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APIS SPECIES OF TROPICAL ASIA AS POLLINATORS, AND SOME REARING METHODS FOR THEM

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Abstract

This paper considers the Asiatic Apis species (cerana, dorsata and florea), and presents published information on them as flower visitors and crop pollinators. Yields of certain crops are increased by the presence of A. cerana, and it may be economically worth while to transport hives to some of the crops. Other crops listed are also likely to benefit from pollination by one or more of the three species. Use of the open-nesting species (A. dorsata and A. florea) for crop pollination shows interesting possibilities, and beekeeping methods that have been practised with them in a few areas are described. It is important to try to estimate the potential economic value of pollination by Asiatic Apis. Much further information is needed, but methods for making a start are suggested, and other recommendations are made for putting the study of the whole subject on a more scientific and quantitative basis.

1. Introduction

I have chosen this subject because it has not received much systematic attention, although there have been many recent advances in knowledge about some other aspects of Asiatic honeybees. I have collected together published information on the capabilities of these bees to pollinate crop plants, hoping that this will tempt some research workers and beekeepers to carry out more, and more systematic, studies in different countries. More of the information available has been obtained in India than in all other countries of Asia together. I have not had access to Chinese literature, which would add more records.

I shall first compare the different Apis species as pollinators of individual crops, and then show what is known about the effects on crop yields of the Asiatic hive bee Apis cerana - which can be taken to crops relatively easily in modern hives. I shall indicate where more information is especially needed, for instance in order to provide estimates of the potential economic value of the Asiatic honeybees to crop pollination.

Finally, I shall describe methods used for beekeeping with A. florea and A. dorsata that I learned about last year, in the Indus valley of Pakistan and the Mekong delta of Vietnam. This may perhaps enable more studies to be made on pollination by these species that nest in the open.

Researches on pollination by Asiatic honeybees have tended to follow the same pattern as many researches in temperate zones on pollination by the European honeybee A. mellifera. This work started in the 1890s, and useful reference books on it are by Free (1970), McGregor (1976) and Crane and Walker (1984). For the tropics, Purseglove's "Tropical crops" (1968) contains much general information, and there are fairly full bibliographies of publications on pollination by bees (Crane, 1987a, 1987b; Crane and Walker, 1983). (Penelope Walker has contributed to the present paper by helping to search the literature and locate reports on Asiatic honeybees in relation to crop pollination.) Proceedings of previous International Symposia on Pollination (1962-1984) may also be consulted.

The earliest report found on pollination by Asiatic honeybees was in 1940 on sarson and toria, by Rahman in Lyallpur (now Faizalabad in Pakistan); A. florea was the only bee he captured on the crops. No model for evaluating the relative importance of three different honeybee species was available from temperate-zone experiments. Perhaps as a result of this, many of the publications from Asia do not make it clear to the reader which of the native Apis species were present in the area of study (for instance foraging on other plant species), or whether introduced A. mellifera was also present.

2. Apis species of tropical Asia

These bees are:

- **the hive bee Apis cerana.** Colonies nest in cavities and can be kept in hives; these bees can therefore be taken to crops that need pollination. Apis koschevnikovi is included here with A. cerana.
- **the giant bee Apis dorsata.** A colony builds a large single-comb nest in the open, and up to 100 or more colonies may nest together on a suitable forest tree or rock face. The bees are large and their foraging range is substantially greater than that of A. cerana. Apis dorsata/laboriosa is included here with A. dorsata.
- **the dwarf honeybee Apis florea.** A colony builds a very small single-comb nest in the open, and the bees have a smaller foraging range than A. cerana. Apis andreniformis is included here with A. florea.

A. dorsata and A. florea cannot be kept in the enclosed type of hive used for A. cerana which can fairly easily transported to crops.

Over twenty countries of Asia have one or more of the Asiatic honeybees (table 1). In the 1980s there were also three introductions of the bees outside Asia. In 1985/86 A. cerana was introduced to Irian Jaya in Indonesia, whence it reached Papua New Guinea. In 1985 A. florea appeared in the Khartoum region of Sudan - whence it spread across the Nile via Tuti Island, and 40 km or more north along the Nile valley, in 1½-2 years (Mogga et al., 1989); I think there may now be several thousand colonies. In 1988, A. florea was seen in the Riyadh region of Saudi Arabia, where it also flourishes. The human actions that led to the introductions of A. florea are still not known, except that those in Riyadh probably came from Oman.

