	2
30	*Vitex doniana* Sweet	Verbenaceae	Black plum	Prunier noir	Dhumnia	Bôye	5;7;11	L	6	6	7
31	*Vitis vinifera* L.	Vitaceae	Grape	Raisin	–	–	–	E	2	2	2
32	*Ziziphus mauritiana* Lam.	Rhamnaceae	Chinese apple	Pomme du sahel	–	–	12	E	6	18	16
33	*Ziziphus spina-christi* (L.) Willd.	Rhamnaceae	Christ's thorn	Jujube	Magaria	Daarey	–	E	18	6	4
Vegetables											
34	*Abelmoschus esculentus* (L.) Moench.	Malvaceae	Okra	Gombo	Miagorro	Lafeu	–	L	25	18	9
35	*Adansonia digitata* L.	Bombacaceae	Monkey bread	Baobab	Kuka	Koo nya	1;11	L	45	45	42
36	*Allium cepa* L. var. *cepa* Grp.	Liliaceae	Onion	Oignon	Albassa	Albassa	–	E	25	0	0
37	*Allium porrum* L.	Liliaceae	Leek	Poireau	–	–	–	E	6	10	7
38	*Amaranthus caudatus* L.	Amaranthaceae	Bush green	Amarante	Chapata	Chapata	–	E	27	24	13
39	*Apium graveolens* L.	Apiaceae	Celery	Céleri	–	–	–	E	2	8	2
40	*Basella rubra* L.	Basellaceae	Malabar nightshade	Baselle	–	–	–	E	4	4	0
41	*Beta vulgaris* L.	Chenopodiaceae	Beetroot	Betterave rouge	–	–	–	E	6	6	0
42	*Brassica oleracea* L. var. *capitata* L.	Brassicaceae	White cabbage	Chou	–	–	–	E	80	24	4
43	*Brassica rapa* L.	Brassicaceae	Rutabaga	Navet	–	–	–	E	6	0	0
44	*Capsicum annuum* L.	Solanaceae	Sweet pepper	Poivron	Tatasey	Tatasey	–	E	16	18	2

Table 7 continued

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
45	*Corchorus olitorius* L.	Tiliaceae	Tossa jute	Corète potagère	Foukou	Foukou	–	L	16	8	2
46	*Cucumis sativus* L.	Cucurbitaceae	Cucumber	Concombre	–	–	–	E	4	8	0
47	*Cucurbita maxima* Duchesne	Cucurbitaceae	Pumpkin	Courge	Kabewa	Laptanda	–	E	39	4	9
48	*Cucurbita pepo* L.	Cucurbitaceae	Summer squash	Courgette	–	–	–	E	16	29	0
49	*Daucus carota* L.	Apiaceae	Carrot	Carotte	–	–	–	E	18	4	0
50	*Eruca sativa* Mill.	Brassicaceae	Garden rocket		–	–	–	E	2	0	0
51	*Gymnanthemum amygdalinum* (Del.) Sch. Bip. ex Walp.	Asteraceae	Bitter leaf	Vernonia	Suaka	Suaka	5	L	24	24	22
52	*Gynandropsis gynandra* (L.) Briq.	Capparaceae	Cat's whiskers	Gynandro	Gasaya	Hubey	5	L	2	10	0
53	*Hibiscus sabdariffa* L.	Malvaceae	Roselle	L'oseille	Sure	Gisma	–	L	27	29	2
54	*Lactuca sativa* L.	Asteraceae	Lettuce	Laitue	–	–	–	E	94	22	29
55	*Lycopersicon esculentum* Mill.	Solanaceae	Tomato	Tomate	Tomati	Tomati	–	E	78	37	9
56	*Moringa oleifera* Lam.	Moringaceae	Drumstick tree	Nevedie	Elmakka	Wimdi boundu	–	E	55	55	49
57	*Phaseolus vulgaris* L.	Fabaceae	French bean	Haricot	Wakei	Dunguri	–	E	43	12	7
58	*Pisum sativum* L.	Fabaceae	Pea	Petit pois	–	–	–	E	14	2	0
59	*Portulaca oleracea* L.	Portulacaceae	Purslane	Pourpier	Karo	Weinya zar	–	E	18	8	0
60	*Raphanus sativus* L.	Brassicaceae	Radish	Radis	–	–	–	E	2	0	0
61	*Solanum gilo* Raddi	Solanaceae	African eggplant	Grand morelle	–	Goma	–	L	18	8	2
62	*Solanum melongena* L.	Solanaceae	Egg plant	Aubergine	–	Batansé	–	E	20	8	2
63	*Talinum triangulare* (Jacq.) Willd.	Portulacaceae	Waterleaf	Epinard de Ceylan	Guré	Pinari	–	L	2	6	0
64	*Vigna unguiculata* (L.) Walp.	Fabaceae	Cowpea	Niébé	Wakei	Dunguri	–	E	0	0	7
Stimulants											
65	*Cannabis sativa* L.	Cannabidaceae	Hemp	Chanvre	–	–	–	E	2	0	0
66	*Cola nitida* (Vent.) Schott and Endl	Sterculiaceae	Cola	Colatier	Goro	Goro	–	L	2	2	2
67	*Saccharum officinarum* L.	Poaceae	Sugar cane	Canne de sucre	Arekie	Aretie	–	E	4	2	0
68	*Theobroma cacao* L.	Sterculiaceae	Cacao	Cacao	–	–	–	E	2	2	0

