Melissopalynology of Honey Beeflora in Khyber Pakhtunkhwa – Pakistan

QUAID-I-AZAM UNIVERSITY

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ABSTRACT

The guiding principles for raising beekeeping products in developing countries provide support for commercializing honey production in order to generate income for beekeepers through the exploration of honeybee flora. The aim of this project was to conduct a detailed study of melissopalynology of honeybee flora in Khyber Pakhtunkhwa-Pakistan. The melissopalynological features, honey analysis, dominant plant families visited by honeybees, and life forms were studied. In total of 114 species belonging to 105 genera and 43 families were identified as visited by honeybees. Acetolysis method was used to prepare the microscopic slides of pollen and describe the qualitative and quantitative features using LM and SEM. Honeybee flora have been characterized by small, small-to-medium, medium and large sized pollen morphotypes. Pollen grains were monad to polyad, zonocolporate, and radially symmetrical. Pollen shape varying from prolate-spheroidal, oblate-spheroidal, spherical, sub-prolate and sub-oblate, sub-spheroidal, prolate to per-prolate. Pantoporate type pollen was observed in Amaranthaceae, monoporate in Poaceae, tricolporate in Fabaceae, trizonocolporate in Asteraceae, tricolpate to tricolporate in Brassicaceae, and tricolporate in Apiaceae, Myrtaceae, and Solanaceae. Fastigium cavities were observed mostly in aperturate grains. The highest polar diameter (120 µm) and equatorial view distance (121µm) was observed in *Alcea rosea*. Scanning electron microscopy revealed diverse exine peculiarities reticulate, psilate, scabrate-verrucate, scabrate-gemmate, granulate, perforate, micro-echinate, micro-reticulate, and regulate to fossulate. Exine thickness was measured maximum for *Boerhavia procumbens* (7.45 µm). Identification of 24 honey samples were authenticated using standard protocol to described pollen spectrum of dominant vegetation. Honey analysis indicated that the highest pollen diversity was observed in *Acacia ssp., Eucalyptus spp.* and *Ziziphus spp.* honey samples. The outcomes of this study aid in the assessment of honeybee flora and help in providing conservation measures for the sustainable development. The data generated in this study may helpful in identification of the floral sources and will enable us to develop the pollen atlas and commercialize honey production to generate revenue through beekeeping practices.

Chapter 1
Introduction

1.1 Melissopalynology

Melissopalynology, is an applied branch of palynology, which involves microscopic examination of pollen grain present in the honey and any confirmatory evaluation of bee plants is incomplete without this (Saklanai and Mattu, 2017). Melissopalynology, the identification of bee-collected pollen, provides insight into the flowers exploited by foraging bees. Information provided by melissopalynology could guide floral enrichment efforts aimed at supporting pollinators (Richarson et al., 2015). Pollen analysis of honey, or melissopalynology, is of great importance for quality control. Honey always includes numerous pollen grains (mainly from the plant species foraged by honeybees) and honeydew elements (like wax tubes, algae and fungal spores) that altogether provide a good fingerprint of the environment where the honey comes from floral species (Ohe et al., 2004). Pollen is an essential tool in the analysis of honey as it indicates the major and minor plant taxa utilized by honeybees. The presence of dominant pollen is used to characterize unifloral honey while if none is dominant, it is of mixed floral species (Selvaraju et al., 2019).

Melissopalynology is of great importance for quality control of honey. Pollen analysis can therefore be useful to determine and control the geographical and botanical origin of honeys (Gençay et al., 2018). The identification and quantification of pollen in honey is known as melissopalynological studies. These studies are quantitative and qualitative microscopic determination of pollen present in honey which helps in determining floral or botanical origin which is essential for standardization of honey and geographical origin of the honey and foraging ecology of honeybees (Rosi et al., 2016).

The determination of the botanical origin of honey is based on the relative frequencies of the pollen types of nectariferous species (Zappi et al., 2018). It deals with the qualitative and quantitative analysis of the pollen contents of honey and pollen loads of an area, establishes the nature and quality of honey, can be used to determine the geographical region of the hive, and provides reliable data on the nectar and pollen sources used by honeybees throughout the year. Furthermore, the melissopalynology study of honey resources can provide a baseline of information for the formulation of national standards for honey products (Sajwani et al., 20114). Melissopalynological studies are beneficial for both beekeepers and consumers (Bryant 2018). Knowing about the botanical composition of the honey that bees produce enables beekeepers to offer high-quality and reliable honey products to their clients who are willing to pay for honey that is attractive in color, flavor and odor (Paredes and Bryant, 2020).

1.2 Importance of Melissopalynology

Pollen analysis of honey or melissopalynology is of great importance for apiculture industry as it gives the information about bee plants, sources of nectar and pollen for the honey bees throughout the year. This type of information is important for launching apiary industry in a locality (Tiwari et al., 2010). In recent years, melissopalynology has attained a global status. This is borne out of the fact that not only is honey useful as a food supplement; it is now increasingly being used in the treatment of various diseases (Abdulrahaman et al., 2013). Pollen is an essential tool in analysis of honey. The floral nectar source utilized by honey bees for honey production can be determined by identification of the pollen taxa (Adekanmbi and Ogundipe, 2009). The relative pollen frequency is often used to verify and label a honey sample as the major or minor nectar source. Identifying and quantifying the pollen in honey sample is one of the best ways to determine the range of nectar types used to produce honey and therefore label it correctly based on actual foraging sources (Bibi et al., 2008).

1.3 Honey

Honey is a natural product consumed without the addition of any ingredient, and is characterized by its complex composition, which varies according to the bee species, geographical region and available floral source. Ordinarily, honey categorized as monofloral (when the majority of the honey produced from single plant species) and polyfloral (honey produced from the contribution of different plants). Honey is a source of natural antioxidants with application in human health, and in the prevention of deteriorative oxidative reactions. Antioxidant properties are strongly related to the chemical composition, which in turn, depends on the floral source and environmental factors (Hailu and Baley, 2020). Honey is essentially a supersaturated solution of monosaccharides in water. It also contains multiple components such as carbohydrates, amino acids, vitamins, organic acids, esters, volatile components, hydroxymethylfurfural, enzymes and phytochemicals. Honey from stingless bees contain higher amount of moisture and Marinus (2006) reported high water content of up to 42%. Stingless bees are native to Malaysia and are common to tropical and sub-tropical areas in South-east Asia region. Honey composition can vary according to seasons, geographical area, entomological and floral sources, environmental, beekeeping and processing factors (Selvaraju et al., 2019). Bee floral resources provide pollen materials to honeybees, as they visit them to collect nectar/honeydew, and stored in honeycomb where with some specific substances added by honeybees, the nectar/honeydew transformed into honey along with pollen (Sunita et al., 2018).

Honey is widely consumed as a health product, but due to its high commercial value, it is often adulterated or labelled falsely for economic gains. Although there exist methods to determine the botanical origin of honey using color, taste, flavour and content of physiologically active ingredients, Kaškonienė et al., (2010) argued that the information obtained by these tests are not always a reliable determination of botanical origin of honey (Siddiqui et al., 2017). Honey is one of the apian products more linked to the territory in which was produced, due to plant communities of the area, climate, soil and apicultural practices drive its characteristics (Ghorab et al., 2021). Different compositions of honey in each area show different tastes as well as medicinal properties depending on the foraged food sources (Thakodee et al., 2018). Honey is a complex food matrix produced by honeybees (*Apis mellifera*) from the nectar collected from plants or from the excretions of plant-sucking insects on the living parts of plants or secretions of living parts of plants (honeydew honey), which the bees transform and mix with their own specific substances. Honey is mainly a supersaturated solution of sugars with low water content and small concentrations of bioactive compounds, such as phenolic acids, flavonoids and other polyphenolic compounds, carotenoids, organic acids, amino acids, peptides, proteins, enzymes, lipids, waxes, aroma compounds, vitamins, minerals and pollen grains (Puścion-Jakubik et al., 2020).

1.4 Honey Composition

Honey is produced by bees from the genus *Apis*, which collect the nectar from plants or from secretions of aphids. It is a sweet and flavorful natural product, supersaturated in sugars, with high nutritive value. Besides the sugars, other minor components are present in honey, such as minerals, polyphenols, vitamins, carotenoids, amino acids, proteins, enzymes (glucose oxidase and catalase), organic acids, and volatile compounds (Miguel et al., 2017). The complex chemical composition depends mainly on the flowers, geographical and climate conditions and honeybee species involved in its production. Parameters such as weather conditions, processing, manipulation, packaging and storage time also affects the honey composition (Lopes et al., 2018). Bee honey is mostly a mixture of sugars (blossom honey average content: 69.5%, honeydew honey: 57.9%) and water (respectively: 17.2% and 16.3%), but also contains many compounds with nutritional and prophylactic properties, including minerals (0.2% and 0.9%), enzymes, amino acids and protein (0.3% and 0.6%), acids (0.5% and 1.1%), vitamins, essential oils, dyes and phenolic compounds (Puścion-Jakubik et al., 2020). The large variation in the chemical composition of honeys, which depends on floral sources, climate, harvesting process, storage conditions and ageing, contributes to the huge diversity of color, aroma, flavour and viscosity of honeys. The high osmolarity of honey, due to its high sugar content, combined with its low water activity (below 0.60) are usually associated with high viscosity (Faustino and Pinheiro, 2021).

1.5 Botanical Origin of Honey

Microscopic analysis is an essential tool to assess the botanical and geographical origin of honey and to understand the foraging ecology of bees. Unfortunately, the technique is still based on a variety of procedures for sample preparation with little experimental evidence to document their reliability and pollen-extraction efficiency (Lutier and Vaissière, 1993). Pollen analysis can therefore be useful to determine and control the geographical and botanical origin of honeys even if sensory and physico-chemical analyses are also needed for a correct diagnosis of botanical origin. Moreover, pollen analysis provides some important information about honey extraction and filtration, fermentation (Ohe et al., 2004). The identification and quantification of pollen grains in honey sediment (melissopalynological) is still the most important method for determining the botanical origin of honey (Feas et al., 2010). Statistical analyses, mainly ordination, have been carried out on melissopalynological data in quantitative studies to obtain more robust characterization of the honeys in terms of their geographic and botanic origins (Ponnuchamy et al., 2014). The botanical and geographical origin of honey may be evaluated through melissopalynology, which is used to assess the pollen types present in the honey and to suggest its floral source (da Saliva et al., 2013).

1.6 Honey Adulteration

Honey adulteration not only affects the quality of the honey, but also its production, since declining sales would reduce the bee-keeping industry. The impact of honey adulteration on the bee-keeping industry will in turn affect the whole ecosystem, since bees are the main pollinators of wild and cultivated plants and contribute to the maintenance of biodiversity. Honey adulteration occurs by direct addition of sucrose syrups that are produced from sugar beet, high-fructose corn syrup (HFCS), maltose syrup or by adding industrial sugar (glucose and fructose) syrups obtained from starch by heat, enzyme or acid treatment, or by feeding the bee colonies excessively with these syrups during the main nectar period (Wu et al., 2017). Honey can be adulterated through various ways that can affect the quality of honey. Various adulterants include chemicals and other substances. If the honey is adulterated with chemicals, it can affect its medicinal value and may prove poisonous to consumers (Anthony and Balasuriya, 2016). Other adulterants include inverted syrup and starch syrup. These are added to feed bees due to which low quality of honey can be added to high quality of honey. Different types of adulterants can be added directly or indirectly. In direct adulteration, adulterants are added directly whereas in indirect adulteration, honeybees are given different substances like honey, chemicals and industrial sugars. Thus, the presence of these types of adulterants is a challenge (Zábrodská and Vorlová, 2015).

1.7 Biological Activities of Honey

Honey is a popular carbohydrate resource for athletes, generally taken before and after resistance exercise. The lower glycemic index of honey also allows its modest use in types I and II diabetes. It elevates hemoglobin concentration, stimulates insulin secretion, decreases blood glucose levels, and improves lipid profile. Several studies have reported the antioxidant activity and phenolic content in honey (Jamróz et al., 2014, Piljac-Žegarac et al., 2009), and established a correlation between phenolic content, antioxidant activity, and color intensity. Due to the presence of phenolic constituents, honey exhibits anti-carcinogenic, anti-inflammatory, anti-atherogenic, anti-thrombotic, immune-modulating, and analgesic activities. Studies have also shown that natural honey decreases cardiovascular risk factors without any increase in body weights (Yaghoobi et al., 2008). Modern research indicates that honey can serve as a remedy for various diseases. Due to the complex mixture of sugars, acids and proteins, honey improves the resistance against pathogenic organisms. Honey is also a useful remedy against helminth diseases, in particular intestinal nematodes, including ascariasis, hookworm infection, etc (Sajid and Azim, 2012). In another study, honey glycoproteins and peptides were found to exhibit immunomodulatory properties by interfering with molecules of the innate immune system in humans (Mesaik et al., 2014; Siddiqui et al., 2017).

1.8 Importance of Honey

For at least 2700 years, honey has been used by humans to treat a variety of ailments through topical application, but only recently have the antiseptic and antibacterial properties of honey been chemically explained (Israili, 2014). Some cultures believed that honey had many practical health uses. It was used as an ointment for rashes and burns and used to help soothe sore throats when no other medicinal practices were available. Wound gels that contain antibacterial raw honey and have regulatory approval for wound care are now available to help conventional medicine in the battle against drug-resistant strains of bacteria. As an antimicrobial agent honey may have the potential for treating a variety of ailments. New Zealand researcher refers to a particular type of honey (Manuka honey) which is useful in treating MRSA infections (Johnston et al., 2018). The antibacterial properties of honey are the result of the low water content causing high osmotic pressure, hydrogen peroxide effect, high acidity, and the antibacterial activity of methylglyoxal. Honey appears to be effective in killing drug-resistant biofilms which are implicated in chronic rhinosinusitis (Murthy et al., 2014). In recent years, melissopalynology has attained a topic of global status. This is borne out of the fact that not only is honey useful as a food supplement; it is now increasingly being used in the treatment of various diseases. These healing properties of honey are as a result of the integration of pollen and nectar containing bio active ingredients from medicinal plants that the bees foraged on (Durazzo et al., 2021).

1.9 Pollen

Pollen of flower is a source of certain macronutrients and is collected by worker honeybees. Collected from floral anthers at the tips of stamens, flower pollen grain stick to bee secretions. They are then assembled by the bee in loads and placed in the baskets of the hind legs of the insect (Nonotte-Varly, 2015). Each plant species has flowers with a distinct pollen type that can be studied to determine the floral source of honey. The pollen analysis is of great importance for quality control of honeys, which can include numerous pollen grains and honeydew, elements that, together, can provide information about their floral origin (Do Nascimento et al., 2015). Pollen grains of each plant species have their own genetic code of inheritance and special structural patterns, which enable pollen grains of one species to be differentiated from another (Bareke and Addi, 2019). Pollen grains are mostly carried from the honey plants during foraging, which is used to fulfill the amino acid, fatty acid and mineral requirement of honeybees' diet (Belay et al., 2017). The presence of floral pollen grains within honey enables the identification of the nectariferous plants that a honey sample was sourced from. Pollen analysis of honey have been used to accurately determine the botanical and geographic origin of honey samples and also help us to verify honey authenticity (Layek et al., 2020).

Melliferous plants produce various shapes, sizes, and surfaces of pollen grains. Their identification is complicated, therefore samples for comparison purposes (plant pollen collected by hand) to be used as reference material should be collected. Currently, depending on the research subject, laboratories use a host of microscopy techniques to study images of pollen grains (Čeksterytė et al., 2013). Moreover, it can potentially be used to characterize the local flora regarding its diversity and phenology (Guimarães et al., 2019). Quantitative identification of pollen is indispensable for investigating the link between forage and foragers, especially those of pollinators (Richardson et al., 2015). Melliferous flora can be identified either by primary or secondary sources of information (Hepburn and Radloff, 1998). Primary sources include analysis of pollen stored in nests or hives (Ramanujam and Kalpana, 1992); analysis of pollen loads removed from returning foragers (Köppler et al., 2007); palynological analysis of honey (Adekanmbi and Ogundipe, 2009); and identification through direct observation of foragers in field (Ayansola and Davies, 2012).

1.10 Pollen Source in Honey

The raw materials for the honey production are mainly pollen and nectar that come from flowering plants. About 500 flowering plant species both wild and cultivated are useful as major or minor sources of nectar and pollen (Adgaba et al., 2017). The term pollen source is often used in the context of beekeeping and refers to flowering plants as a source of pollen for bees or other insects. Bees collect pollen as a protein source to raise their brood. For the plant, this can be an important mechanism for sexual reproduction, as the pollinator distributes its pollen. Few flowering plants self-pollinate; some can self-pollinate but require a pollinator to move the pollen while others are dependent on cross-pollination. During evolution, a special relationship has been established between the plants and the bees (Dohzono and Yokoyama, 2010).

Four natural resources are required by honeybees for survival, namely water, resin, nectar and pollen (Schmickl and Karsai, 2016). Water is used to cool the beehive and dilute honey fed to larvae. Resin reinforces the hive and plugs holes. Nectar is the major source of carbohydrates from which honeybees obtain their energy. According to Layek et al., (2020) pollen is the major source of protein, fatty substances, minerals and vitamins for honeybees. Pollen is essential for the growth of larva and young adult bees. The pollen grains are collected by honeybees from the anthers of the flower during the foraging. At the time of nectar and pollen collection, the body parts of honeybees are covered with pollen grains. These pollen are collected combined and mixed with pollen from the mouth and transferred into the "pollen basket" on her posterior pair of legs. In the hive, worker bees pack the pollen into the comb. To prevent bacterial growth and pollen germination, a phytocidal acid is added to the pollen as it is packed into comb. Other enzymes produced by the worker bees are also added which bring about anaerobic metabolism and fermentation, enhancing the longevity of the stored pollen. The completely processed pollen grain for storage kept in comb is referred to as "bee bread" and is ready for later consumption by the bees. According to Babendreier et al., (2004), the protein source needed for the growth of one worker bee from larvae to adult stage require approximately 120-143 mg of pollen. An average size bee colony collects about 20-57 kg of pollen a year (Jones and Bryant, 2004).

1.11 Palynology

Palynological studies of bee floral resources through scanning electron microscopy provide us an insight into taxonomic problems, morphological studies, and in melissopalynology. SEM studies of honey pollen resources will also benefit melissopalynology. Light microscopy (LM) which is traditionally used in palynology/ melissopalynology to identify and interpret the pollen spectrum has its limitations however the SEM studies is useful in study of pollen morphology as well as in melissopalynology (Saklani et al., 2018). Microscopic studies support in developing taxonomic terminology of pollen ornamentation and their identification) to lower taxonomical level and can be used to differentiate between taxonomic characters of closely related genera Pollen morphological features, viz., shape, size, sculpturing, etc., serve as a useful identification tool for floral taxa, whereas exine sculpturing is an attractive feature in taxonomy and systematic. Moreover, pollen apertures are also observed as critical section of pollen sculpturing. They both play the basic criterion to identify flora after pollen apertures and shapes. Palynology had wider application and served as a tool in the past for identifying related taxa and various major plant families (Hameed et al., 2020; Noor and Ahmad, 2021).

1.12 Melliferous flora

One of the most important phenomena of organic evolution is pollinators. There is a very strong connection between honeybees, honey and pollen which is termed as “Bee Botany”. This well-established system of interdependence that ensures mutual benefits has been established by bees and certain flowering plants. The most significant part of melissopalynology is pollen analysis of honey. A major objective of melissopalynology is the evaluation of the resource value of various plant species to bees (Azmi et al., 2015; Singh et al., 2015). Honey plants were actively examined in 20 century; nowadays the interest to this theme is still alive. The importance of the melliferous group studying is connected with the wish of customers to know the botanical composition of honey and its origin with the aim to identify falsifications. Melliferous capacity of the territory is mostly depended on the area on which the honey plants grow and less on the diversity of species content Therefore it is necessary to determine the diversity of flora that is important for beekeeping (Kopytina et al., 2019; Ozler, 2018). In the world, several studies are devoted to the study of botanical resources through palynological analysis (Ayansola and Davies 2012; Dukku, 2013; Iritie et al., 2014). The information of melliferous flora with common species useful for beekeeping is available in previously cited regional studies; however, there is a shortage of research on melliferous flora at the level of municipalities, communities, or localities related with information of annual seasons or the beekeeping cycle (Escuredo et al., 2019).

Honey plants are those that mainly produce nectar and pollen, although plant species that generate propolis are also considered in this category (Bonilla et al., 2017). These plants have been studied since ancient times, mainly by beekeepers and honey growers, since bees and other insects depend on them for food (de Jaime-Lorén and Jaime-Ruiz, 2012). The study of honey species is related to the beginnings of beekeeping, because beekeepers must know the plants that produce nectar and pollen useful for bees and based on this, choose the ideal site to install their hives (Mondragen and Martinez, 2019). The melliferous potential of an area consists of the capacity of this zone to assure the food of the bees' families (Antonie, 2014). The families that contributed the most to honey production were Asteraceae, Fabaceae and Brassicaceae (Grimau et al., 2014; Kopytina et al., 2019). The Asteraceae and Fabaceae families provide the most floral resources for bees. These studies (González-Suárez et al., 2020; Naab and Tamame, 2007) agree that the Asteraceae family are the most used by bees. In addition, it has been documented that, in general, the species that are important sources of nectar for bees are also sources of pollen (Andrada, 2003). The dominance of Asteraceae family and a few pollen types in most samples of honey led us to consider that this trend could be due to the forage behavior of *Apis mellifera* . Haidamus et al., (2019) and Modro et al., (2011), who also reported Asteraceae as the main floral sources.

1.13 Ethnomedicinal Utilization of Bee flora

Traditional remedies have been made from honey-producing bee vegetation. Honey has been utilized for therapeutic and healing purposes in a variety of ailments, and it even possesses antimicrobial properties (Dureja et al., 2003). Khyber Pakhtunkhwa's flora is critical for bee foraging and honey production. In KPK province, bees feed vegetation and honey is used as folk medicine to treat a variety of ailments. The majority of people in Pakistan are unaware about the flora of bees, their therapeutic benefits, and the source of honey production. The contributions to a better understanding of the flowering seasons of bee floral plants visited by *Apis mellifera*. Scientists studying in the domains of Plant Ecology, Plant Taxonomy, Genetics, Pharmacology, Molecular Biology, and Agriculture can benefit from the knowledge gained from local people (Ahmad et al., 2021)**.**

For many years, many rural communities in Khyber Pakhtunkhwa have employed medicinal implications of honeybee flora and traditional plant knowledge (Jimenez-Arellanes et al., 2003)**.** Traditional knowledge of medicinal plants is a part of Pakistani culture, and it is widely used throughout the country. People in ancient civilizations employed bee foraging plants and honey as treatments for a variety of ailments such as cough, fever, stomach pain, dysentery, kidney issues, and respiratory disorders. When compared to other industrialized countries, knowledge of therapeutic applications of honey and plants has recently been utilized in Pakistan (Khan et al., 2017).