Countries with one or more Asiatic honeybees extend from Oman, Iran, Afghanistan and Pakistan in the west to Taiwan and Japan in the east, and from China in the north to Indonesia in the south. China is by far the largest country, India coming next. Table 1 shows that A. cerana is in all the countries except Oman, and is the only native honeybee in Afghanistan, Japan, Korea and Taiwan. A. dorsata and A. florea are in about three-quarters of the countries.

Nests of A. florea are common in shady parts of urban gardens in some areas, where the bees are therefore potentially useful pollinators of garden crops. Very large aggregations of A. dorsata are not common near cultivated land, but single nests are becoming more frequent in farmland of some countries, such as Bangladesh, owing to the destruction of their natural forest habitat. I have not found any record of crops being cultivated near A. dorsata nests specifically for the purpose of pollination, although this has been done with some other feral native bees. In Nova Scotia, Canada, low bush blueberries (Vaccinium ovatum) have been grown for cropping in cleared forest land where nests of large bumble bees can be fostered (Karmo, 1965). And in Finland, Valle (1966) showed the benefit of siting seed plots of tetraploid red clover in an area with a strong foraging force of long-tongued bumble bees.

This paper is concerned with Asiatic Apis species, but the single European species of Apis, A. mellifera, has been introduced into most countries of Asia (table 1), and is present in parts of them. As far as I know, Bangladesh, Bhutan, Burma and Sri Lanka, are still without A. mellifera, and probably also Cambodia and Laos. In general, A. mellifera beekeeping is done in cultivated areas, especially those with large monocultures of crops. A. mellifera can exploit their honey flows - and pollinate their flowers - more effectively than A. cerana. But when a dearth comes, they do not abscond to a new forage area as A. cerana bees do, so wild colonies have little chance of survival. A. cerana flourishes well in land that is not intensively cultivated, where there is a wide variety of native wild flora. In India, Goyal (1974) regarded native A. cerana and introduced A. mellifera as complementary to each other, concluding that there are many areas where one of the species can survive but the other cannot. Where both can survive, however, introduction of A. mellifera may endanger A. cerana.

Populations of A. dorsata and A. florea are not endangered in the same way by introducing A. mellifera. A. dorsata is widely at risk through deforestation which destroys its nest sites, and this is especially likely to occur at the edge of agricultural land as a result of pressure from an increasing human population. It is my impression, however, that A. dorsata is somewhat adaptable, using new nest sites in agricultural and even urban areas when existing forest sites have been destroyed through human interference. A. dorsata may therefore become available as a crop pollinator in places where it was not even known a few decades ago. A. florea is quite adaptable and can usually find nest sites much more easily; it can also do well in comparatively dry areas - hence its rapid spread in Sudan.

The four species differ in colony size and their foraging range. Colony populations increase in the order: A. florea, A. cerana, A. dorsata, A. mellifera which can be intensively managed. Colonies of European A. mellifera are more amenable to management than those of any other Apis; one well managed colony can provide several times as many potential pollinators as a colony of A. cerana, and very many times more than a colony of A. florea. The foraging flight range of the different species increases roughly with body size: the range of A. cerana is roughly twice that of A. florea, and that of A. dorsata and A. mellifera is greater still (Punchihewa et al., 1985).

3. Pollination of individual crops by different Asiatic Apis species

Table 2 summarizes reports bearing on the relative activity of different species in visiting and pollinating various crops. In a few of the experiments A. mellifera was also present, but it was not the dominant flower visitor. I have tried to follow individual authors in their usage of the terms flower visitor and pollinator, but some authors have regarded them as interchangeable.

A. dorsata was the most frequent visitor to the early flowering trees almond, plum and pear, and also to sunn hemp. Fruit set was increased on a cashew tree where A. dorsata nested, whereas A. cerana did not increase set. A. dorsata collected pollen from male flowers of oil palm where no other Apis were recorded; in one study on pigeon pea where A. cerana was also present, A. dorsata was the only flower visitor.

