Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 7, No. 1, p. 490-500, 2015
http://www.innspub.net

INNSPUB

RESEARCH PAPER

OPEN ACCESS

Addressing indicators species and ecological factors that underline the presence of *Rhamphicarpa fistulosa (Horchst) Benth.* in Senegal (West-Africa)

N. Zossou[1*], M. Sagna[1], L. Sonko[2], K. Noba[1], A. Ahanchede[2], B. Sinsin[2]

[1]*Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin*

[2]*Department of Plant Biology, Faculty of Sciences and Techniques, University of Cheikh Anta Diop, Senegalese Institute of Agricultural Research, Benin*

Article published on July 30, 2015

Key words: *Rhamphicarpa fistulosa*, Lowland, Rice, Ecological Niche, Senegal.

Abstract

Rhamphicarpa fistulosa, widespread specie of wetlands, is a hemiparasitic weed occurring in lowland rice production. It was distributed in Africa, Madagascar, Australia and India. To know more about the habitat of *Rhamphicarpa fistulosa* in Senegal, we addressed two questions: (1) which plant species are indicators of the presence of *R. fistulosa*? (2) What are the ecological variables which predict the presence of *R. fistulosa?* Three agroecological areas were identified following the main lowland rice production. The results showed that *Althernanthera sessilis*, *Echinocloa colona, Aeschynomene indica and Cyperus haspan* combined with the ecological variables such as the pH the presence of the host (rice crops) and the bare soil are indicators of the presence of *R. fistulosa*. It was also appeared that *Rhamphicarpa fistulosa* is following rice production in the colonization of new habitat. Habitat occupied by *R. fistulosa* should be recognized as relict and critically endangered sites where special protection measures must be used. They should be included in the environmental monitoring program with local active protection.

***Corresponding Author:** Norliette Zossou ✉ norliette.zossou@yahoo.fr

Introduction

Rhamphicarpa fistulosa (Hochst.) Benth. is a widespread of natural wetland vegetation in Africa (Muller and Deil, 2005; Muller, 2007). It is an annual facultative parasitic weed, mainly infecting lowland rice a rice in Africa (Ouedraogo *et al.,* 1999, Rodenburg *et al.,* 2014). The species is largely distributed in Africa, Madagascar, Australia and India (Zossou *et al.,* 2013; Rodenburg *et al.,* 2014). In Sub Saharan Africa, most of the time it is due to production constraints that a large gap remains production and consumption (Seck *et al.,* 2010). Like *Striga spp*, it parasitizes the host through a haustorium connected to the host roots (Neumann *et al.,* 1998). *Striga asiatica* is mainly founded in Eastern Africa, where *R. fisutulosa* is distributed Sahelian areas (Senegal to Euthiopia), East and South Africa. *R. fistulosa* and *Striga asiatica* have strictly separated ecological niches (Kabiri *et al.,* 2014). Despite its presence in Senegal, and the negative effect in rice production in the South of the country (Zossou *et al.,* 2015 a), studies relative to the presence of *R. fistulosa* in this were not available. It can cause significant yield reductions in rice, (Kuijt, 1969; Cisse *et al.,* 1996; Ouedraogo *et al.,* 1999; Gbehounou and Assigbe, 2003; Maiti and Singh, 2004; Zossou *et al.,* 2013; Rodenburg *et al.,* 2014).

The rainfed rice in Sub Saharan Africa covers 7 million hectares (Diagne *et al.,* 2013). The areas used for rice production is expanding and *R. fistulosa* may also spread in new inland valleys. If we to find out an integrated control option, it is important to more about its habitat. Habitat concept clarification is crucial in conservation, restoration or reinforcement projects of plant species populations and environment protection, as it requires previous knowledge of their dynamics and ecological requirements (Guisan and Thuillier, 2005; Wolters *et al.,* 2008; Maschinski *et al.,* 2011 and). The use of co-occurring or indicators plant species can be used hence to define more precisely, suitable habitats for the development of the targeted species (Myers *et al.,* 2000). In Benin, some species and ecological parameters were identified by Zossou *et al.,* 2015 as indicative of the presence of *R. fistulosa*. According to Ncho *et al.* (2014), *Rhamphicarpa fistulosa* a lesser-non parasite is considered as a poor-farmers problem; because it is primarily problematic on marginal arable land where water can't be controlled. Here, for *R. fistulosa*, we suggest also a method that integrates co-occurring species and ecological variables allowing identification of its preferred habitats in Senegal. We address two questions: (1) which plants species are indicators of the presence of *R. fistulosa*? (2) What are the ecological variables which predict the presence of *R. fistulosa?*

Materials and methods

Study area

The study was carried out in Senegal between 12°08′ – 16°41″ N and 11°21′– 17°32″ N where important quantities of lowland rice were produced. Data were collected in the sub-guinean zone, where rainfall is not really a constraint on agriculture and where there are some flooded crops. The area is characterized by one rainy season, one from June to September, with a mean annual precipitation of 985 mm and one dry season, from October. The mean annual temperature varies between 20°C and 45°C (Diangar *et al.,* 2003). Generally, soils in this zone are sandy, hydromorphic or vertisols with variable quantities of organic matter and highly leached with a predominance of iron concretions (Blondel, 1971; Badiane *et al.,* 2000).

