

Gymnostachys anceps R. Br.: Fruit, Germination, and a Discussion of the Possible Means of Dispersal

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ABSTRACT

Fruit of *G. anceps* is described, including the presence of a cavity at the apex of the endosperm. Germination occurred without dormancy in 34–40 days, with seedlings producing cataphylls before the first foliar leaf. Roots of seedlings were plump, lacked root hairs, were sparsely branched, and had proximal transverse wrinkles indicative of contractile roots. Possible means of dispersal are discussed, but observations support the contention that the fruit is passively dispersed, i.e. after abscission it falls to the ground around the mother plant and germinates among or under leaf litter and other debris.

INTRODUCTION

The genus *Gymnostachys* and its only species, *G. anceps*, is endemic to Eastern Australia, with a range as given in Shaw *et al.*, (1997). The first description by Brown (1810) was later considerably enlarged by Engler (1905). *Gymnostachys anceps* has been included in anatomical studies by Eyde *et al.* (1967); French (1985, 1986a, 1986b; 1987a–c); French and Tomlinson (1981); French and Kessler (1989); Ray (1987a, 1987b; 1988); Grayum (1990); and in a revised classification of Araceae by Bogner and Nicolson (1991). Its inclusion in the Araceae has been discussed by various investigators including Eyde *et al.* (1967); Tillich (1985); French and Kessler (1989), and French *et al.*, (1995). The present paper describes the fruit and its ger-

mination as well as discussing the possible means of dispersal.

SITES

Gymnostachys anceps occurred at the sites described below as an understory plant in open (wet sclerophyll, *Eucalyptus*, hardwood) forest (Shaw *et al.*, 1997). Fruit was collected on private properties in Queensland at Carbrook and Mt. Cotton, nearly 30 km in direct line southeast of Brisbane (27°28'S and 153°01'E) and in New South Wales (N.S.W.) at Coffs Harbour (30°19'S and 153°08'E). The plants were scattered on the top of a small hill at Mt. Cotton, and occurred in two stands at Carbrook and in four at Coffs Harbour, but a few plants also occurred between and around the main groups at each site.

FRUITING

Many plants at each site were non-flow-ering, even during the main fruiting season from about December to August/September in southeastern (SE) Queensland. For example, during one visit to Carbrook, only eight out of 48 plants in the stand had inflorescences (scapes). Fruit set was usually sparse (Fig. 1). It should be recognized, however, that mature fruit sheds easily, as is evident with a spadix from Coffs Harbour (Fig. 2). Therefore the number of fruit on a spadix at any given date may not reflect the total number of fruit set on that spadix over its entire fruiting period.



Fig. 1. Portion of scapes of *G. anceps* with fruit.



Fig. 2. Spadix of *G. anceps* with fruit attached and shed.

FRUIT

Fruit was first visible to the naked eye as squat domes about 1.5 mm high, pale green but with a purple tip protruding from the tepals (Fig. 3). The mature fruit was attached at its broad end to the spadix (Figs. 1 and 2) and is therefore ovoid, whereas Engler (1905) figured the fruit as being attached at its narrow end. Very occasionally the fruit was obpyriform. The tip of the fruit had a conical point ('apiculatae' in Engler, 1905), set in a slight rise or in a flat or even slightly depressed area about 0.5 to 0.8 mm across, with the conical point extending beyond the shoulders.

The color of the immature fruit was green. During maturation the coat began to darken with the underexposed areas coloring last. The conical point itself, however, was dark purple throughout development. At an intermediate stage the partially-colored coat made the fruit appear grey very occasionally with a faint bluish tinge. Later the color deepened to purplish

black (about 17F6 in the Methuen Handbook of Color, Kornerup & Wanscher, 1967). When five grey fruit were partially embedded in moist soil, three turned purplish black in four days, one in six days and the last in eight days. When five green fruit were so placed, one was grey after four days, two were light purplish black after eight days and another had turned grey; after ten days two were purplish black and three grey, and after sixteen days all had turned purplish black.