A. florea was a more frequent visitor to some fruit crops than any other Apis species; it was reported as the (or a) main pollinator of hog plum, lychee, mango, pomelo and tomato, and mentioned as an important visitor to cucurbits. The same was true of crop plants being grown for seed: A. florea was reported as a main pollinator of radish, and the most frequent visitor to cauliflower - and fennel, where 81% of visitors were A. florea in one study. On berseem, it was the bee least affected by the weather.

A. dorsata and A. florea foragers visiting flowers of agricultural crops would have come from feral colonies, whereas A. cerana visitors would almost always be from hives in the vicinity, since natural nest sites would be scarce. A. cerana was in general a main flower visitor on crops listed in table 2; on a few crops it was recorded as absent, but there may have been no hives in these localities. A. cerana is now considered in more detail.

4. Crops whose yields can be increased by introducing hives of Apis cerana

Results in table 3 relate to the effect of the presence of hives of A. cerana on fruit set or crop yield. They were obtained in two types of experiment, in which crop yields from plants were compared when:

- some were accessible to bees and other insects, and others protected from them, for instance by bagging;
- some were on plots to which hives of A. cerana were taken, and others on plots to which they were not taken.

In most studies a commercial yield seemed to depend on pollination by A. cerana. Increase in yield or fruit set, due entirely or largely to the presence of A. cerana, was quantified for a number of crops.

Fruit set		Seed		Seed for propagation	
apple	x 24	cardamom	x 6	berseem	x 2.7
cranberry	x 5	cardamom,		cauliflower	x 1.2
lemon	x 15-17	greater	c. x 10	onion	x 1.7
loquat	x 3	horsegram	x 6	radish	x 1.2
lychee	x 2	safflower	x 2.2		
peach	x 2	sarson	x 1.4-1.6		
pear	x 14	sesame	x 1.3		
persimmon	x 1.2	sunflower	x 1.5		
plum	x 6				
water melon	x 1.6				

Elsewhere (Crane, 1990) I have quoted information on positive effects of pollination by honeybees (almost all European A. mellifera) on 139 crop plants, 57 relating to increase of crop yield and 51 to increase the seed yield from plants grown for seed needed for propagation. For 53 of the crop plants, a recommended number of hives of European A. mellifera to be used per hectare could be quoted.

Very few recommendations have been made as to the number of hives of A. cerana to be used per hectare on different crops; one report referred to here suggests 4 hives/ha for cardamom. In general, a hive of A. cerana will contain fewer foragers/pollinators than one hive of A. mellifera, and the A. cerana bees will forage over a smaller area. In India, Dhaliwal and Sharma (1973) found that A. cerana foraged within a range of about 1000 m from the hive, on a crop of cauliflower. Many figures have been quoted for the range of A. mellifera; if we take 1400 m as a modest figure for foraging on a uniform crop, the area foraged by an A. cerana colony would be only half that foraged by an A. mellifera colony. In principle therefore, on the same crop, extra hives of A. cerana would be needed so that bees fly to all parts of it, and it is essential that these hives are at more locations on the crop, closer together, than hives of A. mellifera.

Recommendations are quoted by Crane (1990) for A. mellifera hive densities for some of the crops in tables 2 and 3. Most are between 1 and 5 colonies/ha, and more of A. cerana would be needed. Onion can present difficulties in that A. mellifera foragers tend to avoid these flowers, and 12-15 A. mellifera hives/ha have been recommended. Such a high number suggests that it might be worth exploring further the use of A. florea, which appears in table 2B as the most frequent Apis visitor to onion in two studies.

5. Other crops which Asiatic species of Apis are likely to pollinate

Many other crops grown in regions where Asiatic honeybees are present are pollinated by insects, but no quantitative reports either positive or negative have been found for the usefulness of Asiatic honeybees. We could expect them to pollinate some of the crops, either from their general characteristics or from results obtained elsewhere with European A. mellifera, and 24 such crops are listed in table 4. I hope that data can be obtained to establish the rate of visitation of Asiatic honeybees to some of them and, if appropriate, to determine whether crop yields can be increased by introducing hives of A. cerana to them.

