

# Pollinator Contribution to the Production of Cowpea in the Amazon

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**Abstract.** Cowpea, *Vigna unguiculata* (L.) Walp., is a very important legume in the diet of the population of the Amazon. Although it is autogamous, this species has a cross-pollination rate of  $\approx 10\%$ . Over several years, the mean productivity of cowpea has declined. We suggest that this is linked to a decrease in or an absence of pollinating insects in the fields. The objective of this study is to ascertain the pollinator contribution to cowpea production, as well as to determine the pollination type of the 'BR3-Tracueteua' cultivar. In an experimental design, four treatments were compared: no pollination, with flowers in cages to prevent insect visits; open-pollination, with flowers exposed to all visiting insects; self-pollination, with flowers pollinated with their own pollen; and cross-pollination, with emasculated flowers being pollinated manually with pollen from another plant. We observed higher fruit set in the presence of pollinators (83%) than in their absence (77%, caged flowers). However, cross-pollination reduced both the number of seeds per pod and fruit set relative to self-pollination. This result suggests that pollinators have a complementary role in the yield of cowpea, by creating a mixed pollination system where self-pollination dominates.

The "caupi," known in English as cowpea, and in French as "haricot mongette" and "niebé" (Maréchal et al., 1978) is an annual herb crop of the Papilionaceae family (Purseglove, 1968), with an inflorescence composed of two to eight papilionaceous, whitish, yellowish, or violet flowers (McGregor, 1976). The flower is pentamerous, hermaphroditic, and has ten stamens and one carpel (Joly, 1976). Its fruit is a pod, 20 to 50 cm long, bearing from eight to twenty seeds (McGregor, 1976).

This species of African origin (Faris, 1965; Maréchal et al., 1978) is disseminated worldwide, but particularly in the tropics and subtropics (Faris, 1965; Purseglove, 1968; Steele, 1976). In the Amazon, cowpea is one of the most important basic food sources, especially

for rural and riverine populations, often replacing bean (*Phaseolus vulgaris* L.) as a protein source (Yuyama, 1981). Rêgo et al. (1970) obtained 27.1% to 27.2% protein content in *Phaseolus* seeds vs. 22.8% to 24.8% in *Vigna* seeds. Generally, the protein content of cowpea varies between 22.3% and 32% (Ologhobo and Fetuga, 1982; Omueti and Singh, 1987; Purseglove, 1968; Yuyama, 1981).

In the Amazon, cowpea production is nine times that of beans (Teixeira et al., 1988), which are not well adapted to its climatic and edaphic conditions (Yuyama, 1981). However, the mean productivity of cowpea is generally inferior to that of beans, and has declined over the years in the areas under production. Indeed, the productivity of cowpea in Amazonas state fell from 1234 kg·ha<sup>-1</sup> in 1970 to 776 kg·ha<sup>-1</sup> in 1985. In the state of Pará, productivity declined 22% between 1970 and 1985 (Teixeira et al., 1988). According to Teixeira et al. (1988), this may have been caused by its geographic spread into sites that are less ecologically appropriate, as well as because of the infrequent use of adequate cultivation techniques. We hypothesize instead that this decline could be caused by a decrease in, or absence of, pollinators in cowpea fields, as a result of burning during forest clearing, which kills pollinators and destroys their nesting sites. Other factors include the increase in cultivated areas that decreases the availability of potential nesting sites, and the use of pesticides on adjacent crops, e.g., coconut (*Cocos nucifera* L.) and passion fruit

(*Passiflora edulis* Sims.). Thus, the interaction of all of these factors may cause a large reduction in pollinator populations.

Cowpea flowers are capable of self-fertilization, and this is probably the most frequent type of reproduction (Robbins, 1931). According to Blackhurst and Miller (1980), self-pollination occurs even before flower opening. However, the cross-pollination rate can vary between 1% and 4% (Blackhurst and Miller, 1980; Steele, 1976; Williams and Chambliss, 1980), and even up to 10% (Rachie and Silvestre, 1977), depending on the climate (Purseglove, 1968; Rachie and Silvestre, 1977), the cultivar, or, more specifically, the populations of bumblebees or domestic bees that are present (Blackhurst and Miller, 1980; McGregor, 1976; Rachie and Silvestre, 1977).

