Comparative study of herbivory and herbivore diversity on two plant species of the genus *Piper* (piperaceae), *Piper Nigrum* and *P. Umbellatum*, in Amani Nature Reserve

Janice Oduro Dwomoh, University of Cape Coast, Ghana.

Yonas Meherehu, Addis Ababa University, Ethiopia.

Abstract

Leaf herbivory and diversity of herbivores on the native *Piper umbellatum* (L.) and the introduced spice plant, *Piper nigrum* (L.) were studied at seven different sites in the Amani Nature Reserve. Samples of each 20 leafs of both species at each site were randomly collected to measure leaf herbivory. All herbivorous arthropods and molluscs of 30 *P. umbellatum* and 10 *P. nigrum* were collected from each site using a beating tray. Herbivores could be assigned to 46 morpho-species, and for abundant herbivores feeding experiments were conducted. Herbivory was significantly higher on the native species. Average faunal overlap for both plant species between sites were of 30 % and no significant correlation to distance of sites could be found. Only each two species of Lepidoptera larva and Gastropoda feed on the leaves during the feeding experiments only on the native species. No shift of herbivores from the native to the introduced species could be found.

Introduction

Herbivory describes interaction between a plant and its consumer. Herbivory affects the competitive ability of plant species, by retarding growth and reproduction, and also reduces the distribution of plants species within the habitat. (Gullan and Cranston, 1994). The level of herbivore attack on plants depends up on the spectrum of anti-herbivore action the plant species possess. As a result some plant species support large number of herbivores while others are predated up on by few specialist herbivores.

Terrestrial herbivores include insects, nematodes, crustaceans, molluscs, birds, reptiles, mammals, (Huntly, 1991). Insects and small mammals are common. The most diverse and abundant insect herbivore feeding on plants belong to the orders Lepidoptera and Coleoptera (Gullan and Cranston, 1994).

Native plant species are likely to receive greater predation response form co-evolved natural enemies. Comparatively, response of native herbivores to introduced species would be less. Nevertheless, some specialist herbivore may switch and start predating up on the introduced plant species. The chance would be higher if the introduced species has more taxonomic relatedness to native species in the habitat (De Walt, 2003).

Introduction of plant species to natural habitat has been a common practice for many years. Recognition of the effects of exotic species occurs after the effect has been felt in many natural habitats. The objective of introducing exotic plants species from the different parts of the world to Amani Botanical Gardens (ABG) was to screen economically important plant species, ultimately to be planted in the natural forest.

Majority of the introduced plants in Amani Botanical Gardens are spice plants which are now cultivated as spice crops by the local people; nevertheless, *Piper nigrum* L. is among the leading crops (Tsh 4000-5000kg ($4.5). In contrast, *Piper umbellatum* L., which is a native species do not have much economic value; the people use the roots as aphrodiasic. This study tested the the idea that a native species of plant (*P. umbellatum*) will suffer greater herbivory levels than an exotic species (P. nigrum). Since habitat differences in herbivory, plants in adjacent areas were studied to partially control for this.

Materials and methods

Study area

The study was carried out at Amani Nature Reserve and its environs (910m above sae level, 4º 48`-5º135 and 380 32` 380 48E), East Usambara Mountains, North-Eastern Tazania. The field data collection took place between 16th and 21st September 2003. *P. nigrum* was sampled from cultivated areas, as *P. umbellatum* from the nearest forest edge.

Studied plants

Two plants species from the class Dicotyledonae, subclass Magnoliidea, order Piperales, family Pipperaceae and the genus Piper were chosen for the study. The species are *P. umbellatum* L. (native) and *P. nigrum* L. (introduced species).

P. umbellatum L., is a soft-woody herb 1-2m, with leaves of about10-22cm by 10-23cm. The plant is common in Wetter forests and in some countries in sub-Saharan Afrca. Altitude range 1500-2750m. *P. nigrum* L. is a woody climber with ovate leaves and apetalous flowers in spikes. The berries are red when ripe. It is widely dispersed throughout the tropical and subtropical regions of the earth.

Sampling procedure

Seven sites; each with *Piper umbellatum* and *P. nigrum* were chosen for the study. Nearest neighbour distance from the cultivated plants was used for sampling *P. umbellatum* from the reserve in all the sites. Using random sampling technique, leaves from 10 plants were sampled from all the seven sites. Two leaves were taken at random from the 2nd leaves of two branches of *P*. nigrum. Three *P. umbellatum* plants were sampled as one. The second leaves of two of the plants were taken randomly for the measurement of the leaf area and leaf damage. For each of the samples taken, the canopy cover directly above the plant was estimated by direct observation at four points in each plant to obtain an average.