A. florea and A. dorsata are likely to visit crops grown in small-scale agriculture. But in a treeless region, where field crops are grown in large monocultures, the introduction of hives of A. cerana may be particularly beneficial, because adjacent land is unlikely to provide nesting sites for feral colonies of any Apis species.

6. Calculating the economic value of crop pollination by Apis species

I had hoped to include in this paper some estimate of the economic value of pollination by Asiatic species of Apis, either to Asia as a whole or to some of its countries. But I have been defeated by lack of access to data needed for such estimates, including those on production and economic value. I hope that people living in Asia will be able to obtain the data needed, and use them to make estimates such as have been published for European A. mellifera.

Detailed information on methods used in the past and currently are published by Robinson et al. (1989), who also give results of their own calculations for 49 crops in the USA, quoting sources of the data they use. To obtain the annual value attributable to pollination by A. mellifera for each crop in the USA, they multiply together three factors, V, D and P.

V = total annual value of crop produced, in million dollars
D = dependence of the crop on insect pollination (1.0 if complete, otherwise proportionately less)
P = proportion of pollinators that are A. mellifera (the only honeybee in the USA).
V x D x P = annual value attributable to Apis, in million dollars.

The total value quoted for the USA is:

crop value	29 976 million dollars
value attributable to A. mellifera	9 303 million dollars.

Like other aspects of pollination by Asiatic honeybees, the calculations for Asia are more complicated than in other continents because several Apis species are involved. It would be possible in theory to calculate a separate value for each, but it may not be practical.

Tropical crops were not considered for the USA, but three crops included in the present tables are also listed in the USA study, with the following values (in million dollars).

	V	D	P	V x D x P
almond	360.6	1.0	1.0	360.6
cotton:				
lint	3645.4	0.2	0.8	583.3
seed	348.3	0.2	0.8	55.7
sunflower	251.5	1.0	0.9	226.4

7. Beekeeping with Apis florea and Apis dorsata

Both these bees build a single-comb nest in the open. Attempts have been made to keep them in hives accommodating the thickness of one comb, that were partly enclosed and partly open. But these can be complicated and not very satisfactory. I shall describe traditional beekeeping methods in which colonies have been kept in the open, so organized that all or part of the honey store at the top of the comb can be removed without undue disturbance to the bees, and leaving intact the brood area which is below.

Colonies of A. florea are traditionally kept to produce honey for sale in a small area of Pakistan, on either side of the Indus river and its tributaries from the west, between Attock and Dera Ismail Khan. The river banks are surrounded by desert country, and colonies do not abscond. An A. florea beekeeper seeks out nests in his locality; when he finds one he cuts off a suitable stick, and slits it in the middle to make an opening somewhat longer than the width of the brood part of the comb; he inserts a small stone at each end of the slit to keep it open. He slides the slit stick up from the bottom of the comb until it is just above the brood area, then removes the stones so that the comb is held firmly within the slit. He cuts off the brood part of the comb just above the stick; the queen is on this part, and the other bees will join her. Finally he supports the stick (with the brood comb) in a place convenient to himself. The upper part of the comb containing honey constitutes his first honey harvest.

After the next honey season, the procedure is repeated with another slit stick, but this time the honey comb harvested is built from his own earlier stick. In a bazaar near Attock, two shops were devoted to the sale of this honey; all combs were built from the slit stick and sold with it still in place - that is, obtained by beekeeping. I am indebted to Khalid Khan of Peshawar for much of the information on this beekeeping; further details, including seasonal management and feeding colonies, will be published later. The method is similar in many ways to that described in Oman (Dutton & Simpson, 1977), but there the colonies abscond.

