Amer. J. Bot. 70(3): 466–468. 1983.

BREEDING SYSTEMS AND FECUNDITY IN THE AMERICAN GINSENG, PANAX QUINQUEFOLIUM (ARALIACEAE)[1]

WALTER H. LEWIS AND VINCENT E. ZENGER

Department of Biology, Washington University, St. Louis, Missouri 63130

ABSTRACT

American ginseng is self-compatible with fecundity among bagged inflorescences equivalent to (Missouri) or greater (New York) than that observed for nonbagged inflorescences. Population differences in flowering time and synchrony, protandry, autogamy, xenogamy, and fecundity, imply major genetic divergence in the species.

TWO POLLINATORS have been suggested for *Panax quinquefolium* (Duke, 1980a, b), the common visitor *Dialictus* (halictid sweat-bee) and also the less frequent *Toxomerus geminatus* (syrphid hover-fly). Although Bae (1978) reported cultivated Oriental ginseng, *P. ginseng,* as self-pollinating with a success rate of approximately 90% among bagged inflorescences, little information exists on either the breeding system or fecundity of *Panax.* This hiatus prompted us to examine pollination biology and fruit set of *P. quinquefolium* in an indigenous population near Eolia, Missouri and in a woods-grown population near Bovina Center, New York.

Typically, *P. quinquefolium* reproduces sexually, the single inflorescence forming on a solitary, leafy, aerial shoot (Lewis and Zenger, 1982). The inflorescence is a hemispherical umbel with a centripetal maturation of perfect flowers. Shortly after floral buds open, stamens and petals dehisce.

MATERIALS AND METHODS—Random inflorescences of plants with 15–20 leaflets were bagged prior to anthesis on 24 June 1981, and 17 June 1982, (MO) and 13 July 1981, (NY). Bags (Lawson #217, Norfield, IL 60093) were removed 31 August and 25 August (MO) and 15 September (NY), and all infructescences were fixed in a solution of formaldehyde-glycerin and numbers of fruit recorded.

RESULTS—In Missouri, plants began flowering in late June and continued up to 8 wk, with 1–3 flowers open at one time. Flowering in New York began later, on 10 July, and lasted for only 3 wk. As many as eight flowers were open simultaneously. The Missouri plants were weakly protandrous with some flowers having their anthers and stigmas maturing simultaneously, while in New York all flowers were markedly protandrous.

During flowering the Missouri population was visited by *Dialictus zephyrus* Smith and *Evylaeus* sp. (Halictidae). Pollen of *P. quinquefolium* was found on the abdomen of *Dialictus* (Fig. 1). Sweat-bees were also observed among umbels in the New York population, but samples were not obtained for identification.

All plants with bagged umbels produced fruits and were therefore self-compatible. Emasculated floral buds when bagged produced no fruit (Mark A. Schlessman, pers. commun.), thereby excluding apomixis. There was no difference in the proportion of flowers that formed fruit in bagged and nonbagged Missouri plants ($\chi^2 = 0.019$, df = 1), but there was a significant difference in the proportion of New York bagged flowers which formed fruit ($\chi^2 = 124.52$, df = 1, $P < 0.001$) compared to nonbagged flowers. The percent of nonbagged flowers per umbel that set fruit in Missouri was $\bar{x} = 27.1 \pm 9.9$; it was significantly lower in New York, $\bar{x} = 14.2 \pm 12.1$ ($t = 2.96$, df = 28, $P < 0.01$). In contrast, percent fecundity of bagged inflorescences was much greater in New York ($\bar{x} = 77.8 \pm 11.6$) than in Missouri ($\bar{x} = 25.3 \pm 7.6$), the difference being highly significant ($t = 14.81$, df = 28, $P < 0.001$). Clearly fecundity was greatly enhanced by bagging in the New York population, but not among Missouri plants.

On 31 August, 1981 in Missouri there were greater numbers of red compared to green fruits in bagged (5.6 ± 1.7 red and 1.9 ± 1.4 green) versus nonbagged (3.7 ± 2.5 red and 2.7 ± 1.2 green) umbels. The significant difference

[1] Received for publication 29 April 1982; revision accepted 6 November 1982.

We thank Arthur W. Rashap and Edmund Millar, Cold Mountain Farm, Bovina Center, NY for participation and assistance in the research, and Dr. S. W. T. Batra, U.S.D.A., Beltsville, MD for determinations of *Dialictus* and *Evylaeus.*