Extrafloral nectaries are located at the base of the corolla (Gopinathan and Babu, 1987; Purseglove, 1968; Summerfield et al., 1974), and intrafloral nectaries at the base of the ovary (Ojehomon, 1968a), both of which attract many insects. The flowers are often visited by domestic bees and by bumblebees (Hedström and Thulin, 1986; Rachie and Silvestre, 1977; Robbins, 1931), which can pollinate the cowpea (Gopinathan and Babu, 1987; Purseglove, 1968; Summerfield et al., 1974). Thus, the reduction of pollinators could lower the ratio of seeds originating from self-fertilization to those originating from cross-fertilization (Conseil National de Recherches du Canada, 1981). Finally, the importance of cowpea as a food source in the Amazon has led us to the study of the plant-pollinator-production relationships, in order to improve production. Therefore, the objective of this study was to ascertain the contribution of pollinators to cowpea production, as well as to determine the pollination type of the 'BR3-Tracueteua' cultivar.

## Materials and Methods

This study was conducted from July to Sept. 1996 in the Brazilian Amazon, in the state of Pará, at the Centro de Pesquisa Agroflorestal do Trópico Úmido (EMBRAPA-CPATU), located 1 km from the town of Tracueteua (01°16'40"S; 48°20'00"W). We used the cultivar BR3-Tracueteua in an area covering 13.3 ha and containing  $\approx 884,000$  plants.

Seventy-six plots, each 1 m<sup>2</sup>, were randomly selected over the entire field. Each plot contained  $\approx 20$  flower buds distributed on seven plants. The total sample was 1499 flower buds, which were labeled 24 h before anthesis. They were identified by attaching short lengths of colored wool to the peduncle of the inflorescence, so as not to damage the flower bud; each color identified a treatment. After the third day, wool markers were moved to the flower pedicel. Only the two flower buds at the base of the inflorescence were used in this study, in order to standardize fruit set potential.

The following four treatments were applied: 1) no pollination control (NP); 2) open pollination (OP); 3) self-pollination (SP); 4)

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cross-pollination (CP). Except for the open-pollination treatment, the flower buds were kept isolated from pollinators by enclosing them in cages from 1 d before to 1 d after anthesis. Rectangular cage frames (2 × 0.5 × 0.5 m) were constructed and covered with muslin.

For the self-pollination treatment, flowers were pollinated manually with their own pollen, between 7:00 and 9:00 AM, and then covered again. For the cross-pollination treatment, flower buds were emasculated the day before anthesis, between 4:00 and 6:00 PM, using the method described by Rachie et al. (1975a). They were caged until the next day, when the opened flowers were pollinated manually between 7:00 and 9:00 AM, using pollen from another plant, and then covered again.

Fruit set was calculated as the number of pods harvested divided by the initial number of labeled buds. We then compared the fruit set of the four treatments using the Chi-square test. Data for the number of seeds per pod were analyzed by analysis of variance, followed by a Tukey means comparison test (Scherrer, 1984).

## Results and Discussion

**Pollinator contribution.** Open pollination increased fruit set from 77.2% (no pollination treatment) to 83.5% (Fig. 1A;  $X^2 = 4.444$ ;  $\alpha = 0.035$ ).

Pollinators seem to play a relatively important complementary role in cowpea production, especially in genotypes that produce male-sterile flowers and whose fertilization depends exclusively on cross-pollination (Rachie et al., 1975b; Sen and Bhowal, 1962). Furthermore, self-pollination is prevented in some genotypes because the anthers remain trapped in the corolla as the stigma emerges and grows out of reach of the anthers (Rachie et al., 1975b). Pollination in these flowers requires that a pollinator either transfer pollen from another plant or mechanically force the release of the trapped anthers to facilitate self-pollination. We observed the latter action by bees. Arriving on a flower, they would exert some force on the carina while collecting nectar or pollen. They caused a back and forth movement of the wings of the flower, whose edges, by touching the anthers, could transfer pollen grains to the stigma, probably causing self-pollination. Such "tripping" mechanisms have been described previously (Arroyo, 1981; Gopinathan and Babu, 1987; Purseglove, 1968; Summerfield et al., 1974).

Whatever the role of pollinators, their contribution to the production of cowpea in the Amazon is higher than indicated (2% to 4%) by previous studies in Alabama (Williams and Chambliss, 1980) and in Senegal (Steele, 1976). This discrepancy may be a result of the cultivar used (Blackhurst and Miller, 1980) or of the high humidity in the Amazon, a factor that promotes cross-pollination (Purseglove, 1968). Finally, the size of the pollinating insect population could influence the variation in production from one region to another (Blackhurst and Miller, 1980; McGregor,

1976). Indeed, the location where this study was carried out had an abundance of domestic bees (195 visits per 1 m<sup>2</sup> during 3 h), bumblebees, and anthophoridae; a few melipones and hummingbirds also served as pollinators.