A modern method for beekeeping with A. dorsata, developed in India by Mahindre (1983), uses a long wooden "clip", like a giant version of the slit stick for A. florea except that it is open at one end, and the system was rather similar. The traditional beekeeping method I saw, also in 1989, uses half a round pole about 2 m long (called a

rafter), with its flat side uppermost, which is lodged in a tree in a place selected and adapted to be attractive as a nest site for A. dorsata. This was in a Melaleuca leucodendron forest swamp, in the Mekong delta at the southern tip of Vietnam. A similar method has been used in swamps of the Kapuas river lake system in western Kalimantan, Indonesia, in Borneo, but I have not seen this. In the Mekong delta A. dorsata swarms arrive from the coastal mangroves in November, and stay 8 or 9 months. The rafters are so named because they are sloping, like rafters of a house. They are fixed at 15° to the horizontal, and because of this slope, honey is stored near the upper end of the rafter; a triangular piece of comb containing honey can be cut off without endangering the stability of the rest of the comb. While the colonies are in the Melaleuca forest, harvests are taken every two months or so, 4 in all. Further details of these procedures will be published (Crane et al., 1990).

Mahindre (1983) also maintained 150 A. dorsata colonies on "attraction planks", rather similar to the rafters in Vietnam, and these were in apiaries - a more advanced stage still.

8. Recommendations

In view of the frailty of much of the pollination material I have presented, and the richness of the native Apis fauna of Asia, I shall summarize what I have said in the form of Recommendations rather than Conclusions.

1. I would ask the International Commission under whose auspices this Symposium is held to consider preparing and publishing short recommendations on experimental methods for studying individual contributions to crop pollination by the various Apis species, where more than one of them is present.

2. Workers in Asia, and particularly in countries other than India, should make further studies on pollination of crop plants by native Apis species. In reporting results, it is essential to state what species of Apis were present in the area (including introduced A. mellifera), and which of them visited or did not visit the crop plant.

3. People with the necessary facilities should make further studies on crop pollination by the species of Apis that nest in the open: A. dorsata and A. florea. Perhaps in some areas - to be determined - beekeeping with A. florea should be encouraged, for both honey production and crop pollination.*

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*A paper published this month used a "movable frame" for transporting A. florea colonies to crops for pollination (Bhamburkar, B. L. and Peshkar, L. N., 1990. A simple hiving method for the little bee Apis florea. Proc. 11 Int. Congr. IUSSI: 475-476).

4. A group of people (possibly within the new Asian Apicultural Association) should try to assemble the necessary data, assess methods of estimating the economic value of honeybees in pollinating individual crops, and make preliminary estimates for the native Apis species. Where introduced A. mellifera is also present, its contribution must be taken into account.

5. The above estimates will be far from precise, but they should be used to generate interest in the native honeybees among government departments, aid agencies, and the general public. Such interest is likely to have the added benefit of encouraging the preservation of these native bees. Pechhacker et al. (1990) will also stress this in another paper at our Symposium.

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Table 1 - Native honeybees now present in countries of Asia.

Countries west of Iran (where only Apis mellifera is native) are omitted.
In the final column, () indicates that introduced A. mellifera is absent in most of the country.

Country	A.cerana	A.dorsata	A.florea	Introduced A. mellifera
Afghanistan	x	0	0	x
Bangladesh	x	x	x	0
Bhutan	x	x	0	0
Burma	x	x	x	0
Cambodia	x	x	x	0?
China	x	x	x	x
India	x	x	x	(x)
Indonesia	x	x	x	(x)
Iran	x	0	x	native
Japan	x	0	0	x
Korea	x	0	0	x
Laos	x	x	x	0?
Malaysia	x	x	x	(x)
Nepal	x	x	x	(x)
Oman	0	0	x	native
Pakistan	x	x	x	(x)
Philippines	x	x	x	x
Sri Lanka	x	x	x	0
Taiwan	x	0	0	x
Thailand	x	x	x	(x)
Vietnam	x	x	x	(x)

Table 2 - Comparison between three Asiatic honeybees as flower visitors and crop pollinators.

0 = bee did not visit/pollinate flowers; - = bee not mentioned
+ = bee visited/pollinated flowers
++, (+++) = on this crop, bee visited/pollinated flowers more than bee marked +, (++)
Crops marked * also appear in table 3.
Codes on the right lead to references at the end of the paper.

2A - Plants whose crop yields depend on pollination.