Three districts were identified following three major agro-ecological areas of Senegal (Dancette, 1983), where lowland rice is most produced. The methodology used for this choice followed Zossou (2007). The district of Adjohoun and Bonou were choose in the agro-ecological area of "Bar land area" located in the watershed of the river "Ouémé"; the district of Dassa, Glazoué and Bantè were choose in the agroecological areas of "Cotton zone of central Benin"; the district of Ouaké and Bounkoumbé were choose in the agro ecological areas of "West-Atacora zone"; the district of Bembèrèkè was choose in the agrecologial zone of "Food area of Southern Borgou" and the district of Kandi and Gogounou were choose in the agro-ecological ares of "Cotton zone in northern Benin".

Sampling and environmental measurements

In order to encompass rice fields in inland valleys and natural vegetation associated or not with *R. fistulosa*, we monitored 30 plots of 1m × 1 m in the 3 districts. For each plot, we considered the topographical position of the wetland, the vegetation characteristics in the fields and the presence/absence of *R. fistulosa*. Within each plot, phytosociological relevés were carried out following the methodology of Weber (2000). We visually appreciated and estimated the cover of each species in each plot using Braun Blanquet cover/abundance scale (Westhoff and Van Der Maarel, 1978) as follow: +: rare, less than 1% cover ; 1: 1-5% cover; 2: 5-25% cover; 3: 25-50% cover; 4: 50-75% cover; and 5: 75-100% cover. In addition, we measured six variables in each plot: bare floor, number of days after sowing the rice, presence of rice crops, presence of *R. fistulosa*, soil texture, soil pH, type of lowland arrangement (arrange or not). Five samples of soil were randomly collected in each plot. Then we pooled these samples forming one composite soil sample, thoroughly mixed and passed through 4 mm sieve to remove debris. The final samples obtained were analyzed specially for texture using the hydrometer analysis. The soil pH was measured in a field.

Data analysis

The data have been analyzed using PCORD5 software. Phytosociological matrix was submitted to Nonmetric Multidimensional Scaling (NMS) for ordination analysis. The cluster analysis was performed with Sorensen distance based on flexible beta method. Mentel test was run based on Mantel asymptotic approximation, using algorithm based on Douglas and Endler (1982). In order to test the difference between groups, we performed Multi-Response Permutation Procedures (MRPP) testing the hypothesis that, there is no difference between groups. Discriminant species analysis of each group was undertaken according to the method of Dufrene and Legendre (1997). Monte Carlo test was performed to identify the most significant ecological parameters which are introduced in the analysis of Canonical correspondence analysis (CCA). Canonical correspondence analysis was performed based on Hill's (1979) in order to identify the ecological parameters which explain the variation in species composition and the occurrence of *R. fistulosa*. CCA analysis has been used to relate the variance of a response variable to explanatory variables (Masahiro *et al.,* 2012).

Results

Plant species diversity and indicator species of R. fistulosa

A total of 50 taxa from 18 families were recorded in the study (Table 1). The family of Poaceae had 28 % of the total number of taxa identified (Fig. 1). It was followed by the families of Cyperaceae (26%). A total of 16 families had few taxa which number ranged from 1 to 2.

Nonmetric Multidimensional scaling analysis performed on the species abundance data in two-dimensional accounted for 70% of the variation in the data set, with 50% explained by axis 1 and 20% explained by axis 2.

MRPP analysis showed that the four groups were significantly different to each other. As detected by Mantel test, the association of the species matrix based on Sorenson distance and the variables matrix based on Jaccard distance is significantly positive ($t = 5.06$, $P = 0.001$).

The dendrogram generated from the hierarchical cluster analysis was presented in fig. 2. Hierarchical clustering performed with 30 plots produced four groups of plant communities with 30% of the total information within each group. We distinguished based on result: the community of *Ludwigia abyssinica* (C1); the community of *Ipomea aquatica* (C2); the community of *Rhamphicarpa fistulosa* (C3) and the community of *Oryza barthii* (C4). The first community (C1) contained ten plots, the second has five plots, the third contained three plots and in the fourth we have twelve plots.

The communities were located in different agro ecological areas, with different soil texture in developed and undeveloped inland valleys.

Table 1. Species diversity and plant communities. 1= plants communities C1, 2= plant communities C2, 3= plants communities C3, 4= plants communities C4.