Measurement of leaf area

The total area was estimated for each leaf (using transparencies with 2mm *2mm grid). The area of the leaf damage was estimated in a similar way and was expressed as percentage (The leaf damage area was considered as being areas where leaf material was physically absent). Leaf damage for each pair of leaves was combined to get an average value of leaf damage.

Collection of herbivores

A beating tray was used to collect herbivore on the leaves of the plants. Collection was done at the time of leaf sampling. Herbivores were identified in the laboratory to the lowest possible level using identification keys.

Feeding experiment

Abundant herbivore species collected from the field were used for controlled feeding experiment. Three different treatments were used to confirm feeding.

Treatment

1) *P. umbellatum* only
2) *P. nigrum* only
3) P. umbellatum & P. nigrum

Data analysis

All data were entered into excel 1997 and transferred to Minitab for analysis. Differences in the degree of herbivory between the two species were tested using ANOVA (General Linear Model) and 2-sample t-Test.

Results

Piper umbellatum suffers greater significant levels of herbivory then *Piper nigrum* ($F = 317.65$, $p < 0.001$, Fig 1). There were also differences in the level of herbivory between sites of the plant species ($F = 6.08$, $p < 0.001$).

Mean value of percentage canopy cover is significantly different between sites ($F = 10.38$, $p<0.001$); but there is no significant difference between plants ($F = 1.46$, $p<0.230$, Fig 2).

A total of 46 different morpho-species of invertebrate herbivores were collected. Table 1 shows the species identity and abundance of the herbivores collected.

Selected invertebrate taxa were plotted (Fig. 3) to show abundance and overlap of herbivore on each plant species. *P. umbellatum* had more species of herbivore than *P. nigrum*. *P. umbellatum* also had more individuals on it than *P. nigrum*.

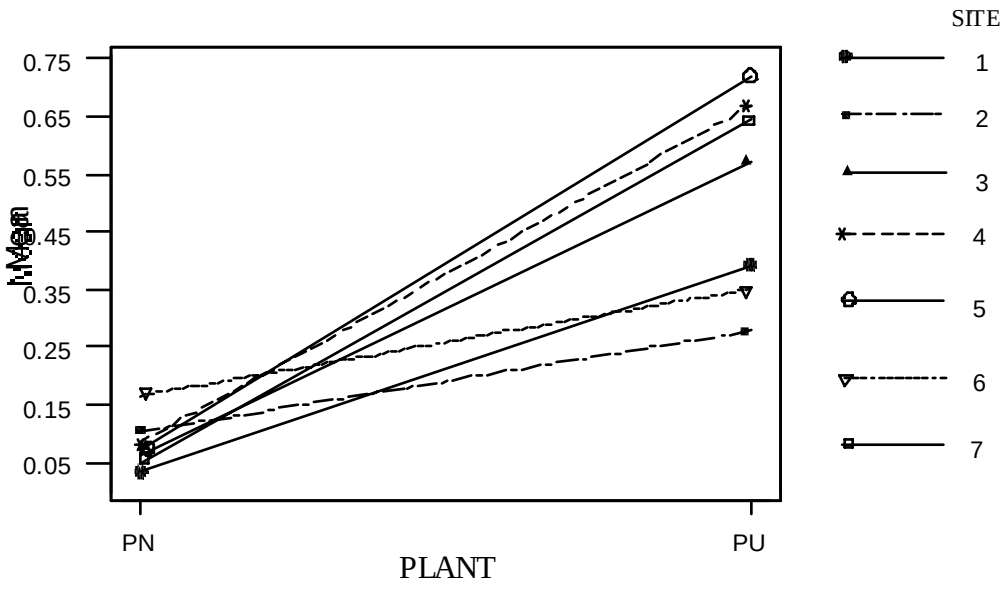

Figure 1. Degree of herbivory on *P. umbellatum* and *P. nigrum* at different sites.

