Ecology of *Amorphophallus* Species in Uttara Kannada District of the Karnataka State, India: Implications For Conservation

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ABSTRACT

Several *Amorphophallus* species are cultivated for their edible tubers. Nine of their congenerics are present in the Western Ghats. The abundance, spatial distribution patterns, and ecology of these species were studied. Based on abundance the habitat preference for these species in decreasing order is as follows: open scrub, mesa, *Acacia auriculiformis* plantations, disturbed evergreen forests, cashew and eucalyptus plantations, casuarina plantations, and betelnut orchards. Within a particular habitat, the spatial distribution patterns were clumped. The reasons behind such clumping could lie in their dispersal, reproductive ecology, and species associations. The implications of such distribution patterns on *in situ* conservation measures for these plant species are discussed. *Amorphophallus* species seem to be plants of humid habitats preferring an intermediate level of disturbance but not large scale habitat transformations. Large scale habitat transformations seem to be breaking their ecological links with their pollinators and dispersal agents resulting in reduction of their populations.

KEY WORDS

Amorphophallus, wild relatives of cultivated plants, habitat preference, seed dispersal, *in situ* conservation.

INTRODUCTION

The aroid genus, *Amorphophallus*, with an estimated number of species ranging from 90 to 170, primarily occurs in tropical Asia and Africa (Willis, 1955; Bogner et al., 1985; Hay, 1988; Hetterscheid, pers. comm.). Of these, 14 or 15 occur in India. Nine of them, namely, *Amorphophallus bonaccordensis* Sivadasan & Manmohan, *A. bulbifer* (Schott) Bl., *A. commutatus* (Schott) Engl., *A. hohenackeri* (Schott) Engl., *A. konkanensis* Hetterscheid, Yadav, & Patil, *A. mysorensis* Barnes & Fisch., *A. nicolsonianus* Sivadasan, *A. paeoniifolius* (Dennst.) Nicolson, and *A. sylvaticus* (Roxb.) Kunth occur on the hill chain of the Western Ghats in southern India. Of these, *Amorphophallus paeoniifolius* (syn. *A. campanulatus* Bl. ex Decne.) is cultivated over an extensive region. It is grown for its edible tubers as well as for its use as a treatment for digestive disorders. Tubers of a few other *Amorphophallus* species, including *A. konjac* K. Koch, *A. muelleri* Bl., and *A. variabilis* Bl. are considered edible (Bailey, 1950). Wild congenerics of the cultivated *Amorphophallus* therefore harbor genetic resources of potential value, especially as the cultivated species are losing their ability to reproduce sexually because of selective pressures to preferentially allocate more photosynthate towards tuber production. The hill chain of the Western Ghats harboring an estimated 436 species of wild relatives and related taxa of cultivated plants is of considerable significance for *in situ* conservation of these genetic resources. The district of Uttara Kannada (13°52'N–15°30'N and 74°05'E–75°05'E) with an area of 10,200 sq. km harbors the most extensive contiguous tropical humid forest tract of this hill chain with about 191 species of wild relatives of cultivated plants, and is therefore of particular interest from this perspective. We are involved in an attempt to work out a strategy for *in situ* conservation of this rich diversity of wild relatives of cultivated plants, including three species in the genus *Amorphophallus*, namely *A. bulbifer*, *A. commutatus*, and *A. paeoniifolius*. This paper reports on the results of this investigation.

STUDY AREA

Uttara Kannada is the northernmost coastal district of Karnataka State in southern India. To the west, it has a narrow strip of coastal plains interspersed with rocky outcrops and hillocks. To the east of these plains are the denuded hilltops of laterite (=mesa) and hills forested with vegetation exhibiting various degrees of human impact. Further east are the steep sloping densely forested areas called the "ghats." The steep slopes rising to about 600 m give way to small hills slowly rolling down toward the east and merging into the Deccan plateau at an altitude of 500 m. Our study area encompasses a wide strip stretching west-east from Kumta town up to the Chandragutti Reserve Forest in the Shimoga District just beyond the border of Uttara Kannada.

MATERIALS AND METHODS

Our investigations of *Amorphophallus* species have encompassed: (a) sampling for the abundance of individuals of the species of interest along 46 transects covering a wide diversity of habitat types; (b) observations on reproductive ecology, pollinators and levels of seed production in natural populations; (c) observations on seed dispersal in *Amorphophallus* plants in the wild as well as those cultivated at our field station in the Uttara Kannada District. We also observed the feeding behavior of a captive koel (*Eudynamys scolopacea* L.), a major seed dispersal agent.

Sampling for Abundance

To study the spatial distribution patterns, habitat preference, and species association, the abundance of *Amorphophallus* species and other flowering plants was investigated with the help of 46 belt transects of 5 m × 500 m divided into 50 quadrats of 5 m × 10 m. These transects were situated so as to cover the entire range of habitat types of the Uttara Kannada District on the basis of prior information and the available vegetation maps (Chandran, 1993; Pascal, 1988; Daniels, 1989). Occurrence of all plants with diameter at breast height (dbh) ≥2 cm was recorded in each quadrat. In each quadrat a subquadrat of either 2 sq. meters or 1 sq. meter was sampled for the abundance of all plants below 2 cm dbh as well. These included three *Amorphophallus* species. Since the younger stages of these three species were not always distinguishable, they are considered together in the quantitative analysis of spatial distribution. These quadrats were also characterized on canopy cover scored over a hundred point scale.

Reproductive Ecology

We kept track of flowering individuals of wild and cultivated species of *Amorphophallus* to understand their biology and relationship with other components of the ecosystem. Insects attracted to the flowers were collected at one locality. Number of seeds per fruit was assessed for all three species of *Amorphophallus*. Vegetative reproduction through the production of offset tubers was assessed through an examination of 68 tubers at five different localities. Number of foliar bulbils were counted in *Amorphophallus bulbifer*.

Seed Dispersal

Birds feeding on fruits of *Amorphophallus* were observed in the wild during the periods of 15 October to 30 November 1992 and 30 September to 15 November 1993. In addition, a very large number of such visits of dispersal agents were observed on ten plants of the three species cultivated at our field station at Kumta (14°20'N, 74°25'E) from 30 September to 15 November 1993. Finally, one individual of the major dispersal agent, a male koel, captured at Kumta was maintained for two days in our laboratory at Bangalore and offered ripened fruits of *Amorphophallus paeoniifolius* and *A. bulbifer* grown on the campus of the Indian Institute of Science.

Data Analysis

The data on abundance of *Amorphophallus* species was analyzed for density estimation to arrive at preferred habitats. Spatial distribution patterns were analyzed using the BASIC Programs POISSON.BAS, NEGBINOM.BAS, BQV.BAS and PQV.BAS provided by the book "Statistical Ecology" (Ludwig & Reynolds, 1988).

The level of association of *Amorphophallus* species with other plant species present in 85 quadrats was computed using Jaccard index (JI) (Eq. 1) as a measure of similarity between pairs of species.

$$JI_{AB} = \frac{a}{a + b + c} \qquad \text{(Eq. 1)}$$

where

a = the number of quadrats where both species (A and B) occur.

b = the number of quadrats where species A occurs, but not B.

c = the number of quadrats where species B occurs, but not A.

A complete linkage clustering dendrogram was generated using these similarity measures with the help of a computer program kumar.c developed by us.

The following 6 parameters were used to characterize the 2,300 quadrats of 50 sq. meters (or small subquadrats) each sampled in the course of this study:

(1) Canopy cover was scored on a scale of zero to 100.
(2) Proportion of three most abundant plant species <2 cm dbh.
(3) Proportion of three most abundant plant species ≥2 cm dbh.
(4) Proportion of plants ≥2 cm dbh with an evergreen phenology
(5) Proportion of exotics in plants ≥2 cm dbh
(6) Proportion of tree seedlings amongst plants <2 cm dbh

A rank test was carried out to check whether the quadrats in which *Amorphophallus* were present significantly differed from the total (2,300) quadrats in the above parameters.

RESULTS

Abundance, Spatial Distribution, and Habitat Preference

Table 1 shows the abundance of *Amorphophallus* species in various habitat types distributed over 46 places. The density of *Amorphophallus* in different habitat types is taken as an index of preference of *Amorphophallus* toward those habitat types. The results of the spatial distribution pattern analysis, given in Table 2, make it clear that the spatial distribution of *Amorphophallus* species does not follow the poisson distribution, i.e. they are not randomly distributed. The distribution was clumped in all the habitats examined. Negative binomial distribution was found to fit the data quite well as judged by the chi-square goodness of fit criterion (Table 2). The negative binomial distribution describes clumped, contagious, or aggregated populations. It has two parameters: (1) the mean of the individuals per sampling unit and (2) a parameter describing the degree of clumping.

