Geographical Distribution of Leaf-cutting Ants and Possible Increase of Damage due to Their Expansion in Southern Brazil and Paraguay (Hymenoptera: Formicidae)

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Abstract

Survey on the geographical distribution and nest density of leaf-cutting ants was conducted in gramineous fields at a total of 64 localities in southern Brazil and Paraguay. Four species of *Acromyrmex* and four species of *Atta* were collected: *Ac. balzani*, *Ac. fracticornis*, *Ac. heyeri*, *Ac. striatus*, *At. capiguara*, *At. laevigata*, *At. sexdens*, and *At. vollenweideri*. *Ac. balzani*, *At. capiguara*, and *At. laevigata*, adapted to tropical-climatic condition, were densely distributed in the north of the surveyed area, seldom in the centre, and not in the south. *Ac. fracticornis*, *Ac. heyeri*, *Ac. striatus*, and *At. vollenweideri*, adapted to subtropical-climatic condition, were collected in the southern part of the surveyed area, while only *Ac. fracticornis* was found also in the northern area. Ants of both types occurred in the centre. A cosmopolitan species, *At. sexdens*, was collected from almost all the regions surveyed but its density was usually low. The surveyed area was divided into eleven regions, for which the mean nest density of each ant species was calculated. A cluster analysis was applied for these regions, and three groups were classified. One group covered the most northern regions and another covered the most southern regions. The last group covered the central regions. The result of the analysis agreed well with the geographical location of the regions. Comparison of our data with those in previous reports suggests that leaf-cutting ants are expanding their distribution, and that tropical species and subtropical ones may occur in

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the central regions. The findings imply that any regions in the surveyed area are likely to be invaded by leaf-cutting ants of either the tropical or subtropical species, or both, and may encounter problems with the ants in future..

Additional key words: leaf-cutting ant, geographical distribution, pest, agricultural damage, South America

Introduction

Leaf-cutting ants, belonging to the Attini tribe and consisted of two genera *Acromyrmex* and *Atta*, have been considered to be major agricultural pests in the tropics and subtropics of the New World Continent[4]. Twenty species of *Acromyrmex* and 10 of *Atta* have been reported from Brazil and 17 *Acromyrmex* and 6 *Atta* from Paraguay[18]. Although not all the species are agricultural pests in southern Brazil or Paraguay[6), 8), 14)], the damage caused by the ants is often very extensive[5), 7)]. Nonetheless, in some areas ants are very scarce and do not cause evident damage to the envrionment. For example, the density of leaf-cutting ants is very low in the Amazonian rain forest, usually less than 0.1 nest per hectare[16] and it is likely that the densities of leaf-cutting ants are low in thick natural forests[10]. In this region, however, problems of the leaf-cutting ants are starting to be reported with the extension of their distribution along with road construction[8]: When a forest where the nest density of leaf-cutting ants maintains very low is cut off for road construction, the ants establish nests on the edge of the road and invade the forest from the road[10].

Another example is seen in the states of Paraná and Santa Catarina, southern Brazil, where the ants are scarce or absent, and farmers believe that they will never have economically serious problem with leaf-cutting ants (Dr. K. Kojima, personal communication). When these two states were covered by thick forest, leaf-cutting ants were very scarce. In the states of São Paulo and Rio Grande do Sul extensive areas were deforested in this century for cultivation of fields, and, consequently, leaf-cutting ants proliferated considerably[14]. Thus the states of São Paulo and Rio Grande do Sul now encounter serious problems with the ants. Paraná and Santa Catarina have been less developed than the former two states. The delay in development may have enabled to maintain a lower density of leaf-cutting ants. Since Paraná and Santa Catarina are located between São Paulo and Rio Grande do Sul, immigration of leaf-cutting ants from the latter states to the former may occur at a very high probability. It is possible that some areas of Paraná and Santa Catarina, especially marginal areas to state boundaries, have been already invaded by the ants and, accordingly, damage is significant. Otherwise the ants can at least hardly or not be distributed there due to geographic conditions and/or biological ones, and may not pose any serious problem.

