Observations on *Amorphophallus titanum* (Becc.) Becc. ex Arcangeli in the Forest of Sumatra

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ABSTRACT

On the occasion of the centenary of the death of Odoardo Beccari the Botanical Garden of Florence organised two expeditions in Sumatra (in September 1994 and 1995) to study *Amorphophallus titanum* in nature and bring it to Florence to try to grow it. In the course of the two expeditions eight inflorescences and four infructescences were found. The inflorescences were at various stages of development and it was possible to sketch a general outline of the flowering process. We will give a detailed description only of the specimen which we observed minute by minute as its blossomed. For the others we will just list the most significant characteristics.

INTRODUCTION

Amorphophallus titanum (Becc.) Becc. ex Arcangeli is a herbaceous plant with a big leaf resembling the foliage of a tree and a petiole that looks like a trunk; it can reach a maximum height of 6 meters. This plant produces the biggest unbranched inflorescence in the world: it can grow up to 2.5 meters in height (Camp, 1937).

The Florentine naturalist Odoardo Beccari, who explored the Indonesian forests for many years, in search of new and interesting plant and animal species to study (Faenzi, 1878; Beccari, 1878), discovered *Amorphophallus titanum* in 1878. Beccari sent tubers and seeds to Italy but the tubers were held at Marseilles customs and never arrived. The seeds, however, germinated, and the following year the little tubers were sent to various botanical gardens throughout Europe, including Kew Gardens in London.

Unfortunately all the plants in Italy died, but a different fate was in store for the Kew specimen: after no less than a decade (1889 vol. IV p. 19) it flowered in captivity for the first time. Since then *Amorphophallus titanum* has flowered many times in many botanical gardens, but never in Italy.

On the occasion of the centenary of the death of Odoardo Beccari the Botanical Garden of Florence decided to resume research on this spectacular plant. Two expeditions were organized (in September 1994 and 1995) to study the plant in nature and bring it once again to Florence to try to grow it.

Morphological Characteristics of *Amorphophallus titanum*

As is well known, *Amorphophallus titanum* is a seasonally dormant perennial monocotyledon. The underground tuber is subspherical depressed-globose and varies in dimension according to the age of the plant: it can reach 80 cm in diameter and can weigh up to 70 kg. The petiole is smooth and green, covered with whitish spots, and can reach the remarkable size of 6 m in height and 30 cm in diameter at the base. The leaf is dark green, pinnatisect, with ovate or oblong acuminate membranous segments, that can grow to half a meter in length and about 15 cm in width.

The solitary inflorescence of *A. titanum* is comprised of a short peduncle (about 40–50 cm in length and 10 cm in diameter) of the same color as the petiole, and culminates in an enormous spathe whence emerges the spadix (Fig. 1). The spathe, which measures about 1.6 m in height and about 3 m in circumference, has a wide-

Fig. 1. Inflorescence of *Amorphophallus titanum* in the forest of Sumatra (175 cm tall).

Fig. 2. Opened inflorescence.

open upper part and is closely ruffled from the lower third to the edge, which is roughly cut into by short-tipped teeth (Fig. 1). At the base it is very light green, with the characteristic white spots, turning whitish towards the stiff, thick folds of the aperture at the top. Inside the spathe the purplish wine-red color of the upper edge gradually lightens until towards the base it turns yellow with marble-pink venations (Fig. 2).

From this base a sessile spadix extends which can reach 1.5 m in the largest individuals. In the immature flowers it is green, turning yellow or purple towards the top, and in the mature flowers it goes from purple with yellow spots to yellow-orange. It feels velvety and if touched becomes shiny. At the base of that structure are the reproductive organs, hidden in the vase formed by the lower part of the spathe; they take up a length of about 25 cm. The female flowers occupy the lower two thirds of the space, while the male flowers take up the upper third (Fig. 2).

When flowering is over, the stem of the spadix is the first to wither, followed by the spathe, which twists on itself, probably sealing the chamber so as to keep the pollinated flowers dry.

It has not yet been established how long *Amorphophallus titanum* takes to flower; we know only that the plant which bloomed at Kew in 1889, the only specimen which has been studied from Beccari's seed, took 10 years. Plants grown in botanical gardens have never been known to flower more than once. After this exhausting effort they all die within a short time, even though at Kew Garden in 1890 (Anonymous, 1890), and in Hamburg in 1929 (Winkler, 1931), the tuber produced one last leaf the year after flowering, and then died.