Amorphophallus plants were present in 85 subquadrats included within the total 2,300 quadrats sampled. A rank test showed that 85 quadrats in which *Amorphophallus* were present significantly differed from the total (2,300) quadrats in the following parameters: (1) canopy cover, (2) proportion of three most abundant plant species <2 cm dbh, (3) proportion of three most abundant plant species ≥2 cm dbh and (4) proportion of plants ≥2 cm dbh with an evergreen phenology. This is also clear from

Table 1. Abundance of *Amorphophallus* species in various habitats.

1	2	3	4	5	6	7	8	9
Open scrub	14°26′	74°25′	2	50	22	2200	5067	I
Open scrub	14°26′	74°24′	1	50	54	10800		
Mesa	14°26′	74°25′	2	80	41	2563		
Mesa	14°27′	74°28′	2	80	0	0		
Mesa	14°24′	74°26′	2	80	54	3375	2125	II
Mesa	14°25′	74°26′	2	80	41	2563		
Acacia auriculiformis pl	14°27′	74°27′	1	50	0	0		
Acacia auriculiformis pl	14°25′	74°23′	2	50	22	2200		
Acacia auriculiformis pl	14°26′	74°24′	1	50	0	0		
Acacia auriculiformis pl	14°26′	74°23′	2	50	0	0	1767	III
Acacia auriculiformis pl	14°21′	74°44′	1	50	0	0		
Acacia auriculiformis pl	14°26′	74°24′	1	50	31	6200		
Disturbed evg forest	14°28′	74°27′	1	50	8	1600	1600	IV
Cashew and *Eucalyptus* pl	14°24′	74°28′	1	50	4	800	800	V
Casuarina pl	14°26′	74°23′	2	50	13	1300		
Casuarina pl	14°26′	74°23′	2	50	0	0	650	VI
Areca garden	14°29′	74°46′	1	50	0	0		
Areca garden	14°35′	74°48′	1	50	0	0		
Areca garden	14°27′	74°29′	1	50	11	2200	550	VII
Areca garden	14°18′	74°50′	1	50	0	0		
Betta land	14°19′	74°43′	1	50	0	0		
Betta land	14°21′	74°45′	1	50	0	0		
Sandy beach and adjoining sand	14°22′	74°24′	1	50	0	0		
Deciduous forest	14°25′	74°37′	1	50	0	0		
Deciduous forest	14°26′	74°54′	1	50	0	0		
Deciduous to semi-evg forest	14°23′	74°35′	1	50	0	0		
Disturbed semi-evg forest	14°25′	74°30′	1	50	0	0		
Disturbed evg to semi-evg forest	14°25′	74°49′	1	50	0	0		
Eucalyptus pl but now polyculture	14°29′	74°33′	1	50	0	0		
Eucalyptus pl in evg forest	14°30′	74°52′	1	50	0	0		
Evg to semi-evg forest	14°25′	74°47′	1	50	0	0		
Evg forest	14°24′	74°44′	1	50	0	0		
Evg forest	14°16′	74°42′	1	50	0	0		
Evg forest	14°22′	74°39′	1	50	0	0		
Evg forest	14°23′	74°39′	1	50	0	0		
Evg forest	14°20′	74°38′	1	50	0	0		
Evg forest	14°29′	74°33′	1	50	0	0		
Evg forest	14°31′	74°34′	1	50	0	0		
Evg forest	14°23′	74°44′	1	50	0	0		
Myristica swamp	14°16′	74°44′	1	50	0	0		
Myristica swamp plus evg forest	14°25′	74°46′	1	50	0	0		
Open scrub	14°26′	74°24′	1	50	0	0		
River-side vegetation	14°41′	74°29′	1	50	0	0		
Sandalwood pl	14°23′	74°55′	1	50	0	0		
Teak pl	14°26′	74°38′	1	50	0	0		
Teak pl	14°29′	74°33′	1	50	0	0		

Abbreviations: pl = plantation; evg = evergreen. Legends for columns in Table 1: 1 = habitat type; 2 = latitude; 3 = longitude; 4 = quadrat size (in m^2); 5 = number of quadrats; 6 = total no of individuals; 7 = density per hectare; 8 = over all density, and 9 = order of preference.

Table 2. Testing goodness of fit for Poisson and Negative Binomial distributions.

1	2	3	4	5	6	7	8	9	10	11	12
Mesa	2	80	41	0.513	6.709	39.33288**	2	NR	0.9297	1	C
Mesa	2	80	41	0.513	3.873	45.66369**	2	NR	5.6499	1	C
Mesa	2	80	54	0.675	6.07	48.20713**	2	NR	2.1657	2	C
Open scrub	2	50	22	0.44	1.027	10.73492**	1	NR	8.6753	2	C
Ac au p	2	50	22	0.44	1.027	8.916841**	1	NR	1.0253	2	C
Ca eq p	2	50	13	0.26	0.727	7.436324**	1	NR	0.1774	1	C
Ac au p	1	50	31	0.62	2.975	21.63098**	2	NR	1.0634	2	C
Minor f	1	50	54	1.08	3.259	49.65658**	3	NR	9.1788	4	C
Dist evg f	1	50	8	0.16	0.994	5.959205*	1	NR	0.4377	1	C
CP & EP	1	50	4	0.08	0.116	5.534192*	1	NR	0.7297	1	C
Areca garden	1	50	11	0.22	0.542	3.883375*	1	NR	1.8923	1	C

* Significant at $p = 0.05$.
** Significant at $p = 0.01$.
Abbreviations: f = forest; p = plantation; Ca eq = *Casuarina equisetifolia*; Ac au = *Acacia auriculiformis*; CP & EP = cashew and *Eucalyptus* plantation; NR = nonrandom; and C = clumped. Legends for columns in Table 2: 1 = habitat type; 2 = quadrat size (in m^2); 3 = number of quadrats; 4 = total number of individuals; 5 = mean; 6 = variance; for Poisson distribution: 7 = calculated chi-square; 8 = degree of freedom; 9 = inference; for negative binomial distribution: 10 = calculated chi-square; 11 = degree of freedom; and 12 = inference.

the bar graphs given in Fig. 2a–2d, respectively. Thus *Amorphophallus* species prefer habitats with a relatively open canopy (10–30% covered) (Fig. 2a). Similarly, *Amorphophallus* species occur proportionately more in quadrats where plants <2 cm and ≥2 cm dbh are dominated by few (one to three) species (Fig. 2b and 2c respectively). Also, *Amorphophallus* plants are proportionately more abundant in quadrats with less proportion of evergreens, that is, in disturbed moist deciduous to semi-evergreen portions (Fig. 2d). Though the quadrats with *Amorphophallus* are not significantly different from the total (2,300) quadrats with respect to proportion of exotics in plants ≥2 cm dbh yet *Amorphophallus* species are still relatively more abundant in quadrats with more exotics (Fig. 2e). This is because monocultures of exotics are being planted in relatively open canopied habitats (the preferred habitats of *Amorphophallus* which are being replaced). Similarly, the quadrats with *Amorphophallus* are not significantly different from the total (2,300) quadrats with respect to the proportion of tree seedlings in plants <2 cm dbh yet *Amorphophallus* plants are more abundant in quadrats where the proportion of tree seedlings is 20–30%. *Amorphophallus* plants are completely absent from quadrats which are dominated by tree seedlings (Fig. 2f).