Table 7 continued

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
Spices											
69	*Allium sativum* L.	Liliaceae	Garlic	Ail	Tafornua	Tafornua	–	E	10	0	0
70	*Anethum graveolens* L.	Apiaceae	Dill	Aneth	–	–	–	E	6	0	0
71	*Arachis hypogaea* L.	Fabaceae	Peanut	Arachide	Gugia	Damsi	–	E	4	4	2
72	*Capsicum frutescens* L.	Solanaceae	Bird chilies	Piment fort	Tonka	Tonko	–	E	29	20	13
73	*Coriandrum sativum* L.	Apiaceae	Coriander	Coriandre	–	–	–	E	2	2	0
74	*Cymbopogon citratus* (DC. ex Nees) Stapf	Poaceae	Citronella	Citronnelle	–	–	–	E	18	14	0
75	*Mentha* sp.	Lamiaceae	Mint	Menthe ordinaire	–	–	–	E	24	20	22
76	*Ocimum basilicum* L.	Apiaceae	Basil	Basilic	–	Daye doye	–	E	25	24	0
77	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don	Mimosaceae	Nitta tree	Néré	Döröwa	Dso	5;9	L	2	2	2
78	*Petroselinum crispum* (Mill.) Nyman ex A. W. Hill	Apiaceae	Parsley	Persil	–		–	E	6	8	0
79	*Sesamum indicum* L.	Pedaliaceae	Sesame	Sésame	Lamti	Lamti	–	E	8	4	0
Medicinals											
80	*Cassia obtusifolia* L.	Caesalpiniaceae	Sicklepod	Casse fétide	Tafasa	Ula	–	E	2	2	0
81	*Cassia occidentalis* L.	Caesalpiniaceae	Negro coffee	Café nègre	Kinkilliba	Sanga-sanga	–	E	12	16	0
82	*Cassia siamea* Lam.	Ceasalpiniaceae	Shower tree	Casse du Siam	–	–	10	E	2	2	2
83	*Gossypium arboreum* L.	Malvaceae	Cotton	Coton	Kada	Habu	–	L	2	0	0
84	*Maerua angolensis* DC.	Capparaceae	Bead-bean tree	–	Buguhi	Kubu hoto	2;7;9	L	2	2	2
85	*Maerua crassifolia* Forssk.*	Capparaceae	–	–	Jiga	Hassu	2	L	2	2	2
Staples											
86	*Colocasia esculenta* (L.) Schott	Araceae	Cocoyam	Taro	–	–	–	E	2	0	0
87	*Ipomoea batatas* (L.) Lam.	Convolvulaceae	Sweet potato	Patate douce	Dinkale	Kudaku	–	E	8	8	2
88	*Manihot esculenta* Crantz	Euphorbiaceae	Manioc	Manioc	Rogo	Rogo	–	E	22	14	0
89	*Oryza sativa* L.	Poaceae	Rice	Riz	Schinkafa	Mo	–	E	2	2	4
90	*Panicum miliaceum* L.	Poaceae	Millet	Mil			–	E	2	2	0