Species	Families	Communities	Probabilities
Ludwigia abyssinica	Onagraceae	1	0,042
Ludwigia decurrens	Onagraceae	1	0,242
Ageratum conyzoides	Asteraceae	1	0,763
Polygonum lanigerum	Polygonaceae	1	0,224
Polygonum salicifolium	Polygonaceae	1	0,23
Fuirena umbellata	Cyperaceae	1	0,301
Kyllinga pumila	Cyperaceae	1	0,604
Fimbristilis ferruginea	Cyperaceae	1	0,6
Panicum subalbidum	Poaceae	1	0,242
Paspalum polystachyum	Poaceae	1	0,242
Paspalum vaginatum	Poaceae	1	0,242
Eclipta prostata	Asteraceae	1	0,313
Cyperus difformis	Cyperaceae	1	0,854
Scirpus jacobi	Cyperaceae	1	0,603
Ludwigia hyssopifolia	onagraceae	1	0,216
Oldenlandia corymbosa	Rubiaceae	1	0,221
Kyllinga bulbosa	Cyperaceae	1	0,86
Scleria verrucosa	Cyperaceae	1	0,306
Echinochloa pyramidalis	Poaceae	1	0,858
Oryza longistaminata	Poaceae	1	0,858
Cyperus iria	Cyperaceae	2	0,119
Kyllinga erecta	Cyperaceae	2	0,807
Fuirena ciliaris	Cyperaceae	2	0,596
Schrankia leptocarpa	Mimosaceae	2	0,753
Ipomea aquatica	Convolvulaceae	2	0,009
Leptochloa caerulescens	Poaceae	2	0,723
Vossia uspidata	Poaceae	2	0,26
Heteranthera callifolia	Pontederiaceae	2	0,26
Clappertonia ficifolia	Tiliaceae	2	0,26
Salvinia nymphellula	Salviniaceae	2	0,26
Pycreus lanceolatus	Cyperaceae	2	0,26
Eichhornia crassipes	Pontederiaceae	2	0,26
Echinochloa crus-pavonis	Poaceae	2	1
Rhamphicarpa fistulosa	Orobanchaceae	3	0,0004
Alternanthera sessilis	Amaranthaceae	3	0,221
Cyperus haspan	Cyperaceae	3	0,144
Aeschynomene indica	Fabaceae	3	0,607
Echinochloa obtusiflora	Poaceae	3	0,232
Pentodon pentandrus	Rubiaceae	4	0,095
Oryza sp	Poaceae	4	0,2
Ludwigia octovalis	Onagraceae	4	0,849
Leersia hexandra	Poaceae	4	0,501
Dissotis rotundilofia	Melastomataceae	4	0,941
Hydrolea glabra	Hydrophyllaceae	4	1
Sacciolepis africana	Poaceae	4	0,932
Melochia corchorifolia	Sterculiaceae	4	1
Oryza barthii	Poaceae	4	0,045
Nymphaea lotus	Nymphaeceae	4	1
Isachenum rugosum	Poaceae	4	1
Fimbristylis littoralis	Cyperaceae	4	1

The first plants community (C1) was mainly distributed in the agro-ecological area of Eastern-Senegal, but also found in the agro-ecological areas of Highest Casamance and rarely in Low and Medium Casamance. Plants community (C2) was mostly distributed in all the three agro-ecological areas. The third plants community (C3) was evenly distributed in the agro-ecological area of Eastern-Senegal and Highest Senegal. The last plants community (C4), was also mostly found in all of the three agro-ecological areas of the study area.

Table 2. Summary statistic of Canonical Correspondence Analysis.

	Axis1	Axis2	Axis3
Eigenvalue	0.571	0.405	0.286
Variance in species data (% of variance explained)	7.9	5.6	4.0
Cumulative % explained	7.9	13.6	17.5
Pearson correlation	0.875	0.860	0.784
Kendall Correlation	0.674	0.655	0.678

We significantly at a level of 5% distinguished the community the community of *Rhamphicarpa fistulosa* (C3) with the lowest amount of importance value (5 species); while those communities of *Oryza bartii* (C4), *Ipomea aquatic* (C2) and *Ludwigia abyssinica* (C1) have the highest amount of importance value (respectively 12, 13 and 20 species).

Effects of ecological parameters and indicative species on the presence of R. fistulosa

Althernanthera sessilis, *Echinocloa obtussiflora, Aeschynomene indica and Cyperus haspan* are species that indicate the habitats of *Rhamphicarpa fistulosa* at a level of 5% (Table 1).

The Canonical Correspondence Analysis performed on the of the floristic data set and the ecological parameters showed that the first two axes explained respectively 57% and 41% of the variation in data considered (Table 2). Ecological parameters which are the age of the host (P1), the presence of the host (P4), the pH (P6) and the percentage of bare soil (P3) appeared as discriminant variable for the presence of *R. fistulosa* (Fig. 3).

The presence *of R. fistulosa* was associated to low value of soil pH, the presence and the age of the host and the percentage of bare soil in case of our study.