Species Associations

Altogether 64 species (Table 4) occurred with *Amorphophallus* species in the 85 subquadrats. Figure 1 represents a dendrogram depicting the level of association of the more strongly associated species. Of these two naturally occurring tree species, *Aglaia talbotii* Sundararaghavan and *Memecylon umbellatum* Burm. were most closely associated, along with a climber *Dalbergia sympathetica* Nimmo. These three species are characteristic of open scrubs. *Sapium insigne* Benth is another significantly associated tree species because of its poisonous latex that enables it to persist in habitats from which most other tree growth has been eliminated. Several

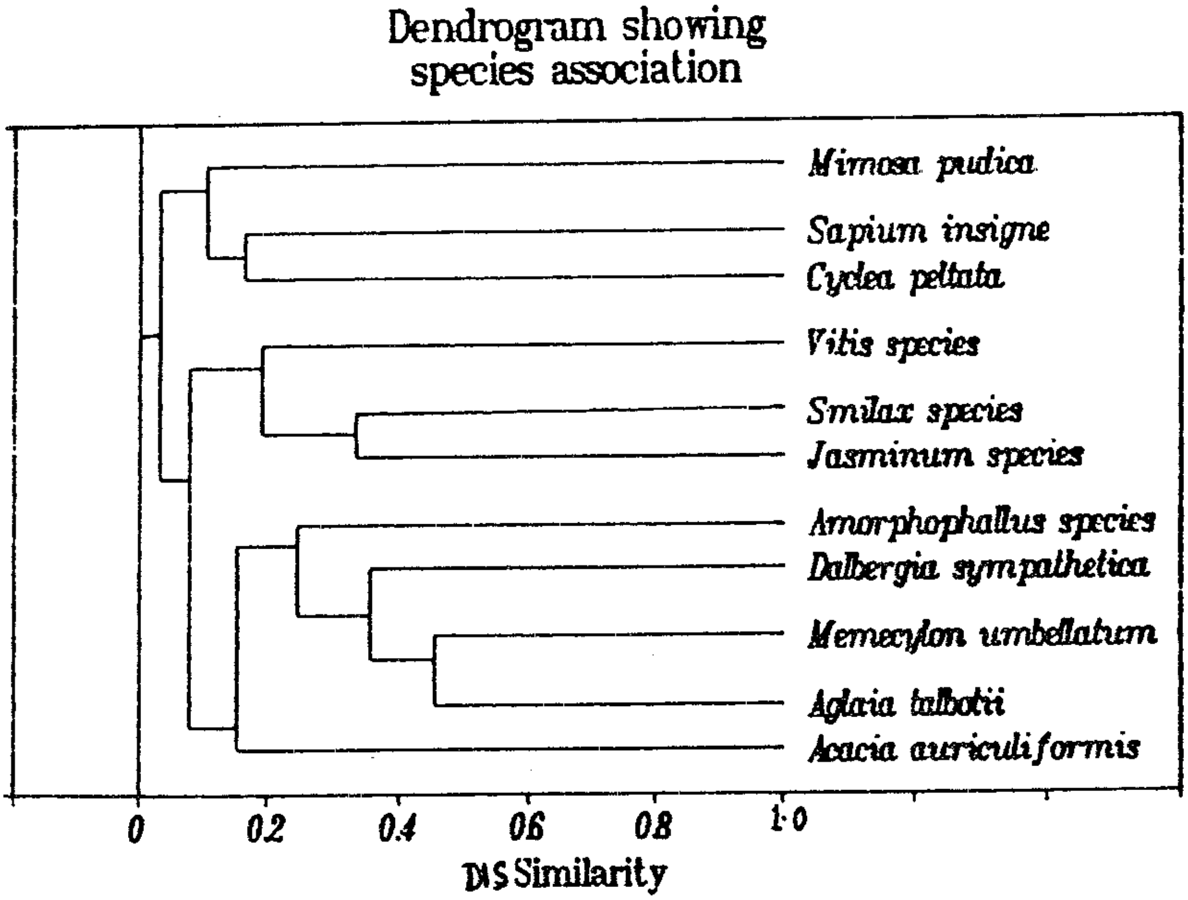


Fig. 1. A dendrogram showing level of species association.

climbers which thrive in forest clearings are also significantly associated with *Amorpbopballus* species, as is the spiny creeper, *Mimosa pudica* L. characteristic of open vegetation under heavy pressure of cattle grazing. However, it was observed that *Amorpbopballus* plants often grow close to some other plant species like *Carissa congesta* Wt. (Apocynaceae), *Cantbium parviflorum* Lam. (Rubiaceae), *Strycbnos nux-vomica* L. (Loganiaceae), *Ervatamia heyneana* (Wall.) Cooke (Apocynaceae), *Syzygium* species (Myrtaceae) in open habitats like *mesa* and open scrub.

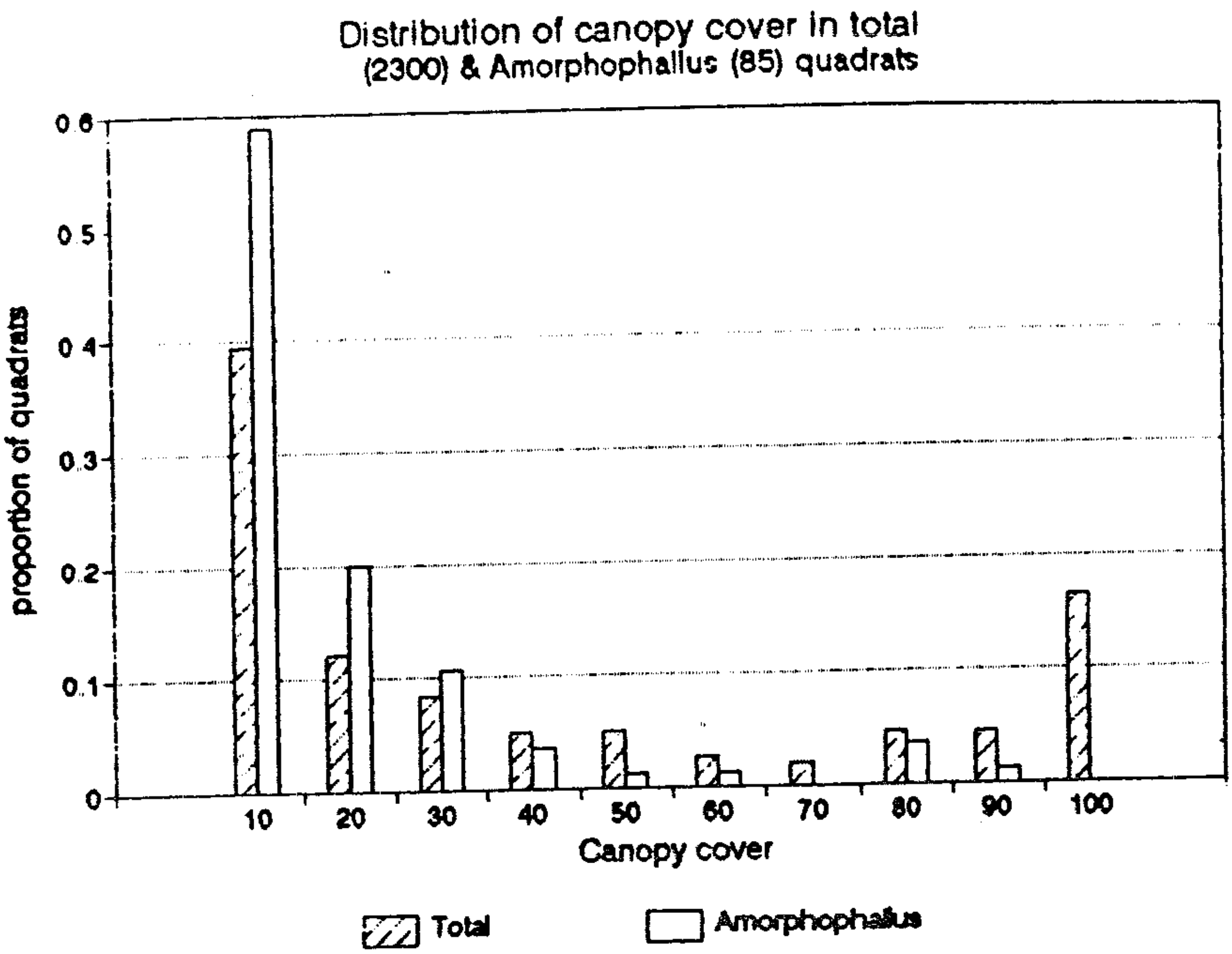
Probable Pollinators and the Reproductive Ecology