**Self-pollination and cross-pollination.** Fruit set following self-pollination and cross-pollination was 69.8% and 17.7%, respectively (Fig. 1A;  $X^2 = 215.022$ ,  $\alpha = 0.0001$ ). The number of seeds per pod also differed significantly among treatments ( $F = 17.59$ ;  $P \leq 0.0001$ ). The mean number of seeds per pod was significantly lower in the cross-pollination treatment than in all other treatments ( $P < 0.05$ ), whereas this parameter did not differ significantly among the other three treatments (Fig. 1B).

The 'BR3-Tracueteua' cultivar is probably autogamous, given the high fruit set obtained following self-pollination, in agreement with the observations of Robbins (1931) and of Blackhurst and Miller (1980) on other cowpea cultivars. Our data indicate higher fruit set than that reported by Ojehomon (1968b), who obtained 6% to 16%. This could be explained by our use of the two basal flower buds, which have a higher fruiting potential than the distal flowers in the inflorescence (Ojehomon, 1968b). Although cowpea is autogamous, considerable fruit set occurred following cross-pollination of emasculated flowers (Fig. 1A). Nevertheless, the pods that developed had fewer seeds than those originating from self-pollination (Fig. 1B). Similar results were obtained with four varieties of cowpea in Nigeria (Ojomo, 1970).

The low rate of fruit set following cross-pollination could have resulted from injury during emasculation, leading to ovule abortion and/or flower abscission. Another factor to be considered is that in emasculated flowers the pollen comes into contact with the stigma only at the moment of hand pollination, and the ovules might not be receptive at this time. In contrast, the pollen was always in contact with the stigma in nonemasculated flowers (self-pollination).

Cross-pollination apparently results in the fertilization of few ovules in a flower; those with few fertilized ovules abscise. Indeed, 23% of the pods formed following cross-pollination had two seeds; those with one seed rarely grew to maturity (Fig. 2A). However, 9% of one-seeded pods did eventually mature, probably because of compensation by the plant when fruit set is low. Only 10% of the pods contained more than nine seeds following cross-pollination. These pods possibly originated from male-sterile plants. This type of plant apparently has the same fertilization potential following cross-pollination as do normal cowpea plants following self-pollination. Rachie et al. (1975b) reported that male-sterile plants produce as many, if not more, pods than normally self-pollinated fertile plants.

However, pollinator visits do not necessarily reduce the number of seeds per pod (Fig. 2B). If a pollinator bearing pollen visits a normal fertile flower, its mechanical action may bring about self-pollination, either be-

cause the flower's own pollen is superior, or because of cross-incompatibility. If the pollinator bearing pollen lands on a male-sterile flower, cross-pollination will occur. This flower will normally produce a pod, except that the seeds will have hybrid vigor. If the pollinator visits a flower with trapped anthers, it can effect self-pollination or cross-pollination, or a combination of both.

## Conclusion

Pollinators make a significant contribution (6.2%) to 'BR3-Tracueteua' cowpea production in the Amazon by their mechanical action on flowers, thus promoting self-pollination, and also by transporting pollen from one plant to another, thus effecting cross-pollination. Whatever the pollination mechanisms, a reduction in number of pollinators may reduce cowpea productivity. Therefore, the adoption of an integrated production program is important, as a tool not only for the protection of the pollinators themselves, but also for environmental protection and conservation. Keeping a wooded reserve near the production area could protect pollinators and provide them with nesting sites. Nevertheless, other factors, such as the infrequent use of adequate cultivation techniques, and wide geographical dispersal in less favorable sites, are also correlated with the observed decline in productivity (Teixeira et al., 1988).

Pollinators increase fruit set, but not the number of seeds per pod. Nevertheless, these effects are not entirely clear and require more detailed study. Several pollinating agents visit cowpeas, such as domestic bees, bumblebees,

Fig. 1A

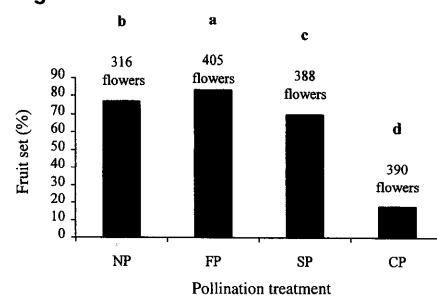


Fig. 1B

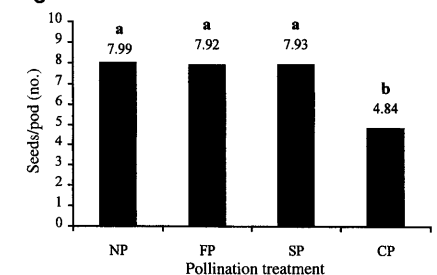


Fig. 1. Effects of pollination treatments on cowpea (A) fruit set, and (B) mean number of seeds per pod, Brazilian Amazon. (NP = not pollinated; OP = open pollination; SP = self-pollination; and CP = cross-pollination). Numbers above bars indicate numbers of flowers treated (A) or number of seeds (B). Letters indicate mean separation by Chi-square (A) or by ANOVA and Tukey's test,  $P \leq 0.05$  (B).