Seed reproduction seems to be the only certain method. Even though after flowering adventitious buds appear on a part of the tuber, a new plant has never been known to grow from these buds, and the many attempts at vegetative propagation made with these buds have all met with failure (Camp, 1937).

FIELD OBSERVATIONS

The vegetative part, unlike the inflorescence, is almost common in certain parts of the island. We came across it not only in Ajer Mantcior, where Beccari first discovered it (Beccari, 1930), but also in three other areas: in the center of Sumatra in the north-western part of the island, and in the hinterland of Padang province. These areas, though far apart, are all marked by the same abiotic factors: they are all between 400 and 1,000 meters above sea level, with a warm humid climate, regular rainfall and wide variation in daily temperature.

The vegetative part lives in more or less degraded secondary forests that are at points encroached upon by gum tree, fruit tree, and coffee plantations. The natives clean up only the part of the forest surrounding the trees they are interested in, the result is called by Laumonier "a mosaic of degraded vegetation and plantations" (Loumonier, 1983).

The plants live in the most varied light conditions and they emerge from very shallow forest undergrowth (<1 m) in the shade of high trunk trees. Although they seem to prefer half-shade, one can find them also in deep shade or in well-lit locales.

The plants occur in clusters of varying size: sometimes three or four are born attached with a few others plants in the immediate vicinity, or various specimens can be scattered within a radius of a few meters; it is quite rare to find completely isolated individuals.

It was very difficult to find plants in flower. We found some only in a circumscribed area of the island, where they are also rare. The flowering stations are on steep hills between 800 and 1,200 m above sea level. At this altitude, without prejudice to other characteristics common to the whole island, the daily temperature variation is remarkably wide: the day can be almost 10 degrees Celsius warmer than the night. Under a thin layer of humus the soil is sandy and quite loamy. In the area in which we found the inflorescence and the vegetative part there are no active volcanoes, but the soil is made up of an expanse of andesitic and rhyolitic lava, and dacitic and rhyolitic tuff (Dr. Guderson, 1995, pers. comm.).

Amorphophallus titanum in flower has been found also in secondary forests, where the spontaneous vegetation is interspersed with trees grown for food and for trade, *Hevea brasiliensis* in particular. In spite of the density of the vegetation, most inflorescences were found in rather open spaces, where there is almost no undergrowth, and where the light is not too direct: often the stations were abandoned plantations or cleared forests near a brook.

Stages of Development

In the course of the two expeditions eight inflorescences and four infructescences were found. The inflorescences were at various stages of development and it was possible to sketch a general outline of the flowering process. We will give a detailed description only of the specimen which we observed minute by minute as its blossomed. For the others we will just list the most significant characteristics.

The youngest specimen—according to our guides it was only a few weeks old, was 116 cm tall (Fig. 3). The spathe, green at the base and white towards the top, was spattered with white spots; it was completely wrapped around the spadix which emerged from it for 30 cm. The appendix was green and odorless with a filamentous interior. Inside the spathe was red at the base turning green towards the top. The purple-brown cataphyll splotched with white was still erect at the side of the spathe.

The spathe of another bud (174 cm tall) was still closed around the spadix, which was quite purple, stiff, and folded in pleats. The spadix's surface was velvety and its circumference at the end of the

Fig. 3. Youngest specimen, bud 116 cm tall.

Fig. 4. Inflorescence opening.

spathe measured 64 cm. Only from very close by could you discern a sharp smell of rotting flesh. The male flowers had not yet emitted pollen and the female flowers had not yet received it. We found some Coleoptera of the family of Curculionidae and Hybosoridae beetles, of the latter there were many *Phaeochroops emarginatus*.

The specimen we followed through the whole duration of the anthesis was in a relatively pristine secondary forest where gum trees grew sporadically. The inflorescence was on very steep terrain (its slope measured about 50%), faced east, and was quite shady in spite of a tree which had just fallen, creating an open, airy space. A few meters downhill was a brook.

When we reached the site at 11:30 A.M. the spathe was about 10 cm away from the spadix, its maximum circumference was 130 cm and the whole inflorescence was 175 cm tall, 159 cm without the peduncle (Fig. 4). In the immediate vicinity there was no smell but if you put your nose to the opening of the calyx you could distinctly perceive the stench of rotting flesh.

Every minute the smell became more and more intense and we supposed that soon the flower would open. We stayed to observe it the whole day and we did indeed witness an extraordinary spectacle: the inflorescence opened in the space of a few hours before our amazed and wondering eyes, revealing itself in all its splendor.