Table 3. Correlations and biplot score for 6 environmental variables.

	Correlations scores			Biplot scores		
Variables	Axis1	Axis2	Axis3	Axis1	Axis2	Axis3
Age of rice	0.118	-0.003	0.809	0.063	-0.002	0.49
Percentage of bare soil	0.082	0.278	0.147	0.043	0.173	0.089
Presence of rice	-0.941	0.105	-0.029	-0.499	0.065	-0.017
Soil texture	0.1	0.818	-0.379	0.053	0.507	-0.23
pH	0.12	-0.019	-0.631	0.063	-0.012	-0.382
Type of inland valley	0.876	0.136	0.366	0.465	0.085	0.222

Discussion

Plant species diversity and indicator species of R in lowland rice production

A high number of species' families were identified in the plots. It is mean that a lot of weeds were present in rice fields or weeding has not been down regularly or consequently based on the frequency of their apparition. Typically, these are the result of crops production with resources-poor subsistence farmers and a high number of female producers (N'cho *et al.*, 2014). Clearly, weeds have negative economic impact and also asked farmers to invest some of them work-time for weeding (N'cho *et al.,* 2014). Generally, weeding is performed by women and children

(Ogwuike *et al.,* 2014) and sometimes, highest infested rice fields are abandoned by farmers (Rodenburg *et al.,* 2011). In Benin, the main weeds management practices are hand weeding, hand-foe weeding and the use of herbicide (Gbèhounou and Assigbe, 2003; N'cho, 2014).

Eastern Senegal was the agro-ecological area which sheltering all plant communities. The species richness in *Rhamphicarpa fistulosa* habits is very important. Wetlands with a history of hydrological disturbance showed more widespread invasions of weeds in rice fields (Zedler and Kercher, 2004). The species community of *Rhamphicarpa fistulosa* was presented in all of the agro-ecological areas. It is mean that, the agro-ecological conditions globally didn't affect the distribution of the parasite. When weed specie have a broad ecological range, it is potentially invasive and may also spread and adapt to ecological conditions beyond the original or moist favourables ones (Booth *et al.,* 2010).

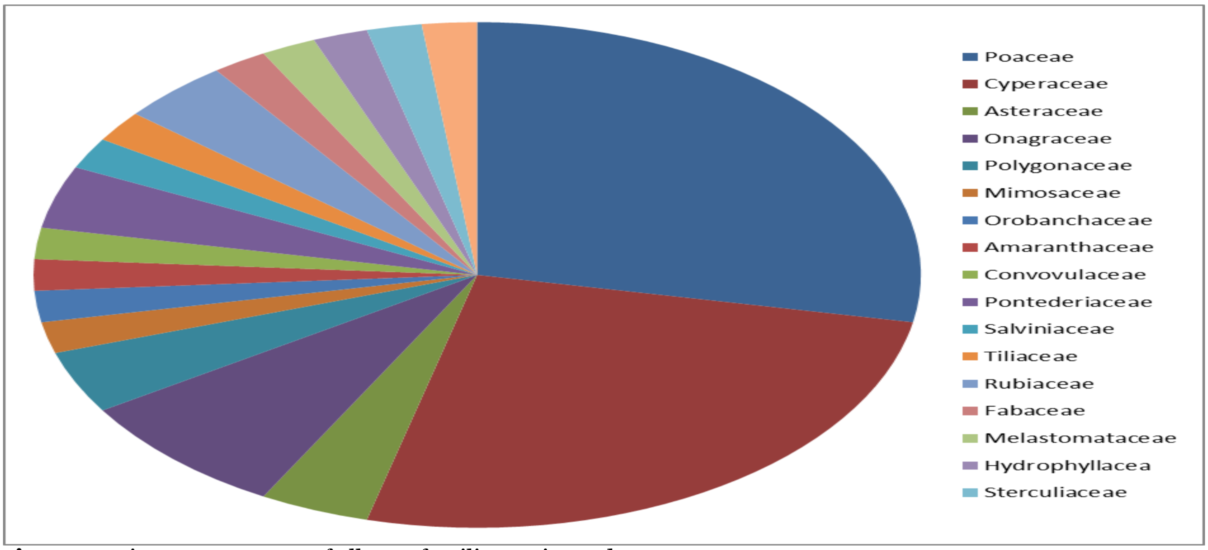

Fig. 1. Dominance spectrum of all taxa families registered.

These species witch are: *Althernanthera sessilis*, *Echinocloa obtussiflora, Aeschynomene indica and Cyperus haspan* are species that indicate habitats of *Rhamphicarpa fistulosa*. In the case of *Limonium girardianum*, indicative species are good predictors of its habitats (Baumberger *et al.,* 2012). In Bénin, *Echinocloa colona* and *Echinocloa obtussiflora* were one of the indicative species of *R. fistulosa* (Zossou *et al.,* 2015 b) of *R. fistulosa*. Hansen (1975) identified the wild rice, *Oryza longistaminata* as an exclusive host of *R. fistulosa*. We need to investigate more on indicative species of *R. fistulosa* in another coutry of Africa. The host range of *Striga asiatica* includes cereals crops and grasses of the *Poaceae* family.