We performed surveys on the geographical distribution and nest density of leaf-cutting ants in southern Brazil and Paraguay. Comparison of our data with those obtained in the past suggests that the ants may expand their distribution and become a serious pest in any of the surveyed areas.

Materials and Methods

1) Field collection

We drove a car on highways in southern Brazil and Paraguay from 1993 to 1996. We stopped the car at least every 100 km and made a survey of the distribution and nest density of leaf-cutting ants, although we shortened the distances in marginal areas of ant distribution reported previously. We selected pasture as survey site, because farmers usually do not implement extensive pest control in pastures. As a result, we anticipated that the

maximum nest density of the ants would be attained there and human influence would be negligible. We recorded the longitude, latitude, and altitude of the survey sites with a global positioning system receiver (Sony IPS-360).

Nest densities of leaf-cutting ant species were determined by either of the following three methods:

(1) Line transect

In a given field, we set at random a 5 m wide and 500 m long line transect for the counts of nests of leaf-cutting ants. The transect corresponded to a quadrat of 0.25 ha. When the centre of a nest was not located in the transect, we excluded the nest from the count;

(2) Binocular observation

When we could not enter a field, we counted nests of leaf-cutting ants with a binocular (10x 25 mm, Carl Zeiss). Since the construction of the nest of leaf-cutting ants is species-specific[14], the species to which the nest observed belonged can be identified even with a binocular. We measured the length of two sides of the rectangles and calculated the area of the field;

(3) Walking

When a given field was too small to draw a 500 m line or we had enough time, we thoroughly walked in the area and detected all nests of leaf-cutting ants. We determined the area of the field as in above (2).

In any method we did not count incipient nests with only one mound, because the number of these small nests may be easily overlooked by the binocular method. Furthermore, when we used the binocular method, we counted nests of only Atta because those of *Acromyrmex* were usually too small to be detected.

2) Statistical analysis

After dividing the surveyed area into eleven regions, we calculated the mean density of each species in each region. It was impossible to divide each region to obtain the same area and/or the same number of sites surveyed. In the current study, we conveniently divided the surveyed area with straight lines in every state so that each region consisted of at least three sites. The regions divided are south-western São Paulo (SPSW), north-eastern Paraná (PANE), north-western Paraná (PANW), south-eastern Paraná (PASE), south-western Paraná (PASW), eastern Santa Catarina (STCE), western Santa Catarina (STCW), south-eastern Paraguay (PGSE), south-western Paraguay (PGSW), north-eastern Rio Grande do Sul (RGNE), and south-eastern Rio Grande do Sul (RGSE). Using the mean nest density calculated for each species, we compared similarity of species composition among the regions by a cluster analysis[13], in which we used the Ward's method and the cosine measure for calculating distances among clusters[15]. We used an SPSS software package (version 6.1J) for the cluster analysis.

Results and Discussion

1) Distribution and density of leaf-cutting ants

We stopped at a total of 64 localities (Fig. 1), where we surveyed the geographical distribution and density of leaf-cutting ants. We collected four *Acromyrmex* species and four *Atta* ones (Table 1). Comparing our data with those obtained previously by other authors[1), 3), 6), 8), 9), 12), 14)], we traced the expansion of the leaf-cutting ant distribution, as Banks et al. did for fire ants[2].

Previous studies revealed that the two congeneric species, *Ac. balzani* and *Ac. fracticornis*, were allopatrically distributed, i.e. the former was distributed in central tropical Brazil and the latter from southern subtropical Brazil to northern subtropical Argentina. Since the distribution of *Ac. balzani* had been previously recorded in São Paulo[2] but not in more southern areas, the southern limit almost corresponded to the state boundary between São Paulo and Paraná. Similarly the northern limit of the distribution of *Ac. fracticornis* was located in southern Paraná[8]. New distributions of both species were revealed in our study: southern location of *Ac. balzani* was