1.14 Beekeeping Practices and Apiaries

Beekeeping plays a significant role in conserving the natural resources and contributes to the globe through environmental protection like all stock's species, bees require feeds for their production and reproduction (Dhawan et al., 2018). Honeybee does not visit all plants for nectar and or pollen ,identification of plants which supply these resources, plant communities and the phonological relationship between honey bee plants and honey bees are paramount importance and in assessing the potential of an area beekeeping (Gebretsadik, 2016). Beekeeping business are very common and varies according to flowering periods of an area. Botanical and geographical origin of flora are concerned with study of pollen morphology (Saibal, 2005). This procedure is very helpful in determining purity and impurity of honey (Ahmad et al., 2019). The, Survey of honeybee plants and their flowering phenology and establishment of the flora calendar helps to indicate the approximate date and duration of the flowering of important bee plant species in specific area and has paramount important for practical beekeeping (Arega, 2020; Bansal et al., 2013; Paray et al., 2021; Singh et al., 2016).

The apiaries must be situated in areas with abundant flora, as they are the nutritional source for *Apis mellifera*. Knowledge of regional bee flora is important for beekeeping globally, and for good honey production strategies, apiary management should be focused on the availability of plant species (Rodríguez et al., 2019). The suitability of an apiary depends mainly on the form, density and distribution of the important flora of the honeybee (Al-Ghamdi et al., 2020). The composition of the local apiary flora mainly depends on the honey harvesting (Pashayan, 2019). Camargo et al., (2014) defined the suitability of beekeeping by measuring 3 km of buffer zone for each established apiary location and assessing the productivity of land use, flora, and honey. The plant communities used in the wild for the production of honey are indispensable for the apiary industry (Chauhan et al., 2017).

1.15 Honeybee Foraging flora around Globe

The most valuable pollinators of plants e.g. the honeybees are important from economic point of view. Absence of pollinators has a direct effect on the yield of fruits, seeds and nuts (Klein et al., 2007). Therefore, knowledge of the bee flora in a region is a basic tool for the development of beekeeping, as pollen is required for the growth of bee colonies (Dimou and Thrasyvoulou, 2009). Honeybees show special movements and get in touch with each other in the form of dance language to inform each other about nearby melliferous flora (Sponsler et al., 2017). Knowledge about bee flora can help develop a floral calendar and to initiate bee keeping practices (Klein et al., 2007). Bista and Shivakoti (2001) reported 119 important Nepalese plants most often visited by honeybees. Abou-Shaara (2015) reported Citrus, clover, cotton, mustard, beans, cabbage, sunflower, coriander, clover, wormwood, radish, herbs, carrots, corn, wild mustard, yellow clover as pollen sources from Egypt.

Similarly, twenty-nine plant species have been identified as honey source plants from Guji Zone, Ethiopia by (Bareke and Addi, 2018). Butz Huryn (1995) reported bees collecting pollen or nectar from 224 plant taxa native to New Zealand. Similarly, 204 species of family Asteraceae, Fabaceae and Rosaceae were reported from Greece by (Dimou & Thrasyvoulou, 2007). Toopchi-Khosroshahi and Lotfalizadeh (2011) reported twenty-two families and 98 species of honey plants have been reported from northwestern Iran. Species such as *Ziziphus spinachristi, Acacia tortilis, Prosopis cineraria, Prosopis juliflora, Maerua crassifolia, Citrus spp., Zygophyllum spp.* and the genus *Fagonia* is the main bee species in Oman (Sajwani et al., 2014). Twenty-two plant species from the Western Ghats of India useful for bees have been reported by (Bhalchandra et al., 2014), of which 29 are crops and 23 are wild plants. The Arecaceae, Myrtaceae, Brassicaceae, Fabaceae, Pedaliaceae, and Apiaceae families are reported to be the major contributors to the flora of bees in southwestern Bengal, India (Layek et al., 2020). Sixty-three plant species from Maharashtra, India were reported as a food source for honeybees, 41 of which were wild and 22 were horticultural plants (Waykar and Baviskar, 2015). In Karnataka, India, more than 340 plants have been reported to be useful for honeybees (Hepburn annd Hepburn, 2007).

1.16 Honeybee Foraging flora in Pakistan

Ibrar et al., (2007) reported four honeybee plants (*Justicia adhatoda, Cannabis sativa and Pimpinella diversifolia*) were reported from the Shangla district Swat, Pakistan. In Islamabad, Pakistan, a total of 40 species of plants were identified as pollen sources for bees from fruit trees, ornamental agricultural crops and weeds (Noor et al., 2009). Similarly, *Acacia nilotica, Cicer arietinum, Sonchus asper* and *Convolvolus arvensis* have been reported as bees feeding flora of the Himalaya region of Pakistan (Saibal, 2005). Durrani and Hussain (2005) reported *Cousinia* spp. as honeybee foraging plant from Kalat, Pakistan while twenty-eight plant species have been reported as bee flora in Gallegei, District Swat, Pakistan (Hussain et al., 2006). Thirty-one honeybee attracting plants from Malam Jabba, District Swat, Pakistan have been reported by (Iqbal and Hamayun, 2004). According to Pınar and Dönmez (2000), a total of 16 weeds belonging to 10 different families is reported from District Bannu, Khyber Pakhtunkhwa, Pakistan. Eighteen species of different families including *Cenchrus biflorus, Cestrum nocturnum, Citrus limon, Combretum indicum, Datura innoxia, Duranta erects, Hamelia patens, Helianthus annuus, Ipomoea cairica, Luffa aegyptiaca, Nerium oleander, Ocimum basilicum, Pennisetum typhoides, Prosopis cineraria, Parthenium hysterophorus, Prosopis juliflora, Saccharum spontaneum* and *Ziziphus jujube* have been reported from District Lakki Marwat, Khyber Pakhtunkhwa, Pakistan (Ahmad et al., 2019; Ullah et al., 2021).

1.17 Justification of the Project

The first scientific investigation on honey was undertaken by Pfister (1895) who analyzed the pollen content of several honey samples collected from France, Switzerland and other parts of Europe. He showed that it is possible to establish the geographical and botanical origin of honey by examining the pollen types present in honey. Toopchi-Khosroshahi and Lotfalizadeh (2011) reported twenty-two families and 98 species of honey plants have been reported from northwestern Iran. Species such as *Ziziphus spinachristi, Acacia tortilis, Prosopis cineraria, Prosopis juliflora, Maerua crassifolia, Citrus spp., Zygophyllum spp.* and the genus *Fagonia* is the main bee species in Oman (Sajwani et al., 2014). The Arecaceae, Myrtaceae, Brassicaceae, Fabaceae, Pedaliaceae, and Apiaceae families are reported to be the major contributors to the flora of bees in southwestern Bengal, India (Layek et al., 2020).

Pakistan has a rich diversity of melliferous plants. Understanding the floral biology of these plants is vital for implementation of the correct or best management practices of their habitats, sustainability and growth of the honey industry. This will also assist to understand potential honey production area, tonnage and, therefore, value; it aids prediction of resource availability, facilitates successful planning by apiarists for efficacious hive placements and capacity; and it provides important base-line information to guide habitat and biodiversity management.

The knowledge of native melliferous flora (MF) may contribute to identify the diversity of species available for beekeeping activities during the spring and monsoon seasons of the year in the Khyber Pakhtunkhwa (KPK) region. The acute shortage of food resources considerably reduces local honey production and needs to be addressed appropriately. The objective of this study has been identifying the local melliferous flora (MF), their nectar and pollen contribution, their flowering patterns, and the criteria of the vegetation to be established adjacent to local apiaries for stable production of quality honey.

The experiences, challenges, problems, and practices as depicted by the local beekeepers of a specific area about of melliferous flora; when they are validated with interviews or painstaking field study, this indigenous knowledge can represent a useful tool for the beekeeping of a region, modern bee researchers, and melliferous flora investigators. It is therefore important to establish relevant, comprehensive strategies for targeted enrichment and assemblages of MF in the surrounding areas of the local apiaries. Such an approach has the potential to increase honey production in the local apiaries and improve the economic conditions of the families that are directly and indirectly dependent on the apiculture industry.

The country has great potential for honey production because of its congenial climate conditions and variety of bee flora. Beekeeping and the honey business trade have been carried out in Khyber Pakhtunkhwa for decades, contributes towards increasing income and better livelihoods (Aimal et al. 2020). KPK also has environmental conditions that are conducive for the growth of high floral biodiversity that contributes to honey production, and its export in international markets (Siraj et al. 2008; Khan et al. 2016). Knowledge of regional bee flora is significant for beekeeping globally and for good honey production strategies. Most of the beekeeping practices in Pakistan are focused on KPK, and beekeeping in this geographical area is not exploiting the full potential of bee forage plants found in forest cover, agriculture land and rangelands. The exploration of melliferous species highly visited by honeybees is of great use with respect to honey production species in this zone, e.g., *Acacia spp., Brassica spp., Citrus spp., Dalbergia spp.*, *Eucalyptus camaldulensis*, *Ligustrum lucidum*, *Malus domestica*, *Melia azadirachta*, *Prosopis juliflora, Trifolium spp.*, *Verbascum Thapsus, Zea mays* and *Ziziphus spp.* (Marwat et al., 2013).

Honey produced in Pakistan enjoys good repute in the Middle East due to its unique taste and quality. The Pakistan honey industry export 4000 tons of honey per year, estimated to be worth 23 million dollars. However, pollen analysis has never been systematically explored as a potential way to verify the floral origins of Pakistan honeys. The few studies of honeybee foraging preferences in Pakistan, have not investigated the pollen content of honey. Moreover, some previous suggested approaches to the detection of adulterated honey in Pakistan have not even considered the possibility of pollen analyses. The agriculture department has said that Khyber Pakhtunkhwa has the capacity to produce more than 30,000 metric tons of standard honey annually. According to local traders, around 300 containers, each containing 20 tons of honey, are exported to the Gulf States, mostly Saudi Arabia and United Arab Emirates. KPK was the most suitable province for apiculture due to the massive increase of bee floral plants courtesy of the Billion Trees Afforestation Project (Khan et al., 2020).

Identification of bee-important flora and their propagation needs will help to improve bee foraging and contribute to the efficiency of the beekeeping industry and commercial honey production. Similarly, the mapping of such vegetation units containing key foraging sources for bees is important for the apiary industry. Once these are known, pollen recovered in produced honey can be used to establish a standardization of honey types based on geographical regions and the plant species contained in KPK regions. Unfortunately, currently these identifications are not verified or supported by published pollen studies of Pakistani honey. Available knowledge and published research on the characterization of Pakistani honey is limited. Thus far, there is only few known research studies on this subject, by Begum et al., (2021), Mangi et al., (2018) and Noor et al., (2009). That study reported the floral sources of some Pakistani honey types, their ecological origin and some of the physical and chemical properties of those honey types.

This project contributes to the knowledge of potentially unexplored biodiversity of melliferous plants in the surroundings of beekeepers by identifying potentially melliferous species as honeybee resources. The study also helps in determining the botanical and geographical origins of honeybees. To the best of our knowledge, the importance of the melliferous flora is unknown, since until now there has been no work that documents the selected studied plants of beekeeping interest, despite the fact that it is among the most productive regions with respect to honey production. Honeybee floral plant based studies from different phytogeographic areas of Pakistan, i.e., District Lakki Marwat (Ahmad et al., 2019), Bannu (Ahmad et al., 2020 Ullah et al., 2021), Islamabad (Noor et al., 2009), the Himalayan region (Ahmad et al., 2019), Dadu Sindh (Mangi et al., 2018), D.I. Khan and (Begum et al., 2021) have been reported. A great variation in pollen morphotypes could be attributed to the systematics of melliferous flora. Data on the honeybee flora and the botanical origin of honey production in Khyber Pakhtunkhwa are scarce and unpublished in international scientific journals.

It is evident from the above account of survey of literature that melissopalynological investigations in Pakistan are mainly confined to southern region of the country. However, from Northern Khyber Pakhtunkhwa province no detailed work in this field has been done. Bee keeping is an important component of agriculture. Honey bees apart from producing honey and honey bee products are also helpful in increasing the crop yield as they are regarded as effective pollinator for the crops. In KPK there is less urbanization and industrialization and the main source of livelihood is agriculture. Here production of honey in commercial scale will provide nutritional and economical security to rural community providing good alternate source of income. Thus the present melissopalynological investigation is undertaken to analyze honey samples collected from four districts of KPK including Charsadda, Mardan, Nowshera and Swabi. Melissopalynological study in these areas will be helpful in the identification of potential area for honey production in commercial scale. So, this research explores the honeybee flora under experimentation are major nectar and pollen sources despite the large variety of flowering plants. The honey production efficiency of bee floral species under investigation is dominant among surrounding vegetation, and data provided in this work can be the foundation for more efficient apiculture practices to manage apiaries and thus take greater advantage of melliferous floral resources year-round.

1.18 Aims of the Study

- Exploring the diversity and to enlist the honeybee floral plants of the Khyber Pakhtunkhwa-Pakistan.
- Bee floral pollen inventory with micro and macro photography for correct identification of the species.
- Comprehensive qualitative and quantitative attributes of pollen among honeybee flora using light and scanning electron microscopy.
- Identification and quantification of pollen in honey samples to determine the range of nectar types based on foraging resources around apiaries.
- This research provide an overview of the prospects of melliferous flora in the beekeeping industry for determining the geographical origin of honey.

Plate 1. Panoramic view of collection areas of honeybee flora (A) Ziarat Kaka Sahib district Nowshera (B) Katlang district Mardan

Plate 2. Panoramic view of collection areas of honeybee flora (A) Lundkhwar Sahib district Mardan (B) Gadoon district Swabi

Plate 3. Panoramic view of collection areas of honeybee flora (A) Sardheri district Charsadda (B) Pabbi district Nowshera

Plate 4. Apiaries sites around Honeybee floral vegetation (A) Zaida district Swabi (B) Takkar district Mardan

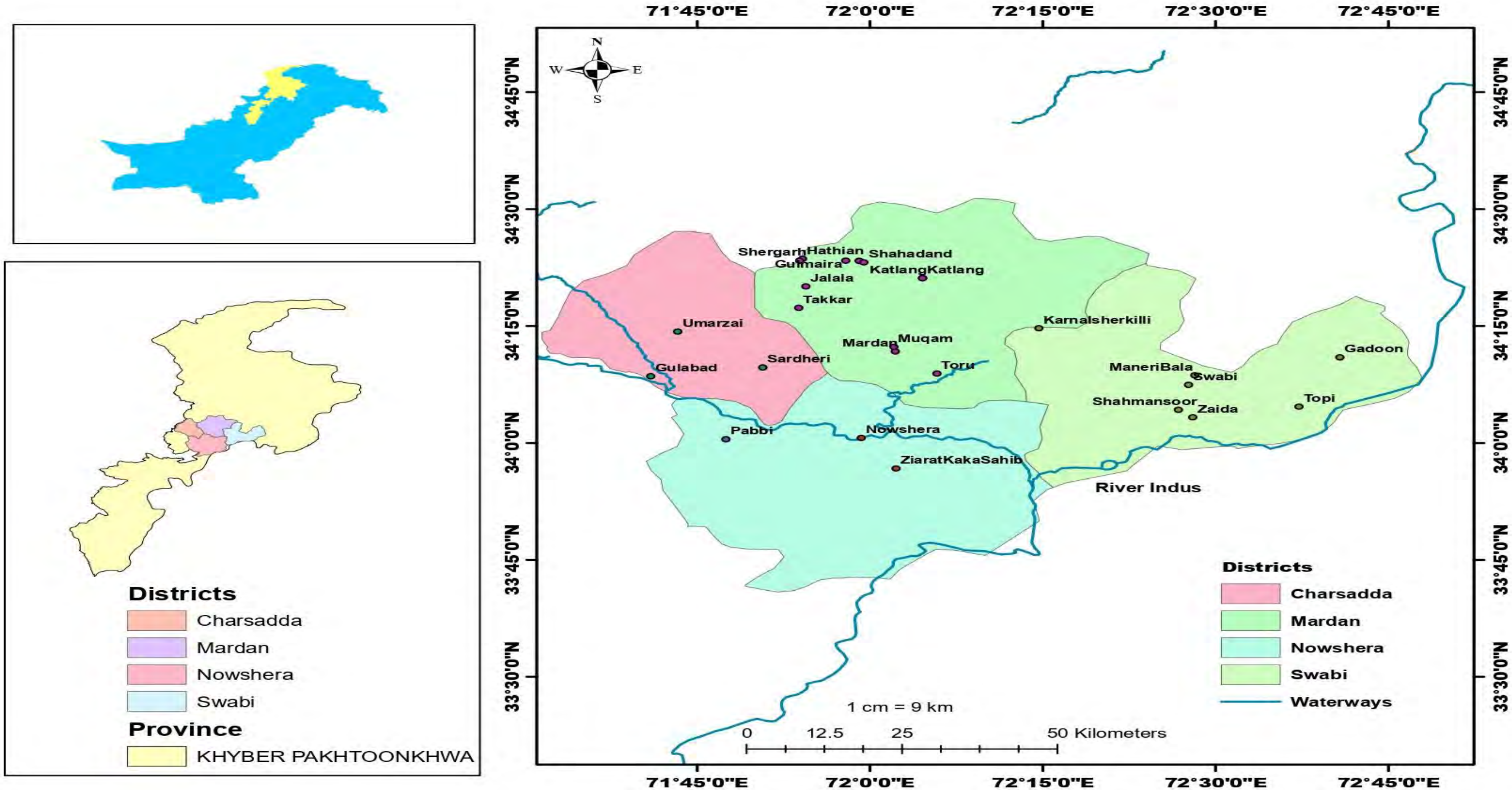

Figure 1. Map of the study area: Khyber Pakhtunkhwa

Chapter 2

Materials and Methods

This project is confined to bee floral diversity with special emphasis on melissopalynology and honey analysis of different apiaries from Khyber Pakhtunkhwa-Pakistan. Plants identification, microscopic investigation and melissopalynological and honey analysis was carried out in Plants Systematic and Biodiversity Lab, Quaid I Azam University Islamabad.

2.1 Study Area: Khyber Pakhtunkhwa

Khyber Pakhtunkhwa Province (KPK) in Pakistan is one of the provinces that identified as the highest hotspots for biodiversity in Pakistan and endowed with several Forests. Forests fragmented and fragile ecosystems, land-use and land-cover changes have faster damaging processes with irreversible effects on ecosystems (Rauf et al., 2019). Area of the province is 46296 Km^2 and population is 30.523371 million. The terrain of the province consists of mountain ranges, undulating areas, and plain areas surrounded by hills. The climate varies with elevation. The hilly areas are cold in winter and cool in summer, and a temperature markedly rises towards South (Ali et al., 2018). The current research was conducted in four adjacent districts of KPK (see Figure 1), namely, Charsadda, Nowshera, Mardan and Swabi. These districts cover a combined area of 5919 km^2. According to the Pakistan Forest Institute (PFI) and the United Nation Development Program, Swabi district is less developed, with the majority of residents living in rural areas. On the other hand, the Charsadda, Nowshera and Mardan districts consist of both urban and rural areas (Khan et al., 2019). Most of the beekeeping apiaries Pakistan are located in KPK and central and north regions of Punjab (Khan, 2020).

2.2 Field Data

During field visits, melliferous plants were collected with flower, stem and root. During fieldwork, all these plants were observed as visited by the honeybee and for confirmation honey samples of the different areas were also collected around apiaries sites for melissopalynological analysis. During field survey, field notes description on melliferous plants and honey samples i.e. habitat, habit, status, collection site, geographical coordinates, flowering period and voucher number were recorded.

2.3 Plant Collection and Bee floral Inventory

The study was confined to the Melissopalynological analysis of honeybee floral diversity in Khyber Pakhtunkhwa Pakistan. The study sites of Khyber Pakhtunkhwa comprised four districts includes Charsadda, Mardan, Nowshera and Swabi generally known as the North KPK (Map 1 and 2). A number of trips to the fields were carried out during various blossoming seasons during 2019-2021. Melliferous plants with floral parts were collected, pressed, dried and placed in blotting papers and newspapers. Field data was recorded in the field notebook regarding date of collection, field number, locality, habit, habitat, phytography, flower color and flowering period. For the microscopic investigation of pollen, the bee flora collected with flowers, the plants were frequently visited by a honeybee in the field for honey production.

2.4 Preservation of Plant Specimens

For preservation, the dried plant specimens were dipped in a solution containing 10 g of Mercuric chloride and 1 litter of ethyl alcohol. The plant specimens were immersed, using forceps, in the solution for about 15-20 seconds depending upon the thickness of the specimen. After poisoning, the plant samples were dried, pressed and then mounted on the herbarium sheets. All the field data was shifted on herbarium labels pasted on the sheet following the previously published protocol of Ahmad et al., (2018).

2.5 Pictorial Guide for Correct Identification

During the field surveys, field photography including different panoramic views and floral photographs of honeybee flora, apiaries sites were developed by means of Sony Digital Camera. The floral pictorial guide aids the melissopalynologist to study bee floral morphology of live plants in the field for correct identification

2.6 Plants Identification

Accessible literature was utilized to identify plant samples. Specimens were further confirmed comparing them with already preserved specimens in the Herbarium of Pakistan (ISL). After correct identification, the plant specimens were submitted in the Herbarium of Pakistan (ISL), Quaid-i-Azam University Islamabad to expedite and facilitate the future references.

2.7 Morphological Attributes

The morphological characteristics of honeybee floral species were studied using binocular light microscope (Bausch and Lomb model W, New York) with different magnifications (10X, 20X, as well as 40X). The morphological measurements were taken 5-7 times to ensure the readings and to find out the mean value for precise results. For study of surface hairs and floral parts, a binocular stereo zoom light microscope (Model SF 2 Kyowa, Japan) was used. The morphological data was further confirmed by comparing with Flora of Pakistan International Plant Name Index (www.ipni.org) was brought into use to verify the plant names (Nasir et al., 1972).

Plate 5. Honeybee floral species field collection (A) *Bidens pilosa*, (B) *Cannabis sativa*

Plate 6. Honeybee floral species (A) Poisoning of drying specimens, (B) Mounting of on Herbarium sheets

2.8 Light Microscopy of Melliferous Pollen

The anthers of flower separated with the help of a needle and kept on the slides. The acetic acid in one drop quantity put on the slides and with the help of metal rod the anther crushed, and pollen came out from anthers. The glycerin jelly is used for staining purposes. Glycerin is one drop put on the slides and covered by a coverslip. In the end, the slides sealed with nail polish and studied through light microscopy. The prepared slides were studied under light microscopy (Model: NIKON Japan) for different palyno-morphological characters at 10x and 40x magnification powers. The pollen photographs were taken at a 40X magnification lens by utilizing a Nikon FX-35 Camera equipped photo-micrographic system (Ullah et al., 2018). Pollen from collected species was classified according to the representative families of melliferous plants (Raza et al., 2020).

Quantitative characters includes equatorial diameter, polar diameter, colpi length, colpi width, spine length and exine thickness. There are five replicated reading was taken for each parameter. Qualitative characters includes spine shape, sculpturing of pollen, colpi shape were noted. The quantitative data of pollen analyzed by excel and used the SPSS software to determined standard error, Min-Max and mean values. The raw data was then transformed into a tubular form, including mean value and standard error.