Effects of ecological parameters on the presence of R. fistulosa

Rhamphicarpa fistulosa is a wide spread species distributed in inland valley in crops and naturals vegetation (Zossou *et al.,* 2015 a). The age of the host (P1), the presence of the host (P4), the pH (P6) and the percentage of bare soil (P3) appeared as discriminant variable for the presence of *R. fistulosa*. Some invasive weeds such as *Bromus tectorum* and *Centaurea solstitialis* L., depend largely on soil moisture for seed germination (Patterson, 1995). According to Padonou *et al.,* 2013, bowalization induced a loss of phytodiversity. This confirmed that, ecological parameters are discriminant for the presence of *Rhamphicarpa fistulosa*. In the case of *R. fistulosa*, only the pH relative to the soil was discriminant for its presence in the habitat. The supply of mineral fertilizer such as, N, P, and K significantly affect he incidence of *R. fistulosa* (Sikirou *et al.,* 2002, Rodenburg *et al.,* 2011).

Table 3 showed that axis1 explained more the total variation into host presence, the age of the host and the soil pH respectively, negatively and positively; axis 2 explained more, positively the variation in the percentage of bare soil.

Axis 1 was named the axis of the host and soil pH. The axis 2 was named the axis of bare soil. Despite *Rhamphicarpa fistulosa* was facultative parasite, the presence and age of the host and the pH were discriminant factors to the presence of its. The presence of the host and basic value of the pH determine the presence of *Rhamphicarpa fistulosa* in plant communities. This observation allowed us to confirm that plant the development of *R. fistulosa* was influenced by the environmental local condition of the habitat particularly the soil pH as demonstrated by Hangelbroek *et al.* (2003) and Ellis and Weis (2006). Abd El-Ghani and Marei (2007) showed that the environment and microhabitat conditions lead to variation of the distributional behavior of *Randonia africana*, a dangerous plant of dessert.

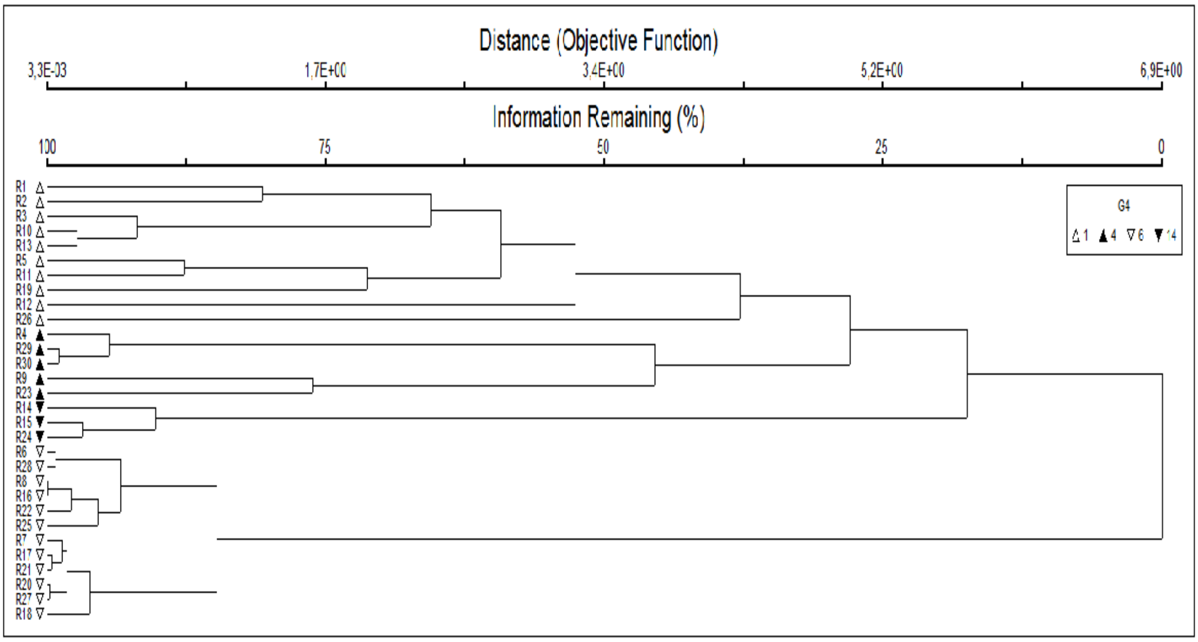

Fig. 2. Hierarchical cluster dendrogram obtained after non metric dimensional analysis.