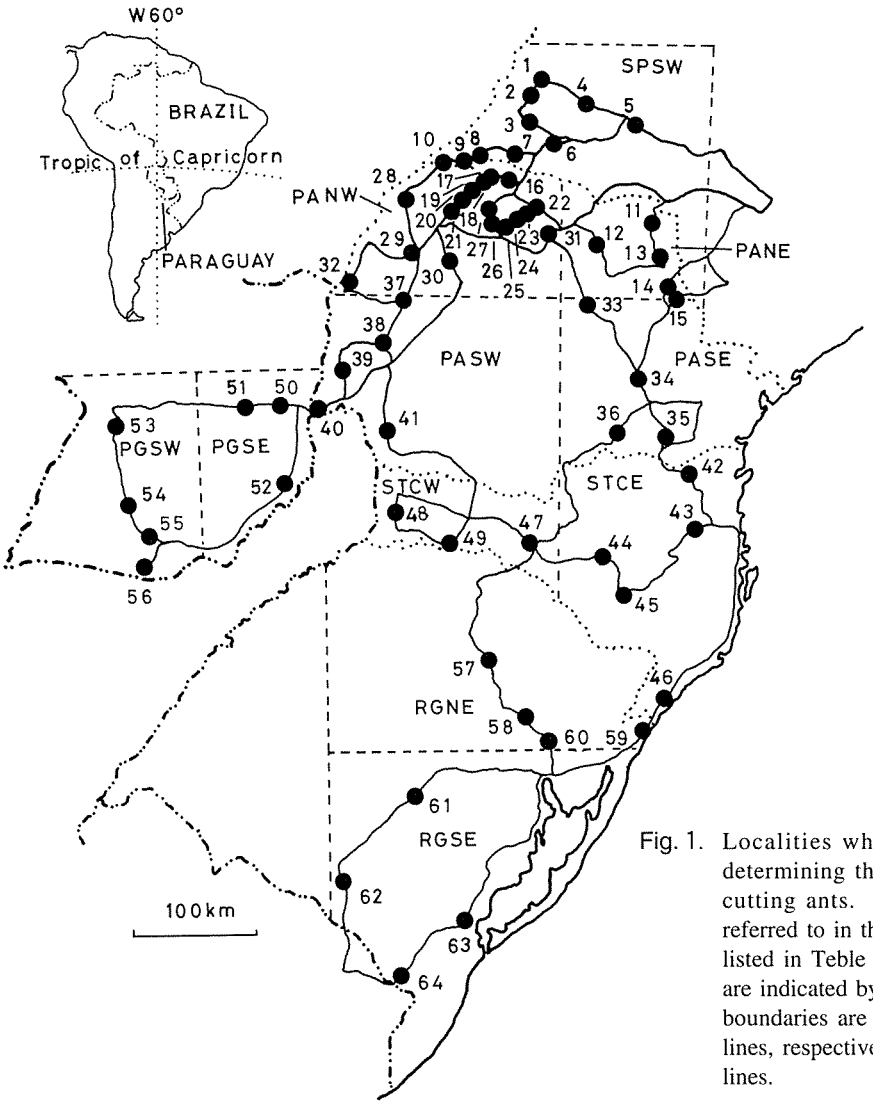

Fig. 1. Localities where surveys were performed for determining the distribution and density of leaf-cutting ants. Abbreviations for 11 regions are referred to in the text. The name of earh locality is listed in Teble 1. Highways passed for the survery are indicated by the solid line. Country and nation boundaries are indicated by chain lines and dotted lines, respectively. Regions are divided by broken lines.

recorded in Nova Esperança (S23° 12'41", no. 26 in Fig. 1) and the most northern location of *Ac. fracticornis* was in Sabaúdia (S23° 16'50", no. 31 in Fig. 1). Hence it took a decade for the former and three decades for the latter to extend their distribution to the same region from southern São Paulo (the former) and from southern Paraná (the latter), respectively. These two species are occurring in northern Paraná now, and it would be interesting to determine whether they exist sympatrically or not due to competition. Since the climate to which they are most adapted is different, tropical for *Ac. balzani* and subtropical for *Ac. fracticornis*, it is unlikely that either of these species will expand their distribution far beyond southern or northern Paraná. If so, both the southern limit of *Ac. balzani* and the northern limit of *Ac. fracticornis* will be fixed in northern Paraná. In turn, the northern area of Paraná may possibly encounter problems with both species.

