Phenology of Blooming and Fruiting Habits in Euro-Japanese Hybrid Chestnut

Giancarlo Bounous,[1] James Hill Craddock,[2] Cristiana Peano[1] and Paolo Salarin[1]

[1]Istituto di Coltivazioni Arboree dell'Universita di Torino, Via Pietro Giuria 15, 10126 Torino; and,
[2]Istituto di Frutticottura Industriale dell'Universita di Torino, Via Ormea 99, 10126 Torino, ITALY

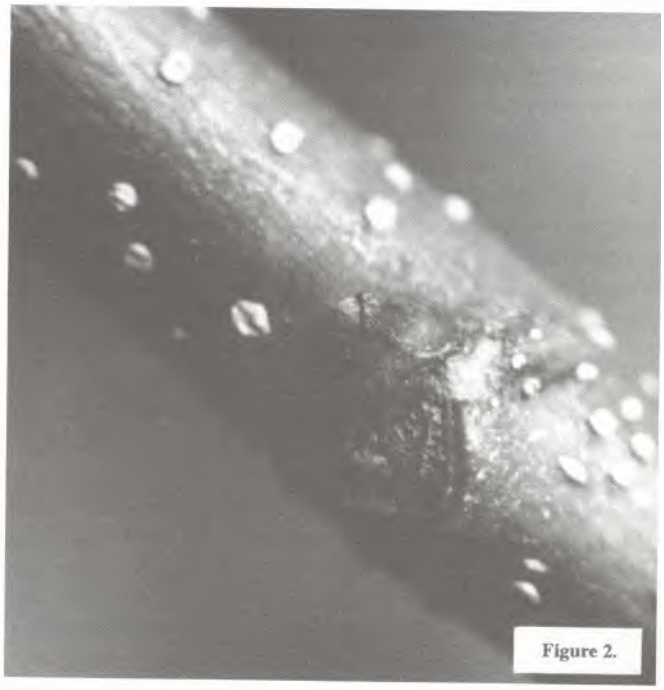
ABSTRACT. Developmental stages of the growth cycle from bud-swelling in the spring, through burr and leaf-drop in the autumn are described for hybrids of *Castanea crenata* and C. *sativa.* Most of the stages are presented in a photographic sequence that details the appearance of dormant vegetative and mixed buds, bud break, leafing out, staminate catkin development, catkin type (astaminate, brachystaminate, mesostaminate, logistaminate) (some examples from *C. sativa),* androgynous catkin development, pistillate flower development, full bloom, fruit set, ripening, fruit drop, yellowing of the foliage and leaf fall. Emphasis has been placed on the floral sequence in order that future work on chestnut may refer more precisely to the particular developmental moment within the phenological phase "bloom."

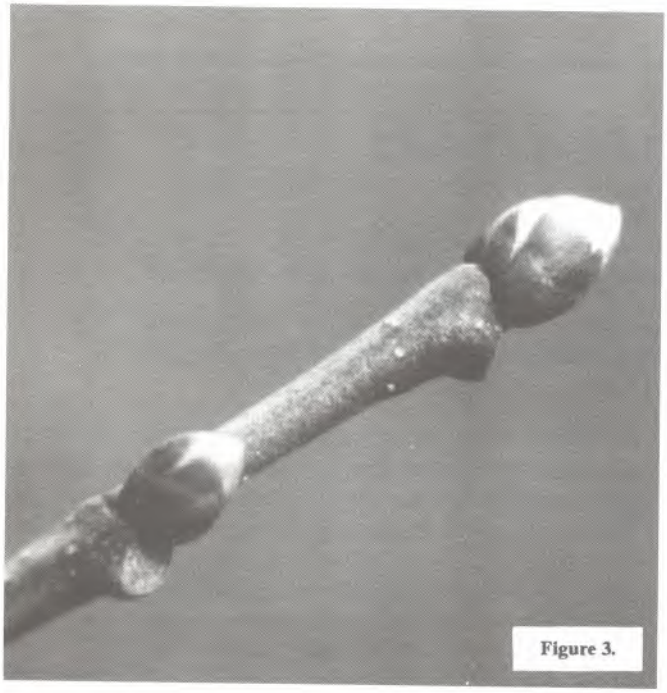
Apart from a few scattered orchards of Euro-Japanese hybrids planted within the last 20 yr, the Italian (and European) chestnut industry is based entirely on cultivars of *Castanea saliva* Mill. These varieties have proven themselves over centuries of selection throughout the different European chestnut-growing areas. However, chestnut blight, Phytophthora root rot and modern nut growing considerations have stimulated interest in cultivars and hybrids of the more resistant *C. crenata* Sieb. and Zucc. from Japan (5). The smaller tree size and more precocious bearing habits of the Japanese cultivars and hybrids would allow for more intensive orchard management and higher early returns.