△ : Plants communities of *Ludwigia abyssinica* (C1)

▲ : Plants communities of *Ipomea aquatica* (C2)

▼ : Plants communities of *Rhamphicarpa fistulosa* (C3)

▽ : Plants communities of *Oryza barthii* (C4).

Preferred plants communities of *Rhamphicarpa fistulosa* species range limit are infrequently discussed in the literature. CCA showed that axis 1 explained 57% of the variation in the distribution of *Rhamphicarpa fistulosa*. The axis 2 witch is the axis of the bare soil's explained 41% of the variations in distribution of the parasite. Howerver, in Benin, Zossou (2007) mentioned that the age of the host is not discriminant for the parasitism of *Rhamphicarpa fistulosa* on rice production; plant of this parasite appeared at any time of development of rice.

The ecological parameters control the dominance of species *via* the effect on demographic traits (Pulliam, 2000). This fact confirms that, the soil pH in inland valleys where famers produced rice influenced significantly the presence and the population of *R. fistulosa*. The result demonstrated that considerable interspecific difference in environmental preference exists among species. The distribution of *Striga asiatica* and *Rhamphicarpa fistulosa* was influenced by the host besides on moisture and nutrients (Kabiri *et al.,* 2014). The relative important of ecological variables differ among taxa and the associated ecology (Gilbert and Lechowiez, 2004).

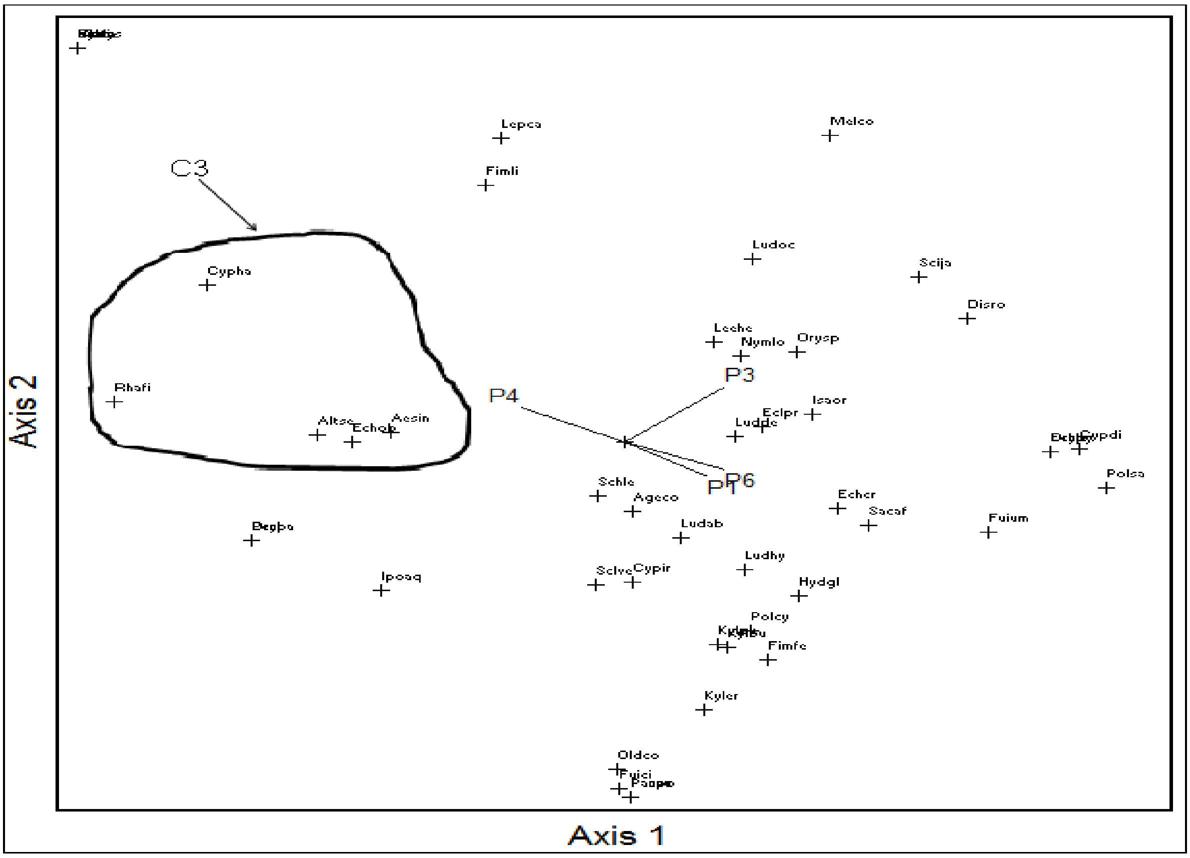

Fig. 3. Canonical Correspondence Analysis graph.

P4: variable relative to the presence of rice (host plant)

P1: variable relative to the age of the rice plants in the fields

P6: variable relative to the pH of the soil

P3: variable relative to bare soil percentage.