Ac. landolti, which is very closely related to the above two species, occasionally causes serious damage in Columbia, Venezuela, and northern Brazil[7], where a density of several thousand nests per hectare has been recorded. Densities of nests of *Ac. balzani* and *Ac. fracticornis* were usually less than one hundred in our study. The low density suggests that these two species are not serious pests in the surveyed area, based on the estimation of the damage per nest on crops[7]. However, they often and preferably attack germinated plants (personal observation), and the farmers in

southern Brazil and Paraguay still should pay attention to them when crops are very young.

Ac. heyeri, which causes occasionally serious problems in southern Brazil and Paraguay[6], was not newly recorded in any locality throughout our study. The northern limit of this species has been fixed in southern Paraná for the past thirty years[8]. It is likely that the expansion of distribution of this species had ceased before these three decades. The low densities of this ant observed throughout our study, as in the case of the former two *Acromyrmex* species, suggest that this ant rarely causes damage to agriculture in the surveyed areas. However, south-western Paraná, where there are few leaf-cutting ants presentely (Table 1), may be subjected to the invasion of this ant, since this region is located at almost the same latitudes as south-eastern Paraná.

Ac. striatus was collected only in Rio Grande do Sul and was not detected in other areas in our study. It is assumed that the distribution of this species had not expanded probably due to its adaptation to cooler climatic condition. This species may be distributed in Santa Catarina and southern Paraguay, where the climate is similar to that in Rio Grande do Sul. In other regions the ant may not invade or proliferate due to the hotter climatic condition and will not be a dangerous pest. However, since *Ac. striatus* severely affects agriculture in Rio Grande Do Sul, the farmers in Santa Catarina and southern Paraguay may anticipate the invasion of the ant into their fields.

Conspicuous expansion of the distribution of *At. capiguara*, which had not been reported in Paraná until twenty years ago[14], suggests that this ant had invaded these regions for the past two decades. The observation of this ant in southern Paraguay by Fowler[6] coincided with our findings. Hence the expansion of the ant in Paraguay which may have ceased in this decade, indicates that the southern limit of the ant lies in southern Paraguay and also suggests that the ant may be distributed in any area in Paraná. However, it is unlikely that the ant invades Santa Catarina, since the state is generally mountainous and is located south of the southern limit of the ant in Paraguay. Fowler et al.[7] reported that this ant becomes a serious pest when its nest density is only one per hectare. From south-western São Paulo to south-eastern Paraguay through north-western Paraná, where the ant was collected in our study, in some locations, the nest density of the ant was larger than one per hectare. Damage by the ant in these localities must be serious. If farmers in Paraná continue to ignore possible invasion of leaf-cutting ants into their fields, they will probably encounter serious problems. We should consider how the expansion of this ant can be controlled.

Distribution of *At laevigata* in our study corresponds well to that described by Herculano[9], suggesting that the expansion of the distribution of this ant had ceased for the past four decades. Although this ant causes severe damage to forestry, the low densities in the pastures surveyed in our study suggest that this ant could be locally serious but that most of the surveyed areas do not encounter problems with the ant at present.

At. sexdens, primarily a pest of forest, is known to be distributed from northern Argentina to central America[17]. No new record of this ant was detected in our study and there is no evidence that the density of this ant has increased or is increasing in the surveyed area. However, the nest density of the ant exceeded 2.0 nests per hectare at some localities in south-western São Paulo and south-western Paraguay (Table 1), where this ant is considered to cause significant damage to agriculture. Its wide adaptation to the climatic conditions may enable the ant to cause serious problems at any location of the surveyed area. Hence we should monitor both the expansion and increase of the distribution of the ant.