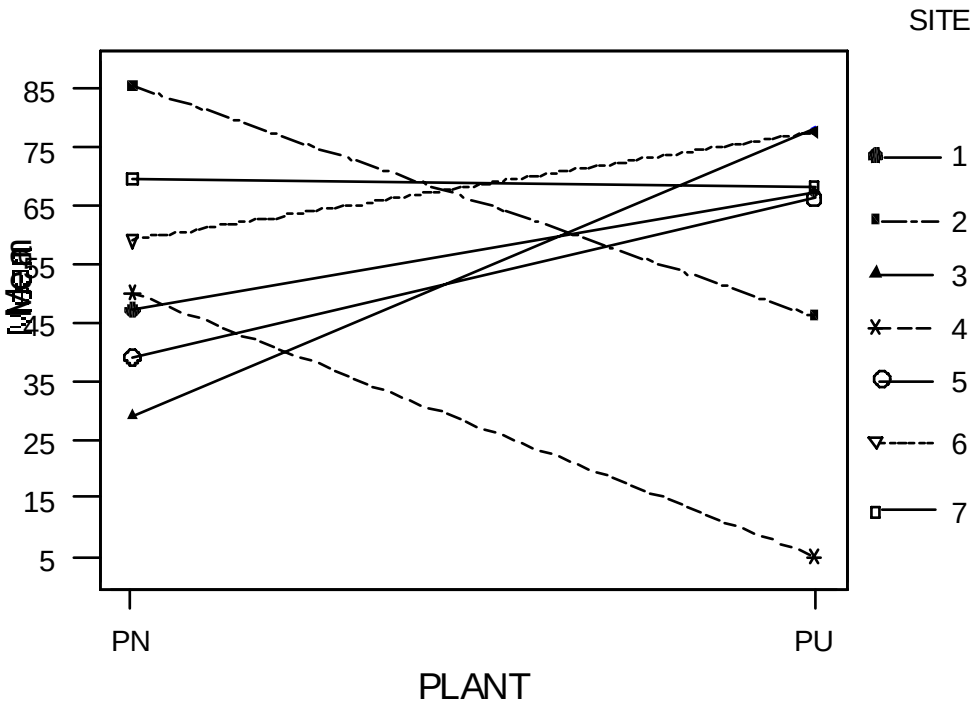

Figure 2. Percentage canopy cover of *P. umbellatum* and *P. nigrum* at different sites.

Table 1. Diversity and abundance of herbivore groups on *P. umbellatum* and *P. nigrum* at different sites.

	S1 U	S1 N	S2 U	S2 N	S3 U	S3 N	S4 U	S4 N	S5 U	S5 N	S6 U	S6 N	S7 U	S7 N	**Total**
Coleoptera															
Elateridae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Lagriidae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	**2**
Cerambycidae	0	5	0	0	0	0	0	3	0	0	0	0	0	0	**8**
Curculionidae	9	1	0	0	5	9	3	3	10	2	3	1	2	5	**53**
Chrysomelidae	0	4	4	3	0	0	0	2	0	0	0	2	3	0	**18**
Anthribidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Lepidoptera															
Geometridae, larva	21	2	12	1	9	9	16	0	15	0	9	1	2	0	**97**
non-Geometridae, l.	0	5	2	14	2	4	0	6	1	3	1	4	0	4	**46**
Homoptera	4	3	2	13	0	6	1	0	0	1	7	5	1	0	**43**
Heteroptera	0	6	0	5	0	0	0	9	0	9	0	5	1	8	**43**
Thysanoptera	0	2	0	0	2	0	0	1	0	2	3	1	0	5	**16**
Ensifera	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Diplopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	6	**6**
Gastropoda, snail	0	0	1	0	0	0	0	0	0	2	0	0	2	4	**9**
Gastropoda, slug	0	0	0	0	0	0	0	0	0	0	0	0	5	0	**5**

The average faunal overlap of herbivore species on *P. nigrum* (PN) and *P. umbellatum* (PU) between all sites was 0.30 and 0.26 respectively, with no significant difference ($T = 1.06$; $p = 0.30$). The betadiversity between and both *Piper* species (PU/PN) showed an average overlap of 0.26 for *P. nigrum* and 0.19 for *P. umbellatum*. The overlap between PN and PU/PN was not significant ($T = 1.95$; $p = 0.06$), while between PU and PU/PN a highly significant difference could be found ($F = 3.64$; $p < 0.001$). This underlines that the herbivore community on *P. umbellatum* is higher specific than that on *P. nigrum*.

The results from the feeding experiments show that Geometridae larva-I, non-Geometridae larva, snails and slugs were the main herbivore feeding on *P. umbellatum*. The rate of feeding of Geometridae larva-I on the plant is higher than of non-Geometridae larva. No species was found too be feeding on *P. nigrum* (Table 2).