The present work shows some aspects of the phenology, morphology and floral biology of Euro-Japanese hybrid chestnut cultivars through photographs that document the various vegetative and reproductive stages from bud-break in the spring to fruit and leaf-drop in the fall.

MATERIALS AND METHODS

Each salient phenological phase and particular detail is described and numbered and most of the phases are documented in photographic sequence. All observations, except where indicated, refer to Euro-Japanese hybrid chestnut *(C. crenata* x *C. sativa)* trees growing at Cumiana, in the province of Torino, 530 m above sea level. All data are from the 1990 and 1991 growing seasons.





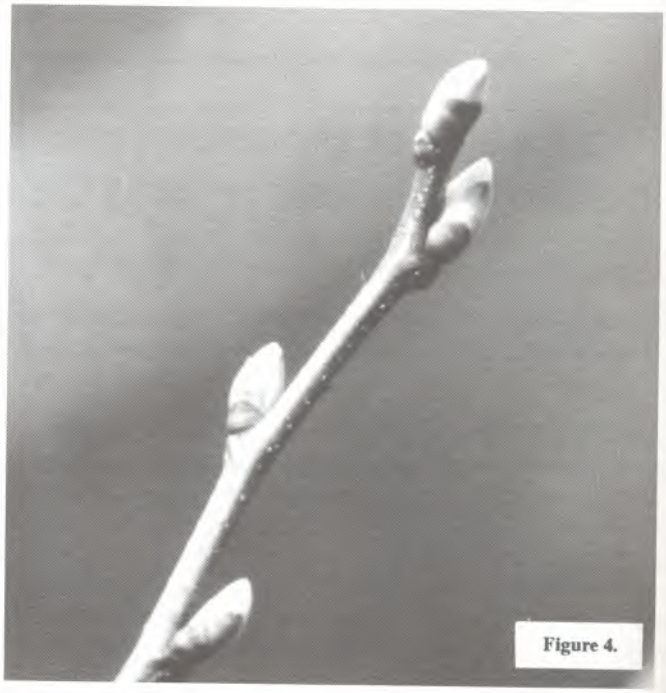


Figure 1. Dormant branchlet with mixed buds.
Figure 2. Vegetative bud.
Figure 3. Bud break.
Figure 4. Green showing.

Figure 5. Leaves evident.

Figure 6. Bud scale drop.

Figure 7. Opening of the leaves.

Figure 8. Leaves well distributed; stipules.

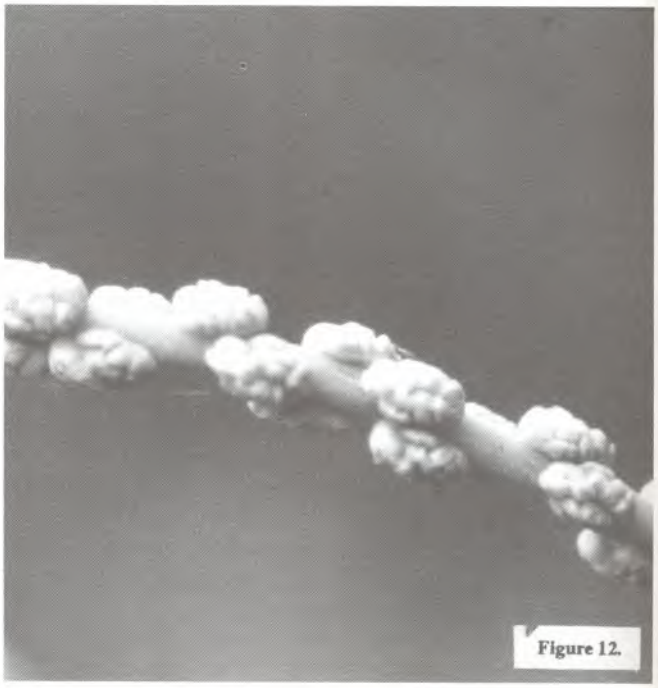


Figure 9. Appearance of the catkins.
Figure 10. Catkin during early development.
Figure 11. Elongating catkins.
Figure 12. Glomerules visible.