At. vollenweideri is an important pest in Paraguay and Argentina[11), 12)], with the eastern limit of distribution in Paraguay being near Asunción[7]. Our collection of the ant in Ayolas (W56° 49'28", no. 55 in Fig. 1) is a new record from the region and corresponds to the eastern limit in Paraguay. This observation suggests that the distribution of the ant is expanding from the west

to the east of Paraguay and that the ant may possibly invade Santa Catarina and southern Paraná. The farmers in these regions should pay close attention to the ant.

Some species of leaf-cutting ants certainly cause serious problems in south-western São Paulo, north-western Paraná, south-western Paraguay, and north-eastern Rio Grande do Sul. In other regions, the damage by the ant seems to be negligible, light, or at most locally serious at

Table 1. Nest density of leaf-cutting ants in southern Brazil and Paraguay. The numbers of localities correspond to those in Fig. 1 and are followed by characters which refer to the methods applied for the survey: t (line transect), b(binocular), and w (walking). Abbreviations for species are Acb (*Acromyrmex balzani*), Acf (*Ac. fracticornis*), Ach (*Ac. heyeri*), Acs (*Ac. striatus*), Atc (*Atta capiguara*), Atl (*At. laevigata*), Ats (*At. sexdens*), and Atv (*At. vollenweideri*). Since *Acromyrmex* species were not counted when the binocular was used, they are omitted from the calculation at the localities where this method was used.

Locality	No.	ha	Species							
			Acb	Acf	Ach	Acs	Atc	Atl	Ats	Atv
Dracena	01w	8.35	666.67	0	0	0	1.32	0	0	0
Rio do Indios	02b	2.25					0	0	2.22	0
Presidente	03b	9.00					0	0	0.89	0
Venceslau										
Flórida Paulista	04b	16.00					2.56	0	0	0
Quintana	05b	8.21					2.07	0	0	0
Presidente Prudente	06t	0.25	60.00	0	0	0	8.00	4.00	0	0
Teodoro Sampaio	07b	51.42					1.26	0	0	0
Porto Primavera	08b	18.72					1.23	0	0	0
Porto Primavera	09t	0.25	20	0	0	0	0	0	0	0
Porto Primavera	10w	2	0	0	0	0	1.50	0	0	0
Jacarezinho	11t	0.25	0	0	0	0	0	0	0	0
Assaí	12t	0.25	0	0	0	0	0	0	0	0
Ibaiti	13t	0.25	0	0	0	0	0	0	0	0
Jaguariaíva	14w	6	0	0	0	0	0	1.10	0	0
Wenceslau Braz	15w	1	0	0	0	0	0	1.00	1.00	0
Colorado	16b	6.00					4.00	0.33	0	0
Inajá	17b	16.98					0.59	0	0	0
Paranacity	18w	0.58	0	0	0	0	5.15	0	0	0
São João do Caiuá	19b	10.57					0.57	0	0	0
Paranavaí	20b	15.73					2.67	0	0	0
Tamboara	21b	12.85					2.57	0	0	0
Florestópolis	22t	0.25	0	0	0	0	0	0	0	0
Guaraci	23w	51.84	0.10	0	0	0	0.04	0	0	0
Flórida	24t	0.25	20.00	0	0	0	48.00	0	0	0
Atalaia	25b	9.06					2.76	0	0	0
Nova Esperança	26w	12.11	100.00	0	0	0	1.82	0	0	0
Paranavaí	27b	23.90					0.38	0	0	0
Vila Alta	28t	0.25	0	0	0	0	0	0	0	0
Umuarama	29t	0.25	0	0	0	0	0	0	0	0
Campo Morão	30t	0.25	0	44.00	0	0	0	0	0	0

present. In particular, practically no damage seems to occur in south-western Paraná. However, since it is likely that some species may invade and increase their distribution in any region of the surveyed area, we should monitor the expansion of the distribution and also consider how we can control the expansion of the ants.

2) Clustering of the regions

We divided the surveyed area into eleven regions and calculated the mean nest density of each species in each region (Fig. 1). Using the means, we compared similarity of species composition among the regions by a cluster analysis.

