APIS MELLIFERA L. IN INDIA AND THE POSSIBILITY OF INBREEDING DEPRESSION OF THE SPECIES IN THE COLONIES

R.C. MISHRA
Yogesh KUMAR
INDIA

Out of many *Apis* species only two viz. *A. cerana* F. and *A. mellifera* L. are hive species. *A. dorsata* F. and *A. florea* F. are the other two well-known species which are wild, whereas *A. koschvenkovi, A. laboriosa* and *A. andreniformis* are other recently described species. Out of the two hive species, *A. mellifera* has many attributes which make it superior to *A. cerana* (MISHRA and SINGH, 1987). With the basic aim of increasing the honey production, extensive introductions and establishments of *A. mellifera* have been made in the Asian countries during the last half of century. The achievements in honey and royal jelly production with this newly introduced species in China are remarkable (LIU, XIANSHU, 1984). The successes obtained by means of newly introduced *A. mellifera* are also noteworthy in other countries like Mexico, Argentina, Thailand and, now, in some parts of Pakistan.

1. Introduction in India

Unsuccessful attempts were made by many workers to introduce and establish *A. mellifera* in India. GHOSH (1920) maintained a small apiary for a few years by importing three colonies, THOMPSON (1940) reported unsuccessful attempts in various parts of India and, in 1944, he reported that Baldry introduced *A. mellifera* in Mahableshwar (m.S.) and maintained the apiary for six years. These colonies were later shifted to Coimbatore where they soon dwindled and perished. BEADNELL (1939) brought many consignments of *A. mellifera* to Nilgiri hills. RAHMAN and SINGH (1940, 1945) received two lots of two and three colonies, but could not establish and maintain them. *A. mellifera* queens were introduced into *A. cerana* colonies, in 1951, in Kashmir, and the colonies were reported to be doing well untill 1959 (VATS 1953). Afterwards, there is no report on the progress of these colonies and they are believed to have perished.

The successful introduction of *A. mellifera* in India dates from the sixth decade of the present century (see ATWAL and SHARMA, 1968). The summary of the consignments received during this successful attempt is given in the following table.

Place from which the bees were imported	Month/ year	No. of queens nuc. cols.	No. of queens col. succeded	Strain
1. Queens of *A. mellifera* introduced in *A. cerana* colonies				
California (USA)	Aug., 1962	8	Nil	California strain
California	Sept., 1962	2	1	California strain
California	Mai, 1963	4	Nil	California strain
California	June, 1963	4	4	California strain
California	June, 1965	10	10	Califonia strain
Italy	June, 1964	4	1	Italian strain
Rothamsted (UK)	Aug., 1964	4	2	English strain
	Strain developed by hybridising indigenous bees in U.K. with Dutch and Italian bees			
2. Nuclei				
California	June, 1964	10	10	California strain
	(3 perished during winter)			
California	June, 1965	10	10	California strain
Florida (USA)	April, 1966	24	24	Mid-west hybrid
Florida (USA)	April, 1966	24	24	Caucasian Hybrid (Midnite strain)
W. Germany	1976	15	15	Carnica

Studies on the comparative performance (ATWAL and SHARMA, 1970) of *A. indica* and of five strains of *A. mellifera* revealed that the Califiornian yellow strain was superior to the others in colony strength, brood rearing activity and capacity for food storage, followed by the Starline strain. The Italian yellow strain was similar to the Californian and Starline strains in general behaviour, but did not show the same excellence in honey production. The queens of *A. mellifera carnica* were imported from Germany in 1976 (unpublished) and were successfully introduced in the existing *A. mellifera* stok in Himachal Pradesh.

Expansion of *A. mellifera* in the Country

Initially, the colonies of the exotic species were maintained at Nagrota, Himachal Pradesh. With the successful establishment of *A. mellifera,* colonies of these species were also given to the *A. cerana* beekeepers and the species gained popularity in the state. There was no beekeeping with *A. cerana* in the plains of Punjab and Haryana till the introduction of *A. mellifera.* On the basis of the superiority of *A. mellifera* colonies which migrated from Nagrota (H.P.) during 1965—1970 (ATWAL and GOYAL, 1978) a few bee colonies, were given to farmers in 1976 and 1977, for the first time. Since 1976, the growth in number of colonies has been enormous (CHAHAL et al., 1981) and, at present, the number has grown to about 0.1 millions, giving about 900 tons of honey. This does not highlight the fullest potentials of the state because of the non-availability of a regulated market for honey and of the pressure on the multiplication of the colonies to meet the requirements of Punjab and of other states. The exotic species spread into the good beekeeping areas of Haryana, which are adjoining to Punjab, the two states having similar floral and environmental conditions. *A. mellifera* colonies were, for the first time, acquired by the coordinating centre of AICRP at Ranikhet (Almora, U.P.) in 1986. The colonies migrated between hills and plains and were found to be superior to *A. cerana.* Some efforts were later made, in 1987, by the state Village and the Khadi Industries Board to popularise beekeeping with these species. From then onwards, *A. mellifera* colonies were obtained by beekeepers in some good areas in Uttar Pradesh.