2.9 Scanning Electron Microscopy (SEM) of Melliferous Pollen

Palynological investigations of melliferous plants was studied using Scanning Electron Microscopy. For SEM investigations, pollen grains were detached from anthers, treated with a few drops of 45% acetic acid, and then crushed and directly mounted on prepared stubs. After that, sputtering of acetolyzed pollen samples was done with a gold palladium coating. Then, peculiarities of pollen grains and their surface ornamentation were observed under a scanning electron microscope in the laboratory (Butt et al., 2018; Mir et al., 2020).

The descriptive terminology of Punt et al., (2007) was employed to describe the pollen features. For shape classes (P/E ratio), the definitions of Nilsson and Praglowski (1992) were followed.

2.10 Statistical Analysis

P/E ratio was calculated using the classification of Erdtman (1986) for determination of pollen shape using following formula.

$$P/E = PA/ED \times 100$$

(PA= polar axis, ED = equatorial diameter of the same pollen)

Percentages of pollen fertility and sterility were calculated based on staining. The number of pollen grains stained and unstained was counted. Pollen that was fully stained was considered fertile, whereas pollen that was unstained and deformed was regarded sterile. The formula proposed by Raza et al., (2020) was used to calculate the fertility and sterility percentages of pollen.

$$Fertility = \frac{F}{F} + S \times 100$$

$$Sterility = S/S + F \times 100$$

Where, F= total number of fertile pollen. S= total number of sterile pollen.

Plate 7. Microscopic identification of morphological characters of honeybee floral specimens

Plate 8. Laboratory work (A) Pollen slides preparation (B) Microscopic quantification of pollen morphometric characters of honeybee floral species

2.11 Bee Species, Beehive Locations, and Vegetation

As part of an ongoing Billion Tree Tsunami Project, particular effort was made to rear the Asiatic honeybee *Apis mellifera* one of the native honeybees of Pakistan. The bees were reared in wooden beehives placed in four locations. The locations were chosen to reflect the complex mosaic of vegetation. One beehive per location was considered in this study.

The four locations are Garden and Lund Khawar (Mardan District), Gadoon (Nowshera District), Gulabad (Charsadda Disrict), and Karnal Sher Killi (Swabi District). Most of the beekeeping practices in Pakistan are focused on KPK, and beekeeping in this geographical area is not exploiting the full potential of bee forage plants found in forest cover, agriculture land and rangelands. The exploration of melliferous species highly visited by honeybees is of great use with respect to honey production species in this zone, e.g., *Acacia spp., Brassica spp., Citrus spp., Dalbergia spp.*, *Eucalyptus camaldulensis*, *Ligustrum lucidum*, *Malus domestica*, *Melia azadirachta*, *Prosopis juliflora, Trifolium spp.*, *Verbascum thapsus, Zea mays* and *Ziziphus spp.*

2.12 Sampling of Honey and Identification of Pollen

Seasonal samples were taken from four places in the months of April, May, August, and November of 2020, later referred to as the independent variables month, year, and location. Each sample was obtained by gently pressing out pollen and honey without harming the bees. For the melissopalynological experiments, samples of pollen and honey were gathered and placed in bottles. We collected 24 honey samples from apiary sites for study. Fresh honey samples (half kg each) were taken from the honeycombs of three replicates beehives at each apiary and placed in a polyethylene disposable jar. The samples were kept at -4 °C before analysis.

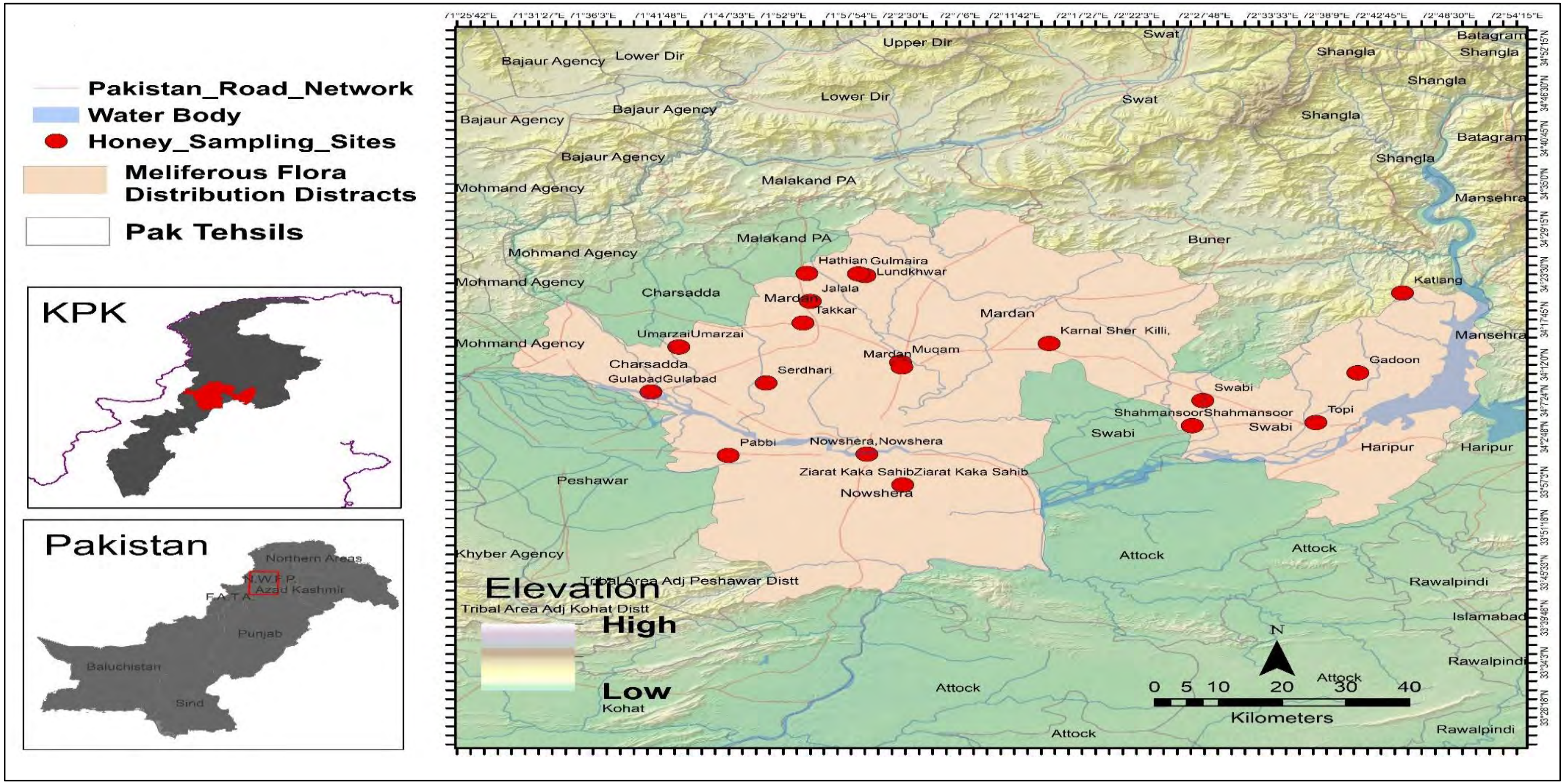

Figure 2. Map of the study area showing honey collection sites

Table 1. Sites of collection, periods, and honey types in apiaries, with voucher number.

S. No	Samples	Voucher No	Side of collection	Coordinates	Period	Common vegetation
1	*Acacia* Honey	AHL-13	Lundkhwar, District Mardan, KPK	34° 23,21.06"N 71°59,04.52"E	April 2020	*Acacia spp., Anagallis arvensis, Bidens spp., Callistemon citrinus, Centaurium pulchellum , Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Eruca spp., Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays*
2	*Eucalyptus* Honey	EHJ-5	Jalala, District Mardan, KPK.	34°20'04.33"N 71°54'27.11"E	May 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Coriandrum sativum, Brassica spp., Eucalyptus spp., Tripleurospermum caucasicum, Eruca sativa, Foeniculum vulgare, Helianthus annuus, Ligustrum lucidium, Parthenium hysterophorus, Pennisetum glaucum, Silybum marianum, Ziziphus spp., Trifolium spp.*
3	*Ziziphus* Honey	ZHN-2	Nowshera District Nowshera, KPK	34°00'37.67"N 71°59'15.19"E	October 2020	*Acacia spp., Bidens spp., Centaurium pulchellum, Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Eruca sativa, Foeniculum vulgare, Helianthus annuus, Lantana camara, Lepidium didymium, Malus domestica, Nicotiana tabacum, Parthenium hysterophorus, Ziziphus spp., Solanum spp., Silybum marianum*
4	*Acacia* Honey	AHN-7	Nowshera District Nowshera, KPK	34°00'37.67"N 71°59'15.19"E	October 2020	*Acacia spp., Anagallis arvensis, Callistemon citrinus,Cleome spp. Coriandrum sativum, Datura spp., Eucalyptus spp, Tripleurospermum caucasicum, Eruca sativa , Helianthus annuus, Lepidium didymium, Malus domestica, Ziziphus spp., Silybum marianum, Trifolium spp., Solanum spp.*
5	*Acacia* Honey	AHS-10	Shahmansoor, District Sawabi, KPK	34° 04'14.38"N 72°26'47.49"E	August 2020	*Acacia spp., Anagallis arvensis, Centaurium pulchellum, Coriandrum sativum, Brassica campestris, Dalbergia spp., Datura spp., Eucalyptus spp., Foeniculum vulgare, Psidium guava Helianthus annuus, Lepidium didymium, Nicotiana tabacum, Parthenium hysterophorus, Pennisetum glaucum, Silybum marianum, Ziziphus spp., Trifolium spp., Datura spp., Ziziphus spp.*
6	*Acacia* Honey	AHG-19	Gadoon, District Nowshera, KPK	34°10'57. 94"N 72°40'48.39"E	September 2020	*Acacia spp., Bidens spp., Cleome spp., Coriandrum sativum, Dalbergia spp., Eucalyptus spp., Tripleurospermum caucasicum, Foeniculum vulgare, Eruca spp ., Lantana camara , Psidium guava*

						Helianthus annuus, Lepidium didymium, Ligustrum lucidium, , Nicotiana tabacum, Parthenium hysterophorus, Silybum marianum, Ziziphus spp., Trifolium spp., Datura spp., Ziziphus spp.
7	*Acacia* Honey	AHT-21	Topi, District Sawabi, KPK	34° 04'38.48"N 72°37'15.71"E	September 2020	*Acacia spp., Anagallis arvensis, Cleome spp., Callistemon citrinus, Brassica campestris, Centaurium pulchellum, Datura spp., Eucalyptus spp., Eruca spp., Foeniculum vulgare, Lantana camara, Malus domestica, Helianthus annuus, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Solanum spp.*
8	*Acacia* Honey	AHGu-12	Gulmaira District Mardan, KPK	71°58,31.85"N 34°23,33.61"E	May 2020	*Acacia spp., Bidens spp., Centaurium pulchellum , Coriandrum sativum, Datura spp., Eucalyptus spp., Eruca spp.,, Tripleurospermum caucasicum Helianthus annuus, Nicotiana tabacum, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Lepidium didymium, Parthenium hysterophorus, Solanum spp.*
9	*Eucalyptus* Honey	EHK-6	Katlang, District Mardan, KPK	34°21'07.41"N 72°04"35.20"E	May 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Centaurium pulchellum , Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays,, Silybum marianum, Tripleurospermum oreades, Lantana camara, Malus domestica, Pennisetum glaucum, Solanum spp.*
10	*Ziziphus* Honey	ZHT-3	Takkar, District Mardan, KPK	34° 17'19.16"N 71°53'49.76"E	April 2020	*Acacia spp., Bidens spp., Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Tripleurospermum caucasicum, Eruca spp., Foeniculum vulgare, Helianthus annuus, Lantana camara, Malus domestica, Lepidium didymium, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Pennisetum glaucum*
11	*Eucalyptus* Honey	EHG-9	Gulabad, District Charsadda, KPK	34°08'32.53"N 71°40'58.47"E	June 2020	*Acacia spp., Anagallis arvensis, Callistemon citrinus, Brassica campestris, Coriandrum sativum, Datura spp., Eucalyptus spp., Tripleurospermum caucasicum Eruca spp , Foeniculum vulgare, Helianthus annuus, Ligustrum lucidium,,Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Silybum marianum, Lepidium didymium, Parthenium hysterophorus, Pennisetum glaucum*
12	*Eucalyptus* Honey	EHU-14	Umarzai, District Charsadda, KPK	34°14'15.86"N 71°43'19.96"E	June 2020	*Acacia spp., Bidens spp., Cleome spp., Brassica campestris, Coriandrum sativum, Dalbergia spp., Eucalyptus spp., Eruca spp.,*

						Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Parthenium hysterophorus, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Solanum spp.
13	*Eucalyptus* Honey	EHS-17	Serdhari, District Charsadda, KPK	34°09’40.22”N 71°50’42.99”E	July 2020	*Acacia spp., Anagallis arvensis, Bidens spp., Callistemon citrinus, Centaurium pulchellum , Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Tripleurospermum caucasicum , Eruca spp., Lepidium didymium, Malus domestica, Helianthus annuus, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays, Parthenium hysterophorus, Pennisetum glaucum , Solanum spp.*
14	*Acacia* Honey	AHH-19	Hathian, District Mardan, KPK	34°23’36.60”N 71°54’09.81”E	April 2020	*Acacia spp., Anagallis arvensis, Bidens spp., Callistemon citrinus, Centaurium pulchellum , Coriandrum sativum, Brassica campestris, Datura spp., Eucalyptus spp., Eruca spp., Foeniculum vulgare, Nicotiana tabacum, Pennisetum glaucum, Malus domestica, Ligustrum lucidium, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea maiz,*
15	*Ziziphus* Honey	ZHM-24	Mardan, District Mardan, KPK	34°11’42.96”N 72°02’12.41”E	May 2020	*Acacia spp., Anagallis arvensis, Callistemon citrinus, Coriandrum sativum, Brassica campestris, Datura spp., Eucalyptus spp., Eruca spp, Foeniculum vulgare, Helianthus annuus, Lepidium didymium, Malus domestica, Parthenium hysterophorus, Ligustrum lucidium, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays*
16	*Ziziphus* Honey	ZHK-8	Karnal Sher Killi, District Sawabi, KPK	34° 14’41.48”N 72°14’40.28”E	October 2020	*Acacia spp., Bidens spp., Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Eruca spp, Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Lepidium didymium, Parthenium hysterophorus, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp., Zea mays*
17	*Ziziphus* Honey	ZHSw-22	Swabi, District Sawabi, KPK	34° 07’26.66”N 72°27’40.75”E	September 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Coriandrum sativum, Dalbergia spp., Datura spp., Eucalyptus spp., Eruca spp., Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Ligustrum lucidium, Psidium guava, Silybum marianum,., Ziziphus spp., Zea mays, Tripleurospermum caucasicum Lepidium didymium, Malus domestica, Pennisetum glaucum*
18	*Ziziphus* Honey	ZHS-11	Shahmansoor, District Sawabi, KPK	34° 04’14.38”N 72°26’47.49”E	November 2020	*Acacia spp., Anagallis arvensis, Bidens spp., Callistemon citrinus, Coriandrum sativum, Brassica campestris, Datura spp., Eucalyptus spp., Eruca spp., Helianthus annuus, Nicotiana tabacum,*

						Psidium guava, Trifolium spp., Ziziphus spp., Zea mays, Silybum marianum
19	*Ziziphus* Honey	ZHG-1	Gulabad, Dstt Charsaddai, KPK	34°08'32.53"N 71°40'58.47"E	June 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Centaurium pulchellum, Brassica campestris Coriandrum sativum, Dalbergia spp., Tripleurospermum caucasicum, Eucalyptus spp., Eruca spp., Parthenium hysterophorus, Helianthus annuus, Nicotiana tabacum, Psidium guava, Trifolium spp., Ziziphus spp., Zea mays, Silybum marianum*
20	*Ziziphus* Honey	ZHU-4	Umarzai, District Charsaddai, KPK	34°14'15.86"N 71°43'19.96"E	June 2020	*Acacia spp., Anagallis arvensis, Coriandrum sativum, Brassica campestris, Datura spp., Eucalyptus spp., Tripleurospermum caucasicum, Eruca spp, Foeniculum vulgare, Helianthus annuus, Malus domestica, Pennisetum glaucum, Ligustrum lucidium, Psidium guava, Trifolium spp., Ziziphus spp., Zea mays, Solanum spp.*
21	*Ziziphus* Honey	ZHP-15	Pabbi, District Nowshera, KPK	34°00'27.84"N 71°47'30.85"E	June 2020	*Acacia spp., Anagallis arvensis, Callistemon citrinus Dalbergia spp., Datura spp., Eucalyptus spp., Eruca spp., Tripleurospermum caucasicum Foeniculum vulgare, Helianthus annuus, Nicotiana tabacum, Lepidium didymium, Ligustrum lucidium, Silybum marianum, Ziziphus spp.*
22	*Ziziphus* Honey	ZHZ-17	Ziarat Kaka Sahib District Nowshera, KPK	33°56'42.92"N 72°02'16.54"E	September 2020	*Acacia spp., Bidens spp., Cleome spp., Coriandrum sativum, Datura spp., Eucalyptus spp., Eruca spp., Malus domestica, Psidium guava, Silybum marianum, Trifolium spp., Ziziphus spp.*
23	*Acacia* Honey	AHZ-20	Ziarat Kaka Sahib District Nowshera, KPK	33°56'42.92"N 72°02'16.54"E	September 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Coriandrum sativum, Brassica campestris, Dalbergia spp., Eucalyptus spp., Eruca spp., Helianthus annuus, Lepidium didymum, Parthenium hysterophorus Ligustrum lucidium,, Silybum marianum, Ziziphus spp., Zea mays, Solanum spp.*
24	*Acacia* Honey	AHM-18	Muqam, District Mardan, KPK	34° 12'18.75"N 72°02'05.49"E	May 2020	*Acacia spp., Bidens spp., Callistemon citrinus, Coriandrum sativum, Brassica campestris, Dalbergia spp., Eucalyptus spp., Eruca spp., Helianthus annuus, Lepidium didymum, Parthenium hysterophorus Ligustrum lucidium,, Silybum marianum, Ziziphus spp., Zea mays, Solanum spp.*

Plate 9. (A) Documentation from apiarist during field collection (B) Apiary site location at Takht Bai

Plate 10. Field panoramic views of apiaries (A) Sardheri Mardan (B) Gulabad Charsadda

Plate 11. (A) Field interview from local beekeepers (B) Honey comb observation during field located on *Prosopis juliflora*

2.13 Analysis of Pollen in Honey

2.13.1 Qualitative Melissopalynological Studies

The melissopalynological method recommended by the International Commission for Bee Botany (ICBB) (Louveaux et al., 1978; Ohe et al., 2004); was used to identify species of pollen in honey. Five-gram samples of each honey were dissolved in 10 ml of water (20-40 °C) in 30 ml Falcon tubes. The diluted honey was centrifuged for 10 min at 4000 rpm. The supernatant liquid was decanted, and 10 ml of distilled water was added to completely dissolve the remaining sugar crystals and a micro-spatula or Pasteur pipette was used to get into the tip of the centrifuge tube. Samples were centrifuged again for 3-5 min at 4000 rpm. The supernatant was then decanted, and the entire sediment was then placed on three slides and spread over an area about 16 × 18 mm, after drying by slight heating at 30-35 °C, sediment was covered with glycerin gelatin liquefied by heating in a water bath at 40 °C and photographed under a Nikon Sendai Japan FX-35 camera. Types of pollen were identified by comparison with reference slides of pollen collected directly from the plants collected from KPK regions. The relative % abundances of each pollen species were determined by an equation (Rosdi et al., 2016).

Abundance (%) = Total number of a particular species x 100/Total number of pollen

The relative frequency classes of at least 300 PGs were estimated using the standard melissopalynological nomenclature (Louveaux et al., 1978); predominant pollen: pollen that accounts for more than 45 % pollen count, secondary pollen (16-45 %), important minor pollen (3-15 %), and minor pollen (3 %). If the representation of pollen was predominant, honey was classified mono-floral. Otherwise, it was regarded as multi-floral.

2.12.2 Quantitative Melissopalynological Studies

The purpose of quantitative microfiltration analysis is to evaluate absolute pollen counts in honey and whether the honey is rich or insufficient in PGs. The pollen content of each honey was measured per 10 g (Von Der Ohe et al., 2004). 10 g of each honey was dissolved in a beaker with 40 ml of distilled water (20-40 °C). The honey solution was transferred through the filtration membrane into a petri plate after the membrane was moistened with a little amount of water. After that, filters were placed on sections and covered with a microscopic slide. Using an acceptable magnification of a microscope, at least 500 PGs were counted. Calculating the surface area of the portion of the filter containing the sediment (S) and the area of the microscope fields at the applied magnification were necessary in order to determine the absolute number of PG (N). A stage micrometer was used to measure the latter. It was determined how many PG there are in 10 g of honey (PG/10 g) (El-Sofany et al., 2020).

$$\boldsymbol{PG/10g = S\ x\ npg\ x\ 10/s\ x\ a\ x\ p}$$

Where S is the surface area of the filter sediment-holding portion (mm^2), s is a single microscopic field's size at the current magnification (mm^2), A is the number of fields counted, p is the weight of honey, and nPG is the total number of grains.

The results were summarized in thousands (10^3), rounding to the closest thousand (for example, N/10 g = 26,342 is represented as 26×10^3). Honey was then classified according to Maurizio's (1939) pollen classes: Class I, honey poor in pollen (PG; $<20 \times 10^3$), Class II, normal pollen (PG; 20–100 × 103), Class III, overrepresented pollen (PG; 100-500 × 103), Class IV, strongly overrepresented pollen (PG; 500×10^3-10^6), and Class V, pressed honey (PG; $> 10^6$).

Plate 12. (A) Labelled collected honey samples (B) Prepared honey samples in falcon tubes to be centrifuged

Plate 13. Honey analysis experimentation (A) Honey samples in beaker string at hot plate species (B) Poured honey sample into falcon tube for centrifugation

Plate 14. (A) Falcon tubes honey samples placed in centrifuge machine (B) Microscopic slide preparations of centrifuged honey sample

Chapter 3
Results

The present research project was planned to collect honey samples from beekeepers of Khyber Pakhtunkhwa around apiaries. This project was cover melissopalynological investigation of collected samples, identification and assessment of botanical origin of honey, analyzing samples authenticity through different analytical techniques. The present research project was also confined to describe significance of palynology in taxonomy of Bee flora. This project was also developed standard techniques for palynological studies to detect adulteration in honey. A very little work has been conducted on authenticity of honey and there is lack of knowledge and authentication techniques to check the purity of honey. There were no comprehensive and detailed pollen studies of Bee flora. This study was become the steppingstones for goal-oriented research in the field of melissopalynology, honey production and quality. It was based on following identification and quantification of pollen in honey samples to determine the range of nectar types based on actual foraging resources. This research identifies geographical source of origin and pollen fertility to understand the geographical stability of the flora from conservation point of view. This study also develops Bee flora pollen inventory with micro and macro photography for correct identification of the species.