Locality	No.	ha	Species							
			Acb	Acf	Ach	Acs	Atc	Atl	Ats	Atv
Sabaúdia	31t	0.25	0	60.00	0	0	0	0	0	0
Cruzeirinho	32t	0.25	0	0	0	0	0	0	0	0
Imbau	33t	0.25	0	0	0	0	0	0	0	0
Ponta Grossa	34t	0.25	0	16.00	0	0	0	0	0	0
Campo do Tonente	35t	0.25	0	0	4.00	0	0	0	0	0
Irati	36w	1.20	0	0	0	0	0	0	0	0
Toledo	37w	0.84	0	0	0	0	0	0	0	0
Vera Cruz	38t	0.25	0	0	0	0	0	0	0	0
Missal	39b	25.00						0	0	0
Foz do Iguaçu	40w	2.00	0	0		0	0	0	0.5	0
Ampére	41t	0.25	0	0	0	0	0	0	0	0
Corupá	42t	0.25	0	0	0	0	0	0	0	0
Ibirama	43t	0.25	0	0	0	0	0	0	0	0
Curitibanos	44t	0.25	0	28.00	0	0	0	0	0.30	0
Lages	45t	0.25	0	0	0	0	0	0	0	0
Criciúma	46w	2.00	0	0	0	0	0	0	0	0
Cunha Porã	47t0.25	0	0	0	0			0	0	0
Joaçava	48t	0.25	0	0	0	0	0	0	0	0
Chapecó	49t	0.25	0	0.50	0	0	0	0	0.17	0
J. L. Mallorquin	50w	11.11	0	0	0	0	0.09	0	0	0
J. D. Ocampos	51w	1.50	0	0		0	4.00	0	1.33	0
Naranja	52w	1.00	0	0	0	0	0	0	1.00	0
Paraguari	53w	3.00	0	0	1.30	0	0	0	0	0
San Juan Bautista	54w	1.00	0	0		0	0	0	6.00	0
San Ignacio	55t	0.25	0	236.00	0	0	0	0	4.00	0
Ayolas	56w	1.50	0	190.00	0	0	0	0	0	0.67
Passo Fundo	57w	1.50	0	0	1	5	0	0	0	0
Bento Gonçalves	58w	2.00	0	0	0	0	0	0	0	0
Torres	59w	1.00	0	0	0	0	0	0	0.10	0
São Leopoldo	60w	0.50		12.5	2.00	2.50	0	0	1.00	0
Santa Maria	61w	1.00	0	0	0.30	0	0	0	0	0
Bagé	62w	1.50	0	0	0		0	0	0	0
Pelotas	63w	1.50	0	0	0	0	0	0	0	0
Jaguarão	64w	1.50	0	0	0	0	0	0	0	0

The result of the analysis revealed three groups at the level of 0.5 relative distance (Fig. 2): PGSW, STCE, PASE, RGSE, STCW, and RGNE; PANW and SPSW; PASW, PGSE, and PANE. The first group is characterised by the occurrence of subtropical species of both *Acromyrmex* and *Atta*. Accordingly, regions of this group are considered to belong to the subtropical zone. The second group is consisted of regions where tropical species of both genera were recorded but few subtropical species occurred. This group is considered to belong to the tropical zone. The third group includes tropical Atta species and a cosmopolitan species, *At. sexdens*. Although no *Acromyrmex* species were collected at localities included in this group, subtropical *Acromyrmex* species should inhabit these regions, if their distribution pattern is taken into account (Table 1). In addition, subtropical *Acromyrmex* species were reported from these regions in other studies[6), 8)]. Hence the third group is considered to belong to the intermediate zone between the first and second groups. The geographical location of this group is in accordance with the intermediate position revealed in this analysis. The presence of the intermediate zone suggests that neither of these two type species were able to expand their distribution over these regions since the climate of the regions of the third group is too cool for tropical species and too hot for subtropical ones. Our data combined with those previously obtained by other authors indicate that neither the southern limit of the tropical species nor the northern limit of the subtropical species spans the intermediate zone, from PANE to PGSE through PASW, except for the case of *Ac. fracticornis*. We should carry out physiological studies on leaf-cutting ants in order to determine exactly the distribution of the species in certain areas. Nonetheless, the present study still suggests that any location in the surveyed area may be invaded by either tropical or subtropical leaf-cutting ants or both with possible damage to agriculture. It is thus important to continue to conduct surveys to monitor the expansion of the distribution of leaf-cutting ants.