Fig. 2A

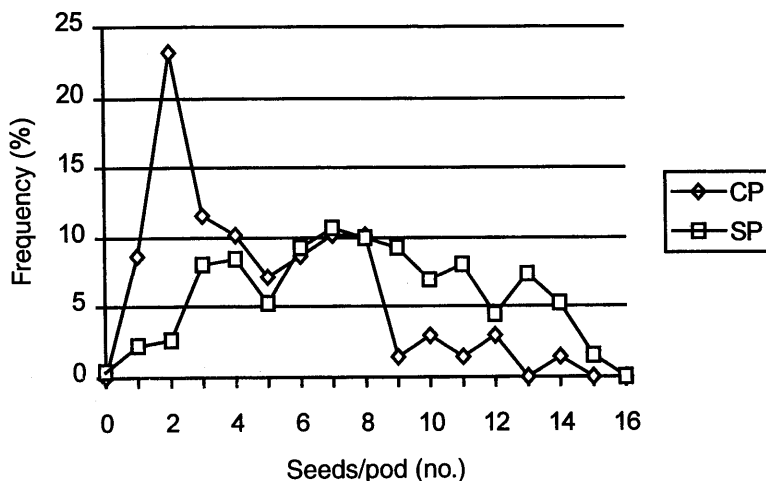


Fig. 2B

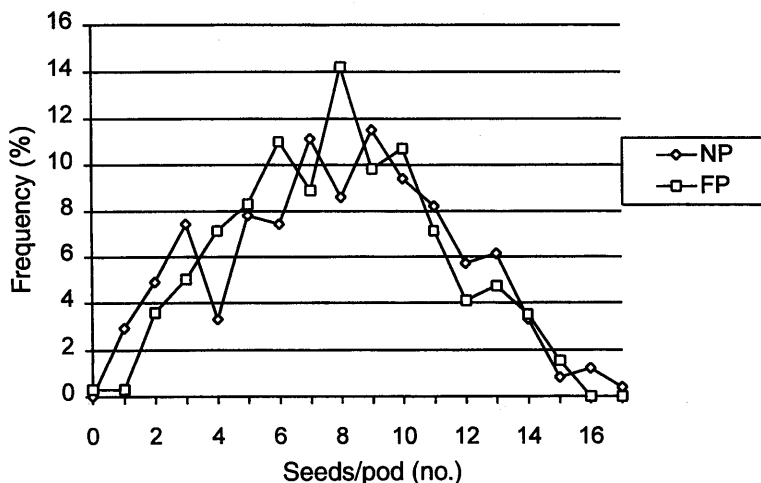


Fig. 2. Distribution of cowpea pods with different numbers of seeds following (A) self-pollination (SP) vs. cross-pollination (CP), and (B) absence (NP) or presence of pollinators.

melipones, and even hummingbirds. Studies to determine their respective efficiencies are necessary in the Amazon.

Although the 'BR3-Tracueteua' cultivar is capable of being selfed, the contribution of pollinators is significant for increasing fruit set. Furthermore, pollinators appear to be responsible for a certain low level of cross-pollination.

#### Literature Cited

Arroyo, M.T.K. 1981. Breeding systems and pollination biology in Leguminosae, p. 723-769. In: R.M. Polhill and P.H. Raven (eds.). *Advances in legume systematics*, part 2: vol. 2. Proc. Intl. Legume Conf. (Kew, 24-29 July 1978). Royal Botanic Garden, Kew.

Blackhurst, H.T. and J.C. Miller, Jr. 1980. Cowpea, p. 327-337. In: W.R. Fehr and H.H. Hadley (eds.). *Hybridization of crop plants*. Univ. of Wisconsin, Madison.

Conseil National de Recherches du Canada. 1981. *Interactions entre pesticides et pollinisateurs*. CNRC 18472. Secrétariat de l'environ., Ottawa.

Faris, D.G. 1965. The origin and evolution of the cultivated forms of *Vigna sinensis*. *Can. J. Genet. Cytol.* 7:433-452.