These results are comprised of 114 important honeybee floral species belonging to 43 diverse families, organized into three sections. First section highlights the floristic checklist in the form of Table 1 that includes taxonomic name, family, life form, voucher specimen number, accession number, geographic coordinates, and include localities; second section include the diversity of pollen features among honeybee flora while the third section deals with the honey analysis via melissopalynological techniques. The results compiled into three sections are:

Section I: Checklist of Bee flora around apiaries sites from Khyber Pakhtunkhwa-Pakistan

Section II: Pollen morphological diversity among honeybee plants used for the their accurate identification

Section III: Melissopalynology of collected Honey samples for identification and assessment of botanical origin of honey

Section I

Checklist of Bee flora around apiaries sites from Khyber Pakhtunkhwa-Pakistan

Table 2. Checklist of Honeybee floral Species from Khyber Pakhtunkhwa-Pakistan

Sr. No.	Taxa	Family	English name	Status	Habit	Locality	District	Coordinates	Date of collection	Voucher Specimen No/ Accession No.
1.	*Abelmoschus esculentus* (L.) Moench	Malvaceae	Okra	Cultivated	Herb	Maneri Bala	Swabi	34° 08'39.28"N 72°28'12.70"E	03/09/2020	S-22/130994
2.	*Acacia modesta* Wall.	Fabaceae	Phulai	Wild	Tree	Gadoon	Swabi	34°10'57. 94"N 72°40'48.39"E	19/8/2020	S-25/130997
3.	*Acacia nilotica* (L.) Delile	Fabaceae	Prickly Acacia	Wild	Tree	Topi	Swabi	34° 04'38.48"N 72°37'15.71"E	24/8/2020	S-4/ 130976
4.	*Achyranthes aspera* L.	Amaranthaceae	Devil horsewhip	Wild	Herb	Gulabad	Charsadda,	34°08'32.53"N 71°40'58.47"E	13/8/2021	Ch-16/131676
5.	*Alcea rosea* L.	Malvaceae	Hollyhock	Cultivated	Herb	Swabi	Swabi	34° 07'26.66"N 72°27'40.75"E	25/8/2020	S-32/ 131004
6.	*Amaranthus viridis* L.	Amaranthaceae	Slender Amaranth	Wild	Herb	Pabbi	Nowshera,	34°00'27.84"N 71°47'30.85"E	13/9/2021	No-5/131684
7.	*Amaranthus spinosus* L.	Amaranthaceae	Spiny amaranth	Wild	Herb	Maneri Bala	Swabi	34° 08'39.28"N 72°28'12.70"E	03/09/2020	S-21/130993
8.	*Anagallis arvensis* L.	Primulaceae	Red scarlet	Wild	Herb	Hathian	Mardan	34°23'36.60"N	19/3/2020	N-29/ 130952
9.	*Aster squamatus* (Spreng.) Hieron.	Asteraceae	Narrow-leaves aster	Wild	Herb	Ziarat Kaka Sahib	Nowshera	33°56'42.92"N 72°02'16.54"E	25/8/2020	No-13/131661
10.	*Barleria cristata* L.	Acanthaceae	Philippine Violet, Bluebell barleria	Wild	Herb	Ziarat Kaka Sahib	Nowshera	33°56'42.92"N 72°02'16.54"E	01/04/2020	No-14/130955
11.	*Bidens pilosa* L.	Astereceae	Black-jack	Wild	Herb	Hathian	Mardan	34°23'36.60"N 71°54'09.81"E	24/04/2020	N-05/130928
12.	*Boerhavia procumbens* Banks ex Roxb	Nyctaginaceae	Red spiderling	Wild	Herb	Pabbi	Nowshera,	34°00'27.84"N 71°47'30.85"E	13/9/2021	No-2/131687
13.	*Brassica campestris* L.	Brassicaceae	Field mustard	Cultivated	Herb	Shergarh	Mardan	34°23'22.33"N 71°53'55.09"E	01/04/2020	N-20/ 130943
14.	*Calendula arvensis* M.Bieb.	Astereceae	Field marigold	Wild	Herb	Sardheri	Charsadda	34°09'40.22"N 71°50'42.99"E	15/04/2020	Ch-1
15.	*Callistemon citrinus* (Curtis) Skeels	Myrtaceae	Bottle brush	Wild	Tree	Mardan	Mardan	34°11'42.96"N 72°02'12.41"E	14/03/2020	N-26/130949

16.	*Campsis radicans* (L.) Seem.	Bignoniaceae	Trumpet vine	Cultivated	Herb	Mardan	Mardan	34°11'42.96"N 72°02'12.41"E	02/08/2020	N-39/130962
17.	*Cannabis sativa* L.	Cannabaceae	Hemp	Wild	Herb	Jalala	Mardan	34°20'04.33"N 71°54'27.11"E	03/03/2020	N-12/130935
18.	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	Shepherd's purse	Wild	Herb	Umarzai	Charsadda ,	34°14'15.86"N 71°43'19.96"E	4/04/2021	Ch-13/131665
19.	*Carthamus oxyacantha* M.Bieb.	Astereceae	Wild Safflower	Wild	Herb	Sardheri	*Charsadda*	34°09'40.22"N 71°50'42.99"E	7/04/2020	Ch-2/131668
20.	*Celosia cristata* L.	Amaranthaceae	Silver cock's comb	Wild	Herb	Shahmansoor	Swabi	4° 04'14.38"N 72°26'47.49"E	13/09/2020	S-12/ 130984
21.	*Centaurea iberica* T revir. ex Spreng.	Astereceae	Iberian star-thistle	Wild	Herb	Lundkhwar	Mardan	34° 23,21.06"N 71°59,04.52"E	17/03/2020	N-27/130950
22.	*Centaurium pulchellum* (Sw.) Druce	Gentianaceae	Pink centaury	Ornamental	Herb	Shahadand	Mardan	34°23'08.28"N 71°59'29.43"E	15/3/2020	N-44/130967
23.	*Chenopodium album* L.	Amaranthaceae	White goosefoot	Wild	Herb	Sardheri	Charsadda	34°09'40.22"N 71°50'42.99"E	10/09/2020	Ch-4/131678
24.	Chrozophora tinctoria (L.) A.Juss.	Euphorbiaceae	Dyers croton	Wild	Herb	Zaida	Swabi	34°03'17. 33"N 72°28'02.05"E	07/09/2020	S-17/ 130989
25.	*Cichorium intybus* L .	Astereceae	Chicory	Cultivated	Herb	Gulmaira	Mardan	71°58'31.85"N 34°23'33.61"E	4/04/2020	N-33/130956
26.	*Cirsium arvense* (L.) Scop.	Astereceae	Creeping thistle	Wild	Herb	Lundkhwar	Mardan	34° 23'21.06"N 71°59'04.52"E	27/04/2020	N-27/130944
27.	*Citharexylum spinosum* L.	Verbenaceae	Fiddle wood	Wild	Shrub	Serdhari	Charsadda ,	34°09'40.22"N 71°50'42.99"E	01/09/2021	Ch-10/131685
28.	*Citrus limon* (L.) Osbeck	Rutaceae	Lemon	Cultivated	Shrub	Hathian	Mardan	34°23'36.60"N 71°54'09.81"E	08/05/2020	N-49/ 131666
29.	*Citrus sinensis* (L.) Osbeck	Rutaceae	Navel Orange	Cultivated	Tree	Gulmaira	Mardan	34°23'22.30"N 71°57'54.42"E	14/03/2020	N-19/130942
30.	*Cleome viscosa* L.	Cleomaceae	Tick weed	Wild	Herb	Karnal sher killi	Swabi	34° 14'41.48"N 72°14'40.28"E	02/08/20	S-2/ 130974
31.	*Clinopodium vulgare* L.	Lamiaceae	Wild basil	Wild	Herb	Karnal sher killi	Sawabi	34° 14'41.48"N 72°14'40.28"E	March-August	S-27/130999
32.	*Commelina benghalensis* L.	Commelinaceae	Tropical spiderwort	Wild	Herb	Gulabad	Charsadda	34°08'32.53"N 71°40'58.47"E	01/09/2021	Ch-8/131679

33.	*Convolvulus arvensis* L.	Convolvulaceae	Sun spurge	Wild	Herb	Jalala	Mardan	34°20'04.33"N 71°54'27.11"E	16/03/2020	N-23/130946
34.	*Corchorus olitorius* L.	Malvaceae	Jute mallow	Wild	Herb	Gulabad	Charsadda,	34°08'32.53"N 71°40'58.47"E	11/09/2021	Ch-11/131675
35.	*Coreopsis tinctoria* Nutt	Asteraceae	Zaire gully	Ornamental	Herb	Hathian	Mardan	34°23'36.60"N 71°54'09.81"E	14/4/2020	N-45/ 130968
36.	*Coriandrum sativum* L.	Apiaceae	Coriander	Cultivated	Herb	Shahadand	Mardan	34°23'08.28"N 71°59'29.43"E	15/04/2020	N-34/130957
37.	*Cucumis melo* L.	Cucurbitaceae	Muskmelon	Cultivated	Herb	Swabi	Swabi	34° 07'26.66"N 72°27'40.75"E	14/08/2020	S-10/ 130982
38.	*Cymbopogon jwarancusa* (Jones) Schult.	Poaceae	Jawarancusa grass	Wild	grass	Topi	Swabi	34° 04'38.48"N 72°37'15.71"E	05/09/2020	S-19/ 130991
39.	*Dalbergia sissoo* D C.	Fabaceae	Indian rosewood	Wild	Tree	Gulmaira	Mardan	34°23'22.30"N 71°57'54.42"E	15/03/2020	N-28/130951
40.	*Datura stramonium* L.	Solanaceae	Jimsonweed	Wild	Herb	Swabi	Swabi	34° 07'26.66"N 72°27'40.75"E	13/04/2020	S-6/ 130978
41.	*Dicliptera bupleuroides* Nees	Acanthaceae	Kalu	Wild	Herb	Pabbi	Nowshera	34°00'27.84"N 71°47'30.85"E	15/03/2020	No-15/131669
42.	*Digera muricata* (L.) Mart.	Amaranthaceae	False amaranth	Wild	Herb	Karnal sher killi	Swabi	34° 14'41.48"N 72°14'40.28"E	21/08/2020	S-29/131001
43.	*Duranta erecta* var. erecta	Verbenaceae	Pigeon berry	Cultivated	Shrub	Mardan	Mardan	34°23,33.61"E 71°58,31.85"N	15/7/2020	Ch-7/
44.	*Erigeron canadensis* L.	Astereceae	Horseweed	Wild	Herb	Zaida	Swabi	34°03'17. 33"N 72°28'02.05"E	08/09/2020	S-16/130988
45.	*Eruca sativa* Mill.	Brassicaceae	Rocket plant	Wild	Herb	Shergarh	Mardan	34°23'22.33"N 71°53'55.09"E	01/04/2020	N-22/130945
46.	*Eucalyptus camaldulensis* Dehnh	Myrtaceae	Lachae	Wild	Tree	Gulmaira	Mardan	34°23,33.61"E 71°58,31.85"N	15/3/2020	N-03/130926
47.	*Euphorbia hirta* L.	Euphorbiaceae	Garden spurge	Wild	Herb	Serdhari	Charsadda,	34°09'40.22"N 71°50'42.99"E	3/07/2021	Ch-14/131686
48.	*Euphorbia helioscopia* L.	Euphorbiaceae	Sun spurge	Wild	Herb	Jalala	Mardan	34°20'04.33"N 71°54'27.11"E	13/04/2020	N-13/130936
49.	*Fagonia indica* Burm.f.	Zygophyllaceae	Fagonia	Wild	Herb	Pabbi	Nowshera	34°00'27.84"N 71°47'30.85"E		No-3/131690

50.	*Foeniculum vulgare* Mill.	Apiaceae	Fennel	Cultivated	Herb	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	16/03/2020	N-15/130938
51.	*Gazania rigens* (L.) Gaertn.	Astereceae	Treasure flower	Cultivated	Herb	Lundkhwar	Mardan	34° 23’21.06”N 71°59’04.52”E	11/03/2020	N-38/130972
52.	*Hamelia patens* Jacq.	Rubiaceae	Firebush	Cultivated	Shrub	Gulabad	Charsadda ,	34°08’32.53”N 71°40’58.47”E	12/08/2021	Ch-6/131663
53.	*Helianthus annuus* L.	Astereceae	*Sunflower*	Cultivated	Herb	Muqam	Mardan	34° 12’18.75”N 72°02’05.49”E	9/04/2020	N-6/130929
54.	*Hibiscus rosa-sinensis* L.	Malvaceae	China rose	Cultivated	Shrub	Swabi	Swabi	34° 07’26.66”N 72°27’40.75”E	07/08/20	S-9/130981
55.	I*ndigofera heteranth a* Brandis	Fabaceae	Himalayan indigo	Wild	Shrub	Gadoon	Swabi	34°10’57. 94”N 72°40’48.39”E	10/09/2020	S-14/130986
56.	I*pomoea purpurea* (L.) Roth	Convolvulacea e	Common morning glory	Wild	Herb	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	18/03/2020	N-30/130953
57.	*Justicia adhatoda* L.	Acanthaceae	Malabar Nut	Wild	Shrub	Nowshera	Nowshera	34°00’27.84”N 71°47’30.85”E	14/4/2021	No-11/131673
58.	*Lagerstroemia indic a* L.	Lythraceae	Crape myrtle	Cultivated	Shrub	Zaida	Swabi	34°03’17. 33”N 72°28’02.05”E	09/09/20	S-15/130987
59.	*Lantana camara* L.	Verbenaceae	West Indian Lantana	Wild	Shrub	Maneri Bala	Swabi	34° 08’39.28”N 72°28’12.70”E	05/08/20	S-37/ 131009
60.	*Launaea procumben s* (Roxb.) Ramayya & Rajagopal	Astereceae	Creeping *launaea*	Wild	Herb	Sardheri	*Charsadd a*	34°09’40.22”N 71°50’42.99”E	29/03/2020	Ch-3/131670
61.	*Lepidium didymum* L.	Brassicaceae	Lesser swinecress	Wild	Herb	Gulmaira	Mardan	34°23’22.30”N 71°57’54.42”E	13/03/2020	N-37/ 130960
62.	*Ligustrum lucidum* W.T.Aiton	Oleaceae	White wax tree	Cultivated	Tree	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	4/4/2020	N-47/130970
63.	*Luffa acutangula* (L.) Roxb.(s)	Cucurbitaceae	Angled luffa	Cultivated	Herb	Maneri Bala	Swabi	34° 08’39.28”N 72°28’12.70”E	11/08/20	S-36/131008
64.	*Malus domestica* Bo rkh.	Rosaceae	Saeb	Cultivated	Tree	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	15/3/2020	N-18/130941
65.	*Malvastrum coroma ndelianum* (L.) Garcke	Malvaceae	Prickly Malvaestrum	Wild	Herb	Topi	Swabi	34° 04’38.48”N 72°37’15.71”E	04/09/20	S-20/130992

66.	*Mangifera indica* L.	Anacardiaceae	Mango	Wild	Tree	Jalala	Mardan	34°20’04.33”N 71°54’27.11”E	03/04/2020	N-24/130947
67.	*Martynia annua* L.	Martyniaceae	Tiger claw	Wild	Herb	Ziarat Kaka Sahib	Nowshera,	33°56’42.92”N 72°02’16.54”E	05/09/2021	No-9/131693
68.	M*edicago minima* (L.) L.	Fabaceae	Small medik	Wild	Herb	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	15/03/2020	N-43/13096
69.	*Melia azadirachta* L .	Meliaceae	Tora shandy/bikyna	Wild	Herb	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	12/4/2020	N-09/130932
70.	*Melilotus indicus* (L.) All.	Fabaceae	Uzmai	Wild	Herb	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	17/3/2020	N-130948
71.	*Mentha arvensis* L.	Lamiaceae	Field Mint	Cultivated	Herb	Sardheri	Charsadda	34°09’40.22”N 71°50’42.99”E	05/08/2021	No-8/
72.	*Mentha spicata* L.	Lamiaceae	Garden mint	Wild	Herb	Sardheri	Charsadda	34°09’40.22”N 71°50’42.99”E	05/08/2021	No-10/131688
73.	*Mentha longifolia* (L.) L.	Lamiaceae	Wild Mint	Wild	Shrub	Maneri Bala	Sawabi	34° 08’39.28”N 72°28’12.70”E	13/04/2020	S-24/130996
74.	*Nerium oleander* L.	Apocynaceae	Oleander	Cultivated	Shrub	Nowshera,	Nowshera	34°00’37.67”N 71°59’15.19”E	05/09/2021	No-7/131672
75.	*Nicotiana tabacum* L.	Solanaceae	Tobacco	Cultivated	Herb	Gulmaira	Mardan	34°23,33.61”E 71°58,31.85”N	04/04/2020	N-7/130930
76.	*Oenothera rosea* L' Hér. ex Aiton	Onagraceae	Sun cups	Wild	Herb	Shahadand	Mardan	34°23’08.28”N 71°59’29.43”E	17/4/2020	N-08/130931
77.	*Opuntia dillenii* (Ker Gawl.) Haw.	Cactaceae	Erect prickly pear	Wild	Shrub	Nowshera,	Nowshera,	34°00’37.67”N 71°59’15.19”E	15/5/2021	No-12/131664
78.	*Oxalis corniculata* L .	Oxalidaceae	Creeping wood sorrel	Wild	Herb	Karnal sher killi	Swabi	34° 14’41.48”N 72°14’40.28”E	31/8/2020	N-31/13003
79.	*Papaver somniferum* L.	Papaveraceae	Opium poppy	Cultivated	Herb	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	03/03/2020	N-16/130939
80.	*Parthenium hystero phorus* L.	Astereceae	Santa-Maria	Wild	Herb	Swabi	Swabi	34° 07’26.66”N 72°27’40.75”E	11/08/2020	S-34/131006
81.	*Peganum harmala* L.	Nitrariaceae	Wild rue	Wild	Herb	Umarzai	Charsadda .	34°14’15.86”N 71°43’19.96”E	8/7/2021	Ch-15/131681
82.	*Pennisetum glaucum* (L.) R.Br.	Poaceae	Pearl millet	Cultivated	Grass	Swabi	Swabi	34° 07’26.66”N 72°27’40.75”E	11/08/2020	S-35/ 131007
83.	*Physalis minima* L.	Solanaceae	Goose beery	Wild	Herb	Nowshera,	Nowshera	34°00’37.67”N 71°59’15.19”E	24/04/2021	No-1/131662
84.	*Prosopis juliflora* (S w.) DC.	Fabaceae	Ironwood	Wild	Shrub	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	15/04/2020	N-48/130971

85.	*Psidium guava* Gris eb.	Myrtaceae	Common guava	Cultivated	Tree	Jalala	Mardan	34°20’04.33”N 71°54’27.11”E	06/03/2020	N-14/130937
86.	*Punica granatum* L.	Lythraceae	Anaar	Cultivated	Shrub	Katlang	Mardan	34°21’07.41”N 72°04”35.20”E	24/4/2020	N-31/130954
87.	*Rosa indica* L.	Rosaceae	Rose	Cultivated	Shrub	Shahmanso or	Swabi	34° 04’14.38”N 72°26’47.49”E	123/09/20	S-11/130983
88.	*Sesbania sesban* (L.) Merr.	Fabaceae	Sesbane	Wild	Tree	Umarzai	Charsadda ,	34°14’15.86”N 71°43’19.96”E	25/9/2021	Ch-9/131680
89.	*Setaria viridis* (L.) P.Beauv.	Poaceae	Green foxtail	Wild	Grass	Karnal sher killi	Swabi	34° 14’41.48”N 72°14’40.28”E	01/08/2020	S-1/ 130973
90.	*Silybum marianum* (L.) Gaertn.	Astereceae	Cardus marianus	Wild	Herb	Takkar	Mardan	34° 17’19.16”N 71°53’49.76”E	6/03/2020	N-35/130958
91.	*Sisymbrium irio* L.	Brassicaceae	Desert mustard	Wild	Herb	Lundkhwar	Mardan	34° 23·21.06”N 71°59·04.52”E	25/3/2020	N-02/130925
92.	*Solanum melongena* L.	Solanaceae	Eggplant	Cultivated	Herb	Maneri Bala	Mardan	34° 08’39.28”N 72°28’12.70”E	02/09/2020	S-23/130995
93.	*Solanum nigrum* L.	Solanaceae	Black nightshade	Wild	Herb	Lundkhwar/ Mardan	Swabi	34° 23,21.06”N 71°59,04.52”E	21/03/2020	N-17/130940
94.	*Solanum surattense* Burm. f.	Solanaceae	Wild Eggplant	Wild	Herb	Karnal sher killi	Mardan	34° 14’41.48”N 72°14’40.28”E	23/08/2020	S-3/ 130975
95.	*Sonchus asper* (L.) Hill	Astereceae	Prickly sow-thistle	Wild	Herb	Swabi	Swabi	34° 07’26.66”N 72°27’40.75”E	01/08/2020	S-33/131005
96.	*Taraxacum campylodes* G.E.Haglund	Astereceae	Dandelion	Wild	Herb	Lundkhwar	Mardan	34° 23’21.06”N 71°59’04.52”E	21/04/2020	N-40/130963
97.	*Thermopsis montana* Torr. & A.Gray	Fabaceae	Mountain thermopsis	Wild	Herb	Swabi	Swabi	34° 07’26.66”N 72°27’40.75”E	17/09/2020	S-8/ 130980
98.	*Torilis leptophylla* (L.) Rchb.f.	Apiaceae	Bristlefruit hedgeparsley	Wild	Herb	Takkar	Mardan	34° 17’19.16”N 71°53’49.76”E	06/03/.2020	N-36/ 130959
99.	*Trianthema portulacastrum* L.	Aizoaceae	Black pigweed	Wild	Herb	Umarzai	Charsadda	34°14’15.86”N 71°43’19.96”E	12/08/2021	Ch-5/131677
100.	*Tribulus terrestris* L.	Zygophyllaceae	Puncture vine	Wild	Herb	Umarzai	Charsadda ,	34°14’15.86”N 71°43’19.96”E	1/09/2021	Ch-7/131674
101.	*Trichodesma indicum* (L.) Lehm.	Boraginaceae	Indian Borage	Wild	Herb	Pabbi	Nowshera	34°00’27.84”N 71°47’30.85”E	24/04/2021	No-4/131692