We tried to handle it as little as possible so as not to affect the unfolding process. The opening of the spathe was measured in 3 places and we saw that it moved away from spadix at the rate of about 2 cm every fifteen minutes. It continued to do so until about 3:30 P.M., when it slowed down; by 5:30 P.M. it had reached its maximum aperture: 102 cm in diameter (Fig. 1).

Ambient temperature remained steady at 26°C until about 2 P.M., when it rose to 27°C. The temperature of the inflorescence was taken at regular intervals with a con-

Fig. 5. *Phaeochroops emarginatus* going out of the cut spathe.

Fig. 6. *Trigona geissleri* resting on the stigma.

tact thermometer (Emplex Digi Mini) in two places: at the base of the calyx, between the spathe and the spadix, and on the surface of the latter.

The base was always one degree cooler than the surrounding environment, while the temperature of the spadix measured 26°C (ambient temperature) until about 2 P.M. when it rose to 28°C—one degree above ambient temperature. Before the inflorescence opened the surface temperature of the male flowers was found to be almost two degrees above ambient temperature.

The odor became more intense during the course of the day, and around 5 o'clock it seemed to change: it now stank of excrement rather than rotting flesh, the same process was noticed in *Arum maculatum* by Bermadinger-Stabentheiner & Stabentheiner (Bermadinger-Stabentheiner & Stabentheiner, 1995). The stench was so sharp and suffocating that it was impossible to approach the plant; it came in waves and only in certain directions, always emanating from the overlap of the spathe and almost always downhill from the flower, perceptible even several meters away. The overlap always faced downhill, southward (this was the case in the above-mentioned specimen as well), and here the stench was almost constant, whereas uphill it was nearly undetectable.

From the beginning we noticed that the same whitish powder we found in the inflorescences was present around the inside circle of the spathe in the lower part.

The appendix was green, shading into yellow toward the bottom. It folded in on itself in thick, stiff invaginations. Its maximum circumference was 62 cm.

As for insects, in the morning we noticed very few flies, but around 1 P.M.

Fig. 7. Inflorescence just after the blooming.

Fig. 8. Inflorescence just after the blooming.

swarms of flies, fruit flies, and bluebottle flies began to arrive. Many flies and *Trigona* bees hovered around the spadix and flew into the inflorescence alighting on the male and female flowers.

During the night there was a violent thunderstorm, and the morning after it was still raining. When we returned to the site at 9 A.M., it had not stopped raining and we found that the inflorescence had closed in four points, forming four loops or eyelets. According to the natives, who had came to check on the inflorescence during the night, the spathe had started closing only after the beginning of the storm, around 4 in the morning.

The overpowering stench of the day before was gone and there was only a bearable scent very close to the appendix, which had became completely yellow except for the tip. The circumference had not changed and neither had the stiffness. Eggs had been deposited along the fold that hosted the spider.

There were only a very few insects hovering around the spadix, nothing compared to the swarms of the day before. By lightly touching the male flowers we found that the pollen had not yet came out of the anthers.

In the course of the day the appendix became yellower and the smell disappeared almost completely. The appendix split open very easily under light pressure from a hard object, and the characteristic unpleasant odor wafted out from this fissure. Late in the afternoon the anthers began to release pollen. On the morrow we found that the inflorescence was even more closed, the loops having narrowed. The spadix had become completely yellow and quite wrinkled.

We proceeded to cut the spathe and only then did we discover the animals living at the bottom of the inflorescence: besides a few spiders there was a great num-

Fig. 9. Inflorescence at a more advanced stage.

Fig. 10. Window cut into the spathe showing male and female flowers.

ber of Coleoptera of the Histeridae and Hybosoridae families: *Phaeochroops emarginatus* (Fig. 5), (which we found also in *Amorphophallus paeoniifolius*), and an insect of the Blattaria order. Almost all the beetles were on the bottom of the spathe; very few were among the female flowers. Once we removed the spathe a great number of *Trigona geissleri* swarmed around the plant, and some were seen resting on the stigma (Fig. 6).

