Diversity and Differential Utilization of *Amaranthus* spp. along the Urban-Rural Continuum of Southern Benin[1]

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Diversity and Differential Utilization of *Amaranthus* spp. along the Urban-Rural Continuum of Southern Benin. Increasing recognition of the importance of traditional vegetables as sources of nutrients, health benefits, and income has raised the need to evaluate and document knowledge of these resources in local communities. Indigenous knowledge is crucial for sustainable utilization of these plant resources, though this might be threatened by urbanization and economic development. We carried out a quantitative ethnobotanical survey to assess the relative importance of amaranth in vegetable production systems of southern Benin and identify the main criteria that determine the choice of this crop by farmers. The diversity, uses, and knowledge of amaranths was investigated to assess how the degree of urbanization affects farmers' knowledge. Our results showed that *Amaranthus cruentus* is the main cultivated vegetable in the surveyed areas despite its low economic value. Reasons raised by communities were related to the species' popularity, resistance to nematodes, nutritional value, and short cultivation cycle. Wild amaranths include *A. dubius*, *A. blitum*, *A. spinosus,* and *A. viridis*. Amaranths were mainly used as vegetables and for their nutraceutical properties. Urbanization was found to negatively affect the knowledge and uses of wild species, whereas the knowledge and utilization of cultivated species was quite homogenous along the urban-rural continuum. We discuss strategies to increase knowledge of wild resources in urban settings and therefore reduce loss of genetic resources.

Diversité et utilisation des amarantes (*Amaranthus* spp.) le long du continuum urbain-rural au Sud-Bénin. La reconnaissance croissante de la valeur nutritionnelle des légumes locaux, leurs bienfaits pour la santé et leur contribution au revenu des populations a révélé la nécessité d'évaluer et de documenter les connaissances associées à ces espèces au sein des communautés locales. En effet, les connaissances endogènes considérées comme importantes pour la conservation et l'utilisation des ressources phytogénétiques pourraient être en voie de disparition du fait de l'urbanisation et du développement économique. La présente étude a porté sur une enquête ethnobotanique réalisée le long du continuum urbain-rural au Sud-Bénin afin d'évaluer l'importance relative des amarantes et d'identifier les principaux critères qui déterminent le choix de cette culture par les agriculteurs. En outre, la diversité, les usages et les connaissances des amarantes ont été étudiés afin d'évaluer comment le degré d'urbanisation affecte les connaissances des agriculteurs. Nos résultats ont montré que *Amaranthus cruentus* est la principale espèce cultivée dans les zones étudiées en dépit de sa faible valeur économique. Les

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raisons évoquées par les producteurs étaient liées à la popularité de l'espèce, sa résistance aux nématodes, sa valeur nutritionnelle et son cycle de culture court. Les amarantes sauvages: *A. dubius*, *A. blitum*, *A. spinosus* et *A. viridis* étaient principalement utilisées pour leurs propriétés nutraceutiques. Le niveau d'urbanisation affecte la connaissance et l'utilisation des espèces sauvages tandis que la connaissance et l'utilisation des espèces cultivées sont assez homogènes le long du continuum urbain-rural. Des stratégies devant permettre de mieux conserver les connaissances en milieu urbain et de réduire l'érosion des ressources phytogénétiques ont également été proposées.

Key Words: *Amaranthus* spp, Benin, farmers' knowledge, urbanization, crop wild relatives, quantitative ethnobotany, vegetables.

Introduction

Erosion of agro-biodiversity as well as nutritional and dietary diversity is partially caused by human activities associated with changes in land use (Robertson and Swinton 2005; Young et al. 2005) and the development of a dual urban food supply system, with a formal and informal sector servicing different sections of urban society (Ambrose-Oji 2009). Modern agriculture is one of the greatest threats to biodiversity, but it also holds some of the keys to its sustainable conservation (Sileshi et al. 2008). Erosion of agro-biodiversity is associated with loss of related knowledge, and for a number of authors, declining indigenous knowledge is a consequence of modernization and acculturation (Brandt et al. 2013; Gandolfo and Hanazaki 2014; Reyes-García et al. 2007; Voeks and Leony 2004). Others working in Mexico (Zarger and Stepp 2004), Panama (Müller-Schwarze 2006), and Bolivia and Peru (Mathez-Stiefel et al. 2012) report that indigenous knowledge of plant resources is resilient to the forces of modernization and economic development (Furusawa 2009; Vandebroek and Balick 2012; Zarger and Stepp 2004). These differences in opinions might be due to the diversity of sociocultural and environmental contexts of the surveyed communities, especially in terms of transmission of knowledge through generations (Cherry 2014; Dovie et al. 2008; Mathez-Stiefel et al. 2012), urban and agricultural development policies (Boillat et al. 2013; Eyssartier et al. 2011; Gomez-Baggethun et al. 2010), and ecological conditions (Ladio and Lozada 2004). In West Africa, where urban areas are growing very rapidly and where local knowledge is not well documented, it is important to understand how urban development is affecting people-plant relationships.

There is a wide diversity of indigenous vegetables in West Africa that are significant sources of vitamins, antioxidants, minerals, and proteins (Odhav et al. 2007). Quite a large number of these species are known to have health protecting properties and uses (Smith and Eyzaguirre 2007). They are important candidates for intensive agriculture and to ensure substantial returns for poor farmers (Ndenga et al. 2013). In Benin, indigenous vegetables occur as cultivated crops or weedy and wild plants. They play a significant role in the daily food and nutritional requirements of local people, not only in rural areas but also increasingly in urban areas (Adéoti et al. 2009). Along with *Solanum macrocarpum* L., amaranth (*Amaranthus cruentus* L.) has been reported as the most cultivated traditional vegetable in the country (Grubben 1975; Pasquini et al. 2009).