C3: Plants community of *Rhamphicarpa fistulosa*.

Conclusion

Habitats occupied by *R. fistulosa* should be recognized as relict and critically endangered sites where special protection measures must be used. They should be included in environmental monitoring program with local active protection. In this case of Senegal, the ecological variables such as the pH (low value) and the presence of the host (rice crops), the number of date after sowing of the rice and the indicative species are the predictors of *Rhamphicarpa fistulosa* habits. It was also appeared that, as in Benin, *Rhamphicarpa fistulosa* is following rice production in the colonization of new ecological niches in Senegal. This fact will be very important for us in the in the integrated management of the parasitism.

Acknowledgement

This work was supported by the Organization of Women in Science for the Developping Word. We thank Aziz CAMARA "Université Cheikh Anta Diop" for him scientific support. We also thank the team of ISRA "Institut Sénégalais de Recherche Agricole" based at Ziguinchor and Kolda in Senegal for their logistic support during data collection.

References

Abdel-Ghani MM, Marei AH. 2007. Environment and vegetation of *Randonia africana*: an endangered desert plant in Egypt. African journal of ecology **45,** 469-475.

Badiane AN, Khouma M, Sene M. 2000. Gestion et transformation de la matière organique. Synthèse des travaux menés au Sénégal depuis 1945, ISRA, INSA, CTA, 131 p.

Baumberger T, Croze T, Affre L, Mesléard F. 2012. Co-occurring species indicate habitats of the rare Limonium girardianum. Plant Ecology and Evolution **145(1),** 31-37.

Blondel D. 1971. Contribution à la dynamique de la matière minérale en zone sableux (Dior) au Sénégal. Agronomie Tropical **26,** 1303-1333.

Booth BD, Stephen DM, Clarence JS. 2010. Invasive plant ecology in natural and agricultural system. CABI, Wallingford, Oxfordshire, UK.

Cissé J, Camara M, Berner DK, Musselman L J. 1996. Rhamphicarpa fistulosa (Scrophulariaceae) damages rice in Guinea. In : *Congresos y Jornadas-Junta de Andalucia (Espana)*, JA, DGIA.Dancette C. 1983. Estimation des besoins en eau des principales cultures pluviales en zone soudano-sahélienne. Agronomie Tropicale **38(4),** 281–294.

Diagne A, Movin-Assagba E, Futakuchi K, Woperis MCS. 2013. Estimation of cultivated area, number of farming households and yield for major rice-growing environnements in Africa. In: Realizing Africa' Rice Promise (eds MCS Woperis, DE Jonhson, N Ahmadi, E Tollens ans A Jalloh), 35-45. CABI, Wallingford, Oxfrordshire, UK.

Diangar S, Fofana A, Diagne M, Yamoah CF, Dick RP. 2004. Pear millet-based intercropping systems in the semi-arid areas of Senegal. African Crops Science Journal **12(2),** 133-139.

Ellis AG, Weis AE. 2006. Coexistence and differentiation of 'flowering stones': the role of local adaptation to soil microenvironment. Journal of Ecology **94,** 322-335.

Gbehounou G, Assigbe P. 2003. *Rhamphicarpa fistulosa* (Hochst.)Benth. (Scrophulariaceae): New pest on lowland rice in Benin, results of a survey and immediate control possibilities. Anales des Sciences Agronomiques du Bénin **4,** 89-103.

Gilbert B, Lechowiez MJ. 2004. Neutrality, niche and dispersal temperate forest under story. In: Proceeding of the National Academy of Sciences of The United States of America **101,** 7651-7656.

Guisan A, Thuillie W. 2005. Predicting species distribution: offering more than simple habitat models. Ecology letters **8,** 993-1009.

Hangelbroek HH, Santamaría L, De Boer T. 2003. Local adaptation of the pondweed Potamogeton pectinatus to contrasting substrate types mediated by changes in propagule provisioning. Journal of Ecology **91,** 1081-1092.

Hansen OJ. 1975. The genus Rhamphicarpa Benth. Emend. Engl. (Scrophulariaceae). A taxonomic revision. Botanisk Tidsskrift **70,** 103-125.

Kabiri S, Rodenburg J, Kayeke J, Van Ast A, Makokha DW, Msangi SH, Bastiaans L. 2014. Can the parasitic weeds S*triga asiatica* and *Rhamphicarpa fistulosa* co-occur in rainfed rice? European Weed Research Society **55,** 145 – 154.

Kuijt J. 1969. The Biology of Parasitic Flowering

Plants. University of California Press, Berkeley.

Maiti RK, Singh VP. 2004. Biotic factors affecting pearl millet (*Pennisetum glaucum* (L.) R. Br.) growth and productivity : a review. Crop Research **27,** 30-39.

Maschinski J, Ross MS, Liu H, O'Brien J, von Wettberg EJ, Haskins KE. 2011. Sinking ships: conservation options for endemic taxa threatened by sea level rise. Climatic Change **107**, 147-167.