Figure 13. Emission of the stamens.
Figure 14. Full anthesis.
Figure 15. Astaminate catkin.
Figure 16. Longistaminate catkin.

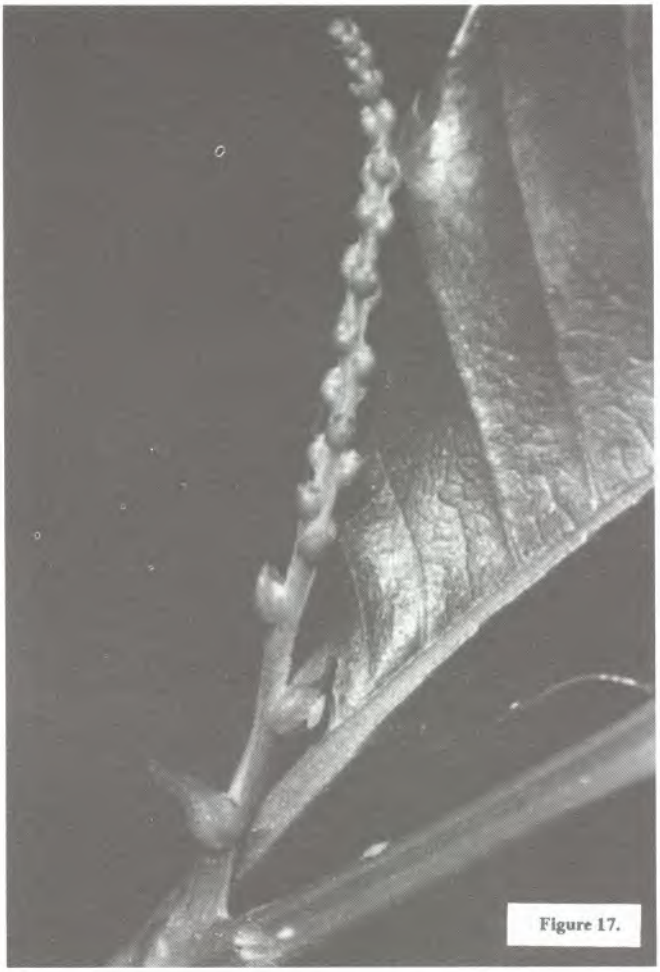
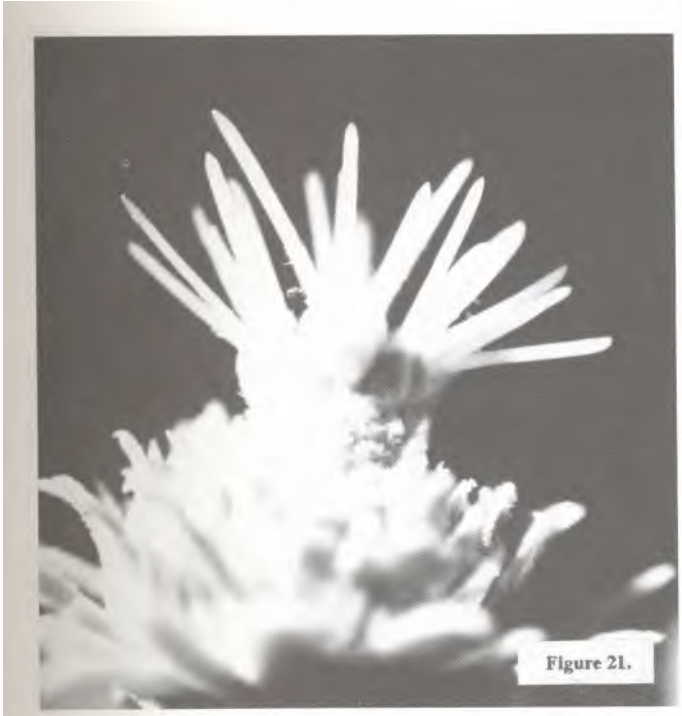
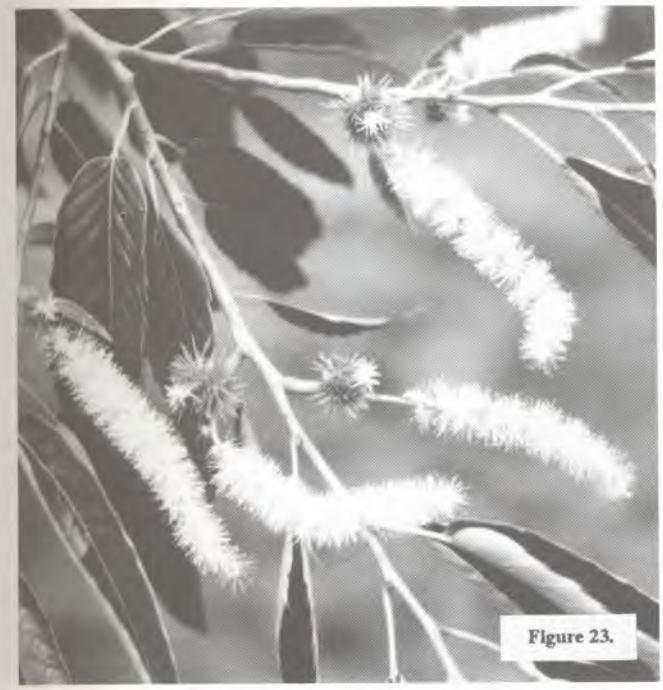


