5. DISCUSSION

Melissopalynogical studies of honey, corbicular load and bee body surface adhered pollens of all seasons, collected from different locations of North 24 Paraganas of West Bengal, have portrayed pollen and nectar foraging behavior of *Apis mellifera* in that biozone. The spectra of pollens recorded in different seasons were in accordance with the time of flowering of different species growing in the locality. Altogether, 56 plant taxa belonging to 33 families were being visited by the bee species either for pollen grains and/ or nectar. Although the spectra are very much characteristic of the locality of the apiculture and the seasons of growing, the presence of heterogeneity in the pollen population in respect of species in the same season but during different years are instances of natural phenomena only. Most naturally the pollen populations in honey samples of any season showed much diversity in comparison to pollens obtained from corbicular loads.

The study of pollens from honey showed prevalence of *Brassica* pollens in the month of January. Even though the relative abundance comes down the pollens of *Brassica* dominate during February as well, followed immediately by *Coriandrum sativum*. *Ziziphus mauritiana* pollens prevail in majority during March, quite in contrast with *Nigella sativa* following next. *Ziziphus mauritiana* and *Borassus flabellifer* predominate in April, *Sesamum indicum* in May, *Amaranthus* sp. in June, *Trema orientalis* and *Anthocephalus cadamba* in July, *Trema orientalis* still prevailing most during August and *Poa gangetica* in September. Likewise, the pollens of *Poa gangetica* in October, *Brassica* sp. in November and December. In consideration of Louvaeux *et al* (1978) in many instances the honey may be designated as mono- or unifloral as the share of predominating species exceeded 45%. Besides the most prevalent species many other species also contribute to the production of honey and are of secondary importance. In absence of the primary ones these species are supposed to be the most prospective producers of honey. Some of these species are *Eucalyptus globules*, *Borassus*

flabellifer, *Cucurbita maxima*, *Sesamum indicum*, *Holoptelia integrifolia*, *Cocos nucifera*, *Basella alba*, *Nigella sativa*, *Moringa olifera*, *Syzygium cumini*, *Hygrophila schulli*, *Mangifera indica*, *Citrus* sp., *Duranta erecta*, *Momordica charantia*, *Delonix regia*, *Polianthes tuberosa* and some others. As a very natural phenomenon the bees have been noticed to go for a preference based foraging for the species growing together and flowering simultaneously. On account of that the major pollen constituent of a honey sample gets changed in a month even though the species that contributed pollen earlier continues blooming. The quality and amount of nectar production by nectariferous plants have been claimed to be very much governed by biotic and abiotic factors (Adgaba *et al*, 2017). Adgabe and fellow researchers also expressed that tree species produce more nectar than herbaceous species. The change might have been taking either due to the reaching of another more preferred nectariferous species in its blooming stage or due to the paucity of nectar in the species that has reached to the fag end of flowering, and still there may be other reasons as well. Such a condition may be adduced with the instances of preponderance of pollens of *Brassica* during January and in February, too, along with a minimum amount of the pollen of *Ziziphus mauritiana*. The scenario changes to a condition of the prevalence of *Ziziphus mauritiana* pollen during March and April, resulting in the minimum presence of *Brassica* pollen in honey. Apiary people place the hive boxes in close proximity with agricultural fields with a purpose of harnessing the maximum production possible. However, a field based witness showed that bees practice preference for one or two nectariferous species amongst the couple of ones growing or being cultivated contiguously and such a condition can be cited with the result obtained here which showed the pollens of *Brassica* to have lion's share of the total pollen population in honey samples collected during January and February, while the pollens of *Coriandrum sativum* followed next. Still then the basis of such preference remains mostly confounding as can be exemplified by the occurrence of *Ziziphus mauritiana* pollen as the major pollen constituent of honey consistently existed for

two months, March and April, the pollens in the second position was found to be of *Nigella sativa* in the month of March, but replaced with *Borassus flabellifer* in April. Most strikingly, even though *Nigella sativa*, *Eucalyptus* sp., *Mangifera indica*, *Litchi chinensis* are well known nectariferous species and their unifloral honey earn much fame, in the present survey they represented quite feebly in the honey samples collected during the respective seasons of flowering.