Muller JV. 2007. Herbaceous vegetation of seasonally wet habitats on inselberg and lateritic crusts in West and Central Africa. Folia Geobotanica **42,** 29-61.

Muller JV, Deil U. 2005. The ephemeral vegetation of seasonal and semipermanent pods in tropical West-Africa. Phytocoenologia **35,** 327-388.

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature **403**, 853-858.

N'Cho S, Mourits M, Rodenburg J, Demont M, Oude Lansink A. 2014. Determinants of parasitic weeds infestation in rainfed lowland rice in Benin. Agricultural Systems **130,** 105-105-115.

Neumann U, Salle G, Weber HC. 1998. Development and structure of the haustorium of the parasite *Rhamphicarpa fistulosa* (Scrophulariaceae). Botanica Acta **111,** 354-365.

Ogwuike P, Rodenburg J, Diagne A, Agboh-Noameshie R, Amovin-Assagba E. 2014. Weed management in upland rice in Sub-Saharan Africa: impact on labour and crops productivity. Food Security **6,** 327-333.

Ouédraogo O, Neumann U, Raynal-Roques A, Sallé G, Tuquet C, Dembélé B. 1999. New insights concerning the ecology and the biology of Rhamphicarpa fistulosa (Scrophulariaceae). Weed research **39(2),** 159-169.

Padonou EA, Assogbadjo A E, Bachmann Y, Sinsin B. 2012. How far bowalization affects phytodiversity, life forms and plant morphology in Sub-humid tropic in West Africa. African Journal of Ecology **51,** 255-262.

Patterson DT. 1995. Weeds in a changing climate. Weed Science **43,** 685-701.

Pulliam HR. 2000. On the relationship between niche and distribution. Ecology letters **3,** 349-361.

Rodenburg J, Zossou-Kouderin N, Gbèhounou G, Ahanchede A, Touré A, Kyalo G, Kiepe P. 2011. *Rhamphicarpa fistulosa*, a parasitic weed threatening rain-fed lowland rice production in sub-Saharan Africa - A case study from Benin. Crop Protection **30,** 1306-1314.

Rodenburg J, Morawetz JJ, Batiaans L. 2014. Rhamphicarpa fistulosa, a widespread facultative hemi-parasitic weed, threatening rice production in Africa. European Weeds Research Society **55,** 118-131.

Seck PA, Diagne A, Mohanty S, Woperis MCS. 2012. Crops that feed the world 7: rice. Food security **4,** 7-24.

Sikirou R, Gbehounou G, Zannou A, Bouraima Y. 2002. Comportement varietal du riz fumé à l'engrais mineral face au parasitisme de *Rhamphicarpa fistulosa*: lutte intégrée et éfficacité économique. In : Actes de l'atelier Scientifique 1, Dassa, Bénin, 42-60.

Weber HE, Moravec J, Theurillat JP. 2000. International code of phytosociological nomenclature. Journal of vegetation Science **11,** 739-768.

Westhoff V, Van Der Maarel D. 1978. The Braun-

Blanquet approach. Springer, 287-399.

Wolters M, Garbutt A, Bekker RM, Bakker JP, Carey PD. 2008. Restoration of salt-marsh vegetation in relation to site suitability, species pool and dispersal traits. Journal of Applied Ecology **45,** 904-912.

Zedler JB, Kercher S. 2004. Causes and consequences of invasive plants in wetlands: opportunities, opportunists, and outcomes. Critical Reviews in Plant sciences **23**, 431-452.

Zossou N. 2007. *Riziculture de bas-fonds au Bénin: évaluation des problèmes phytosanitaires causés par Rhamphicarpa fistulosa dans les communes de Dassa et Glazoué; rôle des NERICA, autres riz de bas-fonds et de la fumure minérale dans le contrôle intégré deRhamphicarpa fistulosa*. Thèse d'Ingénieur Agronome, FSA, UAC, Cotonou, Benin.

Zossou, N, AGbangba CE, Ouatara B, Assogbadjo AE, Ahanchede A, Sinsin B. 2013. *Rhamphicarpa fistulosa* in lowland rice in Benin : a review. Advances in Environmental Biology **7,** 4567-4572.

Zossou N, Adoukonou-Sagbadja H, Fonceka D, Baba-Moussa L, Sall M, Ahanchede A, Sinsin B. 2015.a Genetic diversity of *Rhamphicarpa fistulosa* (Hochst.) Benth. populations in rainfed lowland rice in West-Africa. Weeds Research Journal. In press.

Zossou N, Yaoictha A, Padonou EA, Assogbadjo AE, Noba K, Ahanchede A, Sinsin B. 2015.b. Addressing indicators species and ecological factors that underline the presence of *Rhamphicarpa fistulosa* in Benin. Weeds Research. In press.