Many studies have mentioned amaranths as important leafy vegetables valued in other parts of Africa (Achigan-Dako et al. 2014; Faber et al. 2010; Gueye and Diouf 2008; Vorster and Van Rensburg 2005). Amaranths exhibit C_4 photosynthesis and grow rapidly under heat and drought stress, and they tolerate a variety of unfavorable abiotic conditions, including high salinity, acidity, or alkalinity, making them well suited to subsistence agriculture. These characteristics confer to amaranths a potential for significant beneficial impacts on the problem of malnutrition (Achigan-Dako et al. 2014; Maughan et al. 2011). They are rich sources of proteins (Rastogi and Shukla 2013), vitamin A, vitamin C, and minerals including iron, zinc, phosphorus, calcium (Schönfeldt and Pretorius 2011), magnesium, and manganese (Odhav et al. 2007).

Apart from *A. cruentus*, six other species belonging to the genus *Amaranthus* have been recorded in Benin: *Amaranthus tricolor* L. which has been recently introduced in the country as a vegetable and ornamental (Adjakidjè 2006), and *Amaranthus blitum* L., *Amaranthus dubius* Mart ex Thell., *Amaranthus graecizans* L., *Amaranthus spinosus* L., and *Amaranthus viridis* L., which are considered wild species but are harvested for consumption and other purposes (N'Danikou et al. 2010; Sogbohossou and Achigan-Dako 2014). Wild amaranths represent an invaluable gene pool for improving related cultivated species.

In this study we examine the variation in local knowledge related to the diversity and management of wild and cultivated amaranths among farmers in urban, peri-urban, and rural areas of Southern Benin. We assess the relationships between local communities and both wild and cultivated amaranths and identify attributes that might offer livelihood improvement opportunities and provide insights into the sustainable utilization of these resources. We hypothesize that the diversity and utilization of amaranths changes along the urban-rural continuum, and this variation depends on the status of the species.

Materials and Methods

Study Area

The study was carried out in Southern Benin in four municipalities: Abomey-Calavi, Cotonou, Sèmè-Kpodji, and Sô-ava. The four municipalities belong to the Guinean zone where the rainfall is bimodal. The mean annual rainfall ranges from 900 to 1,200 mm, and the mean temperature is 27°C. In Sèmè-Kpodji and Cotonou, soils are sandy and poor in organic matter but suitable for vegetable production because of the high groundwater which facilitates irrigation. In Abomey-Calavi, vegetable growers are settled around inland valleys on ferralitic or hydromorphic soils. Sô-ava is a lakeside rural municipality, and farming is practiced in exposed areas where the soil is hydromorphic. Details about the demography of each municipality are provided in Table 1.

Information collecting sites were categorized as urban, peri-urban, or rural areas based on the level of urbanization. Urban areas included the municipalities of Cotonou (allotments of Cadjèhoun and Houeyiho) and Sèmè-Kpodji (allotment of VIMAS). Peri-urban areas included the municipality of Abomey-Calavi (vegetable gardens of Togba, Ouèdo, and Hêvié), whereas rural areas included the municipality of Sô-ava (village of Ahomey-Lokpo).

Data Collection

Assessing the Importance of Amaranth Species in Urban and Peri-urban Vegetable Production Systems

A total of five focus-group discussions, including two in Sèmè-Kpodji, two in Cotonou, and one in Abomey-Calavi, were conducted with 10 to 15 farmers in each group. They classified cultivated vegetables based on pair-wise comparisons, and determined the value criteria according to the method used by N'Danikou et al. (2011). Participants were asked to rank the criteria from the most important to the least. From these, the top five were selected. During individual interviews, informants from urban and peri-urban areas were asked to score cultivated species from 1 (lowest) to 4 (highest) based on the top five elicited criteria. The objectives of the survey were clearly explained to farmers in each locality. Verbal consent was obtained from those willing to participate in the survey and those who agreed to allow the information they provided to be published.

Local Knowledge Related to Amaranth Species

Semi-structured interviews were conducted with 40 farmers per municipality. In the first section, they were asked to list and describe useful amaranth species. Photographs were then shown to them and they were asked to identify the species. This method was used because of the similarities among amaranth species and the use of one vernacular name to refer to many species, and vice versa (Achigan-

Table 1. DEMOGRAPHY OF SURVEYED MUNICIPALITIES (INSAE 2004a, b, c).

Municipalities		Sèmè-Kpodji	Cotonou	Abomey-Calavi	Sô-ava
Area (km^2)		250	79	539	209
Population (Inhabitants)		115,238	665,100	307,745	76,315
Gender (%)	Male	48.5	48.6	48.6	50
	Female	51.5	51.4	51.4	50

Dako et al. 2010). This allowed us to make an accurate identification of the species they had listed. The questionnaire was used to elicit information about species uses, status, cultivation systems, and consumption practices. The second section of the questionnaire dealt with informants' age, gender, ethnic group, and education (Table 2).

Data Analysis

Spearman's rank-order correlation (rho) was calculated to analyze the similarity between the results of the scoring and that of the pair-wise ranking. Spearman's non-parametric correlation coefficient was used to examine correlations between value criteria.

For ethnobotanical analysis of knowledge related to amaranth species, the following indices were used: the use value (UV), the fidelity level of uses (FL), the use diversity (UD), the informant diversity value (ID), and the informant equitability value (IE). Details of each index are provided in Table 3. The normality and homogeneity of the ID and IE indices were checked. The non-parametric Kruskal-Wallis test followed by a pairwise Wilcoxon test were carried out to assess differences related to surveyed areas, gender, and age for UV, ID, and IE. Multiple proportions test using the function *prop.test* was performed to assess differences in frequencies of citation of the species. Generalized linear models using Poisson distribution and stepwise selection were used to model the use value as a function of species, areas, categories of age, and gender. All analyses were performed using R version 3.0.2. (R Core Team 2013).