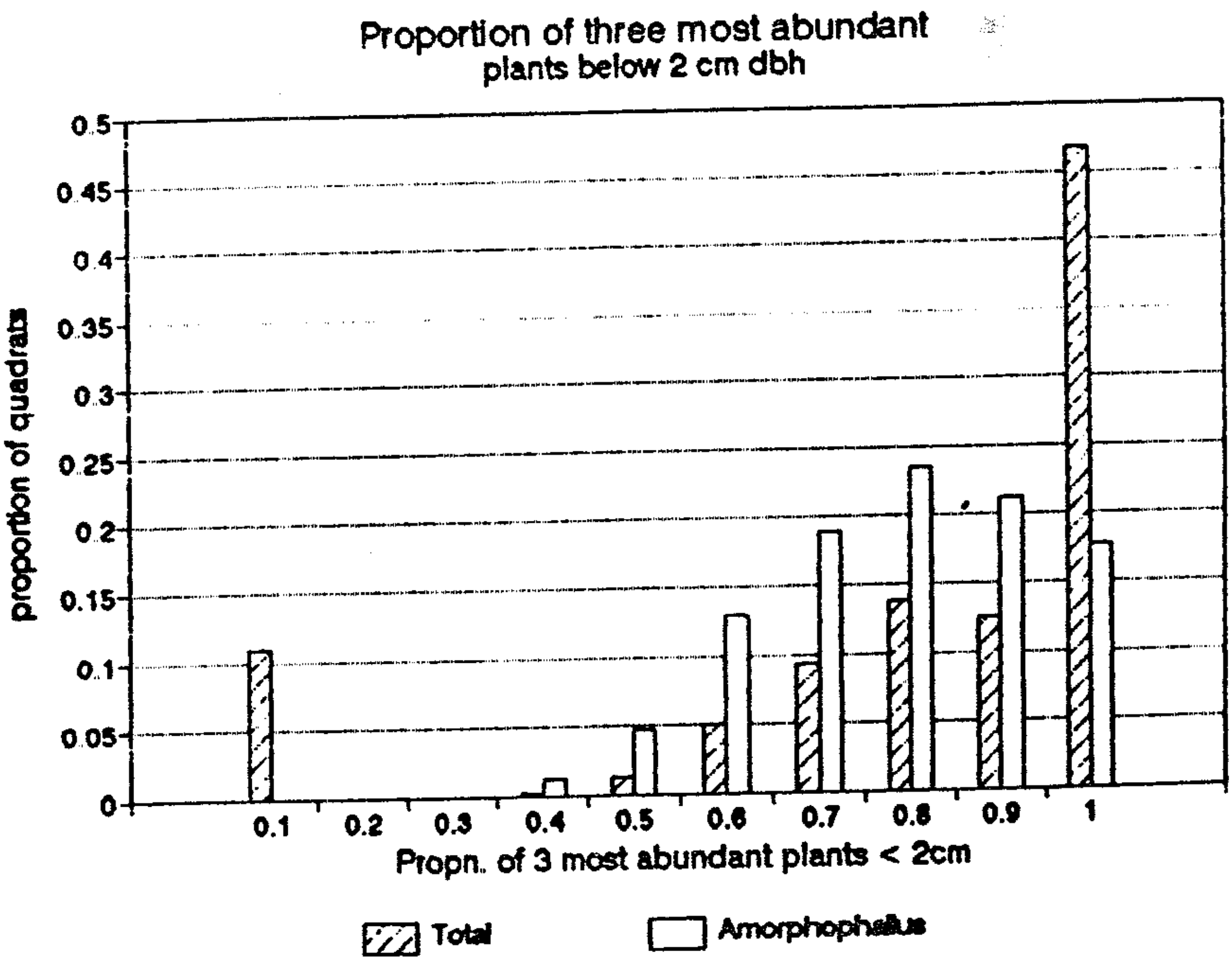
We would like to place on record the identity of some insect species collected from the inflorescences of *Amorpbopballus paeoniifolius*. A large number of beetles of the genus *Adoretus* were seen at the base of the spadices and spathes. Some *Melipona* bees were collecting pollen grains. Two more unidentified insect species were also attracted to the inflorescences of *Amorpbopballus* species planted at the field station. Some insects were occasionally feeding on the appendices. All insects vanished before the withering of the spathe. Some of these insects might be pollinators of the *Amorpbopballus* species.

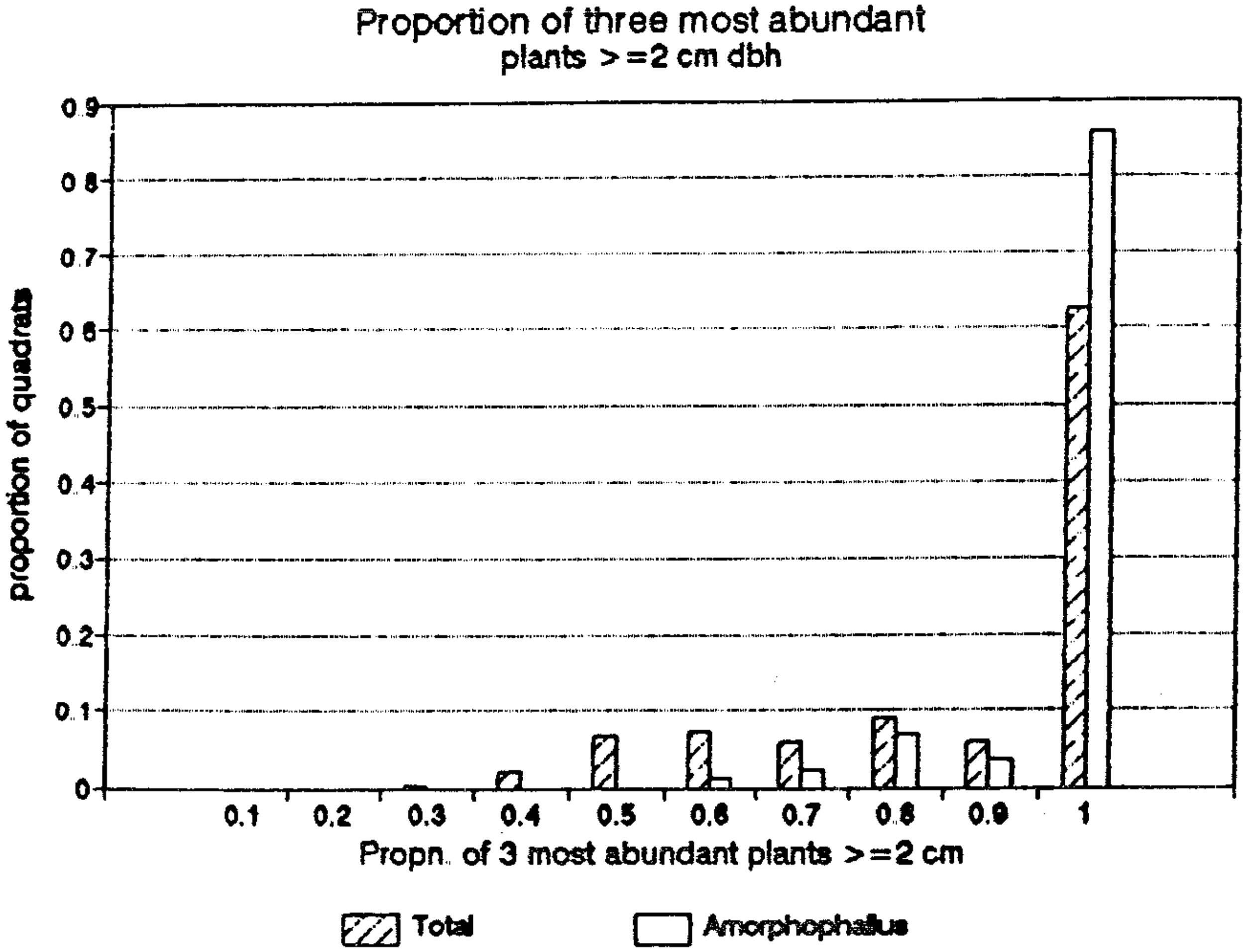
In *Amorpbopballus bulbifer*, *A. commutatus*, and wild *A. paeoniifolius* occasionally flowering shoots decayed without setting seed but in cultivated *A. paeoniifolius* all the flowering shoots decayed without setting fruit. Fresh leafy shoots emerged from tubers in all (both wild and cultivat- →