Table 7 continued

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
91	*Solanum tuberosum* L.	Solanaceae	Potato	Pomme de terre	–	–	–	E	14	0	0
92	*Sorghum bicolor* (L.) Moench	Poaceae	Sorghum	Sorgho	Dawa	Hamo	–	L	10	0	11
93	*Zea mays* L.	Poaceae	Maize	Mais	Massara	Kolkoti	–	E	51	16	24
Wood and multipurpose uses											
94	*Acacia albida* Delile	Mimosaceae	Apple ring tree	Gawo	Gao	Gau	5;7	L	4	4	4
95	*Acacia nilotica* (L.) Willd. ex Delile	Mimosaceae	Egyptian acacia	Gonakier	Bagaroa	Bani	7;13	L	14	14	16
96	*Acacia senegal* (L.) Willd.	Mimosaceae	Gum arabic tree	Gommier	Dakwara	Danga	13	L	6	6	4
97	*Albizia lebbeck* (L.) Benth.	Mimosaceae	Woman's tongue	Langue de femme	–	–	12	E	2	2	2
98	*Azadirachta indica* Juss.	Meliaceae	Neem tree	Nim	Dogo'n yaro	Turi forta	1;5;7;9;12	E	25	25	22
99	*Bauhinia rufescens* Lam.	Caesalpiniaceae	Mountain ebony	Bauhinia	Dirga	Nammary	1;5;9;12	L	2	2	2
100	*Calotropis procera* (Aiton) W.T. Aiton	Asclepiadaceae	Sodom apple	Pomme de Sodome	Tumfafia	Sageye	5;12	L	10	10	11
101	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	Silk cotton tree	Kapokier	Rymy	Bantan	5;10;11;13	E	2	2	0
102	*Crescentia cujete* L.	Bignoniaceae	Calabash tree	Calebassier	Khoria	Gasu	5	E	2	2	2
103	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	Eucalyptus	Eucalyptus	Torare	Torare	5;7;9;12	E	4	4	4
104	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	Quick stock	Madre de cacao	–	–	9;10;12	E	2	0	0
105	*Gmelina arborea* Roxb.	Verbenaceae	White teak	Gmelina	–	–	5;7;9	E	6	6	7
106	*Melia azedarach* L.	Meliaceae	Indian lilac	Lilas des Indes	–	–	–	E	6	6	4
107	*Phyllostachys aureosulcata* McClure	Poaceae	Bamboo	Bambou	–	–	–	E	2	2	2
108	*Piliostigma reticulatum* (DC.) Hochst.*	Caesalpiniaceae	Camel's foot	Pied-de-chameau	Kalgo	Kossey	1;5;7;9;12	L	2	2	2
109	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Honey mesquite	Bayahonde	Bagarua	Koikoi	1;5;7;9;12	E	2	2	2
110	*Terminalia mentalis* L.	Combretaceae	Umbrella tree	Étagaire	–	–	7	E	8	8	7
111	*Vitellaria paradoxa* Gaertn. f.	Sapotaceae	Shea butter	Karité	Kaday	Bulunga	5;7	L	2	2	2
Ornamentals											
112	*Bougainvillea spectabilis* Willd.	Nyctaginaceae	Bougainvillea	Bougainville	–	–	–	E	2	2	2
113	*Canna indica* L.	Cannaceae	Red ginger	Lavande Rouge	–	–	–	E	2	0	0
114	*Helianthus annuus* L.	Asteraceae	Sunflower	Tournesol	–	–	–	E	2	2	0

Table 7 continued

No.	Scientific name	Family	Vernacular name				Secondary use[a]	Origin[b]	Frequency of occurrence in the gardens (%)		
			English	French	Haussa	Djerma			Cold season	Hot season	Rainy season
Others											
115	*Elaeis guineensis* Jacq.	Arecaceae	Oil palm	Palmier a huile	–	–	5;13	L	2	2	2
116	*Lawsonia inermis* L.	Lythraceae	Henna	Henné	Lallé	Lalla	5;11;12	E	4	4	4

Nomenclature of plant species mainly follows Hanelt and Institute of Plant Genetics and Crop Plant Research (2001) or Zander et al. (2002). Nomenclature of species marked with an asterisk follows Missouri Botanical Garden (2007)

[a] 1 = fruit; 2 = vegetable; 3 = stimulant; 4 = spice; 5 = medicine; 6 = staple; 7 = wood; 8 = multipurpose use; 9 = fodder; 10 = ornamental; 11 = mystic/religious; 12 = fence; 13 = vegetable oil; 14 = technical use

[b] *L* local, *E* exotic

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