Thai sac brood disease of the Indian honeybee first appeared in the Meghalaya state in 1978 and it gradually spread in the northern belt of the country by 1985. The disease took about 95% tool of *A. cerana* colonies, but *A. mellifera* colonies were not infested by the virus even in mixed apiaries of the two species. With this background, a coordinating centre of AICRP was sanctioned by the Indian Council of Agricultural Research for the state of Bihar to test the performance of *A. mellifera* and to popularise the species as an alternative to *A. cerana,* if found superior. With this mandate the coordinating center at Rajendra Agricultural University, Pusa, obtained *A. mellifera* colonies from Hisar, Haryana, in February, 1988 (HAMEED et al., 1989). Soon afterwards a field station in Khadi and the Village Industries Commission in the same area also introduced colonies from Punjab. The commercial beekeepers of the area, who had lost their *A. cerana* colonies due to the Thai sac brood, did not wait longer and obtained colonies from Haryana and Punjab in 1989. A few hundreds of colonies were also introduced later in south Bihar. Within the last six years, the species have found their way to all potential areas of the state, though a further increase in the number of colonies is a possibility. Beekeeping with *A. mellifera* in West Bengal was also picked up simultaneously with its growth in Bihar.

Desperate beekeepers of Jamu and Kashmir pinned their hopes on *A. mellifera* after the loss of their *A. cerana* colonies due to the Thai sac brood disease. In this venture, they acquired colonies of the species from the adjoining states of H.P. and Punjab during 1987 and 1988. The species proved very useful and superior to the Indian honeybee.

During later endeavours to spread the use of *A. mellifera* for a larger honey production, the performance of the species was tested in other states under the auspices of the "Whole India Coordinating Project". The species also proved to be better than the *A. cerana* ones in the Southern states. The large scale introduction of *A. mellifera* colonies was made in Kerala through the "Malanadu Development Society", Kanjirapalli and Kerala Agricultural University, in Trivandrum in 1992 —1993 and in Tamil Nadu by the "Martandam Beekeepers Cooperative Society" in the Kanyakumari district. Now, there should be about two thousand colonies in the Kerala and Kanyakumari areas of Tamil Nadu. The performance of the colonies is very satisfactory for the beekeepers. After thorough testing, the colonies have now reached the beekeepers in the Andhra region of Andhra Pradesh. In Orissa, the coordinating centre of AICRP honeybees at the Orissa University of Agriculture and Technology is maintaining the colonies of *A. mellifera* for the last 3—4 years and now, the colonies should go to the beekeepers in good areas of the state. It is necessary to increase the efforts to test the high yielding *A. mellifera* in the north eastern states which seem to have enough resources. Though we have some colonies from the species which are maintained at the coordinating centre of "Whole India Coordinating Project" at Assam Agricultural University, definite recommendations are still expected.

3. The Question of Inbreeding

Fears are expressed by most of the organizations in India regarding the inbreeding hazards in *Apis mellifera,* since a limited number of queens/colonies were imported and no fresh brood from this species has been added. VERMA (1984) stated that the *Apis mellifera* introduced in northern India is facing the serious problem of inbreeding, but his statement was not supported by any factual information. The decision has to be cautious, since the hazards of more importations can destabilize the presently growing beekeeping industry in India. On the other hand, in some cases of free mating and inbreeding, the similar alleles come together in a fertilized egg by pure chance. Drones are produced from such eggs, but bees destroy them, perhaps because they don't have the right odour (RUTTNER, 1988). The loss of brood is manifested under the form of empty cells called "pepperpot brood" (see WOYKE, 1963). By increasing the probability that alleles will occur in the homozygous state, the inbreeding allows the expression of the recessive alleles which are normally hidden. As some of them are deletarious, the result is a decrease in fitness of the inbred individuals and the morphological characters are subject to changes under inbreeding (MACKENSEN, 1956). Inbreeding leads to a clear disruptive selection pattern for the wing vein (cubital index) (CORNUET et al., 1975, BRUCKNER, 1976), the cubital index, the tongue length and the forewing length (ROBERTS, 1961). Keeping these facts in mind, an attempt was made to know the extent of the inbreeding depression in the *A. mellifera* stock in India.