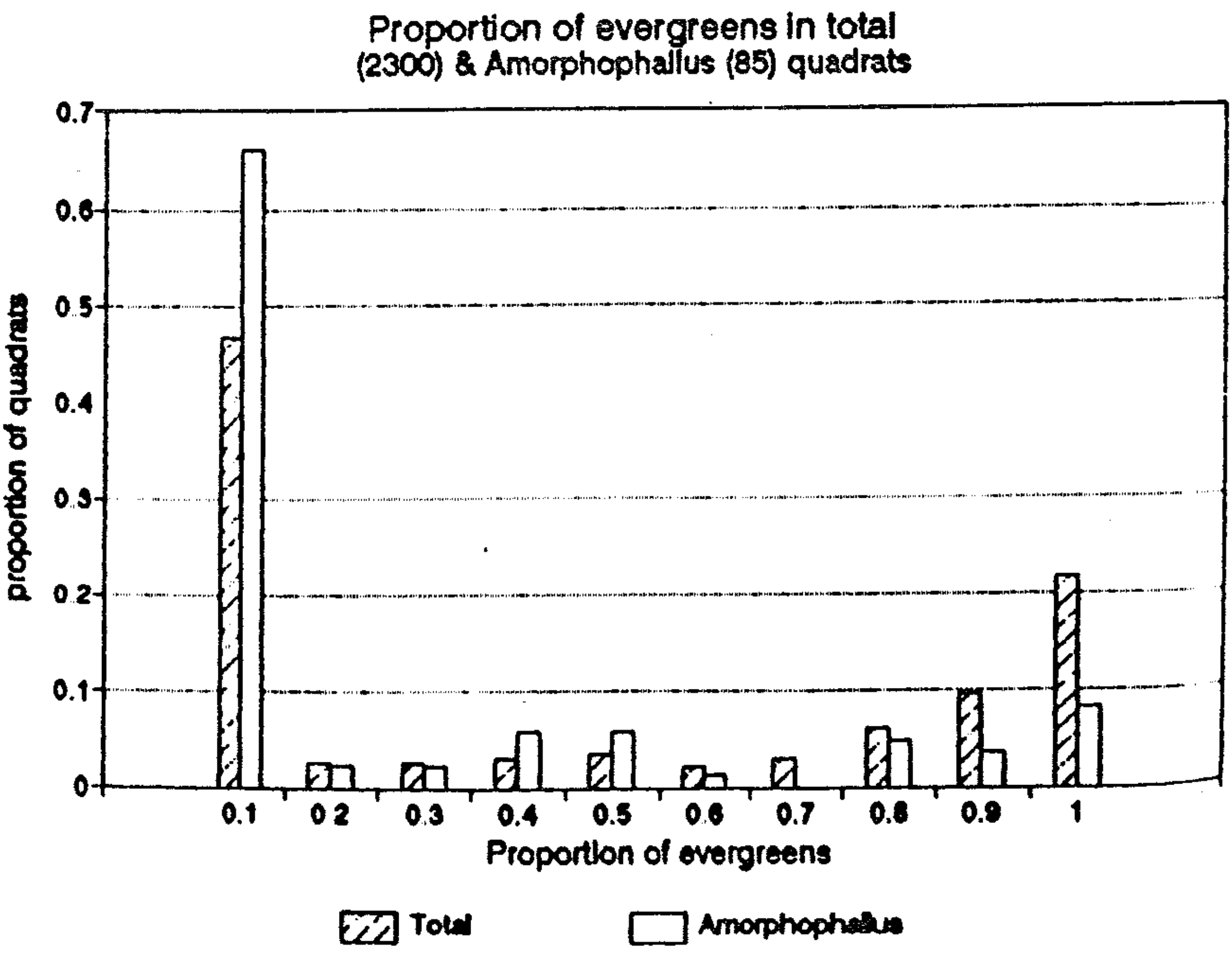
Fig. 2a. Canopy cover and *Amorpbopballus* habitat.

Fig. 2b. Proportion of three most abundant plants <2 cm and *Amorpbopballus* habitat.


Distribution of canopy cover in total
(2300) & Amorphophallus (85) quadrats
proportion of quadrats
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
90
100
Canopy cover
Total
Amorphophallus


Proportion of three most abundant
plants below 2 cm dbh
proportion of quadrats
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Propn. of 3 most abundant plants < 2cm
Total
Amorphophallus


Proportion of three most abundant
plants >=2 cm dbh
proportion of quadrats
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Propn. of 3 most abundant plants >=2 cm
Total
Amorphophallus


Proportion of evergreens in total
(2300) & Amorphophallus (85) quadrats
proportion of quadrats
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Proportion of evergreens
Total
Amorphophallus

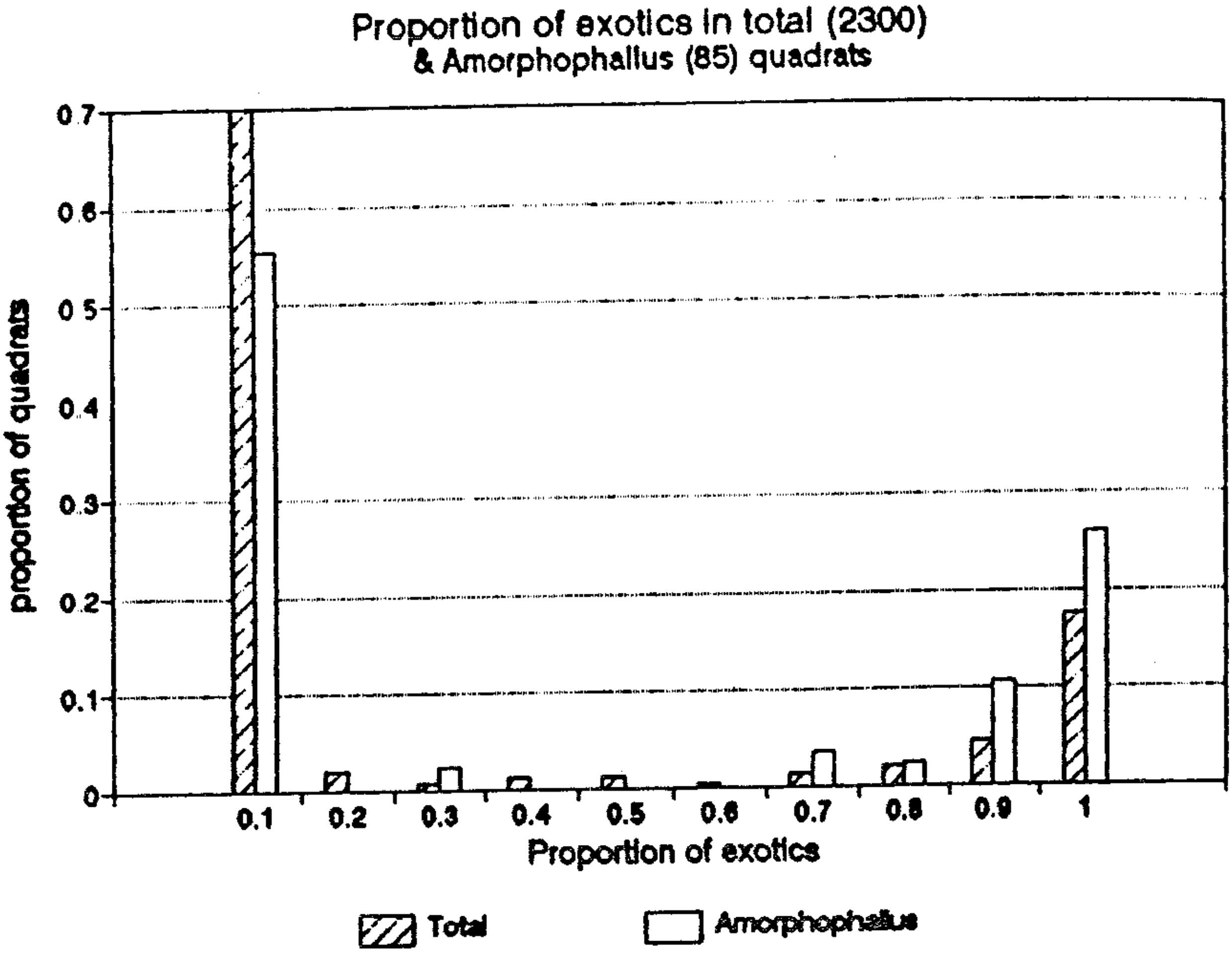


Fig. 2e. Proportion of exotics and *Amorphophallus* habitat.

ed) plants in which flowering shoots had decayed.