Results

Importance of Amaranth in Vegetable Production Systems

Five main criteria were used by farmers to determine the value of vegetables: (1) the availability of markets; (2) the profitability of production; (3) the requirement of labor and inputs; (4) resistance to nematodes; and (5) the nutritive value. According to the scoring, the top five species cultivated in the urban and peri-urban gardens of Cotonou were: amaranth (*Amaranthus cruentus* L.), African eggplant (*Solanum macrocarpum* L.), tree basil (*Ocimum gratissimum* L.), lettuce (*Lactuca sativa* L.), and carrot (*Daucus carota* L.). These species were widely cultivated either because of the availability of the markets and their resistance to nematodes (amaranth and tree basil) or because of their profitability (African eggplant, lettuce, and carrot). They were followed by bitter leaf (*Vernonia amygdalina* Del.; syn. *Gymnanthemum amygdalinum* [Delile] Sch.Bip. ex Walp.), cabbage (*Brassica oleracea* L.), cucumber (*Cucumis sativus* L.), onions (*Allium* spp.), and chili pepper (*Capsicum annuum L.).*

Positive and strong correlations were found between the ranks of the top ten species derived from the scoring and pair-wise ranking in Abomey-Calavi (rho = 0.95, p <0.01), Cotonou (rho = 0.91, p <0.01), and Sèmè-Kpodji (rho = 0.95, p <0.01), which suggests that both methods were valid. The Spearman's correlation among the value criteria (Table 4) showed that there were significant positive correlations between profitability and availability of markets (rho = 0.28, p <0.01), labor and input

Table 2. SOCIO-DEMOGRAPHIC FEATURES OF THE INFORMANTS IN URBAN, PERI-URBAN, AND RURAL AREAS OF SOUTHERN BENIN.

Socio-demographic factors		Urban area		Peri-urban area	Rural area
Municipalities		Sèmè-Kpodji (n = 40)	Cotonou (n = 40)	Abomey-Calavi (n = 40)	Sô-ava (n = 40)
Gender	Male	30	31	33	10
	Female	10	9	7	30
Age	<40 years	29	25	22	20
	≥40 years	11	15	18	20
Education level	Illiterate	5	5	8	23
	Primary	16	18	17	12
	Secondary	16	16	13	5
	University	3	1	2	0
Socio-linguistic groups	Number	9	7	6	2
	Dominant	Goun (35%)	Fon (45%)	Aïzo (45%)	Toffin (87.5%)

Table 3. DESCRIPTION AND SOURCES OF ETHNOBOTANICAL INDICES CALCULATED TO ASSESS THE KNOWLEDGE AND USES OF AMARANTH SPECIES.

Index	Description	Source
Use value (UV) $UV_s = \sum U_{ijs}$	U_{ijs} is the number of uses of the species s reported by the informant in the use category j.	Hoffman and Gallaher (2008)
Fidelity level (FL) $FL = (I_p/I_u) \times 100$	I_p is the number of informants who mentioned a species for a use p. I_u is the number of informants who mentioned the species for any use. It measures the relative importance of each use of a species.	Hoffman and Gallaher (2008)
Interviewee diversity value (ID) $ID = U_x/U_t$	ID = Number of use citations by a given informant (U_x) divided by the total number of uses (U_t). It measures how many informants used a given species and how this knowledge is distributed among the informants.	Byg and Balslev (2001); Dadjo et al. (2012)
Interviewee equitability value (IE) $IE = ID/ID_{max}$	IE = Interviewee diversity value (ID) divided by the highest diversity index value found (IDmax). It measures the degree of homogeneity of the interviewees' knowledge.	Byg and Balslev (2001); Dadjo et al. (2012)
Use diversity value (UD) $ID = U_{cx}/U_{ct}$	UD = Number of indications registered for each category (e.g., food, construction, and fuel) (Ucx) divided by the total number of indications for all of the categories (Uct). It measures the importance of the use categories and how they contribute to the local use value.	Byg and Balslev (2001); Dadjo et al. (2012)

needs and resistance to nematodes (rho = 0.38, p <0.01), labor and input needs and nutritional value (rho = 0.33, p <0.01), and between resistance to nematodes and nutritional value (rho = 0.35, p <0.01). No significant correlation was found between profitability and labor and input needs.

Use and Management of Amaranth Species

Inventory of the Species

Five species were recorded throughout the four municipalities: *A. blitum, A. cruentus, A. dubius*, *A. spinosus*, and *A. viridis*. In all localities, two cultivars of *A. cruentus* were distinguished by informants—a green cultivar and a red cultivar. These two cultivars were thus considered separately for the purposes of this study. The number of species cited by each informant (Fig. 1) was significantly different among areas (p <0.01). No differences were found between peri-urban and rural areas (p = 0.83); however, there was a significant difference between urban and peri-urban on the one hand, and urban and rural areas on the other hand (p <0.01).

The most mentioned species were the green *cruentus*, the red *cruentus*, and *A. dubius*, followed by *A. blitum*, *A. spinosus*, and *A. viridis* (Fig. 2). Green *cruentus* was cited by all informants in the three areas. No significant differences were found between areas for red *cruentus*, *A. blitum*, and *A. spinosus. A. dubius* was cited more in rural areas than urban and peri-urban areas (p = 0.046).

Table 4. Correlation matrix of the five criteria used by farmers to elicit vegetable crops' value.

	Availability of sales market	Profitability	Labor and inputs	Resistance to nematode	Nutritional value
Availability of sales market	1				
Profitability	0.28**	1			
Labor and inputs	0.15*	0.007^{ns}	1		
Resistance to nematode	0.22**	-0.15*	0.38**	1	
Nutritional value	0.19**	0.18**	0.33**	0.35**	1

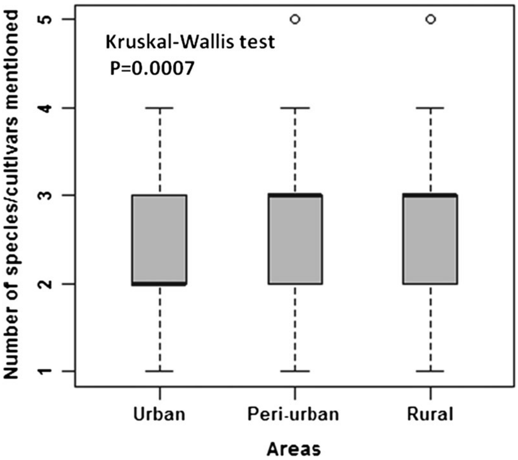

Fig. 1. Number of *Amaranthus* species/cultivars listed by informants in urban, peri-urban, and rural areas of southern Benin.