Pepperpotness in brood was observed thrice during the most active brood rearing season. For this purpose, good combs (one at a time) were moved to the centre of the brood nest area and the empty cells were observed on the 12th day by means of a rhomboidal opening which exposes 10 x 10 (100) cells. Averages of 5 to 10 counts at different positions on the comb were taken. This was repeated thrice in January, February and March, 1994. To avoid errors, the colonies had been treated for ectoparasitic mite control. Along with pepperpotness, the proboscis length, the forewing length and the cubital index in worker bees were also recorded, each with an observation on pepperpotness.

RUTTNER (1988) assumed that a dangerous reduction of the productivity occurs with the degree of inbreeding when more than 25 percent empty cells are present in the sealed brood. A certain degree of inbreeding is possible if the queen rearing and mating control is practised, i.e. if all the colonies are not free to raise and mate their own queens and the extent of inbreeding depends on the number of breeder queens and drones employed. RUTTNER calculated that the 25 percent extet would be reached in 10 generations if 8 breeder animals are used. The present observations showed that there were 4.83 to 7.73 empty cells per 100 cells and this is much lower than the hazardous level (see table 2). In India, there has been no control on queen, raising and mating since the artificial queen rearing and the use of breeder colonies for drone production are not practised by beekeepers. Therefore, the possibility of any degree of inbreeding is very remote. Moreover, the queens are allowed to mate freely in apiaries and potential beekeeping localities are sufficiently saturated with *A. mellifera* colonies. Therefore, this ensures the remedy to any harm, if any at all occurs due to the low chance of inbreeding.

Further work was carried on, regarding the hypothesis that the inbreeding harms the Indian *A. mellifera* stock. Morphometrics with respect to the proboscis length, the forewing length and the worker bee cubital index were effected in eight colonies used for observing pepperpotness. The three values ranged between 6.33 to 6.52 mm, 9.11 to 9.34 mm and 2.42 to 2.75, respectively. The present day stock of *A. mellifera* in India is believed to have descended from *A. m. Ligustica* and *A. m: carnica.* The proboscis length and cubital index are greater than the previously repor-

Table 2

Pepperpotness and morphometrical characteristics of *A. mellifera* in India

Col. No.	January 1994				February 1994				March 1994				Mean			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2	6.0	6.383 (0.881)	9.320 (0.298)	2.656 (0.175)	7.4	6.393 (0.272)	9.033 (0.070)	2.545 (0.332)	5.2	6.433 (0.177)	9.140 (0.082)	2.667 (0.000)	6.36	6.403 (0.179)	9.164 (0.185)	2.622 (0.178)
3	11.2	6.527 (0.158)	9.250 (2.241)	2.677 (0.285)	4.3	6.200 (0.062)	8.973 (0.144)	2.412 (0.201)	6.8	6.266 (0.084)	9.141 (0.147)	2.603 (0.289)	7.20	6.331 (0.177)	9.121 0.196)	2.564 (0.272)
4	5.7	6.390 (0.123)	9.387 (0.306)	2.515 (0.321)	7.0	6.387 (0.098)	8.893 (0.225)	2.626 (0.272)	5.0	6.393 (0.049)	9.053 (0.188)	2.573 (0.115)	5.90	6.390 0.085)	9.111 (0.290)	2.571 (0.214)
8	5.2	6.700 (0.136)	9.510 (0.169)	2.560 (0.303)	4.3	6.460 (0.208)	9.110 (0.184)	2.823 (0.272)	5.0	6.408 (0.157)	9.063 (0.142)	2.636 (0.106)	4.83	6.522 (0.204)	9.227 (0.245)	2.673 (0.203)
12	6.3	6.530 (0.190)	9.560 (0.320)	2.515 (0.143)	4.5	6.367 (0.196)	9.289 (0.107)	2.316 (0.076)	6.0	9.360 (0.076)	9.155 (0.124)	2.689 (0.158)	5.60	6.419 (0.170)	9.334 (0.253)	2.673 (0.158)
14	10.1	6.467 (0.164)	9.247 (0.370)	2.545 (0.120)	4.6	6.275 (0.220)	9.030 (0.186)	2.277 (0.099)	4.6	6.366 (0.411)	9.333 (0.262)	2.454 (0.161)	6.43	6.369 (0.290)	9.203 (0.308)	2.425 (0.197)
23	9.0	6.407 (0.153)	9.230 (0.184)	2.531 (0.276)	6.5	6.375 (0.191)	9.350 (0.277)	2.286 (0.254)	5.8	6.366 (0.122)	9.225 (0.176)	2.821 (0.269)	7.10	6.382 (0.143)	9.268 (0.217)	2.546 (0.340)
31	8.0	6.467 (0.259)	9.687 (0.203)	2.826 (0.138)	4.0	6.640 (0.114)	9.100 (0.033)	2.804 (0.142)	10.5	6.267 (0.147)	9.220 (0.096)	2.636 (0.275)	7.50	6.457 (0.230)	9.335 (0.288)	2.755 (0.201)
A*	7.56	6.483	9.398	2.603	5.57	6.387	9.097	2.511	6.04	6.357	9.166	2.634	6.433	6.409	9.220	2.604