102.	*Trifolium alexandrinum* L.	Fabaceae	Spenigully shawtal	Wild	Herb	Hathian	Mardan	34°23’36.60”N 71°54’09.81”E	11/4/2020	N-10/130933
103.	*Trifolium tomentosum* L.	Fabaceae	Woolly Clover	Wild	Herb	Hathian	Mardan	34°23’36.60”N 71°54’09.81”E	19/03/2020	N-11/130934
104.	*Tripleurospermum caucasicum* (Willd.) Hayek	Astereceae	Ziarh gully	Ornamental	Herb	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	15/3/2020	N-46/130969
105.	*Tropaeolum majus* L.	Tropaeolaceae	Garden Nasturtium	Cultivated	Herb	Maneri Bala	Swabi	34° 08’39.28”N 72°28’12.70”E	14/05/2020	N-50/ 131667
106.	*Verbascum thapsus* L.	Scrophulariaceae	Khardhag	Wild	Herb	Lundkhwar	Mardan	34° 23,21.06”N 71°59,04.52”E	3/04/2020	N-01/130924
107.	*Verbena officinalis* L.	Verbenaceae	Common vervain	Wild	Herb	Karnal sher killi	Sawabi	34° 14’41.48”N 72°14’40.28”E	05/09/2020	S-28/131000
108.	*Verbesina encelioides* (Cav.) Benth. & Hook.f. ex A.Gray	Astereceae	Gold weed	Wild	Herb	Gadoon	Swabi	34°10’57. 94”N 72°40’48.39”E	12/09/2020	S-13/130985
109.	*Viola tricolor* L.	Violaceae	Gull	Ornamental	Herb	Shahadand	Mardan	34°23’08.28”N 71°59’29.43”E	4/4/2020	N-42/130965
110.	*Vitex negundo* L.	Lamiaceae	Chinese chaste tree	Wild	Shrub	Sawabi	Sawabi	34° 07’26.66”N 72°27’40.75”E	13/04/2020	S-7/ 130979
111.	*Youngia japonica* (L.) DC.	Astereceae	Oriental false hawksbeard	Wild	Herb	Kernal sher killi	Swabi	34° 14’41.48”N 72°14’40.28”E	24/08/2020	S-30/131002
112.	*Zea mays* Vell.	Poaceae	Maize	Cultivated	Grass	Topi	Swabi	34° 04’38.48”N 72°37’15.71”E	16/08/2020	S-5/ 130977
113.	*Ziziphus jujuba* Mill.	Rhamnaceae	Common jujube	Wild	Shrub	Gulmaira	Mardan	34°23’22.30”N 71°57’54.42”E	06/09/2020	S-18/130990
114.	*Ziziphus oxyphylla* Edgew	Rhamnaceae	Marhkhaney	Cultivated	Shrub	Gulmaira	Mardan	34°23,33.61”E 71°58,31.85”N	19/4/2020	N-01/130927

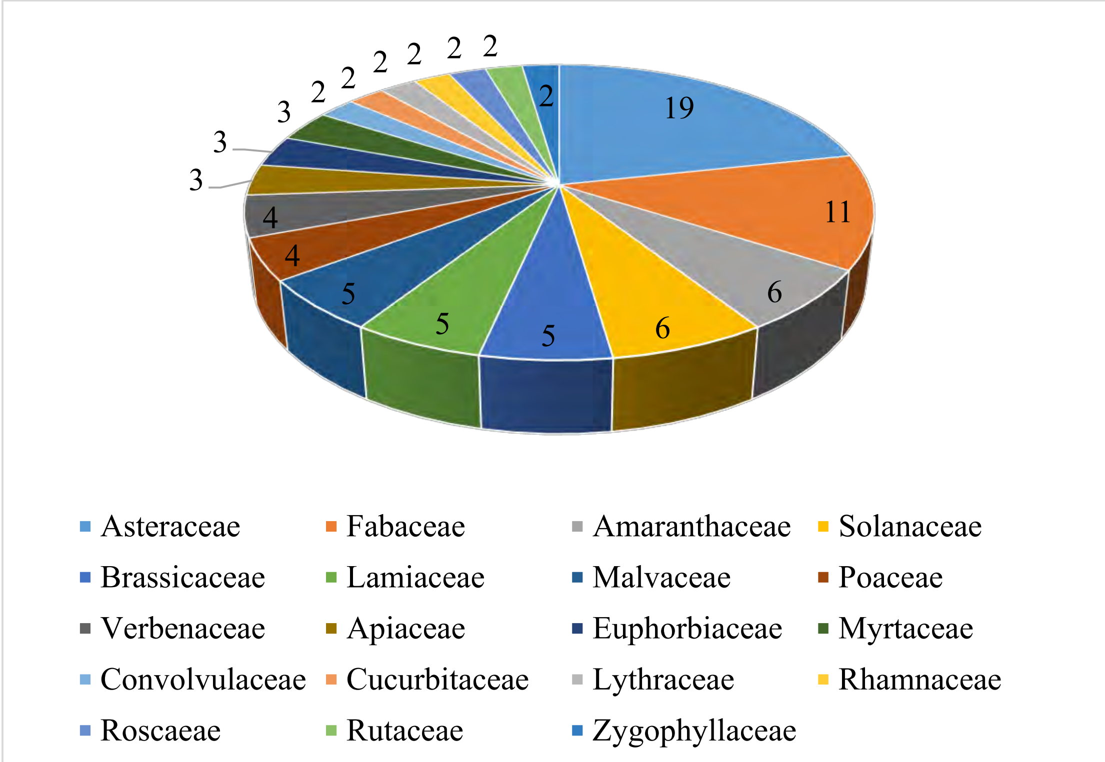

Figure 3. Graphical representation of melliferous species among dominant families

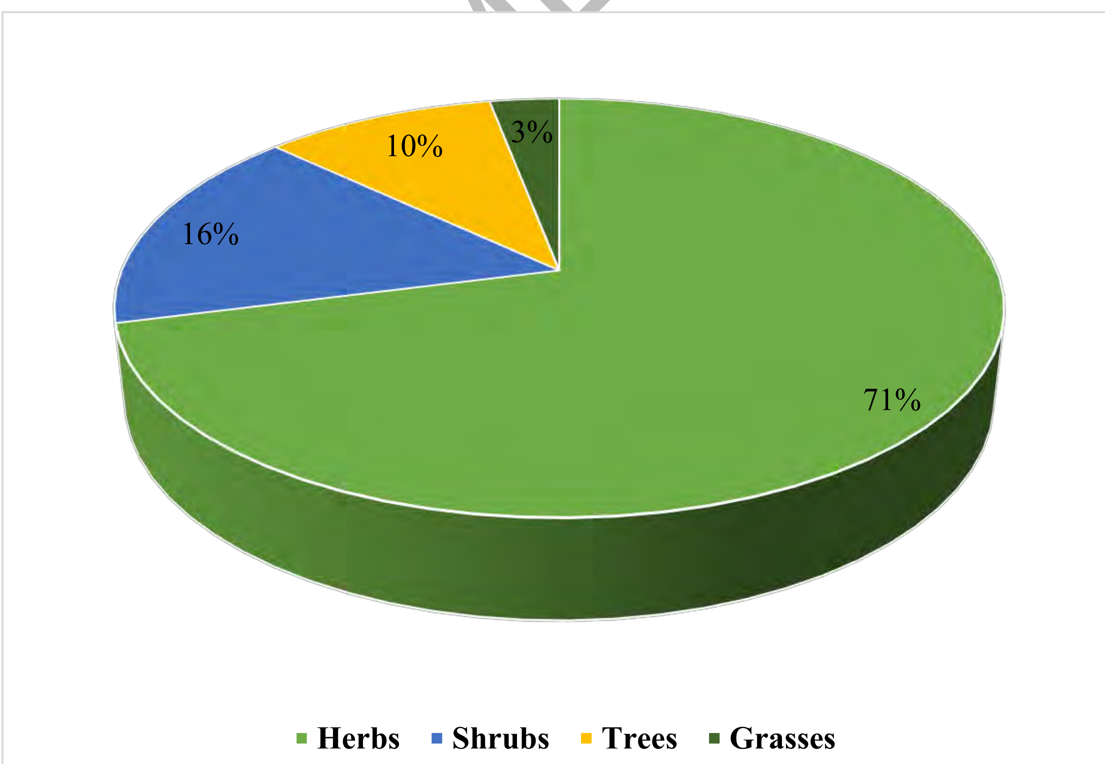

Figure 4. Life Form Classification of honeybee floral species

Section II:

Pollen Morphological Diversity among Honeybee flora

3.2 Morpho-palynological diversity in Honeybee flora

This section elaborates to examine the detailed pollen micro-morphological inventory of 114 honeybee floral species belonging to 43 families were collected from Khyber Pakhtunkhwa Pakistan. Among them Asteraceae (19) was the most dominating family having maximum no. of species followed by Fabaceae (11), Amaranthaceae (6), Solanaceae (6), Brassicaceae (5), Lamiaceae (5), Malvaceae (5), Poaceae (4), Verbenaceae (4), Apiaceae (3), Acanthaceae (3), Euphorbiaceae (3), Myrtaceae (3), Cucurbitaceae (2), Convolvulaceae (2), Lythraceae (2), Rhamnaceae (2), Rosaceae (2), Rutaceae (2), Zygophyllaceae (2), and other remaining honeybee floral species belongs to 23 diverse families.

In morphological study parameters which were studied and given include species scientific name, its synonyms, vernacular/common name, habit, family name, flowering period, morphological description of species and its distribution in world. In morphological study leaf color, shape, margins, surface and apex were studied. Stem morphology was observed and stem surface, rigidity or softness of stem along with stem surface were studied. Flowering featured were described including its parts i.e. calyx, corolla, androecium and gynoecium that were studied in detail. Type of inflorescence, position of ovary, fruit type was also described given below.

Qualitative and quantitative pollen grains characters which were studied include pollen type, shape in (polar view and equatorial view), sculpturing, presence of pore, spines and colpi, equatorial diameter, polar length, mesocolpium distance, exine thickness, P/E ratio, colpi and pore no, length and width of pore/colpi and their fertility percentage

3.2.1 Asteraceous Honeybee flora

1. *Aster squamatus* (Spreng.) Hieron.

Synonym	*Aster asteroides* Rusby
Family	Asteraceae
Common Name	Narrow-leaves aster
Habit	Herb
Habitat	Arable land, market garden and on saline soil
Flowering period	June to November
Status	Wild
Distribution	South America, France, Turkey, Spain, Pakistan, Italy, Australia
Morphology	Annual or biennial herb. Taproot is present. 10-70 cm high. Stem branched and erect, surface is glabrous. Leaves are sessile, glabrous, alternate, shape is linear-lanceolate. Leaf length 4-18 cm and varies from 0.5-1.5 cm. Margins entire. Petals white. involucre bracts in several series. Capitula in symmetrical panicles. Involucral bracts; 3 rows, oblanceolate, tapered purplish, serrulate apex, mucronate point, appressed, longest 4.5-7 mm. Ligules; violet blue, more numerous, than the tubular florets (Plate 15a).
Melissopalynology	Pollen are monad, small and tricolporate. Semicircular polar view and prolate-spheroidal equatorial view. Exine sculpturing Echino-lophate perforate. Lacunae's shape pentagonal and sculpturing fenestrated perforate. Polar diameter 22.25(20.5-23.75) ±0.57µm an equatorial view distance 21.4(19.5-23.5) ±0.74µm. P/E ratio 1.03. Pores rounded elliptical and sunken. Pore length 3.05(2.75-3.50) ±0.14µm and pore width 2.45(1.75-3.25) ±0.28µm. Length of colpi 5.05(4.25-6) ±0.34 µm. Width of colpi 3.05(2.50-3.75) ±0.21 µm. Echini arrangements regular. Average number of spines 27. Spine length 2.6(1.75-3.75)±0.42 µm. Spine width 1.6 (1.25-2)±0.12 µm. Exine thicknesses 4.20(3.25-5.25)±0.32µm. Mesocolpium distance 7.6(5.1-9.5)±0.09 µm. Pollen fertility count 21.4% and sterility 78.6% (Plate 15b,c,d & e).

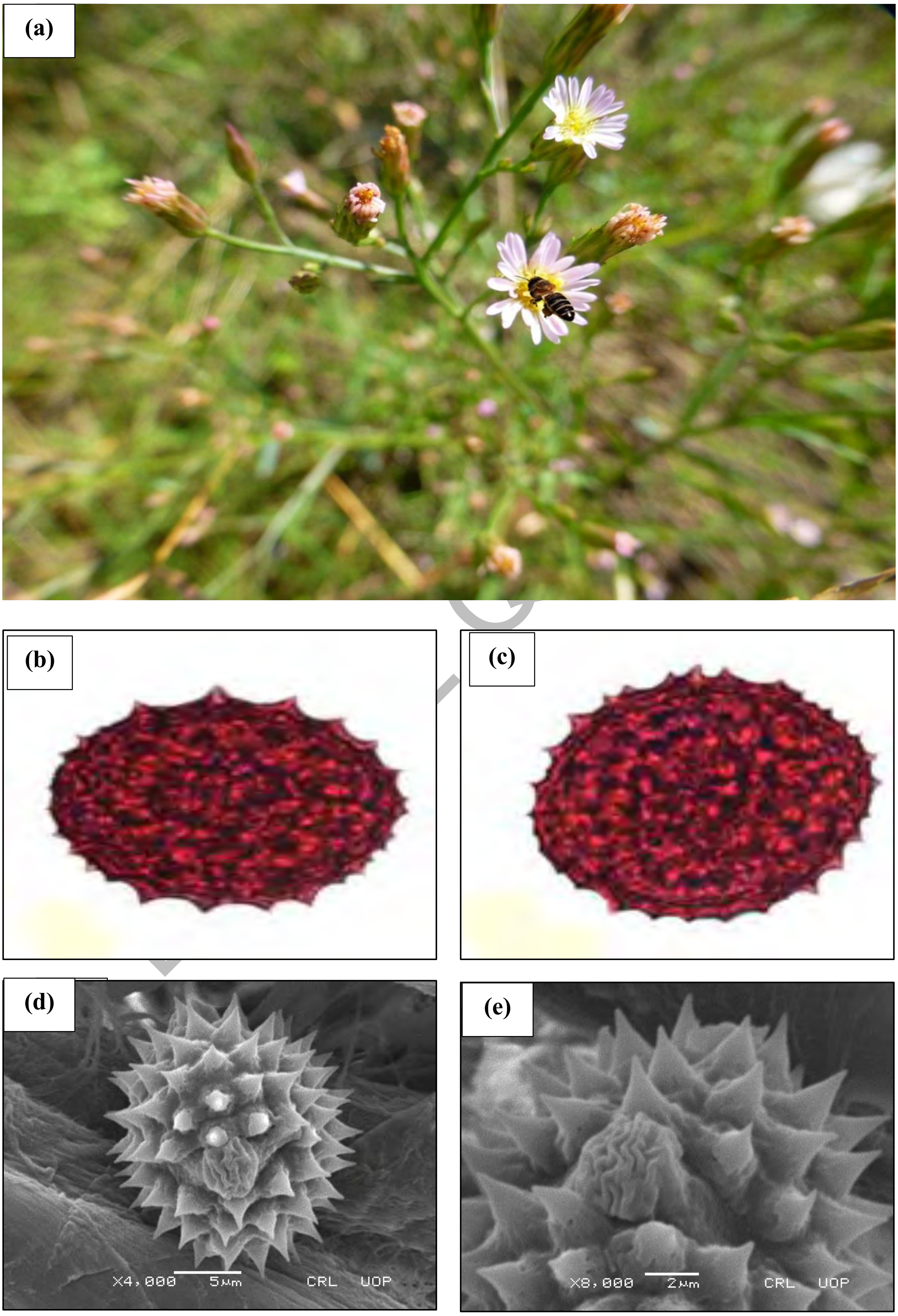

Plate 15: *Aster squamatus* (Spreng.) Hieron. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Bidens pilosa* L.

Synonym	*Bidens abadiae* DC.
Family	Asteraceae
Common Name	Black-jack
Habit	Annual Herb
Habitat	Parks, along roadsides, disturbed sites and waste areas near villages
Flowering period	Throughout year
Status	Wild
Distribution	Mexico, Pakistan, Japan, Peru, Saudi Arabia, Ghana
Morphology	Annuals, Stems 25-150 cm tall, glabrous, sparsely pubescent. Petiole 8-25 mm; leaf blade lanceolate, 20-55 × 10-15 mm, pinnately lobed, ovate, both surfaces sparsely glabrate, bases cuneate, ultimate margin serrate, ciliate. Synflorescence; solitary capitula. Capitula discoid; peduncles 08-16 mm; appressed, spatulate, 3-5 mm, hispidulous, involucres turbinate, 3-7 × 4-7 mm; oblanceolate, Ray florets absent, lamina whitish. Disk florets 15-35; corolla yellowish. Achenes red-brown, flat, narrowly cuneate, apex attenuate; pappus absent, or of 2 or 3 erect, barbed awns (Plate 16a)
Melissopalynology	Pollen are monad, medium sized, echinate and radically symmetrical. Equatorial view shape prolate-spheroidal, Circular polar view and tricolporate. Pollen regions small to moderate, aperture orientation sunken. Exine sculpturing Echino-perforate, echini arrangement regular, spines; with flattened bases, sharps pointed tips and no lacunaes among spines. Equatorial view distance 29.3(23.7-32.7) ±3.71 µm and polar diameter 25.6(23.0-27.7) ±1.79 µm. P/E ratio 0.87. Colpus length 2.80(1.75-3.75) ±0.79 µm, colpus width 2.80(2.25-3.25) ±0.37 µm, spine length 2.20(1.25-3.00) ±0.71 µm and spine width 0.45(0.25-0.75) ±0.20 µm. Mesocolpium distance 21.7(18.5-23.7) ±2.18 µm. Exine thickness 3.35(2.75-4.00) ±0.51 µm. Pollen fertility 87.8% and sterility 12.1% (Plate 16b,c,d & e).

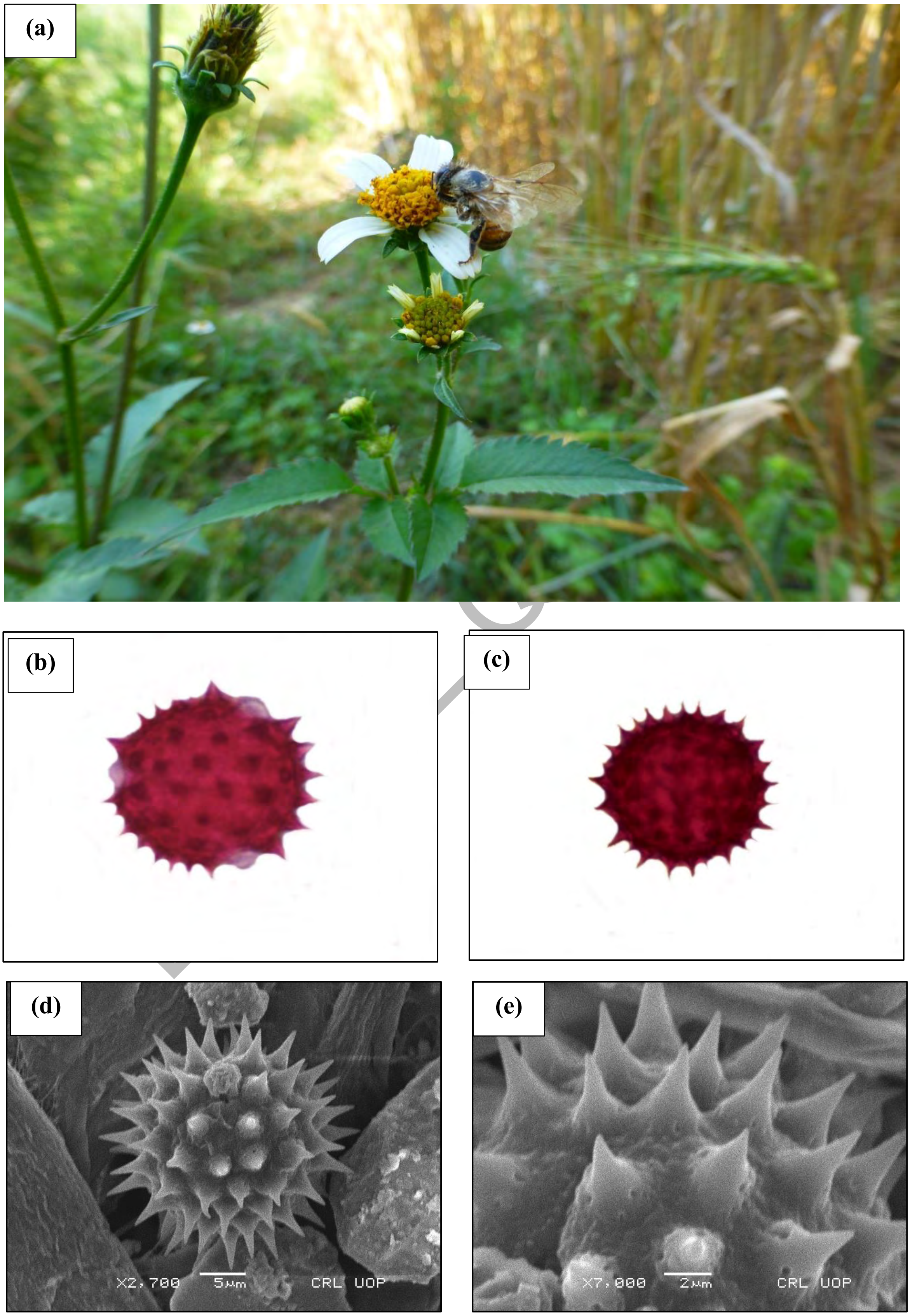

Plate 16: *Bidens pilosa* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Calendula arvensis* M. Bieb.

Synonym	*Calendula aegyptiaca* Pers.
Family	Asteraceae
Common Name	Field marigold
Habit	Annual Herb
Habitat	Sandy and loamy soil, lawns, uncultivated lands
Flowering period	March to April
Status	Wild
Distribution	Central and Southern Europe, Iran, India and Pakistan.
Morphology	Annual herb, erect stem that have reach up to the height of 28.2-48.9 cm. Taproot is present. 10-50 cm high. Stem; erect, scabrous. Leaves; alternate and spatulate which are covered with a dense hair and regularly notched margin. The leaves are lance-shaped and not sessile. The inflorescence is a single flower head up to 4 cm wide with bright yellow to yellow-orange ray florets around a center of yellow disc florets. Inflorescence; flower head with a diameter is 1.4-3.9 cm. Flowers color is yellow and ray flowers have ligulate, having tubular disc like flowers (Plate 17a)
Melissopalynology	Pollen grains are monad, medium sized, iso-polar; and tetracolporate. Equatorial view shape prolate- spheroidal, polar view quadrangular; aperture orientation slightly bulged, echini arrangement slightly irregular**,** spines with broad bases, sharp pointed mucronate tips and no lacunar spaces, and polar region moderately extensive. Exine sculpturing echinate. Polar view diameter 28.7(19.7-41.2) ±5.92 µm, equatorial view distance 27.1(17.7-36.0) ±5.67 µm. P/E ratio 1.05. Colpi length 5.36(2.00-8.00)±2.19 µm, colpi width 5.83(3.75-8.50)±1.64 µm, spine length 4.11(2.00-6.75)±1.43 µm, spine width 3.10(2.00-4.75)±0.89 µm and mesocolpium 19.6(14.7-23.0)±2.53 µm. Exine thickness 3.31(2.25-4.75)±0.70 µm. Pollen fertility 95.6% and sterility 4.36% (Plate 17b,c,d & e).