Number of Seeds per Fruit

Table 3 shows the frequency distribution of number of seeds per fruit in *Amorphophallus paeoniifolius, A. bulbifer,* and *A. commutatus.* In *Amorphophallus paeoniifolius,* seeds per fruit ranged from zero (in failed/undeveloped fruits) to three, rarely four. The fourth seed, however, was very small. The mode was two but the mean was 1.98 showing very slightly positively skewed distribution (Fig. 3a). In *Amorphophallus bulbifer,* seeds per fruit ranged from zero (in failed/undeveloped fruits) to four. The mode was one but the mean was 1.45, showing highly positively skewed distribution (Fig. 3b). In *Amorphophallus commutatus,* all fruits were single seeded (Fig. 3c).

Number of Offset Tubers

The number of offset tubers is highly variable across species as well as within a particular species. In *Amorphophallus commutatus,* it varied from zero to ten ($\bar{x} = 4.6$, $s = 2.25$, $n = 68$).

The number of foliar bulbils at the major intersections of the leaflets of *Amorphophallus bulbifer* ranged from one to 18 depending on the vigor of the plant.

←

Fig. 2c. Proportion of three most abundant plants ≥2 cm and *Amorphophallus* habitat.

Fig. 2d. Proportion of evergreens and *Amorphophallus* habitat.

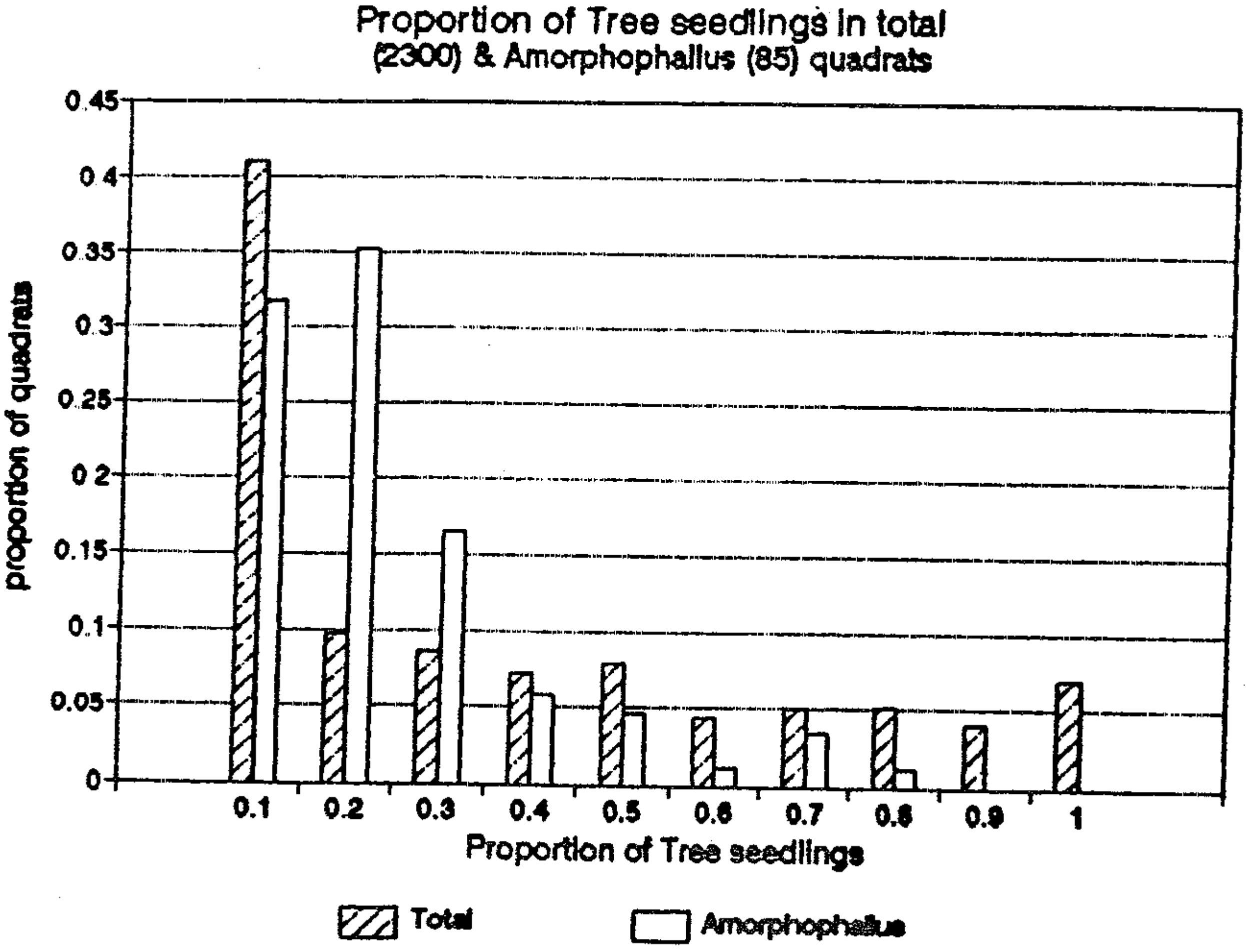


Fig. 2f. Proportion of tree seedlings and *Amorphophallus* habitat.

Table 3. Frequency distribution of number of seeds/fruit in *Amorphophallus paeoniifolius* (Ap), *A. bulbifer* (Ab), and *A. commutatus* (Ac).

Frequency distribution			
No. of seeds	Frequency		
	Ap	Ab	Ac
0	0	0	0
1	11	67	73
2	92	32	0
3	9	5	0
4	0	2	0
Total	112	106	73
Mean	1.98214	1.45283	1
Variance	0.17825	0.45532	0

Note: Failed/undeveloped fruits were not counted.

The Seed Dispersal Agents

We would like to record that the two bird species of bulbuls (red-whiskered bulbul, *Pycnonotus jocosus* L. and red-vented bulbul, *Pycnonotus cafer* L.) and the koel (*Eudynamys scolopacea* L.) are locally well known to favor *Amorphophallus* fruits, and are snared at these plants by some people belonging to Mukri and Kari Vokkaliga communities. Once a very rare case of an Indian myna (*Acridotheres tristis* L.) tasting one *Amorphophallus* fruit was also seen. A captive male koel consumed hundreds of fruits of *Amorphophallus paeoniifolius*, *A. bulbifer*, and *Santalum album* L. (Santalaceae) which were offered over two days. The koel regurgitated as well as defecated the seeds. The time gap between the last feeding of the fruits and regurgitation was about 35 minutes and defecation commenced only later.