Figure 17. Appearance of pistillate inflorescence.
Figure 18. Emission of styles.
Figure 19. Elongation of styles.
Figure 20. Pistillate flowers at full bloom.





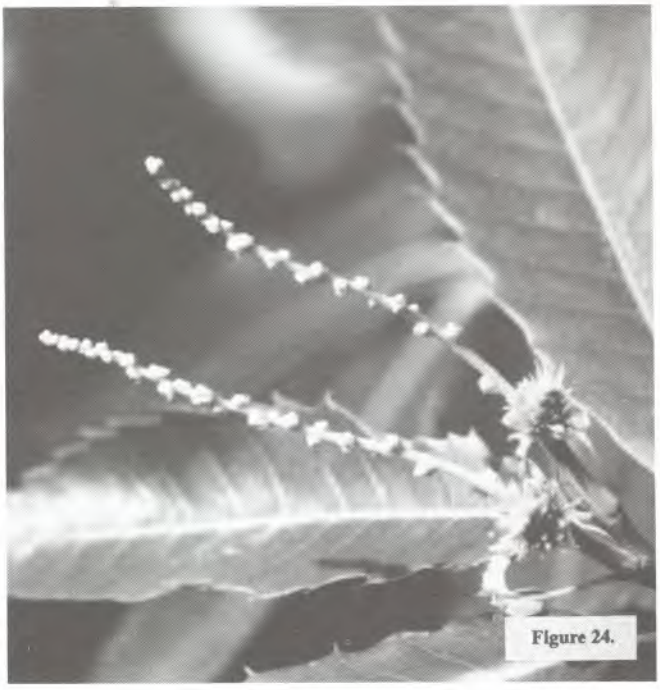


Figure 21. Pistillate flower, detail.
Figure 22. Pistillate flower, section.
Figure 23. Full anthesis, androgynous catkins of C. *crenata.*
Figure 24. Full anthesis, androgynous catkins of *C. saliva.*