Crop	Ac	Ad	Af	Remarks by author	Ref.
almond	0	++	+	visitors	Mg81a
(Prunus dulcis)	+	-	-	most common visitors	Bh83
ber	+	-	-	Ac and Musca domestica most common visitors	Sp84
(Ziziphus maritima)					
beans	0	+	+	visitors	Di65
(various)					
*cardamom	++	+	+	visitors	Ch83
(Elettaria cardamomum)					
*cardamom, greater	+++	++	+	visitors	Ve87
(Amomum subulatum)					
*cashew	-	+	-	fruit set increased in tree with Ad	Mo85
(Anacardium occidentale)					
*coriander	0	+	+	visitors; bees increased yield	Ba84
(Coriandrum sativum)	+	-	++	Trigona iridipennis also visited	Sh81
*cotton	+	++	-	visits/min	Ta83
(Gossypium	++	++	+	probable importance in	various,
arboreum, etc.)				pollination	e.g.Sk62
cucurbits	+	+	++	Af important in Punjab and	various,
(Cucurbitaceae)				Haryana	e.g.Gr83
eggplant	-	+	+	main pollinators	Co73
(Solanum melongena)					
hog plum	-	-	+	important pollinator	By80
(Spondias sp.)					
groundnuts	0	+	+	visitors	Di65
(Arachis hypogaea)					
*lychee	++	+	+++	visitors	Pk74
(Litchi chinensis)	-	-	+	Af important pollinator; Trigona sp. also visited	By80
mandarin	-	+	+	main pollinators	Mn78
(Citrus reticulata)					

cont.

Table 2A - cont.

Crop	Ac	Ad	Af	Remarks	Ref.
mango (Mangifera indica)	-	-	+	important pollinator	By80
mustard (Brassica juncea)	+	+	+	Af, Ad and Andrena ilerda most important, except Ac dominant at lower altitudes	Ka71a
oil palm (Elaeis guineensis)	-	+	-	collects pollen from male flowers	Tu69
okra	+	-	-	a main pollinator	Ta85
(Abelmoschus esculentum)	+	-	-	a main pollinator, with Halictus sp.	Co73
*peach	-	+	+	visitors	Mg81b
(Prunus persica)	+	-	-	visitors, preferred certain cvs	Ku85a
*pear (Pyrus communis)	-	++	+	visitors	Mg80
pigeon pea (Cajanus cajan)	0	+	-	hives of Ac present; bees considered important potential pollinators	Wi83
	++	+	-	visitors	Pa85
*plum	-	++	+	visitors	Mg83
(Prunus domestica)	+	-	-	most common flower visitors	Bh83
pomelo, shaddock (Citrus grandis)	-	-	+	important pollinator; Xylocopa sp. also visited	By80
*rape "Pusa Kalyani"	++	-	+	Ac 62%, Af 36% of visitors; see note under mustard	Bs83 Ka71a
*safflower (Carthamus tinctorius)	+	+	+	together, 81% of flower visitors	De85
*sarson, Indian colza (Brassica campestris v. sarson)	+	-	+	pollinators	Ra40, La60
*sesame (Sesamum indicum)	++	+	+	visitors; Af preferred extrafloral nectaries	Ro81
strawberry (Fragaria x ananassa)	+	-	-	Ac most frequent insect visitor	Yo79
*sunflower (Helianthus annuus)	+	+	+	each species a main pollinator; order of importance varies from place to place; see text	various, e.g.In81, Sb82
tomato (Lycopersicon esculentum)	-	-	+	a main pollinator, with Halictus sp.	Co73
*toria, brown sarson	+	+	+	visitors; Andrena ilerda also visited	Ka71b
(Brassica campestris v. dichotoma)	++	-	+	visitors	Mu81
	+++	++	+	foraging speed	Mu81
	-	-	+	visitors	Ra40
*water melon (Citrullus lanatus)	++	-	+	Ac foraged slightly longer	Ro88

cont.

2B - Crop plants whose propagation by seed depends on pollination by honeybees.