Amaranthus viridis was mentioned only in peri-urban areas. Leaf color, shape, and size, inflorescence color, presence of spines, and the relative plant height at maturity were the main criteria used to describe the species.

Species Status

In the three areas, green *cruentus* and red *cruentus* were considered cultivated species by all the informants who mentioned them. All informants who mentioned green *cruentus* cultivate it. About 25% of the informants who mentioned red *cruentus* cultivate it, and among them 80% were in rural areas, 12% in urban, and 8% in peri-urban areas. None of the informants who mentioned *A. dubius* cultivate it. However, 20% reported that it was cultivated for home consumption in some

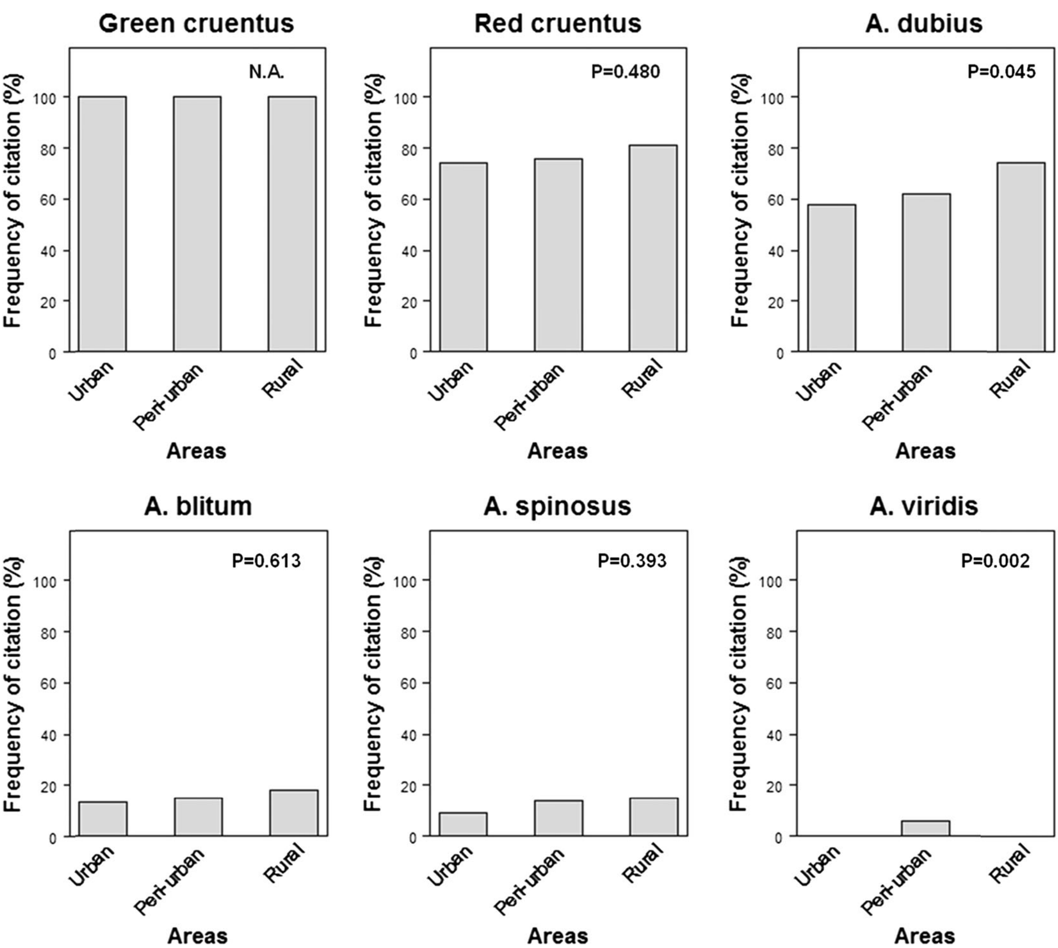

Fig. 2. Frequency of citation of *Amaranthus* species in urban, peri-urban, and rural areas of southern Benin.

areas of the country, and 80% reported that it was harvested in the wild. *Amaranthus blitum*, *A. spinosus*, and *A. viridis* were considered wild species by all informants who cited them.

Diversity of Knowledge among Informants

The comparison of informants in terms of diversity value (ID) and equitability value (IE) (Table 5) revealed significant differences for green *cruentus* (p <0.01). Knowledge related to green *cruentus* was more diversified and homogeneously distributed among informants in rural areas than peri-urban and urban areas. The equitability value of *A. dubius* was also higher in rural areas than urban and peri-urban areas, showing that knowledge related to this species was well distributed in these rural areas. No differences were found for the other species. Also, the ID and IE values were low, indicating that knowledge about these species was less diversified and held by a low proportion of informants.

Species Uses

For all species, the parts used are the leaves and young stems, which are harvested together. Uses were grouped in three categories: food, fodder, and nutraceutical properties. We define nutraceutical as any food or part of a food that provides medical or health benefits, including the prevention and treatment of disease (DeFelice 1992). The use values of the species differed significantly among areas (Fig. 3) except for red *cruentus*. Differences were noticeable between urban and rural areas for green *cruentus* (p = 0.038), *A. dubius* (p = 0.0004), *A. blitum* (p = 0.009), and *A. spinosus* (p = 0.003). Between urban and peri-urban areas, differences of use values were observed for *A. blitum* (p = 0.005), *A. spinosus* (p = 0.030), and *A. viridis* (p = 0.028). Finally, between peri-urban and rural areas, there were significant differences for use values of *A. dubius* (p = 0.002). Fig. 4 shows the contribution of each use category to the species use value. Overall, the nutraceutical uses were the most diversified for all species except *A. viridis*, which was only mentioned as a vegetable by three informants in peri-urban areas. Detailed uses of each species are summarized in Table 6. Overall, nine uses were mentioned for green *cruentus* and *A. dubius*, eight for red *cruentus*, five for *A. blitum* and *A. spinosus*, and only one for *A. viridis*. More uses were reported in rural areas than in others for red *cruentus*, *A. dubius*, *A. blitum*, and *A. spinosus*; the green *cruentus* was more diversely used in urban area (eight uses) than in other areas (respectively six uses). Use as a vegetable was the most popular for all species in the three areas. For nutraceutical properties, green *cruentus* and *A. dubius* were considered as excellent tonic and used to fight against fatigue. The use of red *cruentus* to prevent or cure anemia was popular in the three areas. In urban and rural areas, *A. blitum* is mainly used to prevent and treat weak bones, and *A. spinosus* is efficient in treating skin disorders. *A. cruentus* and *A. spinosus* were mentioned as fodder for pigs. Other uses mentioned by a few informants included treatment of constipation, anemia, hypertension, ulcers, weak bones, brain and liver disorders for *A. cruentus*, treatment of malaria, diarrhea, weak bones, anemia, liver and brain disorders for *A. dubius*, the use of *A. blitum* against fatigue and liver disorders, and the use of *A. spinosus* as a febrifuge and anti-inflammatory, especially for angina.