The productivity of apiary falls during monsoon as bees fail to go for foraging in rain and also with the cessation of rain the collection of nectar and pollen remains unachievable. The productivity gets affected both in respect of amount and quality. Notwithstanding the presence of such unsurmountable problem the record of present investigation highlights the promising role of *Trema orientalis*, the pollens of which though appeared as the minor one during May, became an 'important minor member' in June, and the predominant one during July and August, while again phased out in September as an important minor pollen. *Trema orientalis* is a very insignificant wild tree that grows gregariously along roadside and on fallow land. During monsoon when contribution of other nectariferous plants becomes quite bleak, the pollen of *T. oriantalis* succours well. This revelation seems to be quite significant to take further measure to boost up the honey production with this species during this period of decline in productivity and to get rid of feeding bees artificially with sugar syrup, which is only effective for the sustenance of the bees in artificial captivity and of no use for the production of quality honey. But, the claim by Nguemo *et al* (2016) is quite in contrast with this as they illustrated quite large amount of pollen of diversified nature during rainy season while working in Cameroon. In their experience the predominant and important minor pollens are more in number and of varied nature during monsoon in comparison to the dry seasons.

Poa gangetica, another weed, was recorded to be the predominant species as a contributor of pollen in honey during the months of September and October. From November onwards

Brassica made a lead till February. The entire spectrum of pollens obtained in the honey samples collected from the area, under study, displayed the characteristic vegetation of it, which in turn attests the botanical and geographical origin of honey, too. This very basic fact regarding utility of melissopalynological study has been reiterated through the works of many researchers (Maurizio, 1951, Mistry, 1987, White *et al*, 1991, Jones and Jones, 2001, Sodre *et al*, 2007, Saboi *et al*, 2011, Ige and Obasanmi, 2014, Mushtaq *et al*, 2016, Dhawan *et al*, 2018) and many others.

The complete study reveals the predominating pollen species in honey samples obtained throughout the year as *Brassica* sp., *Ziziphus mauritiana*, *Sesamum indicum*, *Amaranthus* sp., *Trema oriantalis* and *Poa gangetica* in different months, though their status changed even to 'minor' in a different month. The species represented highest at the level of 'secondary' in any month in a year were, *Acacia auriculiformis*, *Amaranthus* sp. *Anthocephalus cadamba* and *Coriandrum sativum*. *Ziziphus* sp. and *Acacia* sp. have been stated to be rich source of honey in other works, too (Khan et al, 2016, Dhawan et al, 2018). Saklani and. Mattu (2018) recounts the pollens of different species present in collected honey and assign them to different classes based on the relative occurrence of pollens. A host of species representing as 'important minor pollen' were noted as, *Acacia nilotica*, *Anthocephalus cadamba*, *Borassus flabellifer*, *Cocos nucifera*, *Croton bonplandianum*, *Cyanotis axillaris*, *Delonix regia*, *Duranta erecta*, *Holoptelia integrifolia*, *Hygrophila schulli*, *Jatropha carcus*, *Mangifera indica*, *Momordica charantia*, *Moringa oleifera*, *Nigella sativa*, *Phoenix sylvestris*, *Syzygium cumini*, *Trichosanthes dioica* and *Vernonia cinerea*. The presence of pollens of *Eucalyptus globules*, *Syzygium cumini* and *Brassica* sp. in honey has also been reported by Chauhan *et al* (2017). The occurrence of *Ageratum conyzoides* as a major constituent in honey in their report is however quite in contrast with the finding of present study. Some other species always remained as 'minor' pollen due to their least presence in the honey and those were *Alangium*

salvifolium, *Basella alba*, *Bombax ceiba*, *Citrullus lanatus*, *Cucumis sativus*, *Cucurbita maxima*, *Eucalyptus globules*, *Leucaena leucocephala*, *Lippia nodiflora*, *Litchi chinensis*, *Luffa cylindrica*, *Madhuca indica*, *Mikania scandens*, *Monochoria hastata* and *Polianthes tuberosa*.

Assurance about source plant increases the value of the commercialized honey. There is a craze worldwide for unifloral or monofloral honey of some well recognized plant species having medicinal significance. Melissopalynological evidence gives indirect information about this. In accordance with Louveaux *et al* (1978) during three years of study only the honey samples collected during January and December was found to be consistently unifloral for *Brassica* sp., that of September as unifloral for *Poa gangetica*, of August as unifloral for *Trema oriantalis*. Besides these the honey procured during March is unifloral for *Ziziphus mauritiana*, that of May is unifloral for *Sesamum indicum*, in June the honey is unifloral of *Amaranthus* sp. and of *Poa gangetica* in October. Such a simplified consideration based on Louveaux *et al* (1978) has been contradicted by other researchers (Bryant and Jones, 2001; Bryant, 2013), soliciting for R value.