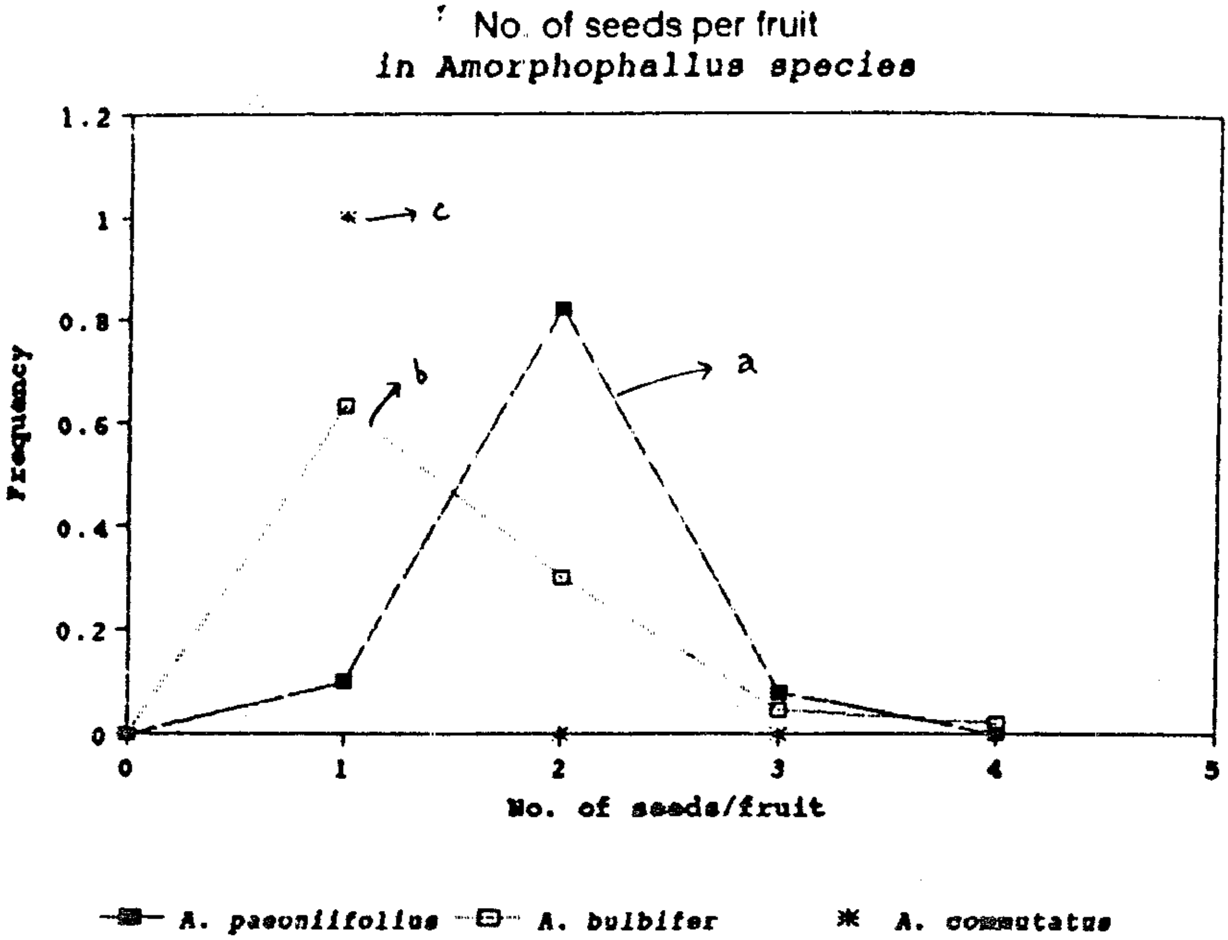


Fig. 3a–c put together. a = *A. paeoniifolius*, b = *A. bulbifer*, c = *A. commutatus*.

DISCUSSION

The following could be the possible reasons behind the clumped distribution of *Amorphophallus* species:

1. Since many fruits of *Amorphophallus* species are eaten in one sitting and dispersed by koel and bulbuls, many seeds are dispersed simultaneously. The upper fruits ripen first, and when they ripen, they are consumed by these birds. In plants where some fruits are left behind, they rot and fall near the mother tuber. Plants growing from these seeds are thus likely to be clumped. Often, the dispersal agents perch on particular perching sites repeatedly. Therefore, many seeds fall in the same place. This too may result in a clumped distribution.

2. In *Amorphophallus paeoniifolius*, the number of seeds per fruit ranges from zero to three (rarely four) with the mode at two. In the case of *Amorphophallus bulbifer*, it ranges from zero to four while the mode is at one (Table 3). Thus, even if a single fruit is eaten at a time by a bird, the chance that more seeds are dispersed together is high. However, *Amorphophallus commutatus* has only single-seeded fruits, but since its fruits are smaller as compared to the other two species, they are more likely to be eaten and dispersed together in greater numbers.

3. *Amorphophallus* species reproduce asexually as well. Therefore, more than one leafy shoot can develop from a single tuber. Though apical dominance is very strong in these plants and usually one leafy shoot is seen per tuber, some offset tubers often succeed in producing additional leafy shoots. In Antravalli, it was quite common to see two leafy shoots coming from a single tuber. There is much variation in the number of offset tubers per tuber. Sometimes the mother tuber rots and the offset tubers start developing independently. Naturally such plants will be clumped. *Amorphophallus bulbifer* produces foliar bulbils at

Table 4. List of species which co-occurred with *Amorphophallus* species.

S. No.	Species	Family
1	*Acacia auriculiformis* A. Cunn. ex Benth.	Fabaceae
2	*Acacia catechu* (L.f.) Willd.	Fabaceae
3	*Acanthus* species	Acanthaceae
4	*Aglaia talbotii* Sundararaghavan	Meliaceae
5	*Alseodaphne semecarpifolia* Nees	Lauraceae
6	*Anacardium occidentale* L.	Anacardiaceae
7	*Annona squamosa* L.	Annonaceae
8	*Aporosa lindleyana* (Wt.) Baill.	Euphorbiaceae
9	*Areca catechu* L.	Arecaceae
10	*Bombax ceiba* L.	Malvaceae
11	*Calycopteris floribunda* (Roxb.) Poir.	Combretaceae
12	*Canthium parviflorum* Lam	Rubiaceae
13	*Carissa carandas* L.	Apocynaceae
14	*Cassia tora* L.	Fabaceae
15	*Casuarina equisetifolia* Forst.	Casuarinaceae
16	*Colocasia* species	Araceae
17	*Costus speciosus* (Koenig) Sm.	Zingiberaceae
18	*Crinum* species	Amaryllidaceae
19	*Curculigo orchioides* Gaertn.	Amaryllidaceae
20	*Curcuma neilgherrensis* Wt.	Zingiberaceae
21	*Curcuma* species	Zingiberaceae
22	*Cyclea peltata* (Lam.) Hook. & Thoms.	Menispermaceae
23	*Cyperus* species	Cyperaceae
24	*Dalbergia sympathetica* Nimmo	Fabaceae
25	*Dioscorea bulbifera* L.	Dioscoreaceae
26	*Dioscorea oppositifolia* L.	Dioscoreaceae
27	*Dioscorea pentaphylla* L.	Dioscoreaceae
28	*Ervatamia heyneana* (Wall.) Cooke	Apocynaceae
29	*Eupatorium odoratum* L.	Asteraceae
30	*Flacourtia sepiaria* Roxb.	Flacourtiaceae
31	*Grewia* species	Tiliaceae
32	*Impatiens* species	Balsaminaceae
33	*Indigofera* species	Fabaceae
34	*Ixora brachiata* Roxb.	Rubiaceae
35	*Ixora coccinea* L.	Rubiaceae
36	*Jasminum* species	Oleaceae
37	*Lannea coromandelica* (Houtt.) Merr	Anacardiaceae
38	*Laportea interrupta* (L.) Chew	Urticaceae
39	*Memecylon* species	Melastomataceae
40	*Memecylon umbellatum* N. Burman	Melastomataceae
41	*Mimosa pudica* L.	Mimosaceae
42	*Mimusops elengii* L.	Sapotaceae
43	*Musa* species (in Areca garden)	Musaceae
44	*Naregamia alata* Wt. & Arn.	Meliaceae
45	*Nothopodytes foetida* (Wt.) Sleumer	Olacaceae
46	*Ochrocarpus longifolius* (Wt.) Benth. & Hook.	Guttiferae
47	*Pavetta indica* L.	Rubiaceae
48	*Phyllanthus fraternus* Webster	Euphorbiaceae

Table 4. Continued.

S. No.	Species	Family
49	*Piper betle* L. (in Areca garden)	Piperaceae
50	*Sapium insigne* Benth	Euphorbiaceae
51	*Securinega microcarpa* Blume	Euphorbiaceae
52	*Smilax* species	Liliaceae
53	*Solanum indicum* L.	Solanaceae
54	*Strychnos nux-vomica* L.	Loganiaceae
55	*Syzygium caryophyllatum* (L.) Alton	Myrtaceae
56	*Syzygium cumini* (L.) Skeels	Myrtaceae
57	*Syzygium laetum* (Ham.) Gandhi	Myrtaceae
58	*Xyzygium* species	Myrtaceae
59	*Terminalia paniculata* Roth	Combretaceae
60	*Theobroma cacao* L. (in Areca garden)	Sterculiaceae
61	*Theriophonum dalzellii* Schott	Araceae
62	*Vitis indica* Wight & Arn. non L.	Vitaceae
63	*Xeromphis spinosa* (Thunb.) Keay	Rubiaceae
64	*Zizyphus oenoplia* Miller	Rhamnaceae

the major intersections of its leaflets. The number of foliar bulbils varies from one to 18 per leaf depending on the vigor of the plants. These foliar bulbils fall fairly close to the mother plant—at a distance equal to the length of the petiole or less. This also contributes to a clumped distribution.

4. There is polyembryony in some *Amorphophallus* species like cultivated *A. paeoniifolius* (Jos & Vijaya Bai, 1986) and wild *A. paeoniifolius* (pers. observ.). Therefore, a number of leafy shoots develop from a single seed in these cases. This again leads to a clumped distribution.