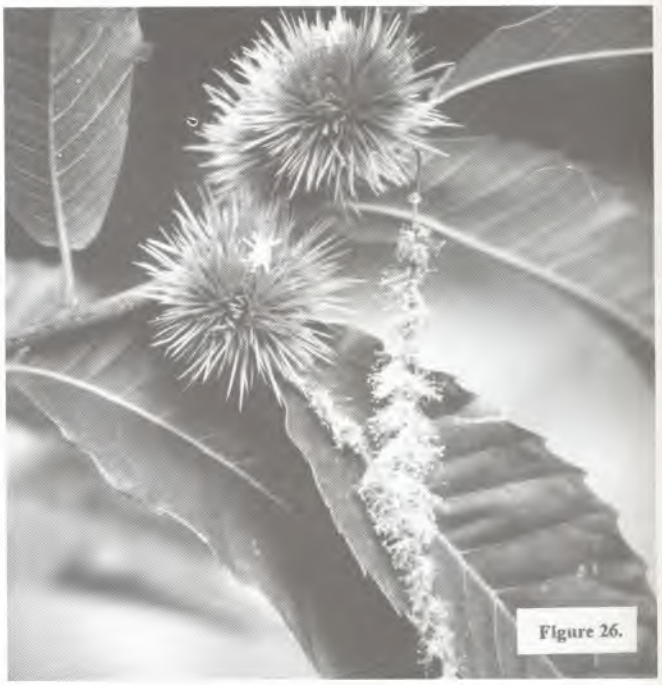


Figure 25. End of pistillate receptivity.
Figure 26. Androgynous catkin drop.
Figure 27. Growing burrs.
Figure 28. Yellowing of burrs.


Figure 29.


Figure 30.


Figure 31.


Figure 32.

Figure 29. Burrs opening.

Figure 30. Burr open, nuts fallen.

Figure 31. Fallen burr with nuts enclosed.

Figure 32. Yellow leaf and mixed bud.

RESULTS

Vegetative and mixed buds

1. Dormant branchlet with mixed buds. The branchlets have vegetative and mixed (vegetative/flower) buds present in more or less equal proportions. New shoots will arise from these buds. The apical and sub-apical mixed buds in *C. sativa,* and the intermediate and sub-apical buds in *C. crenata, C. mollissima* Bl. and their hybrids are born on last year's growth of the twig and give rise to the male and female inflorescences.

2. Vegetative bud. The bud scales enclose the primordia of the vegetative axes.

Bud-break and leafing-out

Chestnuts are generally late to begin leaf growth in the spring. Depending on the cultivar and the region where it is grown, leafing-out may begin any time from the end of March to the end of April. The time from leafing out to fruit maturation is normally between 140 and 185 days.

3. Bud break. The buds become turgid, causing within the span of a few days the breaking of the bud scales.

4. Opening of the bud scales with branchlet. Green showing.

5. Leaves evident. The young leaves may be distinguished.

6. Bud scales drop. The young leaves begin to unfurl and the bud scales fall away.

7. Opening of the leaves. The definite shape of the leaves begins to show.

8. Leaves well distributed along the new shoot. The leaves emerge with linear stipules that quickly fall. The leaf shape is generally elliptic-lanceolate, with round-acuminate base, crenate-serrate to coarsely dentate margins and with an acuminate tip. The average leaf length is 12-20 cm and width is 3-7 cm. The veins are very evident. The leaves of *C. sativa* have a leathery texture, are dark green above and lighter green below. *C. crenata* has smaller leaves with serrate, less dentate margins. *C. mollissima* leaves are intermediate in size and tomentose below with lepidote glands along midrib both above and below (10).

Staminate catkin development

9. Appearance of the catkins. The unisexual staminate inflorescences (catkins) may be distinguished from the androgynous inflorescences, which are catkins with pistillate inflorescences at the base. The appearance of the staminate catkins precedes that of the androgynous catkins. The process of flower differentiation in the buds is complex, involving numerous anatomical-morphological modifications and requiring a lengthy developmental period. Flower differentiation may begin during the last year's growth (13). Bergamini and Ramina (2) have observed that the final development of the single male and female flowers occurs during the first part of the vegetative cycle of the current year's growth.

10. Catkin during early development, length 10-15 mm. Both staminate and androgynous catkins are born in the leaf axils.

11. Distal portion of branchlet with elongating catkins.

12. Glomerules visible along the catkin. The staminate flowers are united into axillary glomerules of seven flowers each. An average of 40 glomerules are distributed along the axis of the catkin. Catkin length may vary from 10-40 cm according to the species and cultivar.

13. Emission of the stamens. The individual staminate flower is composed of a six-parted perianth and 8-12 stamens. The pollen is characterized by a very pungent odor. Breviglieri (7, 8) has suggested the following division of catkin types according to the presence or absence of stamens and the length of the anther filaments: astaminate; brachystaminate; mesostaminate; and, longistaminate.