Brown (1810) described the color of the fruit of *G. anceps* as "caeruleae" and Engler (1905) as "coeruleae." Stern (1973) defines "caeruleus" as "blue, especially the deep blue of the Mediterranean sky at midday." However, Lewis & Short (1958) define "caeruleus" as "dark colored, dark blue, dark green, caeruleum, azure." "Purplish black" seems the most appropriate term for the color of the mature fruit examined. Some authors have described the color of the fruit as "blue," which may be



Fig. 3. Portion of spadix of *G. anceps* showing one developing fruit and many unfertilized florets.

an observed color but which was not encountered in the present study.

The fruit coat, which could be easily removed from the rest of the fruit, was about 0.4 to 0.6 mm thick. It consisted of an outer, soft, pigmented layer and an inner white, slightly translucent, soft layer traversed longitudinally from the base to the tip by vascular elements in the form of flat-tish white cords, some bifurcate, totalling about 14–16 and which could be lifted away from the pigmented layer with dissecting needles. Microscopically, the color of the outer fruit coat in thin sections was bright reddish purple, about 12C7 in Kernerup & Wanscher (1967). No starch granules were present in the seed coat.

Longitudinal median sections of fruit showed that the endosperm was firm and that a small cavity occurred just below the



Fig. 4. Longitudinal median views of four fruit of *G. anceps* showing cavity near apex of each endosperm.

tip (Fig. 4) somewhat similar to that described by Klotz (1992) in the mature embryo of *Orontium aquaticum* L. Microscopically the cells were packed with starch grains that were simple, round, oval to angular, mainly 2–4 μm long by 2–3 μm wide but up to 13.3 μm long by up to 7.6 μm wide.

The embryo was axile (central) in the mature fruit, pendulous from the distal half of the fruit, linear (i.e. several times at least longer than broad), not minute, fusiform to slightly clavate and about one-third to one-half the length of the endosperm. For example, in one fruit 11 mm long, the embryo was 5 mm long by 1.5 mm wide, while in another fruit 12 mm long, the embryo was 5.5 mm long by 1 mm wide. The embryo was white, often with a slightly bulbous greenish head towards the base of the fruit. The starchy embryo (Fig. 5d) could be easily lifted out of its lacuna with dissecting needles.

The sizes and weights of a sample of eleven fruit ex Carbrook collected in March were as follows: six purplish black fruit: 6–9 mm long by 4–6 mm wide, with mean weight of 0.1 g; green fruit: 7–11 mm long by 4.5–6 mm wide, with mean weight of 0.2 g. The sizes and weights of another group of 44 purplish black fruit ex Carbrook collected in April were: 6–15.5 mm long by 4.5–9.5 mm wide (with 28

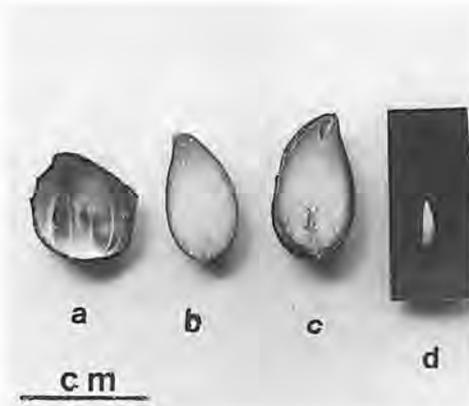


Fig. 5. Dissection of a mature fruit of *G. anceps*: a. One half of peeled fruit coat. b. Half of fruit after removal of coat, showing endosperm. c. Half of fruit with coat, endosperm with cavity at tip and lacuna near base after excision of embryo. d. Excised embryo (white).

fruit between 8 and 13 mm long) with weights from 0.12 to 0.72 g (with 26 fruit between 0.2 and 0.4 g).

The fruit is monospermous (with one seed), firmly succulent (starchy) and indehiscent (as the fruit does not split open to release the seed).

Purplish black fruit abscised naturally at the point of attachment of the spadix and fell to the ground. Purplish black fruit on scapes, collected in the field and placed in plastic bags, had sometimes abscised during transport to the laboratory. Mature fruit two days after collection, deliberately dropped into water from heights of 10, 20, 50 cm and 1 m sank immediately, as did a range of green fruit when dropped from a height of 50 cm. No odor was detected with the human nose, and small black ants (*Iridomyrmex* sp.) were not attracted to the fruit, which in any case, lacked elaiosomes.