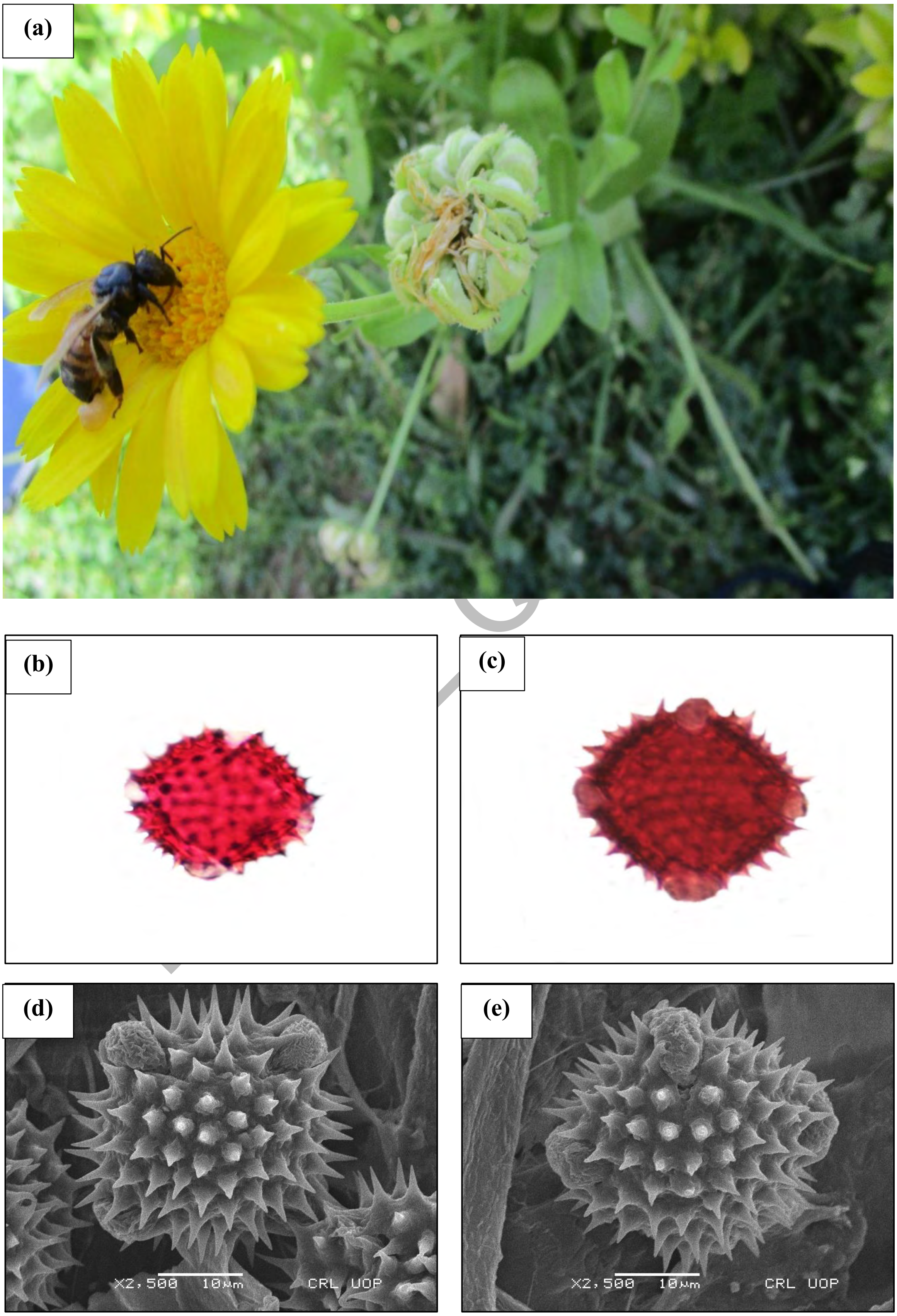

Plate 17: *Calendula arvensis* M. Bieb. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Carthamus oxyacantha* M.Bieb.

Synonym	*Carduus flavescens* Willd.
Family	Asteraceae
Common Name	Wild Safflower
Habit	Annual Herb
Habitat	Occurs along fallow field, waste places and roadsides
Flowering period	March to July
Status	Wild
Distribution	Afghanistan, India, Iran, Iraq, Kyrgyzstan, Pakistan, Tajikistan
Morphology	Annual, herbaceous stout, armed, much branched, puberulous 1- 1.5 feet tall. Tap root is present. 12-30 cm high. Stem color white, much branched, scabrous. Leaves sessile, 1-4 inches long, oblong-lanceolate; often pinnatified, spinulose-toothed; upper amplexicaul, very spinous. Heads 0.5 inches in diameter; outer involucral bracts, white below the contracted portion, yellow spines. Flowers; orange yellow. Achenes obovoid, tetra angled, smooth shinning truncate at the top, pappus (Plate 18a).
Melissopalynology	Pollen are monad, radically symmetrical, large sized, and tricolporate. Angular polar view, oblate-spheroidal equatorial view. Aperture orientation bulged, polar region small to medium, spine irregular with very short broad bases and lacunaes absent. Exine sculpturing echinate, micro perforate. Polar diameter 54.2(25.5-83.0) ±25.0 µm and equatorial diameter 56.1(26.25-83.0) ±23.1 µm. P/E ratio 0.96. Colpi length 5.70(2.75-8.50)±2.51 µm, colpi width 3.82(0.75-6.50)±2.33 µm, spine length 2.05(0.75-3.25)±0.88 µm and spine width 1.67(0.50-3.00)±0.91 µm. Mesocolpium length 25.07(18.2-33.0)±6.26 µm. Exine thickness 3.22(1.75-4.75) ±1.01 µm. Pollen fertility 82.6% and sterility 17.3% (Plate 18b,c,d & e).

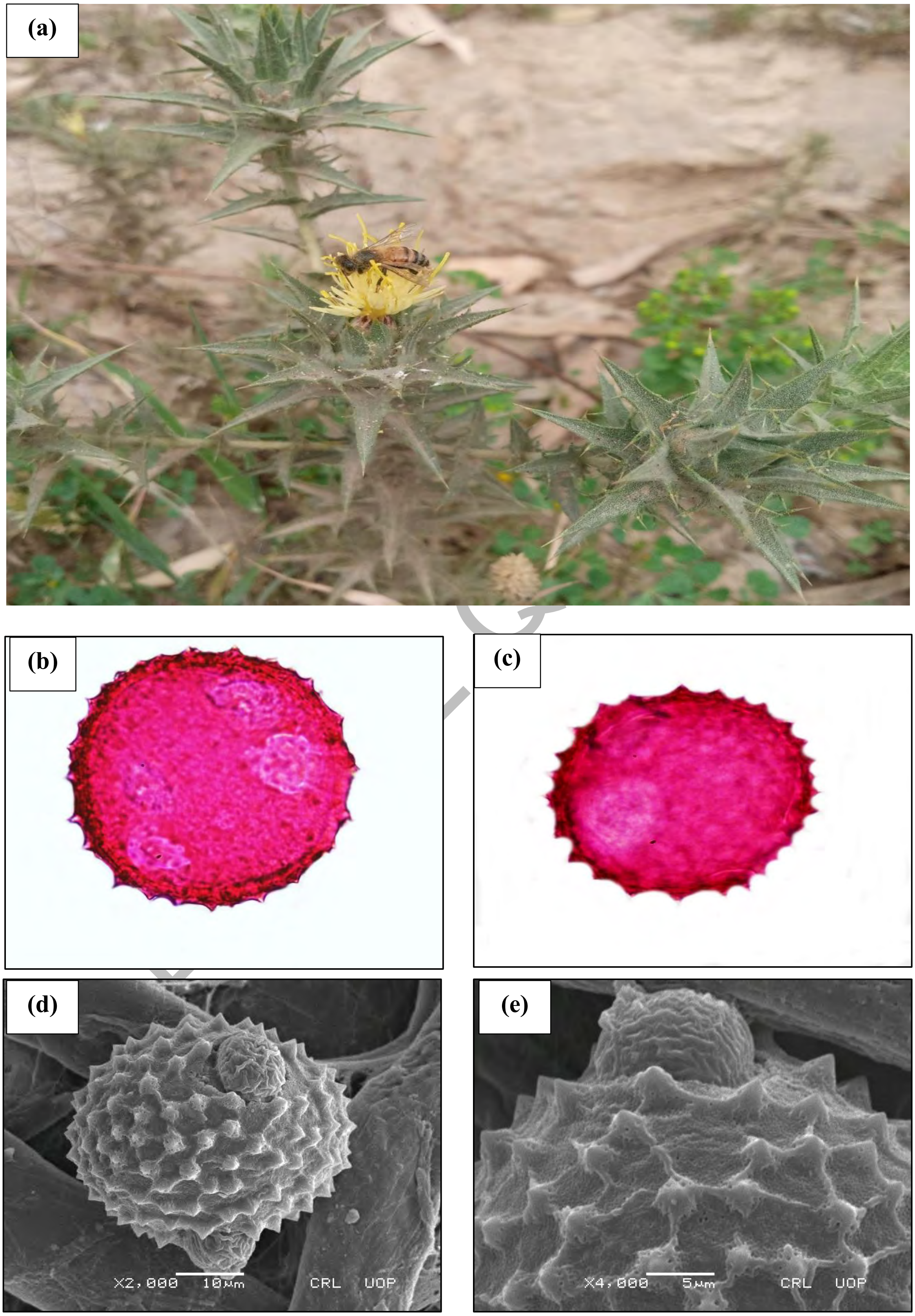

Plate 18: *Carthamus oxyacantha* M.Bieb. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Cichorium intybus* L.

Synonym	*Cichorium balearicum* Porta
Family	Asteraceae
Common Name	Chicory
Habit	Perennial Herb
Habitat	Grows in open fields, disturbed areas, bare land, ditches
Flowering period	February to May
Status	Cultivated
Distribution	Uzbekistan, Armenia, Pakistan, Egypt, Spain, Iran, Afghanistan
Morphology	Herb, 30 to 100 cm tall, strong taproot. Stem; solitary, erect, ascending branches, sub-glabrous. Basal leaves; rosulate, 10-30 × 1.5-3 cm, attenuate, pinnatipartite, sparsely multicellular hairs, attenuate base, dentate margins; 3-6 pairs of lateral lobes, triangular. Synflorescence; spiciform paniculiform. Capitula; axillary, terminal, solitary or clusters, sessile thick, apically inflated peduncle and 12-20 florets. Involucre cylindric, 1.1-1.5 cm. Florets blue; pink or bluish white. Achene brown, sub-cylindric to obovoid, 1.5-4 mm, stout, rugulose, truncate. Pappus 0.3 to 0.5 mm (Plate 19a).
Melissopalynology	Pollen grains are monad, medium sized, and tricolporate. Circular polar view and prolate-spheroidal equatorial view shape. Polar region moderate. Aperture orientation slightly sunken. Exine sculpturing fenestrate and Echino-perforate. Flattened base regular spines with sharp pointed tips. Lacunaes; trigonal to tetragonal with narrow inter lacunar gaps. Polar diameter 30.2(16.2-460) ±3.82 µm and equatorial diameter distance 29.9(19.5-42.5) ±3.26 µm. P/E ratio 1.01. Length of colpi 8.12(4.25-22.5)±1.68 µm and width of colpi 5.72(4.50-7.50)±0.35 µm. Mesocolpium distance 14.2(10.0-18.7)±1.10 µm. Spine length 3.10(1.75-5.00)±0.57 µm and spine width 1.35(0.75-2.75)±0.37 µm. Exine thickness 2.47(1.00-4.50)±0.36 µm. Pollen fertility 77.7% and sterility 20.8% (Plate 19b,c,d & e).

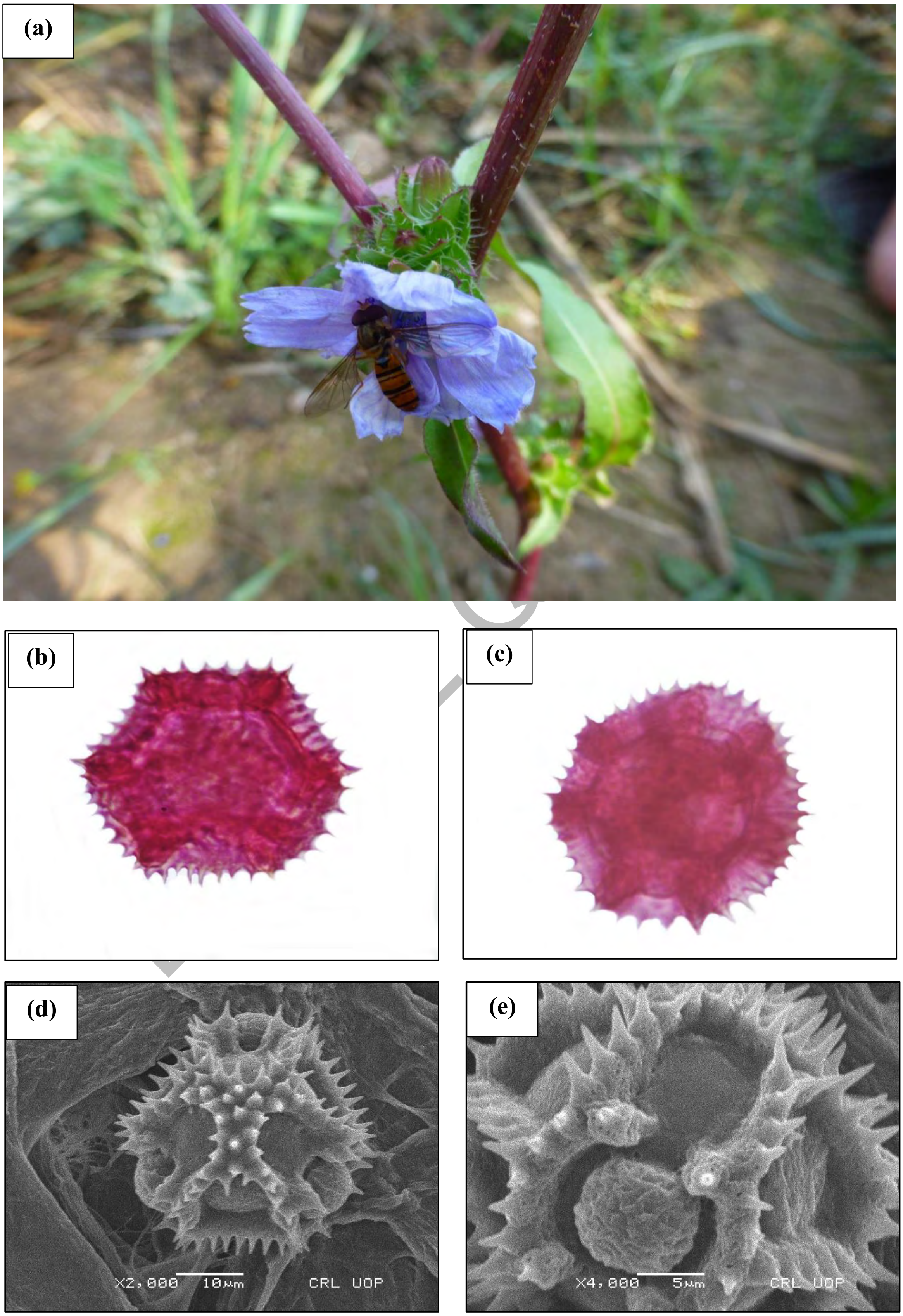

Plate 19: *Cichorium intybus* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

6. *Centaurea iberica* Trevir. ex Spreng.

Synonym	*Calcitrapa iberica* (Trevir. ex Spreng.) Schur
Family	Asteraceae
Common Name	Iberian star-thistle
Habit	Annual/Biennial Herb
Habitat	In fields and on roadsides and wasteland
Flowering period	Marcht to May
Status	Wild
Distribution	Jordan, Syria, Turkey, Pakistan, California, Bulgaria
Morphology	Herbs, 15-80 cm tall. Stem; erect, stem and branches setiferous. Leaves; sparsely strigose. Basal leaves petiolate; leaf blade pinnatipartite. Stem leaves sessile, pinnatisect; lateral lobes 4 pairs, narrowly elliptic, apex obtuse and mucronulate. Upper leaves narrowly elliptic, lanceolate, margin denticulate. Capitula; corymbose-paniculate synflorescence. Involucre ovoid, 0.8-2 cm in diameter. Phyllaries 4 to 6 rows; outer and middle ovate, 3-6 × 5-8 mm, scarious margin, outer and middle phyllaries spines straw-colored, 1.3-2.2 cm, apex pungent; appendage in inner phyllaries white, scarious, entire. Corolla; pink to purple and Achenes; grayish brown, ellipsoid, pubescent, with inconspicuous rim. Outer pappus; few rows elements (Plate 20a).
Melissopalynology	Pollen are monad, medium sized, radically symmetrical and tricolporate. Triangular polar view and prolate spheroidal equatorial view. Aperture orientation slightly bulged. Exine sculpturing scabrate. Irregular minute spines with flattened bases. Lacunas absent. Polar diameter 31.4(26.2-35.2) ±3.75 µm, equatorial diameter 30.4(27.7-32.7) ±2.07 µm. P/E ratio 1.03. Colpi length 3.95(2.25-5.25)±1.15 µm and colpi width 8.40(7.75-9.25) ±0.60 µm. Spine length 2.90(2.00-3.75) ±0.65 µm, spine width 1.95(1.25-2.75) ±0.59 µm and mesocolpium length 24.3(22.2-26.25) ±1.51 µm. Exine thickness 2.60(2.00-3.25) ±0.48 µm. Pollen fertility 80.76% and sterility 19.2% (Plate 20b,c,d & e).

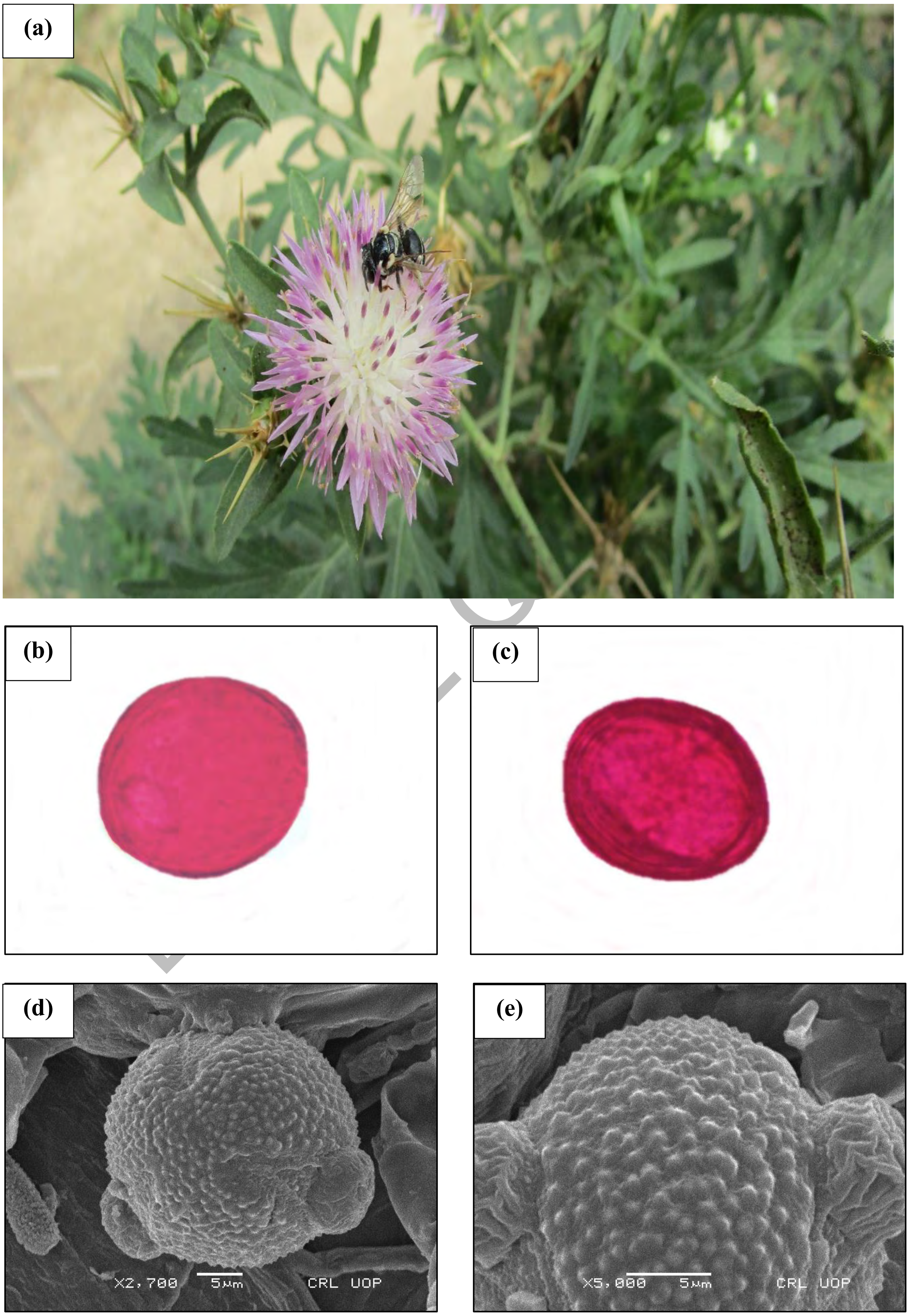

Plate 20: *Centaurea iberica* Trevir. ex Spreng. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

7. *Cirsium arvense* (L.) Scop.

Synonym	*Breea dioica* (Cass.) Less.
Family	Asteraceae
Common Name	Creeping thistle
Habit	Perennial Herb
Habitat	Tillage agricultural fields and non-cropped undisturbed roadsides.
Flowering period	March to May
Status	Wild
Distribution	Georgia, Belgium, Japan, France, Arizona, Pakistan
Morphology	Herb, perennial, dioecious and 25-125 cm tall. Roots; creeping, adventitious shoots. Stems; erect, branched, and unwinged. Leaf; surface smooth. Capitula; numerous, terminal and corymbose. Involucre; narrowly ovoid, 1.1-2.3 cm in diameter. Phyllaries; imbricate, 5 to 7 in rows, lacking scarious appendage, outer phyllaries; triangular, 2.5-7 × 1.5-3 mm, acute apex, inner phyllaries; elliptic-lanceolate, 6-17 × 2-3.5 mm, apex acuminate and scarious. Corolla reddish purple, rarely white and female florets 1.3 to 2.5 cm, tube 1.5-1.9 cm, male florets; 1-16 cm, tube; 1.4 cm. Achene; yellowish, 4-5.4 mm. Pappus; bristles dirty white (Plate 21a).
Melissopalynology	Pollen are monad, tricolporate and medium sized. Circular polar view and oblate-spheroidal equatorial view shape. Aperture bulged orientated, spines regular, flattened base and sharp pointed tips. Polar region: small to moderate and lacunas absent**.** Exine sculpturing Echino-perforate reticulate. Polar diameter 36.7(23.0-55.25) ±10.58 µm and equatorial diameter 38.03(23.75-55.75) ±9.99 µm. P/E ratio 0.96. Colpi length 10.9(1.75-50.25) ±15.49 µm, colpi width 6.51(2.25-10.25)±2.86 µm, echini length 4.16(1.25-5.75)±2.86 µm, echini width 2.70(0.25-6.25)±1.88 µm and mesocolpium distance 26.2(18.5-35.2)±4.70 µm. Exine thickness 4.40(2.75-5.75)±0.90 µm. Pollen fertility 95% and sterility 4.9% (Plate 21b,c,d & e).