Gopinathan, M.C. and C.R. Babu. 1987. Breeding systems and pollination in *Vigna minima* (Leguminosae, Papilionoideae). *Plant System. Evol.* 156:117-126.

Hedström, I. and M. Thulin. 1986. Pollination by a hugging mechanism in *Vigna vexillata* (Leguminosae—papilionoideae). *Plant System. Evol.* 154:275-283.

Joly, A.B. 1976. *Botânica: Introdução à taxonomia vegetal*. 3th. ed. Companhia Editora Nac., São Paulo.

Maréchal, R., J.M. Mascherpa, and F. Stainier. 1978. Etude taxonomique d'un groupe complexe d'espèces des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de données morphologiques et polliniques, traitées par l'analyse informatique. *Boissiera* 28:1-273.

McGregor, S.E. 1976. Crops dependent upon or benefited by insect pollination: Cowpea, p. 190-192. In: S.E. McGregor (ed.). *Insect pollination of cultivated plants*. U.S. Dept. Agr. Hdbk. No. 496, Washington, D.C.

Ojehomon, O.O. 1968a. The development of the inflorescence and extra-floral nectaries of *Vigna unguiculata* (L.) Walp. *West Afr. Sci. Assn.* 13(1):93-111.

Ojehomon, O.O. 1968b. Flowering, fruit production and abscission in cowpea, *Vigna unguiculata* (L.) Walp. *West Afr. Sci. Assn.* 13:227-234.

Ojomo, O.A. 1970. Pollination, fertilization and fruiting characteristics of cowpeas (*Vigna unguiculata* (L.) Walp.). *Ghana J. Sci.* 10(1):33-37.

Ologhobo, A.D. and B.L. Fetuga. 1982. Chemical composition of promising cowpea (*Vigna unguiculata*) varieties. *Nutr. Rpt. Intl.* 25(6):913-919.

Omuetti, O. and B.B. Singh. 1987. Nutritional attributes of improved varieties of cowpea (*Vigna unguiculata* (L.) Walp.). *Hum. Nutr.* 41F:103-112.

Purseglove, J.W. 1968. *Tropical crops: Dicotyledons 1, Dicotyledons 2*. Longmans, London.

Rachie, K.O., K. Rawal, and J.D. Franckowiak. 1975a. A rapid method of hand crossing cowpeas, *Vigna unguiculata* (L.) Walp. IITA Tech. Bul. No. 2, Ibadan.

Rachie, K.O., K. Rawal, J. D. Franckowiak, and M.A. Akinpelu. 1975b. Two outcrossing mechanisms in cowpeas, *Vigna unguiculata* (L.) Walp. *Euphytica* 24:159-163.

Rachie, K.O. and P. Silvestre. 1977. Grain legumes, p. 41-74. In: C.L.A. Lealey and J.B. Wills. *Food crops of the lowland tropics*. Oxford Univ. Press, Oxford.

Rêgo, F.P., G.P. Pinto, J.P.S. Oliveira Filho, and F.M.M. Jesus. 1970. *Composição de Phaseolus e Vigna*. Inst. Pesquisa Expt. Agropecuária do Nordeste, Recife, Brazil. (Cited by Yuyama, 1981).

Robbins, W.W. 1931. *The botany of crop plants*. 3th. ed. P. Blakiston's Son, Philadelphia.

Scherrer, B. 1984. *Biostatistique*. Gaëtan Morin, Boucherville, Quebec.

Sen, N.K. and J.G. Bhowal. 1962. A male-sterile mutant cowpea. *J. Hered.* 53:44-46.

Steele, W.M. 1976. Cowpeas: *Vigna unguiculata* (Leguminosae—Papilionatae), p. 183-185. In: N.M. Simmonds (ed.). *Evolution of crop plants*. Longman, London.

Summerfield, R.J., P.A. Huxley, and W. Steele. 1974. Cowpea (*Vigna unguiculata* (L.) Walp.). *Field Crop Abstr.* 27(7):301-312.

Teixeira, S.M., P.H. May, and A.C. de Santana. 1988. Produção e importância econômica do caupi no Brasil, p. 99-136. In: J.P.P. de Araújo and E.E. Watt (eds.). *O caupi no Brasil*. Empresa Brasileira de Pesquisa Agropecuária—Dept. de Publicações, Brasília.

Williams, C.B., III, and O.L. Chambliss. 1980. Outcrossing in southernpea. *HortScience* 15:174-174.

Yuyama, K. 1981. Comportamento de vinte cultivares de feijão-de-praia (*Vigna unguiculata* (L.) Walp.) em terra firme do Estado do Amazonas, durante o ano de 1977. *Acta Amaz.* 11(4):671-677.