GERMINATION

Fruit was half embedded (with the long axis horizontal) at the surface of moist sterile soil in pots covered by Petri dish lids, and watered from basal saucers. After

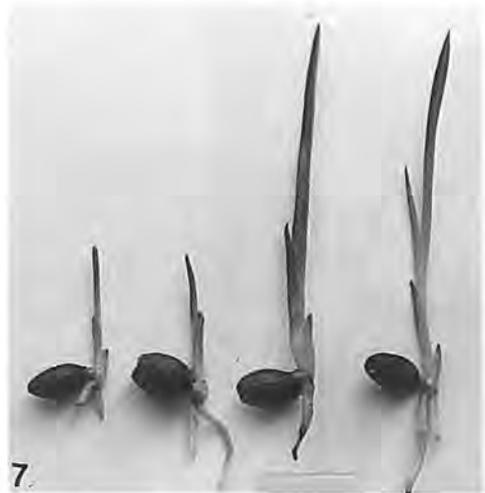
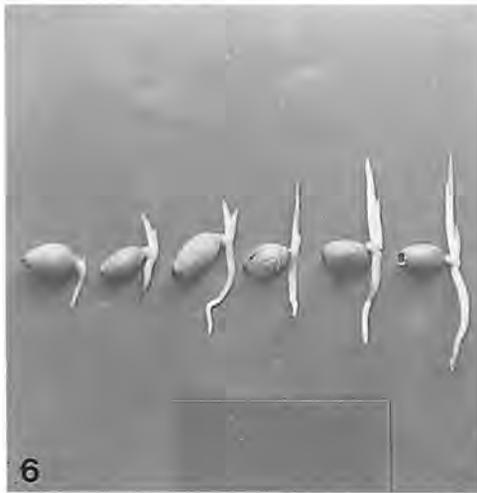
the appearance of the shoots the lids were removed and still later some of the seedlings were transplanted into the field.

The coats of fruit placed on moist soil began to decay after two weeks. By the time the first sign of germination occurred most coats had completely decayed, revealing the green endosperm, although occasionally the surface of the green endosperm was itself irregularly speckled purplish black. Fruit sown on 23 January showed the first sign of germination after 40 days. Fruit from the same collection sown on 29 April after being held at ambient temperature germinated in 34 days. Freshly collected fruit sown on 8 February showed the first sign of germination after 37 days. Fruit collected on 5 and 7 February germinated in 35 days. Purplish black fruit, collected on 18 April, held at ambient temperature and sown on 9 June were still viable and produced seedlings.

The first visible sign of germination was the appearance of the radicle at or near the basal end of the fruit. The pale green plumule later emerged through a "V" shaped slit in a short colorless sheath (perceptible under the stereomicroscope) on the upper side of the pale green hypocotyl. A sequence showing the progression of germination is shown in Figs. 6 and 7.

At this stage (Fig. 6) a few fruit still had the conical point at the apex intact, but in most the point had decayed, leaving a hole about 0.9 mm wide set in a brown ring of tissue 0.5 mm wide around the hole. In a few fruit the hole had enlarged to take up all the former apex of the fruit to the shoulders, as in the last fruit on the right in Fig. 6. This hole connected with the cavity at the tip of the endosperm.

The first cataphyll appeared on the side opposite to the attachment, followed by the second on the other side, a third often followed, and then the first foliar leaf (Figs. 6 and 7). The cataphylls were colorless with greenish tips but later became green throughout and showed lateral compression. Production of leaves of potted plants and field transplants was very slow; fruit sown on 18 April produced seedlings that at 9 months had only two or three



Figs. 6. Seedlings of *G. anceps* showing stages of germination, with radicles and cataphylls. Last fruit on right with large hole at apex. Fig. 7. Later stages of germination. Two larger seedlings with cataphylls and first leaves.

leaves each, the longest 42 cm. Seven seedlings raised in pots had a total of 19 leaves (mean of 2.7 leaves per plant, equivalent to 3.1 leaves per year) to 29 cm long, and 18 roots with six branches from four roots 10 1/2 months after sowing (Fig. 8).