Table 5. SUMMARY OF INFORMANT KNOWLEDGE OF AMARANTHS IN URBAN, PERI-URBAN, AND RURAL AREAS OF SOUTHERN BENIN. PARAMETERS MEASURED INCLUDE DIVERSITY VALUE (ID) AND EQUITABILITY VALUE (IE) OF INFORMANTS PER SURVEYED AREA.

	Urban		Peri-urban		Rural	
Species	ID (mean ± se)	IE (mean ± se)	ID (mean ± se)	IE (mean ± se)	ID (mean ± se)	IE (mean ± se)
Green *cruentus*	0.27±0.01	0.56±0.02	0.24±0.02	0.55±0.04	0.34±0.02	0.68±0.04
Red *cruentus*	0.23±0.02	0.49±0.04	0.29±0.03	0.39±0.04	0.25±0.03	0.51±0.06
A. dubius	0.14±0.02	0.29±0.04	0.28±0.04	0.28±0.04	0.14±0.02	0.44±0.06
A. blitum	0.05±0.03	0.05±0.03	0.14±0.04	0.14±0.04	0.08±0.03	0.13±0.05
A. spinosus	0.02±0.02	0.05±0.03	0.08±0.03	0.15±0.06	0.05	0.2
A. viridis	–	–	0.08±0.04	0.08±0.04	–	–

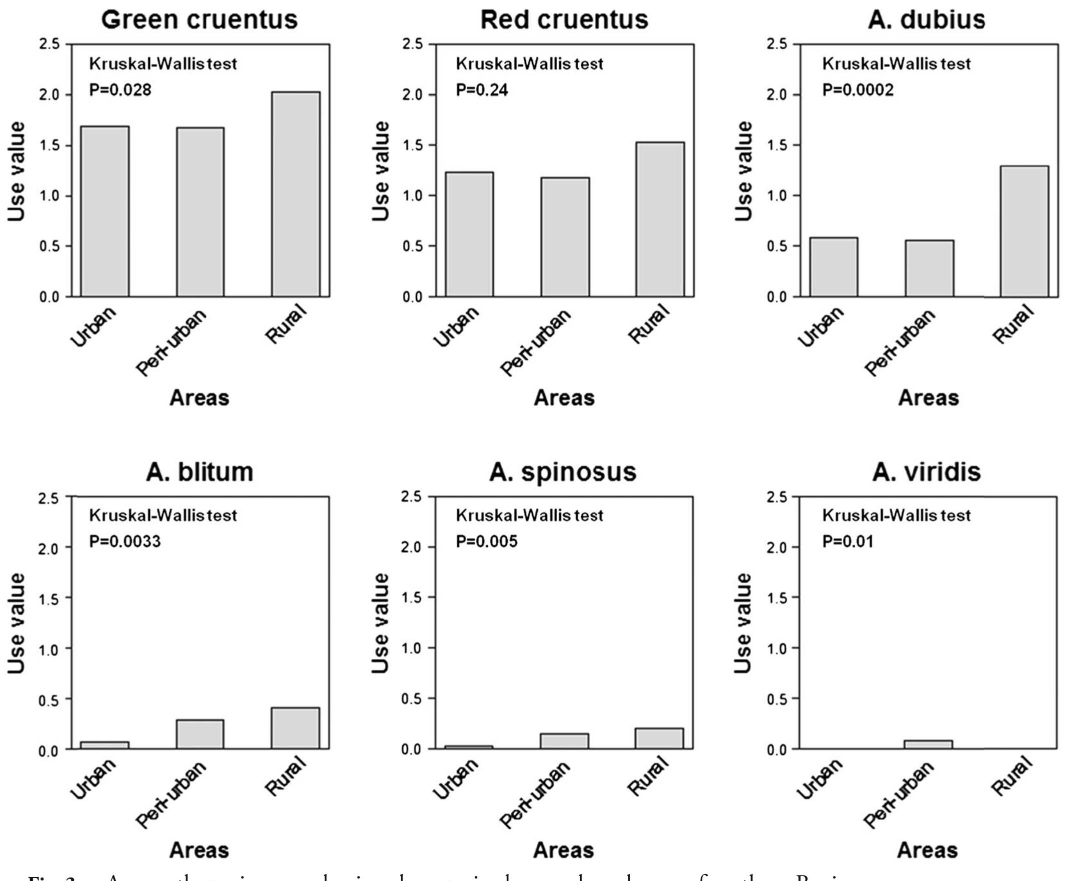

Fig. 3. Amaranth species use value in urban, peri-urban, and rural areas of southern Benin.

Factors Affecting Use Values

The analysis of the variation of the use value according to age, area, and species (Table 7) showed that the age of informants had no significant effect on the use value. The use value varied significantly according to the species, the area, and their interaction. Green and red *cruentus* had a higher use value than wild species. The use value of both cultivars and *A. dubius* varied significantly according to area, while no significant variation was found for other species.