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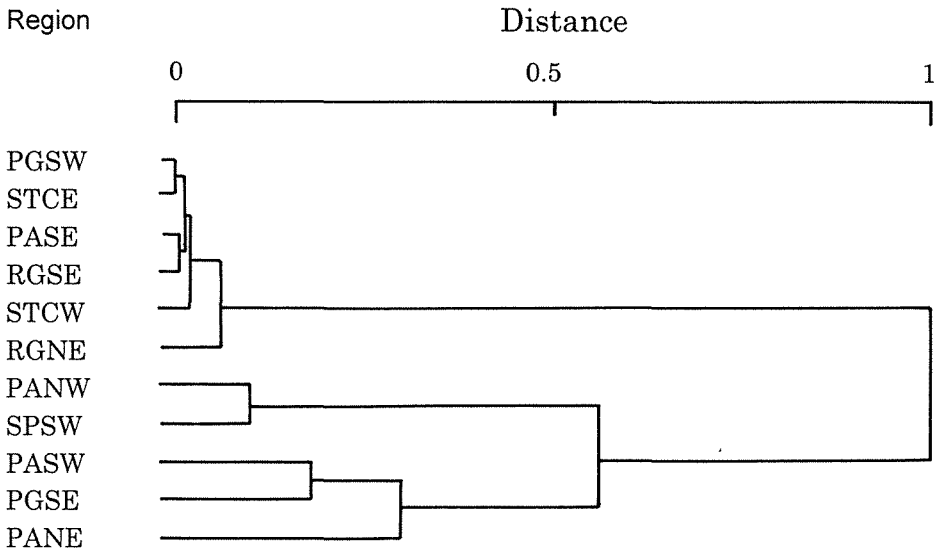

Fig. 2. Dendrogeam of eleven regions obtained by a cluster analysis for which the Ward's method and the cosine measure were used. The distance was adjusted by dividing the distance of each cluster by the mixmum distance of the cluster in this analysis. See the text for abbreviations of regions

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ブラジルとパラグアイの南部におけるハキリアリの地理的分布と，その分布拡大による農業への被害の増加の可能性

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摘　要

ブラジル及びパラグアイ南部の64地点における草本作物の畑で，ハキリアリの地理的分布と密度の調査を行った。この調査において，コブハキリアリ属（*Acromyrmex*）とハキリアリ属（*Atta*）よりそれぞれ４種類づつが得られた。調査地域を11の小地域に分割し，各小地域における各種類のハキリアリの平均密度を計算し，それに基づき考察を行った。調査の結果，調査地域の北部では熱帯性のハキリアリが主として採集され，南部では亜熱帯性のハキリアリのみが得られた。これらの両地方に挟まれる中間の地方では，熱帯性のハキリアリが採集されたが，その密度は北部より低かった。我々の調査では，この中間地方において亜熱帯性のハキリアリは採集されなかったが，他の研究者による調査では，この地方で亜熱帯性のハキリアリが採集されている。これらの結果より，調査地域の北部を熱帯性ハキリアリ地方，南部を亜熱帯性ハキリアリ地方，中間を両ハキリアリ混在地方と分類でき，この結果は11に分けた小地域に対して行ったクラスター分析の結果と完全に一致している。我々の調査と過去に行われた他の研究者の調査結果から，本調査地域のいずれの場所でも，熱帯性，亜熱帯性，もしくは両方のハキリアリが分布できることが示され，さらに何種類かのハキリアリについては，その分布の拡大が認められた。このことより，今まではハキリアリが少ないかもしくは全くおらずその被害がなかった地域でも，今後はハキリアリの分布の拡大からその被害が出てくる可能性があることが指摘される。

キーワード：ハキリアリ，地理的分布，農業害虫，南米

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