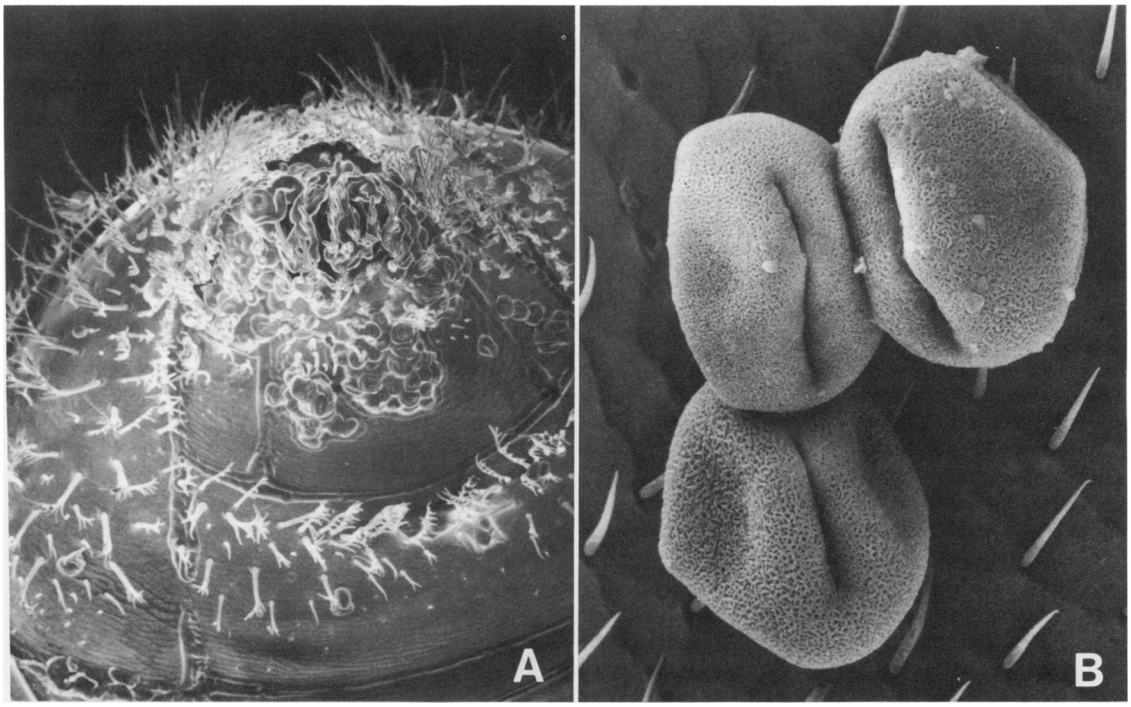

Fig. 1. SEM of *Dialictus* sp. (Halictidae) female with pollen grains. **A.** Abdomen showing attachment of various pollen grains. ×100. **B.** Foreleg with pollen of *Panax quinquefolium.* ×1,400.

($\chi^2 = 4.61$, $P < 0.05$) implies that some environmental factor, such as greater concentration of ethylene or increased temperature in bagged infructescences, contributed to more rapid fruit maturation. Such a distinction was not observed in 1982.

DISCUSSION—Bell (1971) observed that apiaceous umbels produce flowers in large numbers that are small and closely spaced, and that each insect visitor to the inflorescence is a potential and probable pollinator. Certainly the promiscuous *Dialictus,* and perhaps also *Evylaeus* and *Toxomerus,* contribute to cross-pollination in *P. quinquefolium.* Yet for *Aralia hispida* both major and minor pollinators showed preference for umbels with many open flowers (Thomson and Barrett, 1981), suggesting that vector visits to the few-flowering inflorescences of Missouri ginseng may be limited because of pollinator discrimination. Thus, potential pollinators may not show sustained preference for umbels having few open flowers, and thereby effectively limit xenogamy. On the other hand, as dichogamy is poorly developed or absent and as self-compatibility has been demonstrated, autogamy must account for some, or perhaps a significant proportion of total fertilizations. Geitonogamy is also undoubtedly involved largely because of visitors and resident thrips in ginseng inflorescences (also found in the Apiaceae, Bell, 1971); these insects could also contribute to autogamy. Even with xenogamy, autogamy, and geitonogamy, however, only about one-quarter (27.1%) of flowers among Missouri ginseng set fruit during the prolonged flowering season. Perhaps resource depletion is sufficient to prevent maximum fruit production of fertilized flowers after a critical time during the summer.

Even fewer flowers (14.2%) from the New York population set fruit following a more synchronized period of flowering in July. As these plants produce multiflowering umbels, pollinator discrimination should be limited and xenogamy a major factor in fertilization. Moreover, as protandry is well-developed, autogamy must be rare. Presumably the opportunity for geitonogamy exists, but rapid staminal dehiscence with synchronized flowering allows little pollen for insects and interfloral contacts to affect pollination within umbels.

These observations suggest major diversity in floral biology, breeding, and fecundity among two populations of American ginseng. The breeding system found in the Missouri popu-

lation has greater reproductive potential but should lead to greater homozygosity, while in New York reduced reproductive potential was observed but greater heterozygosity can be expected. Additional populations from other regions must be studied, however, before adaptive significance can be implied from this divergence.

LITERATURE CITED

BAE, H.-W. (ed.). 1978. Korean Ginseng, p. 54. Korea Ginseng Research Institute, Seoul.

BELL, C. R. 1971. Breeding systems and floral biology of the Umbelliferae or evidence for specialization in unspecialized flowers. *In* V. H. Heywood [ed.], The biology and chemistry of the Umbelliferae, pp. 93–108. Academic Press, New York.

DUKE, J. A. 1980a. Pollinators of *Panax*? Castanea 45: 141.

———. 1980b. Preliminary studies on a Maryland ginseng population, pp. 49–52. Proc. 3rd Internat. Ginseng Symp., Korea Ginseng Research Institute, Seoul.

LEWIS, W. H., AND V. E. ZENGER. 1982. Population dynamics of the American ginseng *Panax quinquefolium* (Araliaceae). Amer. J. Bot. 69: 1483–1490.

THOMSON, J. D., AND S. C. H. BARRETT. 1981. Temporal variation of gender in *Aralia hispida* Vent. (Araliaceae). Evolution 35: 1094–1107.