Discussion

Importance of *Amaranthus cruentus* in Vegetable Production Systems of Urban and Peri-urban Cotonou

The use of quantitative ethnobotany to rank cultivated vegetables in urban and peri-urban areas revealed that amaranth is the first vegetable cultivated in terms of production area, which corroborates the results of Pasquini et al. (2009). According to farmers, the choice of one species rather than another is highly dependent on the availability of sales market, profitability, labor and inputs, resistance to nematodes, and the nutritional value of the species. Despite its low profitability, amaranth is widely cultivated because of its short cycle and resistance to nematodes, which makes it a choice crop, often combined with long cycle vegetables such as African eggplant, cabbages, and lettuce.

The use of this species in combination with others in the same plots also allow farmers to save inputs such as water, fertilizers, and pesticides and provides shade to seedlings of other crops. *Amaranthus cruentus* is often included in crop rotations to reduce the prevalence of nematodes on susceptible species such as African eggplant and carrot, among others species. Wilson and Caveness (1980) found that *Amaranthus* sp.

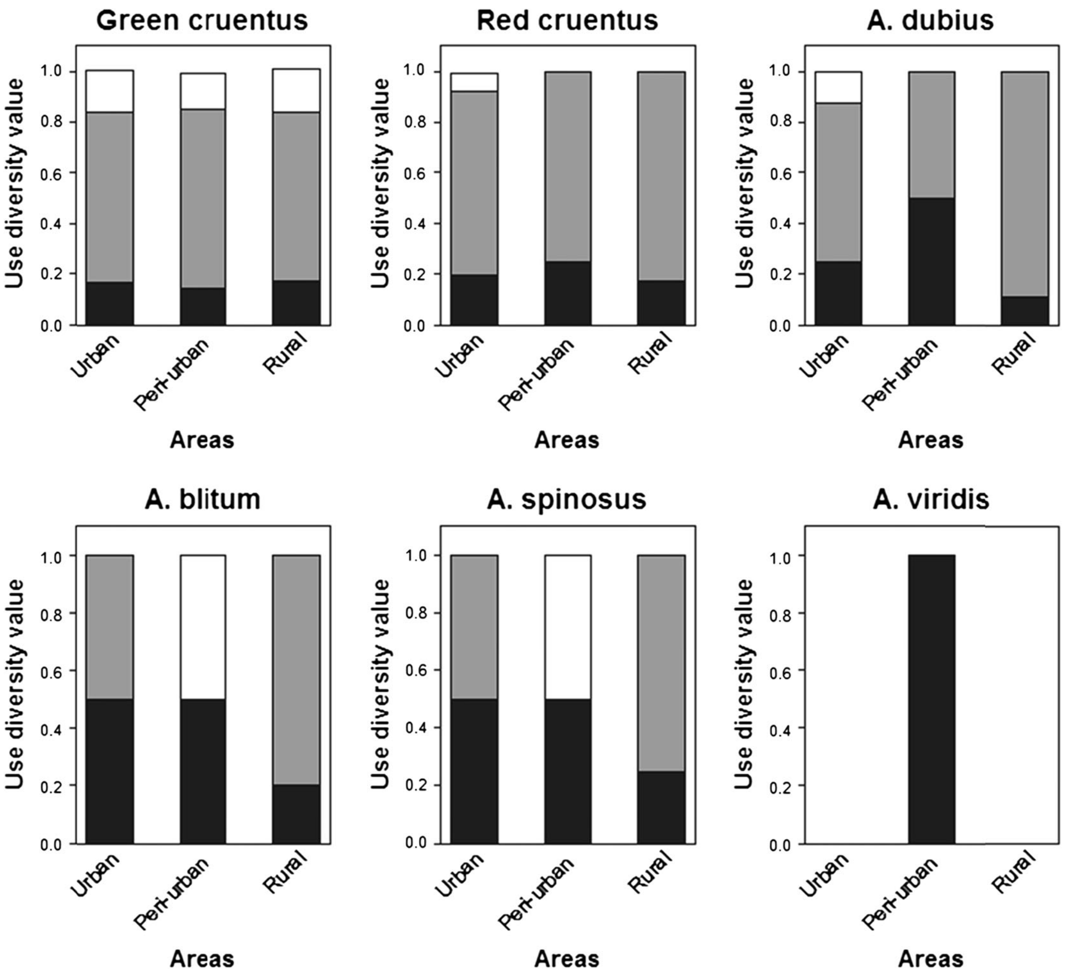

Fig. 4. Contribution of categories of use to species use value in urban, peri-urban, and rural areas of southern Benin. Categories of use include: food (black bars), nutraceutical (grey bars), and fodder (white bars).

significantly reduced populations of spiral nematode (*Helicotylenchus pseudorobustus*). The resistance of *Amaranthus cruentus* to root knot nematodes (*Meloidogyne* spp.) was also reported (Afouda et al. 2012, 2008; Desaeger and Rao 1999; Ferris et al. 1993). According to respondents in urban and peri-urban areas, the use of *A. cruentus* in crop rotation systems has a soil sanitation effect and provides a cleaner environment for the next crop. This result highlights the potential of amaranth species to reduce the harm of nematodes in vegetable production systems.

Correlation tests were performed between the criteria used to elicit the place of amaranths in urban and peri-urban production systems. The correlation value was negative between the profitability and the resistance to nematodes, indicating that nematodes-resistant vegetables such as amaranths have a low profitability.

We observed no correlation between the "profitability" and the '"labor and inputs" criteria. This result was unexpected but could be explained on the one hand by the fact that labor in vegetable production systems mostly comes from the farmer's household and is not counted as an important input. On the other hand, the profitability/labor and input relationship greatly varied among vegetable species. Some vegetables like cabbage require considerable labor with decreasing profitability. Others like parsley (*Petroselinum crispum* [Mill.] Fuss) and mint (*Mentha* spp.) were cultivated on very small plots without intense labor but can be highly profitable. To clarify the profitability/labor and input relationship, we suggest a full economic

Table 6. Description of uses of amaranth species for each use category and related fidelity level per area.