Crop	Ac	Ad	Af	Remarks	Ref.
*berseem (Trifolium alexandrinum)	-	+	++	visitors; Af least affected by weather	Dh76
	++	+	+	Ac visited flowers longer in afternoon; Ac stored honey even at high temperatures	At70
*cauliflower (Brassica oleracea v. botrytis)	+	+	+	Apis spp. c.80% of visitors to 2 cvs and increased yield; Af predominant on one, Ad on the other	Ss83
	+	-	-	max. foraging range 900 m; most bees within 400 m	Dh73
	+	+	++	Af 33%, Ad 18%, Ac 15% of visitors	Ru72
fennel (Foeniculum vulgare)	+	+	++	visitors; in April more syrphid flies than Af	Sa81
	+	+	+++	Af 81% of visitors, must be encouraged	Na60
	0	+	+	visitors; bees increased yield	Ba84
lucerne (Medicago sativa)	+	+	++	collected nectar and pollen	Sh83
	-	-	+	most common visitor, but tripped few flowers	Go75
*onion (Allium cepa)	+	-	++	Af 43%, Ac 7% (Trigona sp. 47%) of visitors	Ro83a
	-	+	++	Af 80%, Ad 15% of visitors; seed yield 20 times greater than on bagged flowers	Ja81a
	0	+	+	visitors	Ja81b
	++	+	-	visitors	Ku85b
*radish (Raphanus sativus)	-	-	+	a main pollinator, with Anthophora sp.	Co73
sunn hemp (Crotalaria juncea)	-	++	+	Ad more efficient at exposing stigma; 2 Megachile spp. and Xylocopa were even more important pollinators	Gr79
	0	-	-	caged Ac bored hole through keel petal and did not pollinate; one Xylocopa fenestroides notably increased seed set	Ji73

Table 3 - Crops whose yields can be increased by the presence of Apis cerana colonies.

Crops marked * also appear in table 2.
Codes on the right lead to references at the end of the paper.
It seems likely that all entries below refer to Ac, even where the entry has "bee" or "honeybee", which is in accordance with the author's usage.

3A - Plants whose crop yields depend on pollination.

Crop, and effects/benefits of presence of bees	Ref.
apple, Malus domestica (Red Delicious):	
Ac 77% of insect visitors; fruit set 24 times as great on unbagged as on bagged flowers (Golden Delicious, American Mother gave no fruit on bagged flowers)	Sc61
apricot, Prunus armeniaca:	
in UP, India, commercial crop depends on honeybee pollination	Ro83b
balsam pear, Momordica charantia:	
Ac increased yield by 99% in Philippines	Si82
buckwheat, Fagopyrum esculentum:	
in UP, India, commercial crop depends on honeybee pollination	Ro83b
*cardamom, Elettaria cardamomum:	
bee pollination gave 66% fruit set; controls 11%	Ph73
on plots caged with 480 and 200 plants, 8 and 3 colonies, respectively, increased yields by 35-45%	Ma81
honeybees increased yield; Ac main visitor	Co83
when 22 colonies were near 1-ha plot, 98% of visitors were Ac	Sj83
mean fruit set with 0, 2, 4 and 6 hives/ha was 32-42%, 33-52%, 34-57% and 34-57%	Jo85
*cardamom, greater, Amomum subulatum:	
fruit set mostly 80% on open flowers, 5-7% on bagged flowers	Ve87
*cashew, Anacardium occidentale:	
introduced colonies did not increase fruit set; fruit set is too low in India for reasons not clear; introduction of colonies (8 frames) is recommended	Mo85
coconut, Cocos nucifera:	
hives of Ac in orchards increased yield up to twice	In82
*coriander, Coriandrum sativum:	
yields higher on plots caged with than without Ac	Sh81
*cotton, Gossypium sp.:	
with Ac and Af, more bolls/plant, greater wt of seed cotton, lint and seeds, than without insects	Sk62
cranberry, Vaccinium sp.:	
Ac 69-78% of insect visitors; fruit set 5.3 times as great on unbagged as on bagged flowers	Sc61

cont.

Table 3A - cont.