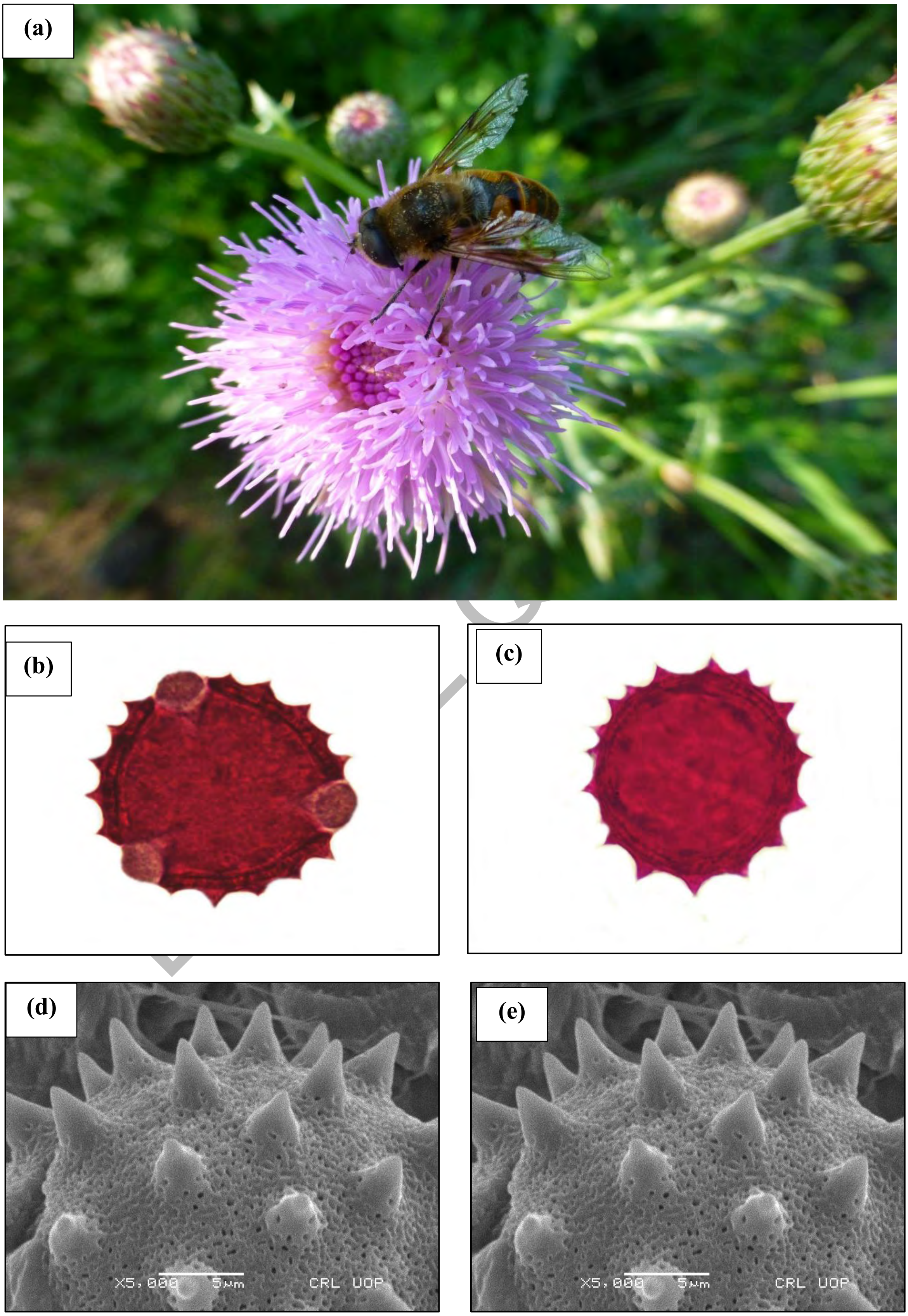

Plate 21: *Cirsium arvense* (L.) Scop. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

8. *Coreopsis tinctoria* Nutt.

Synonym	*Coreopsis tinctoria* var. *tinctoria*.
Family	Asteraceae
Common Name	Golden tickseed
Habit	Annual Herb
Habitat	Moist places, roadsides, waste places
Flowering period	April to July
Status	Ornamental
Distribution	USA, West Indies, Armenia, Iran, India, Pakistan
Morphology	Annual, 30 to 100 cm in height. Leaves: proximal blades, lobes oblanceolate, linear, filiform, pinnately divided, glabrous and tending to thin at the top of the plant where 2.4 to 4.2 cm flower heads sit atop slim stems. Inflorescence: heads, bracted cyme clusters; Peduncles: 3-11 cm. Calyculi: deltate lanceolate. Phyllaries: lance-ovate. Flower: brilliant yellow with maroon disc like florets. Disc corolla: 2.2-3.5 mm. Fruit: 1.1--2.7 mm, linear-oblong, black, minutely rough. Achenes: 1.2-3.6 mm, wings absent, 0.2-0.8 mm wide and pappus absent. Cypselae: 1.4–3.6 mm (Plate 22a)
Melissopalynology	Pollen grains are monad, small sized and tricolpate. Circular polar view and equatorial view shape prolate-spheroidal. Exine sculpturing echinate. Polar diameter 21.4(23.7-20.0) ±1.31µm and equatorial view distance 20.4(25.0-17.5) ±2.46 µm. P/E ratio 1.04. Colpi length 7.37(15.0-0.50)±6.80 µm and colpi width 4.22(8.75-0.5)4±3.84 µm. Exine thickness 3.9(7.75-1.75)±1.91 µm. Mesocolpium 4.22(8.75-0.50)±3.84 µm. Pollen fertility 85.3% and sterility 14.7% (Plate 22b,c,d & e).

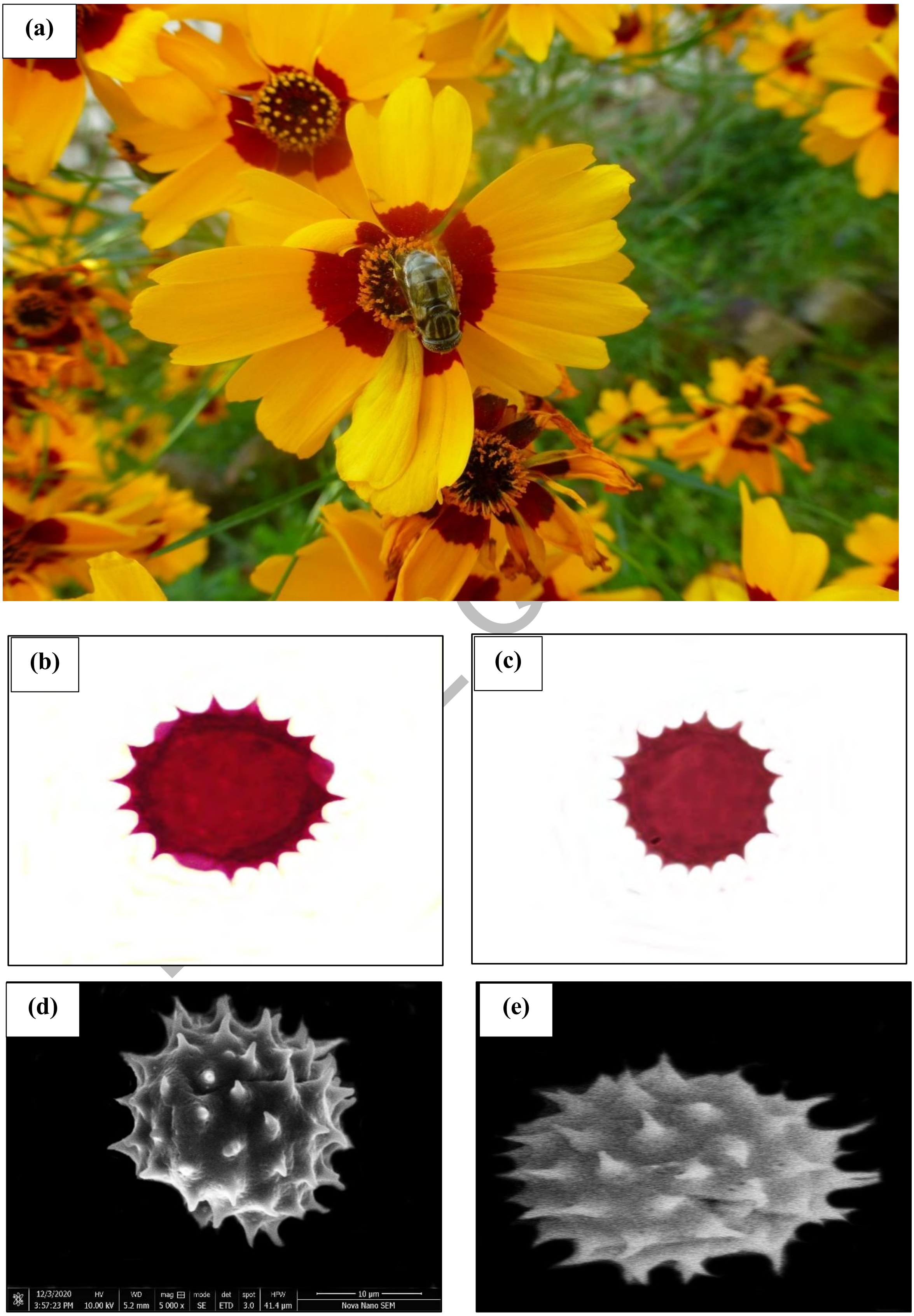

Plate 22: *Coreopsis tinctoria* Nutt. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

9. *Erigeron canadensis* L.

Synonym	*Caenotus pusillus* (Nutt.) Raf.
Family	Asteraceae
Common Name	Horse weed
Habit	Annual Herb
Habitat	Grows among orchard and in grassland and forage crops
Flowering period	July to October
Status	Wild
Distribution	Ohio, New York, Costa Rica, Finland, Bhutan, Pakistan
Morphology	Annual herb, 35-80 cm tall. Root; fusiform and fibrous. Stems; erect, hirsute, branched and densely leafy. Leaves: basal, petiolate, oblanceolate, 4-8 × 1.2-2 cm, surface pilose, margin sparsely serrate, apex acute, blade lanceolate, smaller, entire margin and toothed. Capitula; 2.5 to 4 mm diameter and numerous. Synflorescences; peduncle slender, 4-9 mm. Involucre sub-cylindric, 1.4 to 4 mm. Phyllaries; 3 seriate, greenish, sparsely strigose, lanceolate, acuminate, margin scarious and glabrous. Ray florets; 15-35, white, 1.5 to 3 mm, longer lamina and denticulate apex. Disk florets; 5 to 30, yellowish, 2-4.5 mm, puberulent and 5 lobed. Achenes; linear, lanceoloid, compressed and strigillose. Pappus; seriate and white dirty (Plate 23a).
Melissopalynology	Grains are monad, medium sized and tricolpate. Circular polar view and prolate-spheroidal equatorial view shape. Aperture orientation slightly sunken. Polar area small to moderately extensive. Exine sculpturing echinate. Polar diameter 25.3(18.7-35.2) ±5.34 µm and equatorial view distance 23.2(13.7-29.7) ±4.75 µm. P/E ratio 1.08. Colpi length 5.63(3.75-8.75) ±1.86 µm and colpi width 4.46(3.25-5.75) ±0.74 µm. Spine length 2.45(0.25-4.75) ±1.47 µm and spine width 1.70(0.25-3.00)1.00 µm. Mesocolpium measurement 17.3(12.7-25.2) ±3.87 µm. Exine thickness 3.36(0.25-6.25) ±1.80 µm. Pollen fertility 88.5% and sterility 14.8% (Plate 23b,c,d & e).

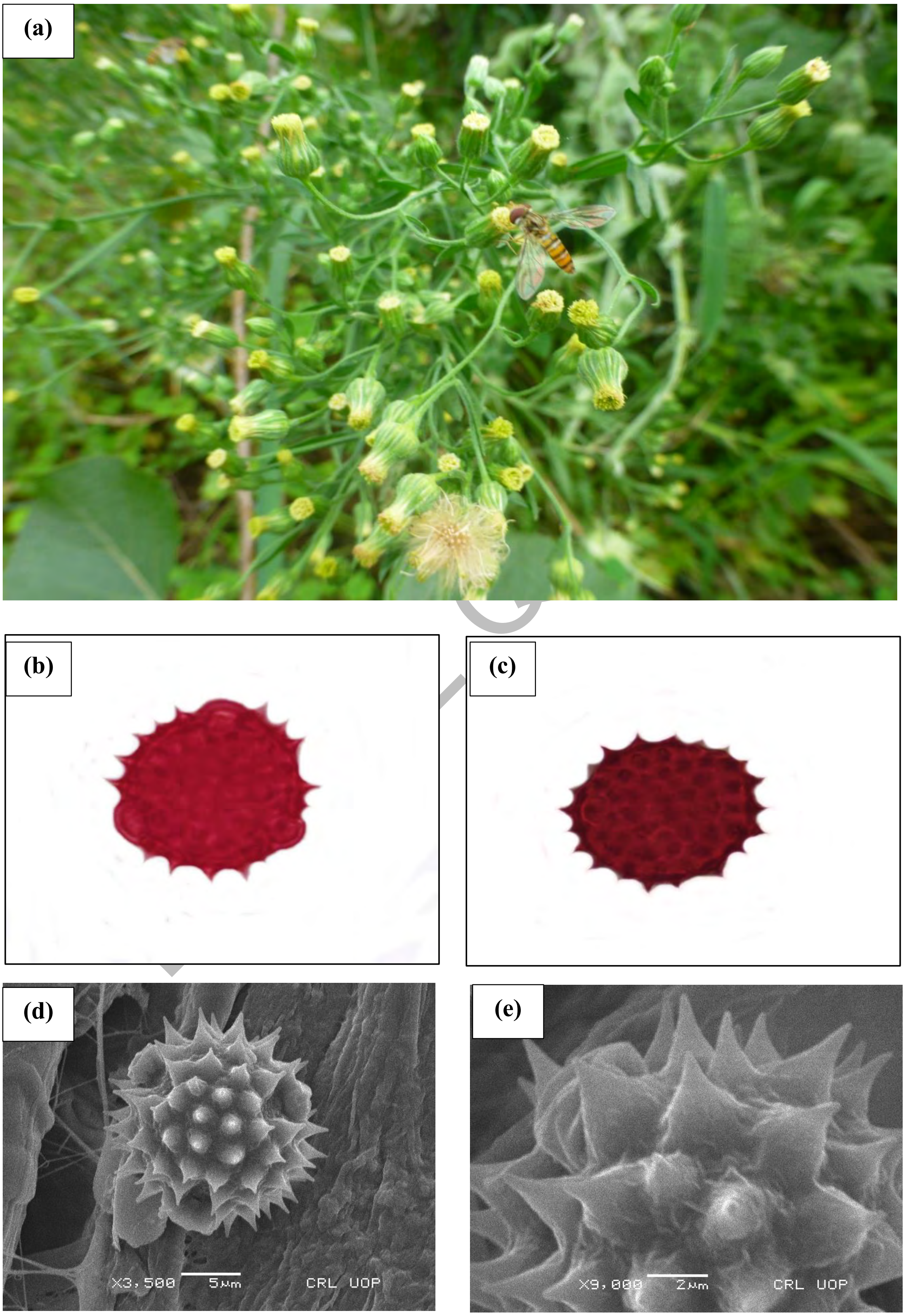

Plate 23: *Erigeron canadensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

10. *Gazania rigens* (L.) Gaertn.

Synonym	*Gazania leucolaena* DC.
Family	Asteraceae
Common Name	Treasure flower
Habit	Perennial Herb
Habitat	Grow in sandy well drained soils prefers consistent moisture
Flowering period	Throughout year
Status	Cultivated
Distribution	South Africa, Victoria, Tasmania, Pakistan, Western Australia
Morphology	Perennial herbaceous growing 13 to 25 cm tall. Branched stems; relatively short and decumbent. Alternately arranged leaves; 5-15 cm long and 4-30 mm wide, densely clustered, variable in shape, narrowly-oblanceolate and entire margins. Upper surfaces; usually green, hairless, while lower surfaces; densely covered with white hairs. Leaf tips; pointed. Flower heads; daisy capitula and borne singly. Peduncles; erect and 5 to 20 cm long. Flower-heads; large, showy, 5 to 11 cm across, numerous petals and bright orange. Capitulum; cup like structure involucre, 7-15 mm across. 2-3 rows of lanceolate green involucral bracts. Centre of the flower heads; numerous tiny tubular disc florets arranged on a receptacle, yellow in color are bisexual (Plate 24a)
Melissopalynology	Pollen grains are monad, medium sized and tricolporate. Circular polar view and equatorial view shape oblate-spheroidal. Exine sculpturing micro-reticulate. Polar region; small to moderate, aperture slightly sunken. Polar diameter 38.5(33.0-43.7) ±4.32µm and equatorial view distance 40.9(31.2-48.0) ±6.7 µm. P/E ratio 0.94. Colpi length 4.80(4.25-5.25)±0.44 µm and colpi width 7.45(7.00-8.00)±0.41 µm. Spine length 2.65(2.00-3.25)±0.51 µm, spine width 2.00(1.75-2.25)0.25 µm and mesocolpium distance 19.3(17.7-20.7)±1.19 µm. Exine thickness 3.25(2.25-4.25)±0.7 µm. Pollen fertility 92.5% and sterility 7.44% (Plate 24b,c,d & e).

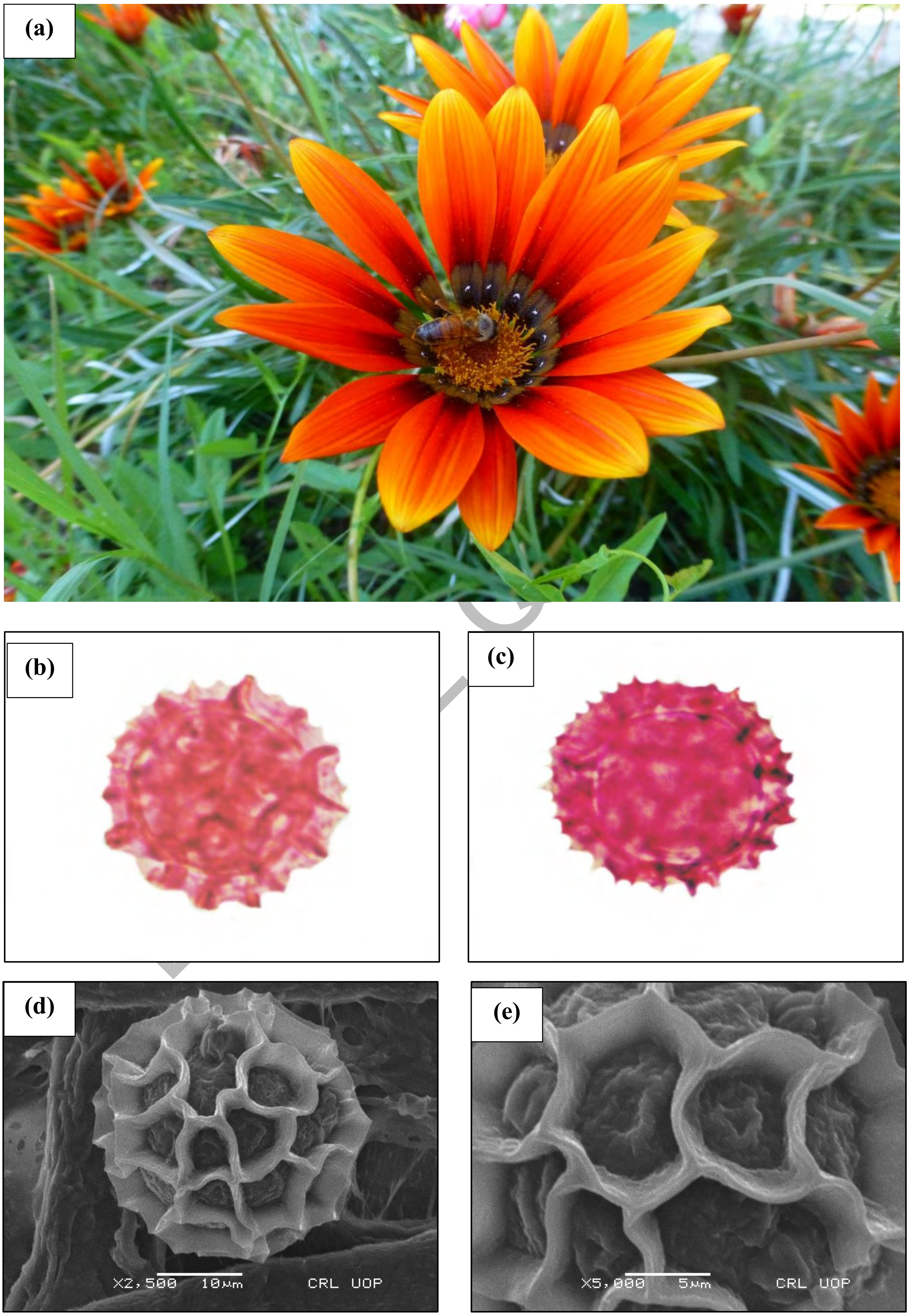

Plate 24: *Gazania rigens* (L.) Gaertn. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

11. *Helianthus annus* L.

Synonym	*Helianthus aristatus* Elliott
Family	Asteraceae
Common Name	Sunflower
Habit	Annual Herb
Habitat	Mostly in cultivated fields
Flowering period	June to October
Status	Cultivated
Distribution	North America, Canada, Mexico, Pakistan, Europe
Morphology	Herb, erect rough hairy stem, up to height of 3.3 meter. The highest lengths of the sunflowers were record up to 10.18 meter. Leaves are broad, rough, mostly alternate and coarsely toothed. Pseudanthium of numerous small individual five-petaled flowers (florets). The outer flowers, which resemble petals that are called ray flowers. Every petal consists of a ligule composed of fused petals of an asymmetrical ray flower (Plate 25a).
Melissopalynology	Pollen are monad, isopolar, radically symmetrical, medium sized, and tricolporate. Circular polar view and equatorial view shape oblate spheroidal. Pollen regions small to moderate and aperture orientation sunken. Exine sculpturing echinate-perforate tectate. Echini arrangement regular, with flattened bases and narrow sharply pointed tips. Lacunas absent. Polar diameter 30.3(23.0-37.7) ±5.38 μm and equatorial view distance 31.5(23.7-35.2) ±3.44 μm. P/E ratio 0.96. Colpi length 4.77(1.75-7.75)±2.21 μm, colpi width 5.22(2.25-8.25)±2.59 μm and mesocolpium distance 23.6(18.5-27.7)±2.71 μm. Spine length 3.65(1.25-5.75)±1.63 μm and spine width 2.15(0.25-6.25)±2.01 μm. Exine thickness 4.00(2.75-5.25)±0.80 μm. Pollen fertility 86.4% and sterility 13.5% (Plate 25b,c,d & e).