Species/Cultivars	Use category	Description of uses	Fidelity level (%) Urban area	Fidelity level (%) Peri-urban area	Fidelity level (%) Rural area
Green *cruentus*	Food	Consumed as vegetable in soups.	**100**	**100**	**100**
	Nutraceutical	Prevention and treatment of fatigue through consumption as vegetable.	42.5	32.5	47.5
		Prevention and treatment of anemia, especially for children, pregnant, or breastfeeding women: through consumption as vegetable and use of cooking water to prepare porridges for children.	13.75	17.5	20
		Laxative.	3.75	7.5	8
		Treatment of hypertension through consumption as vegetable.	1.25	15	15
		Treatment of brain disorders through consumption as vegetable.	–	2.5	–
		Treatment of liver disorders through consumption as vegetable.	1.25	–	–
		Treatment of ulcers through consumption as vegetable.	1.25	–	–
	Fodder	Feed for pigs.	2.5	5	7.5
Red *cruentus*	Food	Consumed as vegetable in soups.	**100**	**100**	**100**
	Nutraceutical	Prevention and treatment of anemia, especially for children, pregnant, or breastfeeding women through consumption as vegetable and use of cooking water to prepare porridges for children.	29.4	35.7	63
		Prevention and treatment of fatigue through consumption as vegetable.	–	6.4	20.7
		Treatment of weak bones through consumption as vegetable.	1.7	–	–
		Treatment of liver disorders through consumption as vegetable.	1.7	–	3.5
		Laxative through consumption as vegetable.	–	6.4	13.5
		Treatment of hypertension through consumption as vegetable.	–	–	10.5
	Fodder	Feed for pigs.	1.7	–	–
A. dubius	Food	Consumed as vegetable in soups.	**100**	**100**	**100**
	Nutraceutical	Prevention and treatment of fatigue through consumption as vegetable.	30.3	4.8	20.6
		Prevention and treatment of anemia, especially for children, pregnant or breastfeeding women through consumption as vegetable.	6	–	3.6
		Treatment of liver disorders through consumption as vegetable.	3	–	3.5
		Treatment of malaria through consumption as vegetable.	–	–	3.5
		Treatment of hypertension through consumption as vegetable.	–	–	14
		Treatment of brain disorders through consumption as vegetable.	–	–	3.5
		Treatment of weak bones through consumption as vegetable.	–	–	7
		Treatment of diarrhea through consumption as vegetable.	–	–	3.5
A. blitum	Food	Consumed as vegetable in soups.	**100**	**100**	**100**
	Nutraceutical	Treatment of weak bones through consumption as vegetable.	33.3	–	12.5

		Prevention and treatment of fatigue.	–	–	12.5
		Treatment of liver disorders through consumption as vegetable.	–	–	12.5
	Fodder	Feed for pigs.			
A. spinosus	Food	Consumed as vegetable in soups.	**50**	**100**	**50**
	Nutraceutical	Treatment of skin disorders: ash of burnt plants is directly applied on the skin or mixed with ointments.	50	–	16.7
		Treatment of angina through drinking of the juice of crushed leaves.	–	–	16.7
		Treatment of fever through decoction of leaves.	–	–	16.7
	Fodder	Feed for pigs.	–	15	–
A. viridis	Food	Consumed as vegetable in soups.	–	**100**	–

analysis over several seasons including major and minor vegetable species.

The results of scoring and ranking of the species were highly correlated. The same findings were reported by N'Danikou et al. (2011), who recommended the scoring method to assess local value of edible wild plants and prioritize them for conservation actions. Given the dynamics of production in vegetable gardens, these methods might be regularly used as a rapid ethnobotanical appraisal tool to assess knowledge and trends in the urban and peri-urban vegetable production systems.

Local Uses of Amaranth Species

Of the seven amaranth species recorded in Benin (Adjakidjè 2006), five were mentioned as being used in Southern Benin. They are used as vegetable, fodder for pigs, and for their nutraceutical properties. *Amaranthus cruentus*, the only species cultivated in this study, has two cultivars: the green *cruentus* with green leaves, stem, and inflorescences, and the red *cruentus*, which has amaranthine pigmented leaves, inflorescences, and stems. The first cultivar, the most often cultivated, is considered by farmers as a tonic and stimulant and is rich in vitamins and minerals (Fasuyi 2007; Schönfeldt and Pretorius 2011). Both cultivars are recommended for children and pregnant or lactating mothers to prevent or cure anemia. This therapeutic use has been confirmed by other studies (Koffi et al. 2012; Lyimo et al. 2003; Peter et al. 2014). However, the red *cruentus* was considered a more popular source of iron among informants. Hels et al. (2004) found that red leaf cultivars of amaranth (*A. gangeticus*) had a higher content of iron, calcium, zinc, and β-carotene than green cultivars. According to Yadav and Sehgal (2002), blanching and cooking amaranth leaves increases availability of iron. *Amaranthus cruentus* is also used to treat constipation, hypertension, liver and brain disorders. Grubben (2004a) reported the same uses for the species in various parts of Africa.

Amaranthus dubius was considered by a large proportion of informants as a wild species, while some reported its cultivation, especially in rural areas of the Valley of Ouémé where leafy vegetables are widely cultivated. According to Ambrose-Oji (2009), the distinction between wild and cultivated is not clear since there are complex relationships between urban and peri-urban vegetable production and the harvesting of wild species.

Amaranthus dubius was the most popular among non-cultivated amaranths in the surveyed areas and

Table 7. VARIATION OF THE USE VALUE IN RELATION WITH AREAS, SPECIES, AND AGE REVEALED BY STEPWISE METHOD. THE GENDER WAS REMOVED FROM THE FINAL MODEL.

		Age > 40	Urban	Green *cruentus*	Red *cruentus*	*A. dubius*	Urban*Green *cruentus*	Urban*Red *cruentus*	Urban**A. dubius*	df	AIC
Use value	Estimate	0.149	-1.342	1.807	1.452	0.693	1.489	1.523	1.526	939	1528.8
	SD	0.160	0.546	0.325	0.335	0.369	0.560	0.568	0.598		
	Pr(>|z|)	0.351	**0.014**	**0.000**	**0.000**	0.060	**0.008**	**0.007**	**0.0108**		

is a promising species for introduction into cultivation systems in southern Benin. Its large-scale cultivation has been reported in Kenya and it is widely used in East Africa (Maundu et al. 2009). Moreover, Sogbohossou and Achigan-Dako (2014) revealed that this species has interesting leaf yield in southern Benin conditions and could be easily cultivated. The species is used by informants to combat fatigue, anemia, malaria, hypertension, diarrhea, weak bones, and brain disorders. In Ethiopia, the use of the species has been reported against skeleton-muscular diseases (Giday et al. 2010). Analysis of variation of nutrient content among *Amaranthus* species showed that *A. dubius* had a high protein content (Andini et al. 2013), vitamin C, calcium, and zinc (Yang and Keding 2009). Research on the reported pharmacological properties of the species is scanty.