14. Full anthesis. The blossoming period may vary according to the species, the cultivar and the climatic conditions. Full anthesis is considered to be the moment at which at least 50% of the catkins have open flowers. Pollen may be produced for more than a month due to the scaled anther dehiscence. Catkin drop (photo not shown), progressive drying and falling of the catkins correspond to diminishing pollen production.

Catkin type

15. Astaminate catkin. The flowers without stamens are morphologically sterile; no pollen is produced. The central portion of the flower is occupied by silky filaments. The Italian cultivars known as 'Marrone' are generally characterized as having astaminate catkins.

Brachystaminate catkin (not shown). The stamens *are* from 1-3 mm long and do not extend beyond the perianth. The anthers appear normal yet pollen emission is very scarce.

Mesostaminate catkin (not shown). The stamens are from 4-5 mm long and extend barely beyond the margin of the perianth. Pollen production is limited.

16. Longistaminate catkin. The stamens extend well beyond the perianth and are from 7-9 mm long. Abundant pollen is produced.

Androgynous catkin development

17. Appearance of the pistillate inflorescences at the base of the more distal catkins. The female flowers are united in groups of usually three in a prickly involucre. From two to five (sometimes many) of these involucres may develop yet rarely more than 3 will be fertile.

Pistillate flowers

18. Emission of the styles. Seven to nine styles are held within each individual six-parted pistillate flower.

19. Elongation of the styles. The styles will eventually reach a length of 4 to 6 mm.

20. Pistillate flowers at full bloom. The styles are ridged, cylindrical, woolly at the base and glabrous at the

tip. Their color may vary from greenish white to very light yellow. The stigmatic surface is located at the very tip (11).

21. Pistillate flower, detail. It is the spiny involucre that develops into the burr.

22. Pistillate flower, section. Each female flower contains 6-9 ovules and an inferior 6-9 celled ovary. Each flower will give rise to one chestnut that may, however, contain one or more embryos.

Full bloom

Full anthesis in androgynous catkins. The central of the three flowers in each pistillate inflorescence will reach peak receptivity four or five days before the lateral flowers (14). Full bloom is considered to be when styles of all of the three flowers are completely visible.

23. C. crenata. The androgynous catkins of the Japanese and Euro-Japanese cultivars will be mesostaminate or longistaminate.

24. C. sativa. The androgynous catkins of the European cultivars will be astaminate or brachystaminate.

25. End of pistillate receptivity. Pistillate bloom may last from three to four weeks, after which the styles begin to brown and the ovules, if fertilized, begin to grow.

26. Androgynous catkin drop. The staminate portion of the androgynous catkin will dry at the end of pistillate receptivity yet may remain intact throughout the development of the burrs.

Fruit set

27. Growing burrs. The fecundated pistillate inflorescences begin immediately developing into spiny burrs. The burrs grow steadily from July through September/ October when they reach their maximum size.

Ripening **and nut drop**

28. Yellowing of the burrs. When the chestnuts have reached maturity the burr begins to turn color from green to yellowish brown. The ripening process may follow one of several different possibilities; the burrs may open, splitting at maturity into two to four valves (29), dropping the nuts to the ground while remaining on the tree (30), or the burrs may fall more or less intact with the nuts enclosed (31). Each of these two modes has consequences on the subsequent harvest and handling of the chestnuts. Nut drop in the burr (protected by the involucre) may facilitate mechanical harvest and help prevent damage to the nuts. If, instead, the burrs were to remain on the tree, one of the major burdens of hand harvest would be eliminated.

Yellowing of the foliage and leaf fall

32. Yellowing and abscission of the leaves and mixed bud. The chestnut tree begins its vegetative rest period sometime between the end of October and the middle of November.