Another inflorescence was found to have completely shut after flowering: the spathe was closed around the spadix, but rather than wrapping around the appendix (as it would in a bud), it narrowed, like a bottleneck, at the upper fifth, forming a kind of collar under the top part of the petal (Fig. 7). Inside, the female flowers had already been pollinated and the male flowers had already released the pollen. The appendix was yellow and odorless and had secreted very sticky foamy yellowish droplets. The inner walls of the spathe (which had closed around the spadix) were wet, and at the bottom there was a yellowish liquid. Inside this inflorescence we found Formicidae and a Coleoptera (Brentidae): *Hormocerus compressitarsus.*

We found another inflorescence that had just opened, but in this one the spathe was close to the spadix and stuck to it in only a few points (Fig. 8). The spadix was yellow-orange and emitted a strong odor only if you smelled it from very close by. The female flowers had been pollinated and pollen was hanging from the male flowers in thin threads about 1 cm in length.

The appendix of a specimen at a more advanced stage was folded over the spathe, having lost its rigid structure (Fig. 9); it was yellow at the apex, turning red towards the bottom, with irregular yellow spots where the tissue was decaying; this was the only part which gave out a strong

Fig. 11. Threads of pollen going out of the male flowers.

Fig. 12. Inflorescence at the most advanced stage.

putrid smell. The female flowers had been pollinated, and the stigmas were covered with pollen. The inflorescence, which had wilted a few days before, did not give out any odor; only inside the appendix was the smell strong. The spathe, loosely closed around the appendix with a bottleneck three quarters of the length up, formed a liver-red crown. Without the appendix the spathe measured 1.57 m and with the erect spadix it measured 2 m.

Through the window cut into the spathe (Fig. 10) we saw that the inside was covered with a whitish powder and there was a yellowish skin of fungi at the base of the appendix. The ovaries were turgid and wine-red in color. The stamens were perfectly preserved and only in one point could you see the threads of pollen on them (Fig. 11).

The tuber was irregularly shaped, with a maximum circumference of 160 cm; it was 40 cm tall and weighed about 40 kg. Inside the inflorescence we found Coleoptera: Staphilinidae (already noticed by Jacobson in Van der Pijl L., 1937) and Scarabeidi, and *Trigona geissleri*.

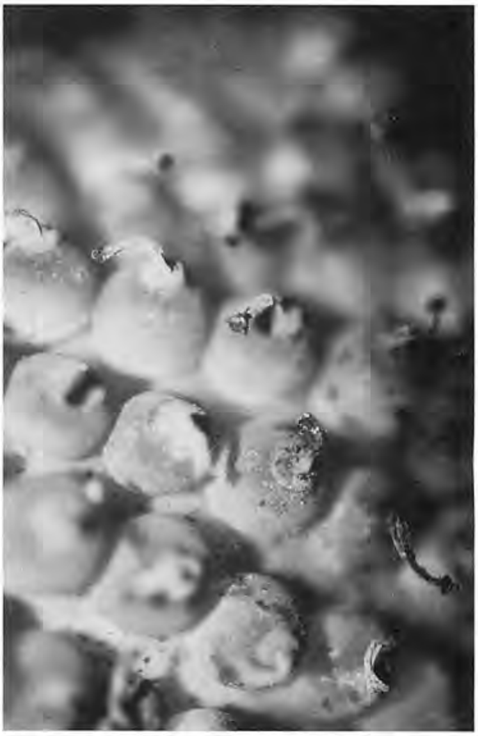

Fig. 13. Female flowers.

Fig. 14. Infructescence.

Fig. 15. Fruits.

The inflorescence that had reached the most advanced stage had wilted at least two weeks before (Fig. 12). The spathe and the spadix were completely rotten and they covered the part of the appendix that held the flowers, practically sealing it. The male flowers, which had maintained their original structure, were rotten and brown. In contrast, the ovaries of the female flowers were turgid and white, turning pink toward the top; the styles were wrinkled and dark-purple, almost black, and the white, turning pink toward the top; the styles and the stigmas were wrinkled and dark-purple (Fig. 13). Inside the spathe was completely wet.

The infructescences we found (Fig. 14) measured 140 cm in height: the 80 cm tall stalk was topped by an upper part, measuring 60 cm. The fruits jut out vertically from this upper part; they are quite numerous and at fructification the top of the plant resembles a cylinder covered with little tomatoes. At the base there are smaller fruits, some not yet developed, while towards the top the fruits were riper. When ripe the fruits are 3–4 cm long, red, smooth, and pulpy; in shape they resemble olives (Fig. 15).

The fruits have a rather large pulpy pericarp and contain 2–3 seeds, 4–4.5 cm by 2–3 cm. They are smooth and black on the outside; the external face is convex and the inner side is flat or carinate, with a central ridge.

Amorphophallus titanum has now been grown in the Botanical Garden of Florence since 1994. Its flowering is much longed for event as it has never bloomed in the city of its discoverer.

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