Amaranthus blitum, *A. spinosus*, and *A. viridis* are not cultivated. They are either harvested in the wild when needed or spared by farmers during weeding. Their use as vegetables and to a lesser extent as nutraceuticals has been reported by farmers. *A. blitum* is considered a remedy against liver disorders, weak bones, and fatigue. Neuwinger (2000) reported its use to treat warts, blennorrhagia, angina, fracture, nervousness, swellings, and tumors. There is still a lack of scientific information about these properties. *A. spinosus* is used by informants to treat skin disorders, angina, and fever. Antipyretic (Kumar et al. 2011) and anti-inflammatory (Olajide et al. 2004; Zeashan et al. 2009a) properties of the species have been demonstrated. It has also shown diuretic (Amuthan et al. 2012), anthelmintic (Kumar et al. 2010), hepatoprotective (Zeashan et al. 2009b), and anti-malarial activities (Hilou et al. 2006). *A. viridis* was only mentioned as a vegetable. However, Grubben and Denton (2004) reported its use as diuretic, purgative, and anti-inflammatory. Anti-diabetic and anti-hyperlipidemic potential of the species has also been highlighted (Kumar et al. 2012; Pandhare et al. 2012). The leaves of *A. viridis* are particularly rich in proteins, vitamin A, and iron (Yang and Keding 2009). Overall, amaranth species have interesting nutraceutical properties and are used to treat various diseases.

Knowledge Dynamics along the Urban-Rural Continuum

The comparison of use values in urban, peri-urban, and rural areas revealed significant differences. These differences were particularly pronounced between urban and rural areas, with peri-urban areas often intermediate between the two. The variation of use value along the continuum was higher for wild species, while very few differences were noticed for both cultivars of *A. cruentus*. In urban and peri-urban areas, there is a greater diversity of exotic vegetables than in rural areas (pers. obs.). This trend was also observed in Tanzania, where demand for exotic vegetables increased with urbanization (Yang and Keding 2009).

Cocks (2006) reported the use of wild plants by most of the urban households surveyed in South Africa. However, the bulk of these species were used for their cultural significance and only wild fruits were harvested for consumption. This underscores the lack of interest for wild vegetables in urban areas and corroborates our findings.

Overall, for the green *cruentus* that is commonly cultivated, more uses were cited in urban areas than other areas. No significant differences occurred among areas in terms of distribution and diversity of knowledge related to other species. This trend might be explained by the importance of this cultivar in urban vegetable production systems. Indeed, people adjust to economic and practical realities through selective maintenance of useful plant knowledge (Müller-Schwarze 2006). Comparison of species knowledge showed that it was more homogenously distributed and diversified for cultivated species compared with wild species. The low popularity of wild species compared with cultivated amaranth is associated with great variations of levels of knowledge which is held by a small part of the farmers. This distribution of knowledge is because wild amaranths are considered useless weeds by most urban growers. The low use value and fidelity level of uses of wild amaranths suggest that the traditional knowledge of these species is at risk of erosion, as also reported by Srithi et al. (2009) in northern Thailand for medicinal plants. Nevertheless, although wild amaranths were not among the preferred species used as vegetables, their health benefits should be considered as additional advantages to promote their consumption. Maintenance of knowledge for wild leafy vegetables identification and preparation will be necessary for their continued use (Powell et al. 2014). The persistence of knowledge related to wild amaranths, although held by a small portion of farmers, can be used as a starting point for promoting these species.

The variation of the use value of the species was not significantly associated with age and gender, showing that the distribution of knowledge among farmers is independent of both factors. Some studies (Gandolfo and Hanazaki 2014; Mathez-Stiefel et al. 2012; Müller-Schwarze 2006) have demonstrated that traditional knowledge was not systematically declining among younger people, but rather was shaped by changing sociocultural and economic contexts. Likewise, even though the connection between local knowledge and gender has been demonstrated elsewhere (Dovie et al. 2008; Souto and Ticktin 2012; Voeks 2007), our results showed that amaranths are similarly used by men and women, pointing out the importance of these indigenous vegetables for local communities.

Implications for Research and Development

Amaranthus cruentus is a vegetable of considerable importance in southern Benin. Despite its low economic value, this species plays multiple roles in production systems and provides various nutritional and health benefits for consumers. However, more investigations are needed to clarify the nematode-suppressing ability of the species in crop rotation. It might also be useful to explore the possibility of developing botanical extracts from amaranth species that can be used in the integrated management of nematodes in horticultural production systems.

The knowledge associated with wild related species such as *A. dubius*, *A. blitum*, *A. spinosus*, and *A. viridis* is diversely distributed among farmers in both rural and urban areas. In urban and peri-urban areas where amaranth is the most cultivated vegetable, knowledge related to wild species are less known and used by farmers even though the plants exhibit rapid growth, are well adapted to environmental constraints, and can substantially contribute to healthy diets and mitigation of hidden hunger. There are currently limited reports about the cultivation status and growth ability of wild amaranth species in Benin (e.g., Achigan-Dako et al. 2010; Sogbohossou and Achigan-Dako 2014). In order to integrate wild amaranths in vegetable production systems, it is important to check the validity of nutraceutical properties attributed to them and to raise awareness of consumers about their benefits. These actions might increase the economic value of amaranth and provide incentives for conservation, cultivation and sustainable utilization of its wild relatives along the urban-rural continuum. Emphasis should be put on *A. dubius* which is already cultivated in other areas and exhibits interesting leaf production potential (Grubben 2004b).

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