The roots of all seedlings were plump, sparsely branched, and lacked root hairs (Fig. 8). In the Araceae, *Pistia stratiotes* L. has been recorded lacking root hairs (Schwarz, 1883; Tillich, 1985; and Shaw, 1992); *Typhonodorum lindleyanum* Schott (Shaw, 1992) and now *G. anceps*. The seedling roots also had irregular proximal transverse wrinkles (Fig. 8) indicative of contractile roots which are being described in a separate paper.

At Carbrook young plants (Fig. 9) were found around established flowering and fruiting plants. Inspection of the roots of a few of these showed that they were not connected with the mature plants and were therefore probably seedlings.

DISPERSAL

Shelton (1980) stated that "It is not known as to how the seeds of *G. anceps* are dispersed. It has been suggested that

they are dispersed by birds or water but this is only a supposition."

In considering the dispersal of *G. anceps*, it should be noted that the fruit itself, being indehiscent, is the disseminule [the smallest unit of seed dispersal (Spjut, 1994)] or the diaspore (a term given to dispersal units such as pollen, seed, fruit, and other propagules).

Suites of morphological characteristics of diaspores that are broadly although not absolutely associated with particular dispersal modes or agents have been recognized, although, as Howe (1986) stated, these are at best marginally predictive. They have been summarized by van der Pijl (1982) [as listed by Tiffney (1986)] and form the basis of the discussion below.

Fruit of *G. anceps* does not have the features which often indicate wind-borne diaspores, such as smallness, or wings, plumes or hairs, or other means of increasing the surface area. The fruit is also too heavy to be normally wind-borne, and although very high winds might deflect some of the smaller fruit, it would probably be incidental although not without import.

Fruit of *G. anceps* does not have any



Fig. 8. Seedlings of *G. anceps* showing proximal transverse wrinkles, sparse branching, and absence of root hairs; 10½ months-old.

specific adaptation for flotation, and it is unlikely that the fruit are water-borne diaspores, especially as fruit sank immediately when deliberately dropped into water. Of course, fruit lying on, in, and under leaf litter could be carried by surface runoff if the water were deep enough and the flow sufficiently strong, although if such did occur it would also probably be incidental although again not without import.

Gymnostachys anceps does not have any mechanism for active dispersal, as the fruit is not sticky and lacks hooks or stiff hairs, so it is unlikely to be transported on the outer surface of animals. Nor are there any oil or fat-rich elaiosomes that might attract ants, nor is it brightly colored or strongly scented and so is unlikely to attract reptiles.

It would also seem unlikely that the fruit would be dispersed by birds or mammals, because, even if eaten, it lacks a hard protective shell about the kernel necessary to protect the embryo during digestion.

It does not appear, therefore, that the fruit of *G. anceps* falls readily into any of the above modes. The presence of what appear to be seedlings (Fig. 9) has been noted in the vicinity of mature plants and this supports the contention, based on observations during the present study, that the fruit falls to the ground around the mother plant and germinates among or under leaf litter and other debris. Some plant species do have very limited distribution, with limitation of dispersal to the already occupied, obviously suitable spot. The stands at Mt. Cotton, Carbrook, and Coffs Harbour occupied by *G. anceps* are obviously 'suitable spots'.

The fact that germination occurs without dormancy means that fallen fruit are probably not long-term members of the soil seed bank. That is, their presence on or in soil as fruit would probably not be much longer than 5 to 6 weeks before the appearance of the radicles and plumules, if their behavior in nature is similar to that under laboratory conditions.

The above discussion refers specifically to what might be called local dispersal. It does not directly (although some of the lo-



Fig. 9. Two presumed seedlings (arrowed) of *G. anceps* at Carbrook, after partial removal of surface debris.

cal factors may be important) address the question of the geographical distribution of the species, which covers a range of over 2,000 km in Eastern Australia (Shaw *et al.*, 1997) and which is non-continuous with small and large breaks within areas and large breaks between regions.

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