Table 2. Feeding of various herbivore on *P. umbellatum* (PU) and *P. nigrum* (PN)

Herbivore	Treatment	Results
Lepidoptera		
Geometridae, larva I	PN (mature leaf)	No feeding
Geometridae, larva I	PN (mature leaf)	No feeding
Geometridae, larva I	PN (mature leaf)	Feeding at faster rate
Geometridae, larva I	PN (young leaf)	Feeding at faster rate
Geometridae, larva	PN &PU (young leaf)	Feeding on PU
Non-Geometridae,larva	PN (mature + young leaf)	No feeding
Non-Geometridae,larva	PU (mature + young leaf)	Feeding on both
Non-Geometridae,larva	PN&PU (mature + young leaf)	Feeding on PU
Non-Geometridae,larva	PN&PU (mature + young leaf)	No feeding
Non-Geometridae,larva	PN (mature + young leaf)	No feeding
Non-Geometridae,larva	PN (mature + young leaf)	No feeding
Coleoptera		
Curculionidae large, greenish	PN&PU (mature + young leaf)	No feeding
Curculionidae large, greenish	PU (mature + young leaf)	No feeding
Curculionidae large, greenish	PN&PU (mature + young leaf)	No feeding
Chrysomelidae Galerucinae,	PN&PU (mature + young leaf)	No feeding
Heteroptera	PN&PU (mature + young leaf)	No feeding
Anthocoridae, large	PN&PU (mature + young leaf)	No feeding
Anthocoridae, small	PN&PU (mature + young leaf)	No feeding
Snail	PU (matured +young leaf)	Feeding
Snail	PU (mature leaf)	No feeding
Slug	PU (mature +young leaf)	Feeding