The association of *Amorphophallus* species with some of the other plant species may be related to the fact that its dispersal agents perch repeatedly on some perching sites provided by other plant species. Naturally, the *Amorphophallus* plants coming from these seeds would seem to be associated with those plants. A number of climber species are also associated with *Amorphophallus* species because they also need some mechanical support. Moreover, these plant species may also provide some sort of "safe sites" with better soil, moisture and other ecological conditions and safer places from being trampled by cattle, human beings, or other animals.

There are differences in the preferred habitats of different *Amorphophallus* species. *Amorphophallus commutatus* prefers to grow on *mesas* where it does well in the scant soil sheltered below bushes of its associated species and/or between laterite rocks while *A. paeoniifolius* prefers habitats where soil conditions are better. *Amorphophallus bulbifer* prefers more shade and moist habitats compared to the other two *Amorphophallus* species. Apart from these, there are differences in the preferences of dispersal agents, mainly birds, for the fruits of different *Amorphophallus* species. *Amorphophallus commutatus* fruits are eaten by both the dispersal agents (koel and bulbuls) with equal interest since its fruits are small enough to be swallowed easily by both. But since the koel does not prefer open habitats like *mesas*, most of the seeds of *Amorphophallus commutatus* on *mesas* are dispersed by bulbuls and much less by koels. Both wild and cultivated *Amorphophallus paeoniifolius* spadices produce fruits very systematically arranged on them. Almost all fruits are somewhat oval-cylindrical except the few lowermost ones. The upper fruits are smaller and ripen early. Since bulbuls are smaller birds, they have a smaller gape size as compared to the koel. Therefore, bulbuls have difficulty in swallowing fruits located at lower positions on the spadix, but not the koels. When lowermost fruits are left on very robust spadices of *Amorphophallus paeoniifolius* then bulbuls stop visiting them. Then these fruits are dispersed by koels only. The fruits of *Amorphophallus bulbifer* are irregularly shaped and less systematically arranged on the spadix. That is why its fruit are not much sought out by either of the dispersal agents. Moreover, the peduncle of this species is more watery, thin, tall, and weak. When birds perch on it, it tends to bend. These might be some reasons why *Amorphophallus bulbifer* is overall dispersed less effectively and therefore is less common compared to the other two species. Various *Amorphophallus* species occur in different patches with a certain amount of niche overlap and diversification.

As we move from open habitats to the canopied habitats, we notice a change in the distribution of *Amorphophallus* species in that, by and large, both the tuber size and fruit size of the available species increase with an increase in leaf litter depth and improvement in soil conditions. Therefore, it is more likely that *Amorphophallus* species with big tubers would prefer habitats where soil conditions are better and leaf litter depth is greater. For an *Amorphophallus* seed to germinate and establish itself in an undisturbed forest, it should have enough food reserves to produce a long radicle that can penetrate through the deep litter and a stout plumule to push through the leaf litter above it. This means that such species should have big seeds (certainly in larger fruits). To disperse such big seeds, larger dispersal agents with wider gape and vent opening would be required. Peckover (1985) reported such dispersal agents from Papua New Guinea, though in very cautiously-worded sentences because of the limitations of his observations. Similarly, Sastrapradja et al. (1984) reported that villagers in different places in West Java had seen bulbuls (*Pycnonotus aurigaster*) feeding on the fruits of *Amorphophallus variabilis* Bl. It was also reported that the fruits of the *Amorphophallus variabilis* were occasionally fed to the birds sold in the market in Bogor. Wilbert Hetterscheid (pers. comm.) reports that six centimeter large fruits of *Amorphophallus titanum* (Becc.) Becc. ex Arcangeli (in Sumatra) are eaten by the large Hornbills. Obviously, we have an ecological equivalent of this phenomenon in India as well.

Many fruit-eating birds regurgitate large seeds and pass small seeds through their alimentary canal unharmed (Howe and Westley, 1988). Since dispersal agents regurgitate as well as defecate, the defecated seeds would tend to disperse over larger distances compared to the regurgitated ones because there is a longer time gap between feeding and defecating than between feeding and regurgitating. This time gap could be one major factor governing dispersal distance of seeds from the mother plants. There are reports of physiological and morphological modifications of the digestive systems in frugivorous birds and mammals, such as the shortening of the alimentary canal in both birds and mammals and the lack of a properly developed gizzard in birds. Hladik (1967) reports that the obligately fruit-eating spider monkey (*Ateles*) has only half the colon surface area as that of a howler monkey (*Alouatta*), a leaf-eater of roughly the same size. Similarly, Walsberg (1975) has reported that a mistletoe specialist bird, *Phainopepla nitens*, eats the fruits of a mistletoe, *Phoradendron californicum*, and can defecate the seeds in as little as 12 minutes. Bulky seeds are regurgitated in even less time. In the case of *Santalum album* L. (Santalaceae) fruits, which are dispersed by the same bulbuls and koel as are the *Amorphophallus* species, the seeds are defecated or regurgitated depending on their size (Hegde et al., 1991). Anyway, if there are any morphological or physiological modifications for speedy processing of fruits of *Amorphophallus* in their dispersal agents, this could conceivably tend to reduce the effective dispersal distances. This could result in a very fast shrinking of *Amorphophallus* populations especially if the habitats of *Amorphophallus* species and their dispersal agents are allowed to deteriorate. It must be remembered, however, that the restoration of *Amorphophallus* populations would be slow even if such habitats with its dispersal agents and safe sites for *Amorphophallus* are improved. Therefore, for *in situ* conservation of these plant species, the habitats of both groups of organisms should not be allowed to deteriorate to the point of no return.

Populations of *Amorphophallus* species have shrunken (and continue to do so) because of large-scale habitat transformation. The following evidence is a clear indication of declining populations of *Amorphophallus* species throughout their range of distribution:

1. Sastrapradja et al. (1984), while describing edible *Amorphophallus* and its related species in Indonesia, wrote the following:

"With the expansion of agricultural resettlement and other human activities, the population of *Amorphophallus* is decreasing, especially in the densely populated islands such as Java, Madura, and Bali. Even *Amorphophallus campanulatus* which was one of the most common species is nowadays considered a strange plant in some areas because of its unusual inflorescence shape and smell. (*Amorphophallus campanulatus* is now considered a synonym of *A. paeoniifolius.*) An attempt to collect some species from their type localities and surrounding places has not succeeded yet."

2. Old literature (Hooker, 1897) suggests that *Amorphophallus* species (especially *A. paeoniifolius*) were present right from Punjab to West Bengal only about 100 years ago. But wild populations of *Amorphophallus paeoniifolius* are now either rare or completely absent in the Gangetic plains.

In our study area (and in other areas of the Western Ghats) there is human population pressure from adjacent areas—the coast on the west and the Deccan plateau on the east. Therefore, forests are shrinking from both sides. Under such a situation *Amorphophallus* populations are likely to shrink drastically with the disappearance of their habitats. At the same time, large-scale habitat transformations might be adversely affecting the populations of pollinators and dispersal agents as well. Some of the wild *Amorphophallus* inflorescences observed to decay without setting fruit might be because of lack of pollinators and/or presence of sterility. But in cultivated *Amorphophallus* the decay of all inflorescences might be because of lack of pollinators coupled with presence of sterility and extreme protogyny. Therefore long term maintenance of *Amorphophallus* populations in the wild would require simultaneous attention to the conservation of preferred habitats of the plants, as well as the quality of the habitat for their pollinators and seed dispersal agents.

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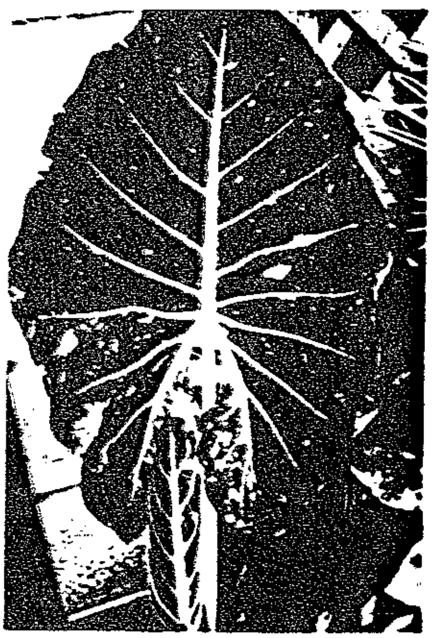

Alocasia macrorrhizos (L.) G. Don var. 'New Guinea Gold' growing at the editor's home. Leaves are variegated with yellow, petioles are yellow. Photo by Jim Donovan.