DISCUSSION

The genus *Castanea* is ascribed to the order Fagales and to the family Fagaceae (Cupuliferae) (9). It includes some 7-13 species (9, 12) native to the temperate zones of Asia, Asia Minor, Mediterranean Europe and the eastern portion of North America. The species of major importance are *C. mollissima* (Chinese chestnut), *C. sativa* (European chestnut) and C. *crenata* (Japanese chestnut). A monoecious plant, the chestnut has an annual vegetative and reproductive cycle that involves a winter rest period, from November to April in north-temperate climates, and a period of intensely active vegetation during which shoots, leaves, floral organs and fruit grow and develop. Italian (1, 2, 3, 4, 6, 15) and French authors (3, 15) have proposed graphic representations of the developmental stages. However, as far as the particular structures of the flowers are concerned, and the differences among the different species, there appears to be a lack of specific references.

Accurate descriptions of the phenological phases may facilitate selection of cross compatible pollinizer varieties and may be useful to chestnut breeders. The present work should allow chestnut researchers to standardize their field observations from year to year and from location to location. It is hoped that this work will contribute to the knowledge of the ontology of the buds and flowers of the chestnut by clarifying the different stages of development and that it may have some practical application as well.

LITERATURE CITED

1. Bergamini, A. 1975. Osservazioni sulla morfologia fiorale di alcune cultivar di castagno. Riv. Ortoflorofrut. Italiana 59:103-109.
2. Bergamini, A. and Ramina, A. 1971. Contributo allo studio della differenziazione a fiore del castagno *(Castanea saliva* L.). Riv. Ortoflorofrut. Italiana 55:484-491.
3. Bergougnoux, F., Verlhac, C., Breisch, H. and Chapa, J. 1978. Le Chataigner-Production et Culture. INVUFLEC (Malmort) Paris, France. 192 pp.
4. Bounous, G. and Ottino, M. 1984. Rilievi fenologici su 14 cultivar di castagno giapponese ed ibridi eurogiapponesi in Piemonte. Pages 63-84 in: Cogreso Internacional sobre el Castaño, Lourizan 1-5 Octubre 1984. Dept. Invest. Forest. de Lourizan, Pontevedra, Spain. 429 pp.
5. Bounous, G. and Paglietta, R. 1982. Castanicoltura da frutto: situazione e possibility di rilancio. Frutticoltura 44:15-24.
6. Breviglieri, N. 1951. Ricerca sulla biologia fiorale e di fruttificazione della *Castanea sativa* e *Castanea crenata* nel territorio di Vallombrosa. Pubblicazione n. 1, Centro di Studio sul Castagno (C.N.R.). La Ricerca Scientifica (suppl.) 21:15-49.
7. Breviglieri, N. 1955. Ricerche sulla disseminazione e sulla germinazione del polline nel castagno. Pubblicazione n. 2, supp. del Centro di studio sul Castagno, (C.N.R.). La Ricerca Scientifica 25:5-25.
8. Breviglieri, N. 1955. Indagini ed osservazione sulle migliori varieta italiane di castagno. *(Castanea saliva,* Mill.). (Primo contributo). Pubblicazione n. 2, Centro Studio sul Castagno (C.N.R.). La Ricerca Scientifica (suppl.) 25:27-166.
9. Camus, A. 1929. Les châtaigniers. Monographie des genres *Castanea et Castanopsis.* Encyclopedia economique de sylviculture, t. III. Lechevalier, Paris, France. 600 pp.
10. Graves, A.H. 1961. Keys to chestnut species. Ann. Rep. North. Nut Growers Assoc. 52:78-90.
11. Harrison, R.E. 1991. Determining the location of the receptive stigmatic surfaces in *Castanea dentata* Borkh. J. Am. Chestnut Foundation 6:107-109.

12. Johnson, G.P. 1987. Chinkapins: Taxonomy, distribution, ecology and importance. Ann. Rep. North. Nut Growers Assoc. 78:58-62.
13. Pisani, P.L. and Rinaldelli, E. 1991. Alcuni aspetti della biologia fiorale del castagno. Frutticoltura 53:25-30.
14. Shimura, I., Yasuno, M. and Otomo, C. 1971. Studies on the breeding behaviors of several characters in chestnuts, *Castanea spp.* II. Effects of the pollination time on the number of nuts in the burr. (Japanese with English summary). Japan. J. Breed. 21:77-80.
15. Solignat, G. and Chapa, J. 1975. La biologie Borate du Chataignier. Institute National de Vulgarisation pour les Fruits, Legumes et Champignons, INVUFLEC (Paris), France.