1. Pepperpotness.
2. Proboscis length.
3. Forewing length.
4. Cubital index.

A* = Average

Figures in parentheses are standard deviations.

Table 3

Comparisons of the morphological characteristics of *A. mellifera*

Race	Reference	Proboscis length (mm)	Forewing length (mm)	Cubital index
A.m. ligustica				
Kangaroo Island	RUTTNER, 1976	6.175—6.332	9.01—9.13	2.14—2.41
Italy (Bologna)	RUTTNER, 1976	6.275—6.298	9.02—9.24	2.53—2.74
Different races from countries with indigenous *A. mellifera*	RUTTNER et al., 1978	5.51—7.19	7.98—6.69	1.58—3.62
A. mellifera				
Mandi (H.P.), India	MATTU & VERMA, 1985	6.298	9.130	2.3512
Shimla (H.P.), India	MATTU & VERMA, 1985	5.3039	8.561	3.828
A. mellifera mellifera	RUTTNER, 1988	5.8—6.2	—	1.5—1.9
A.m. carnica	RUTTNER, 1988	6.4—6.8	8	2.4—3.0
A.m. ligustica	RUTTNER, 1988	6.4—6.7	8	2.0—2.7
Italian race	RUTTNER, 1988	6.5—6.8	—	2.2—2.8
A.m. mellifera	Present observations	6.33—6.52	9.11—9.33	2.42—2.76

ted values (see table 2) in *A. mellifera,* but are slightly lower or in close proximity with those of *carnica* and *ligustica.* These values also lie within the range reported by RUTTNER et al., (1978) for different races from countries with indigenous *A. mellifera.* Similarly, in the present study, the forewing length is of 9.22 mm, being situated within the range of 7.98— 9.69 mm given by RUTTNER et al., (1978). MATTU and VERMA (1979) reported that, out of the characteristics, only the tongue length, the forewing width, the wing venation and the angle and the breadth of the 6th sternite in the introduced *A. mellifera* were significantly different from those in the original Italian bees from Bologna (RUTTNER, 1976). But the biometry of worker bees differs with seasons, being smaller in size during the dearth periods. This might have happened especially in samples from Shimla (H.P.) Moreover, the imported bees came from different sources i.e. hybrids and strains, therefore, the *A. mellifera* bees in India cannot be compared with any other race and the minor deviations cannot be ruled out. The comparisons of the present observations with those of the earlier authors (table 3), show that no inbreeding hazards have occured in the *A. mellifera* stock after importation, for 30 years now. This idea is supported by the fact that the Italian bees living in a protected isolation on the Kangaroo Island (South Australia) still show the typical morphological characters of the *A. ligustica* bees from Italy (RUTTNER, 1976). The bees on the Island are purely Italian because of the "Ligurian Bee Act" which made the whole Island a sanctuary for these bees, in 1985. It is expected that, similarly to the introduction of *A. mellifera* in India, only a limited number of colonies might have been introduced to the Kangaroo Island and they have not undergone morphological or behavioural changes due to the acclimatization or the inbreeding. But caution is necessary and the efforts are increased to import semen for hybridization and infuse new brood in the present stock in India. Moreover, colonies which show very few holes in the sealed brood should be used for queen rearing. To settle the question of inbreeding hazards, more extensive and exhaustive studies have been planned for implementation through the network of our "Whole India Project" in the states where *A. mellifera* is flourishing.

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The Author's Address:
R.C. MISHRA and Yogesh KUMAR
Whole India Co-ordinated Project on Honeybee Research
Haryana Agriculture University, Hisar
Haryana — 125004, INDE