Slug	PN (mature leaf)	No feeding

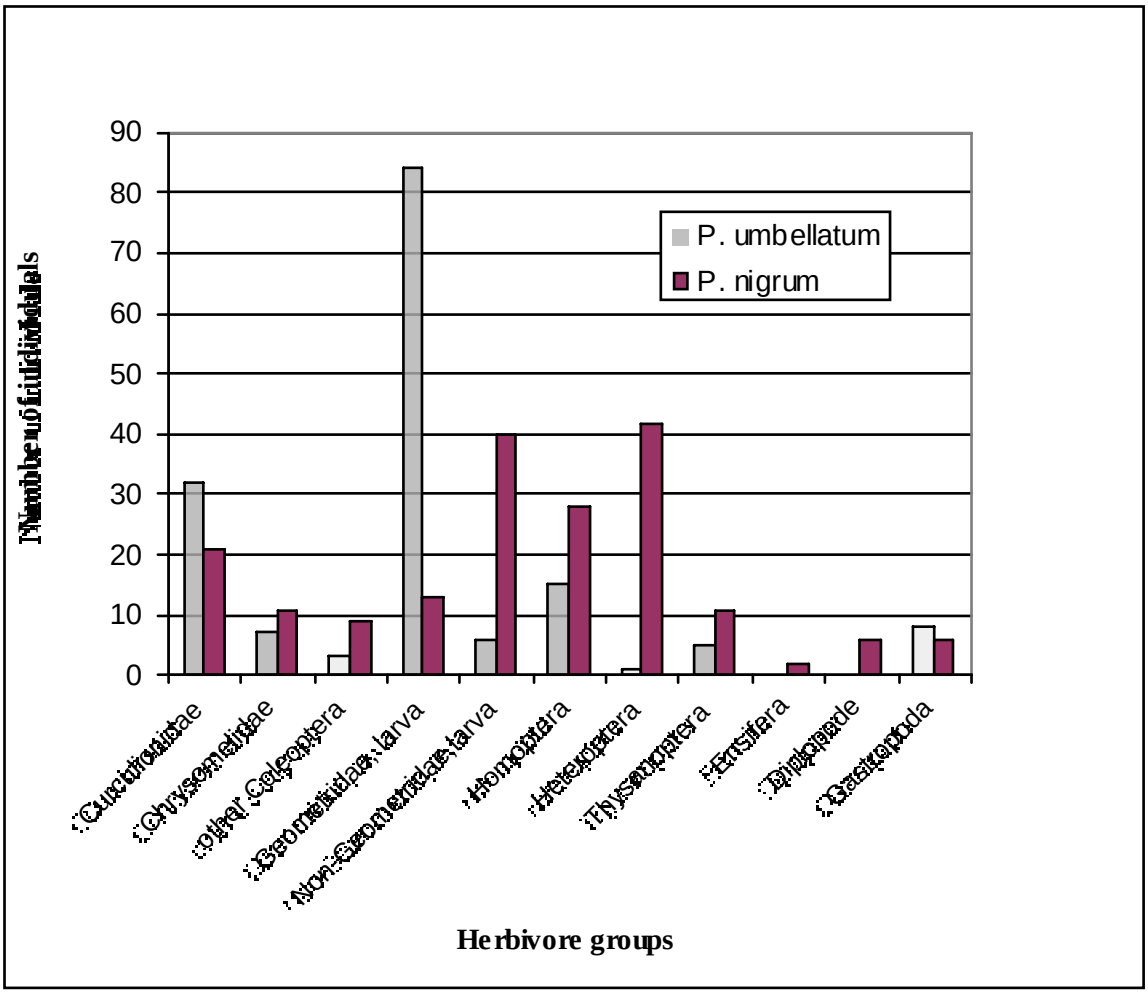

Figure 3. Comparison herbivore diversity abundance and overlap between *P. umbellatum and P. nigrum*

Discussion

Our data indicate that the level of herbivory on the native species was significantly higher than on the invasive species. This confirms the statement that co-evolution of native herbivore with local plant species would result in greater herbivory since there was longer time for co-evolutive adaptation. However, leaf damage in the native *P. umbellatum* showed also strong differences between sites, depending on the presence or absence of important species of herbivores. Effects of the habitat structure and inhomogeneous spatial and temporal distribution of the peculiar herbivore species might be a crucial factor.

There was no significant difference in herbivory measured in percent of leaf damage and the canopy cover. Canopy cover has obviously no effect on the level of herbivory and the diversity and abundance of herbivores on the plant. A comparison of the herbivore communities using Soerensen-Index of faunal overlap for all sites studied, showed no correlation with distance of sites, indicating a again a high influence of habitat structures.

The results show that *P. umbellatum* had a higher herbivore species diversity and abundance than *P. nigum.* This might be as a result of lack of the absence of the natural enemies of the plant. The most abundant herbivore is one species of Geometridae which larvae could be found frequently on *P. umbellatum* and was an effective herbivore of its leaves in the feeding experiments. This species was not able to use *P. nigrum* as food-plant, and larva died when only this species was provided. Also all other species studied, including snails and slugs which are most extremely polyphagous, were not able to switch from the native to the introduced species.

Acknowledgement

We are indebted to TBA for giving us this opportunity to participate on the TBA training course. In producing this paper from the beginning to the end we owe a great debt of gratitude to Dr Rosie Trevelyan, Dr Thomas Wagner, Dr Claire de Mazancourt, Prof. Brain Moss and Mr Anthony Kuria for their support and contribution. Finally we

would like to thank and appreciate the kindness of ANR staff and the farmers whose farms we used for the field work.

Reference

Coley, P.D.(1983*)* Herbivory and defensive characterstics of tree species in a lowland tropical forest. *Ecological Society of America*, pp.209-233.

Coley, P.D. and Barone, J.A. (1996) *Herbivory and Plant Defence in Tropical Forests*. *Annu. Rev. Ecol. Syst*.27: 305-35. Annual Reviews Inc.

De Walt, S. J., Denslow, J.S. and Ickes, K. (2003) Natural enemy release facilitates habitat expansion of the invasive tropical shrub *Clidemia hirta* (Melastomatacae). *Ecology*, in press.

Gullan, P. J. and Cranson P. S. (1994) *The Insects: An outline of Entomology*, Chapman and Hall.

Huntly, N. (1991) Herbivores on the dynamic of community and ecosystem, *Annual Review of Ecology and Systematics*, 22: 499-503.

Kaban, R. and Agrawal, A.A. (2002) Herbivore Offence. *Annual Review of Systematics*, 33: 641-64.

Ketende, A.B, Birnie, A. and Tengnas, B. (1995) *Useful Trees and Shrubs for Uganda*: Identification, Propagation and Management for Agricultural and Pastoral Communities, Regional Soil Conservation Unit

Neentje, H. J. (1994) *Kenya Trees, Shrubs and Lianas*. National Museum of Kenya.
Sandy, R.P., Boniface,G. And Rajabu, I (1997). *A Survey of Amani Botanic Garden, Technical* Paper 38, East Usambara Cachtment. Forest Project.