Crop, and effects/benefits of presence of bees	Ref.
horsegram, Macrotyloma uniflorum v. uniflorum:	
seed yield 6 times as great on bee-pollinated as on control plots	In81
lemon, Citrus aurantifolia:	
yield 15 to 17 times as great on bee-pollinated as on control plants	In81
linseed, Linum usitatissimum:	
yield probably greater when honeybee-pollinated	Ro83b
loquat, Eriobotrya japonica:	
fruit yield three times as great on bee-pollinated as on bagged plants	Kh86
*lychee, Litchi chinensis	
fruit yield twice as great on bee-pollinated as on control plots	In81
niger, Guizotia abyssinica:	
seed yield increased when more hives taken to crop	Bm58
*peach, Prunus persica:	
Ac 63% of insect visitors; fruit set twice as great on unbagged as on bagged flowers	Sc61
*pear, Pyrus communis:	
Ac 51-67% insect visitors; fruit set 14 times as great on unbagged as on bagged flowers	Sc61
persimmon, Diospyros kaki:	
fruit set 21% higher on unbagged than bagged flowers (percentage of Ac not stated)	Sc61
*plum, Prunus domestica:	
Ac 33% of insect visitors; fruit set 6.4 times as great on unbagged as on bagged flowers	Sc61
*rape "Pusa Kalyani":	
Ac most common visitor/pollinator; when plants were bagged against insects, no. pods/plant dropped to less than 1%	Bs83
*safflower, Carthamus tinctorius:	
seed yield 122% higher on bee-pollinated than on control plots	In81
seed yield higher on 2 plots with introduced Ac, 10 hives/ha	De85
*sarson, Brassica campestris v. sarson:	
yield higher with Ac	La60
seed yield 36-64% higher on bee-pollinated than on control plots	In81
*sesame, Sesamum indicum:	
seed yield 32% higher on bee-pollinated than on control plots	In81
*sunflower, Helianthus annuus:	
seed yield 46% higher on bee-pollinated than on control plots	In81
*toria, Brassica campestris v. dichotoma	
yield higher with Ac	La60
*water melon, Citrullus lanatus:	
total weight of fruit 58% higher with than without bee pollination	Ro88

3B - Crops being grown for propagation whose seed yields depend on pollination.

Crop, and effects/benefits of presence of bees	Ref.
*berseem, Trifolium alexandrinum:	
seed yield on plot caged with Ac was 2.7 times greater than in unvisited fields	La56
*cauliflower, Brassica oleracea v. botrytis:	
use of Ac increased seed yield by 24%	Ms73
Chinese cabbage, Brassica chinensis:	
on caged plots Ac increased seed yield	Ne82
*onion, Allium cepa:	
honeybees 70% of visitors, Ac most common; seed set 72-79% higher on uncaged than on caged plots	Sn70
radish, Raphanus sativus:	
use of Ac increased seed yield by 19%	Ms73

Table 4 - Some other insect-pollinated crops grown in Asia for which Asiatic Apis are likely to be important.

Asiatic honeybees are likely to be important for satisfactory crop yields or (for plants entered in brackets) for satisfactory seed yields for propagation.

allspice, Pimenta dioica
avocado, Persea americana
ash gourd, Benincasa hispida
carambola, Averrhoa carambola
castor, Ricinus communis
(chickling pea, Lathyrus sativus)
chili pepper, Capsicum frutescens; also sweet pepper, C. annuum
clove, Syzygium aromaticum
coffee, some Coffea spp. grown in Asia
guava, Psidium guajava
(kenaf, Hibiscus cannabinus)
kiwi fruit, Actinidia chinensis
(kudzu, Pueraria phaseoloides, P. thunbergiana)
nutmeg/mace, Myristica fragrans
pyrethrum, Chrysanthemum cinerariifolium
(quinine, Cinchona spp.)
(sisal, Agave sisalana)
tamarind, Tamarindus indica
(tea, Camellia sinensis)
(tobacco, Nicotiana spp.)
tung, Aleurites fordii

Mo85 Mohamad, B. M., and Mardan, M., 1985. Effect of the presence of Apis cerana colonies on cashew fruit set. Proc. 3 int. Conf. Apic. trop. Climates, 1984: 140-144. 104/86

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