The appearance of many well established nectariferous species as 'minor' or 'important minor', in the present study, does not necessarily mean any deviation of their efficacy as a prospective honey source, instead, might be so due to paucity of the individuals of that species in the surroundings or due to other reasons. In consideration of all these facts the findings of the present survey seem to be significant in showing the remarkable plants in different localities of North 24 Paraganas mostly contributing in the production of honey there. The species in secondary position are the supportive ones, which might have the potential for restoring honey production and providing sustenance of apiary in absence of the species in predominant position. It is also quite interesting to note that though in almost all cases the apiaries are migratory in nature and hive boxes are placed in close proximity to the cultivated land, in many

cases pollens of naturally growing trees or weedy herbs represent as predominant pollens; so, the natural vegetation of the studied area is supposed to be comprised of many nectariferous plants quite apt in supporting apiary in that locality. The study also envisaged difference in the pollen constituents of honey in the collection of same month but in different years. Thus, in February of the year 2014 *Coriandrum sativum* was found to be the most prevalent one, followed sequentially by *Brassica, Holoptelia integrifolia, Moringa oleifera, Cocos nucifera, Croton bonplandianum*, *Trema orientalis, Phoenix sylvestris*; whereas, *Brassica* sp. as the most dominating one in 2015 and 2016. While pollens of ten more species were recorded in 2015, only five other members are noted in 2016. Likewise, difference had been met in other months as well. Such a variation is nothing unnatural, as blooming of flower may vary in regard of its time of appearance, amount of emergence and might be also due to some other reasons.

Corbicular loads carried on the hind legs of bees are purely pollen and showed a spectrum of pollen, quite different from those obtained from honey. Though earlier records showed different species to act as nectariferous and polliniferous, the present study showed pollens of *Brassica* to predominate in January in corbicular load, quite similar to the pollens from honey in the same month. Whereas, in February pollens in loads were noted to be of *Coriandrum sativum* and *Phoenix sylvestris*, instead of *Brassica* sp. Similarly, in March instead of *Ziziphus mauritiana* as a predominant pollen in honey, *Citrus* sp. and *Hygrophila schulli* were obtained. This trend is met in other months as well. Such a change points toward the difference in the source plants for nectar and pollen, though some species provide both nectar and pollen. Species of the pollens, obtained only in the pollen loads, were *Ageratum conyzoides, Flacourtia jangomas, Foeniculum vulgare, Jatropha curcas, Punica granatum, Raphanus sativus, Spondius pinnata, Terminalia arjuna* and *Tridax procumbens*. *Ageratum conyzoides*, an obnoxious weed though, was also reported by Chauhan *et al* (2017) from different parts of Uttar Pradesh, however as pollen constituent of honey. Some species *e.g. Acacia*

auriculiformis, *Acacia nilotica*, *Alangium salvifolium*, *Amaranthus* sp., *Anthocephalus cadamba*, *Bombax ceiba*, *Borassus flabellifer*, *Brassica* sp., *Citrus* sp., *Coccinia grandis* and a host of species (Table 4.15) were common for honey and corbicular loads.

After analyzing the pollens which get smeared to the body surface of *Apis mellifera* were quantitatively and qualitatively measured to estimate the presence of relative amount of pollens of different plant species during their foraging. In total, pollens of thirtyfive plant species belonging to twentyfive families were found from the body surface of the bees (without pollen loads in the corbiculae) signifies the nectar foraging pattern of the bee species. This picture again confirmed by the analyses of honey samples. Three species viz. *Carica papaya*, *Dalbergia sissoo* and *Tamarindus indica* were obtained from body surface which were neither found in honey nor in corbicular load.

From the foregoing observations it was understood that twentyone agri-horticultural plants were being foraged vigorously by the bee species during different seasons at various locations of the district 24 Parganas. Those important agri-horticultural taxa are *Brassica* sp., *Citrus* sp., *Coccinia grandis*, *Cocos nucifera*, *Coriandrum sativum*, *Cucumis sativus*, *Cucurbita maxima*, *Foeniculum vulgare*, *Litchi chinensis*, *Luffa cylindrica*, *Momordica charantia*, *Moringa oleifera*, *Nigella sativa*, *Phoenix sylvestris*, *Punica granatum*, *Raphanus sativus*, *Sesamum indicum*, *Spondias pinnata*, *Trichosanthes dioica* and *Ziziphus mauritiana*. During foraging *A. mellifera* by virtue of the nature of floral fidelity help in the pollination processes of those crops that lead to increase the yield (Nandi and Karmakar, 2018). It was also noted that the present work provides significant information regarding plant variety and the annual blooming pattern. By knowing the blooming pattern and the preferred plant taxa for the collection of nectar and pollen by *A. mellifera*, the beekeepers will get a suitable understanding regarding fruitful establishment of apiaries in that area.