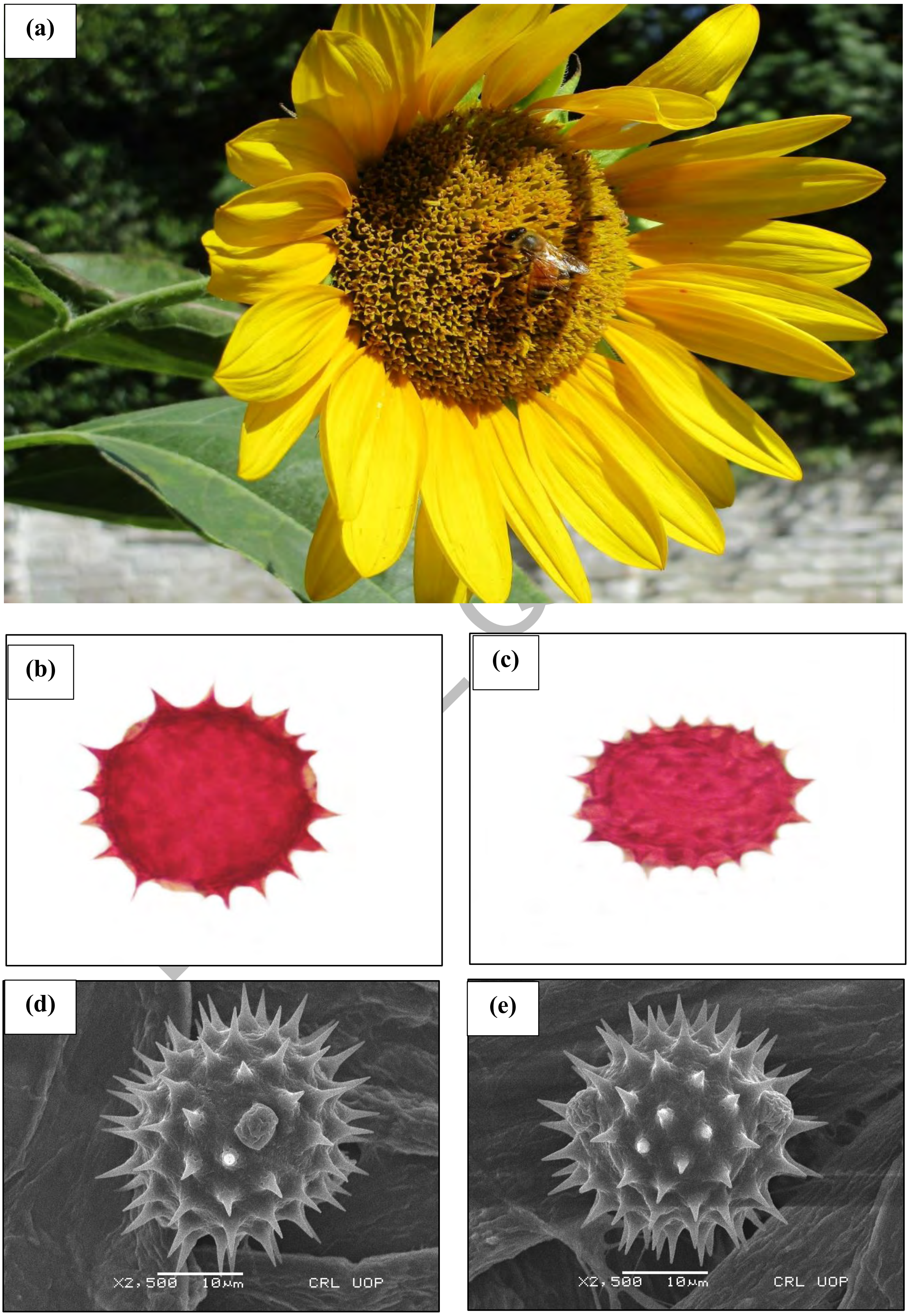

Plate 25: *Helianthus annus* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

12. *Launaea procumbens* (Roxb.) Ramayya & Rajagopal

Synonym	*Launaea procumbens* (Roxb.) Amin
Family	Asteraceae
Common Name	Creeping Launea
Habit	Perennial Herb
Habitat	Flooded areas, disturbed and undisturbed areas
Flowering period	March to November
Status	Wild
Distribution	Egypt, Arabian countries, Iraq, Pakistan, Iran, Afghanistan, India
Morphology	Polymorphic perennial herb, shoot bearing roots, flowering up to 19 to 39 cm high, basal rather weak, procumbent to ascending erect leaf rosette, rather weak, procumbent to ascending-erect, leafy to leafless flowering stems. Rosette leaves; 2.2-27 x 0.8-5.5 cm, mostly to narrowly spathulate in outline, tapering into a narrow base, with roundish to somehow acute apex, sinuate-dentate to variably pinnatifid. Cauline leaves, otherwise similar, higher up grading into inconspicuous bracts (Plate 26a).
Melissopalynology	Pollen grains are monad, radially symmetrical, medium sized, tricolporate and fenestrate. Triangular polar view oblate spheroidal equatorial shape. Exine sculpturing Echino-perforate and slightly bulged oriented aperture. Spines short, regular with narrow base. Lacunaes, trigonal to tetragonal with narrow inter lacunar gap. Polar diameter 30.7(25.5-35.50)3.82 µm and equatorial view distance 34.5(26.2-40.2)5.19 µm. P/E ratio 0.88. Colpi length 8.05(7.75-8.50)0.39 µm, width 6.00(5.50-6.50)0.39 µm, spine length 1.30(0.75-2.00)0.48 µm, spine width 0.90(0.50-1.50)0.48 µm and mesocolpium distance 19.2(18.2-20.2)0.79 µm. Exine thickness 4.05(3.50-4.75)0.48 µm. Pollen fertility 96.2% and sterility 3.7% (Plate 26b,c,d & e).

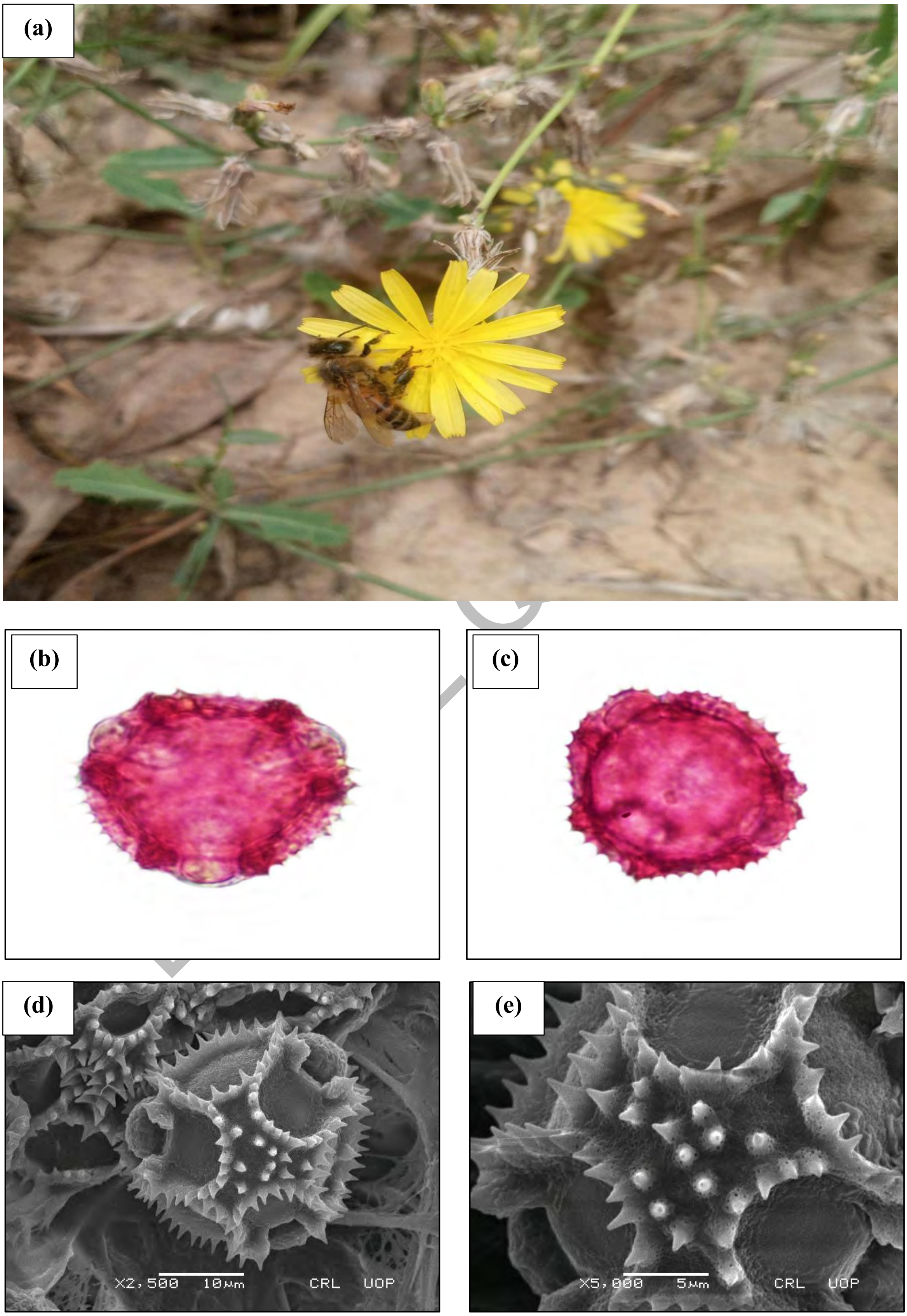

Plate 26: *Launaea procumbens* (Roxb.) Ramayya & Rajagopal (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

13. *Parthenium hysterophorus* L.

Synonym	*Argyrochaeta parviflora* Cav.
Family	Asteraceae
Common Name	Congress weed
Habit	Annual Herb
Habitat	floodplains, grasslands, open woodlands and disturbed sites
Flowering period	February to August
Status	Wild
Distribution	Netherland, Japan, India, Uruguay, Pakistan, Panama, Colombia
Morphology	Annual, 30-110 cm tall. Leaf blade ovate to elliptic, 3-18×1-5 cm, pinnately (1 or 2-lobed), ultimate lobes lanceolate to linear, 3-50 × 2-15 mm, both surfaces sparsely to densely scaberulose and gland-dotted. Synflorescences of open panicles. Capitula obscurely radiate; peduncles 1-8 mm; outer phyllaries 5, elliptic-lanceolate, 2 to 4 mm, inner 6 ovate to orbicular, 2.5-4 mm. Female florets 5(or 6); corolla limbs reniform or orbicular to oblong, 0.3-1 mm. Disk florets 12-30. Achenes obovoid, 1.5-2(-3.5) mm; pappus like enations erect, deltate to ovate, 0.5-1 mm (Plate 27a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Circular polar view and prolate-spheroidal equatorial view shape. Aperture orientation sunken. Exine sculpturing echinate-perforate spinulate. Short regular spines, broad bases and small narrow tips. Polar area moderately extensive. Lacunas absent. Polar diameter 27.6(21.2-35.3) ±5.00 µm and equatorial view distance 26.1(24.2-29.7) ±2.08 µm. P/E ratio 1.05. Colpi length 6.15(3.75-8.75) ±2.05 µm, colpi width 4.65(3.25-5.75)±0.76 µm, spine length 3.35(2.25-4.75) ±0.35 µm, spine width 2.35(2.00-3.00) ±0.35 µm and mesocolpium distance 18.45(13.5-25.2) ±4.07 µm. Exine thickness 4.35(2.75-6.25) ±1.26 µm. Fertility 89.7% and sterility 10.2% (Plate 27b,c,d & e).

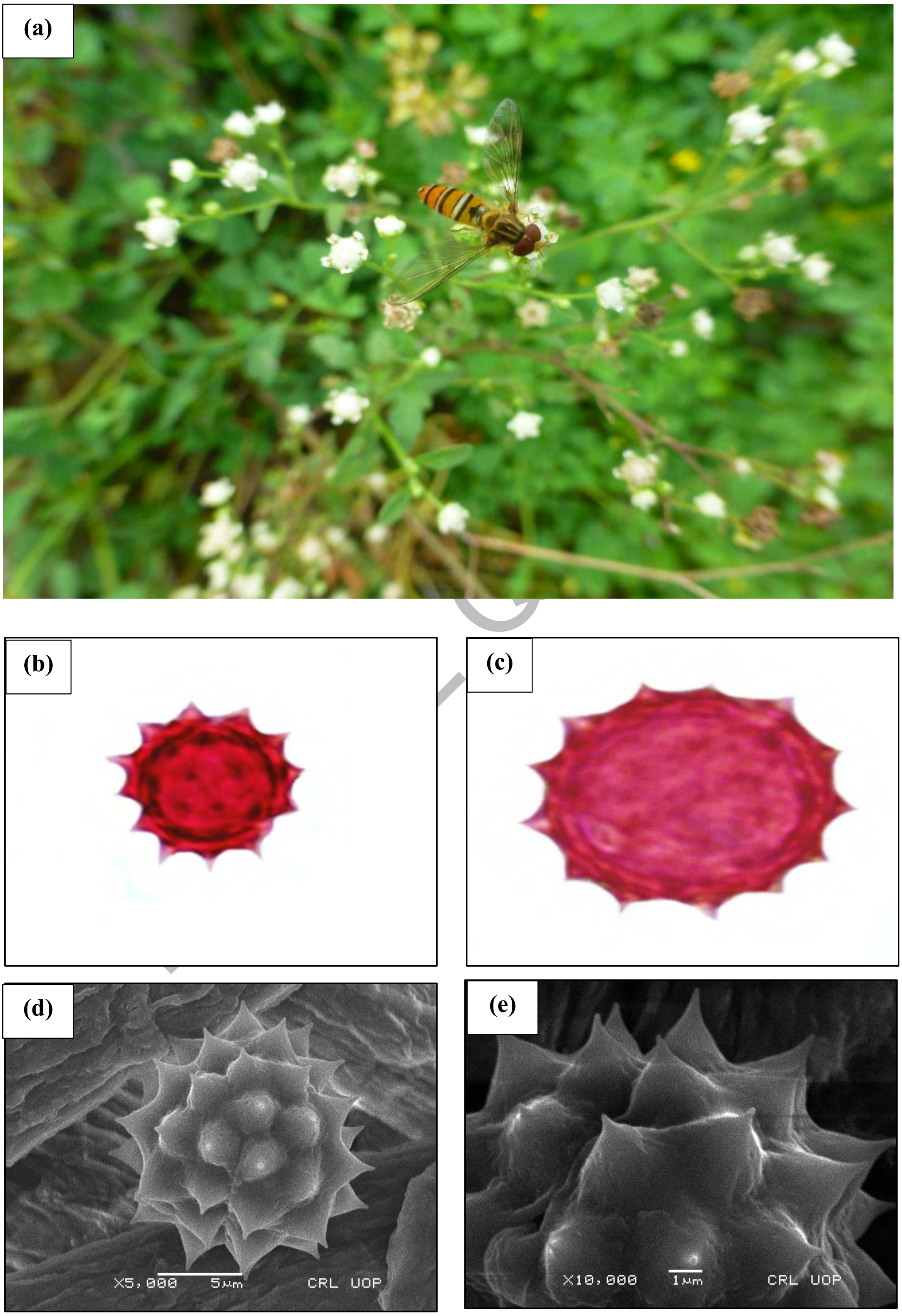

Plate 27: *Parthenium hysterophorus* L.. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

14. *Silybum marianum* (L.) Gaertn.

Synonym	*Cirsium maculatum* Scop.
Family	Asteraceae
Common Name	Milk thistle
Habit	Annual Herb
Habitat	In crop fields, pastures, coastal areas and along roadsides
Flowering period	March to June
Status	Wild
Distribution	Libya, Iran, Uzbekistan, Estonia, Texas, Italy, Pakistan
Morphology	Annual or biennial herb and rises to height 0.8-2 m and width of 1.1 meters. Leaves; shiny, upper surface green and variegated with white markings. Basal leaves; 12-65 cm long, spiny margins. Much smaller stem leaves clasp the stem. Flowers; Purple or white thistle and single. Many tubular florets, 4.5 to 6 cm in diameter, bordered rigid bracts and sharp spines and heads develop apically, 1.6-4.5 cm in diameter at the base, enclosed in a spiny involucre. Fruit; black and brown achenes, 0.8-1.1 cm long, flattened, ring of bristles at the apex (Plate 28a).
Melissopalynology	Pollen are monad, medium to large sized, radially symmetrical and tricolporate. Rounded polar view and oblate-spheroidal equatorial view shape. Exine sculpturing echinate. Short regular echini with sharp circular pointed tips. Lacunaes absent, polar region moderately extensive. Polar diameter 49.1(43.5-56.7) ±2.22 µm and equatorial view distance 51.0(43.5-57.5)±2.33 µm. P/E ratio 0.96. Colpi length 7.90(7.00-9.25) ±0.42 µm, colpi width 13.2(11.7-16.0) ±0.75 µm, spine length 5.50(4.50-2.50)±0.50 µm, spine width 1.40(0.25-2.50)±0.43 µm and mesocolpium distance 20.4(17.5-23.5)±1.07 µm. Exine thickness 5.10(4.50-6.0)±0.25 µm. Pollen fertility 85.7% and sterility 14.2% (Plate 28b,c,d & e).

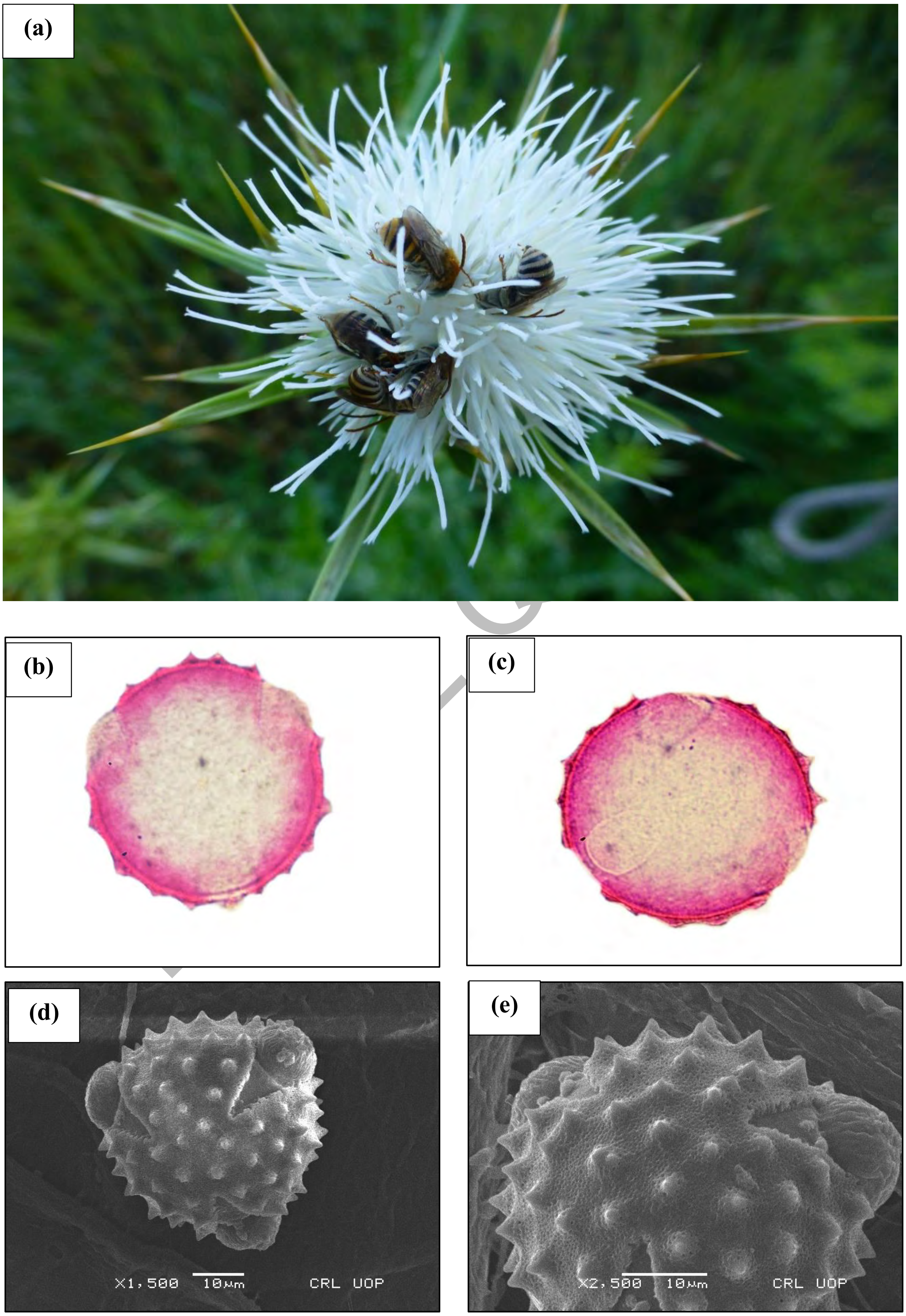

Plate 28: *Silybum marianum* (L.) Gaertn. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

15. *Sonchus asper* (L.) Hill.

Synonym	*Sonchus aemulus* Merino
Family	Asteraceae
Common Name	Prickly Sow Thistle
Habit	Annual Herb
Habitat	Moist places, roadside, loamy soil
Flowering period	August to October
Status	Wild
Distribution	China, Australia, Pakistan, Brazil, Canada, Chili, Greenland, India
Morphology	Annual herb, 21-51 cm tall. Stem; generally unbranched and glabrous below Synflorescence. Basal and lower stem leaves extremely variable, obovate, elliptic, or spatulate, 5-12 × 1.5-5 cm, undivided or irregularly pinnatisect, glabrous, adaxial dark green and glossy, base attenuate and auriculate, margin usually densely spinulosely dentate, apex acute, acuminate, or obtuse; lateral lobes triangular, semi-orbicular or elliptic. Capitula: many florets, peduncle; 0.4-4.5 cm, slender and glandular-hairy. Involucre: campanulate, 0.8-1.2 cm. Achene: broadly obcolumnar, 1.6-2.8 mm, strongly compressed and winged (Plate 29a).
Melissopalynology	Pollen grains monad, medium size, fenestrate and tricolporate. Pentagonal polar view and oblate-spheroidal equatorial view shape. Aperture: slightly sunken, broad base spines surrounded lacunaes, echini arrangement regular, lacunaes trigonal to tetragonal, narrow with interlacunaer gap. Polar area small to moderate. Exine sculpturing echino-perforate. Polar diameter is 26.05(21.2-33.75) ±5.14 µm and equatorial view distance 27.55(25.2-29.7) ±2.13 µm. P/E ratio 0.94. Colpi length 8.05(7.25-8.05) ±0.59 µm, colpi width 4.15(2.75-4.7) ±0.65 µm, spine length 3.90((2.75-4.75) ±0.74 µm, spine width 2.45(2.00-3.00) ±0.41 µm and mesocolpium distance 15.5(13.5- 20.2) ±2.84 µm. Exine thickness 4.25(2.75-6.25) ±1.45 µm. Pollen fertility 92.8% and sterility 7.14% (Plate 29b,c,d & e).

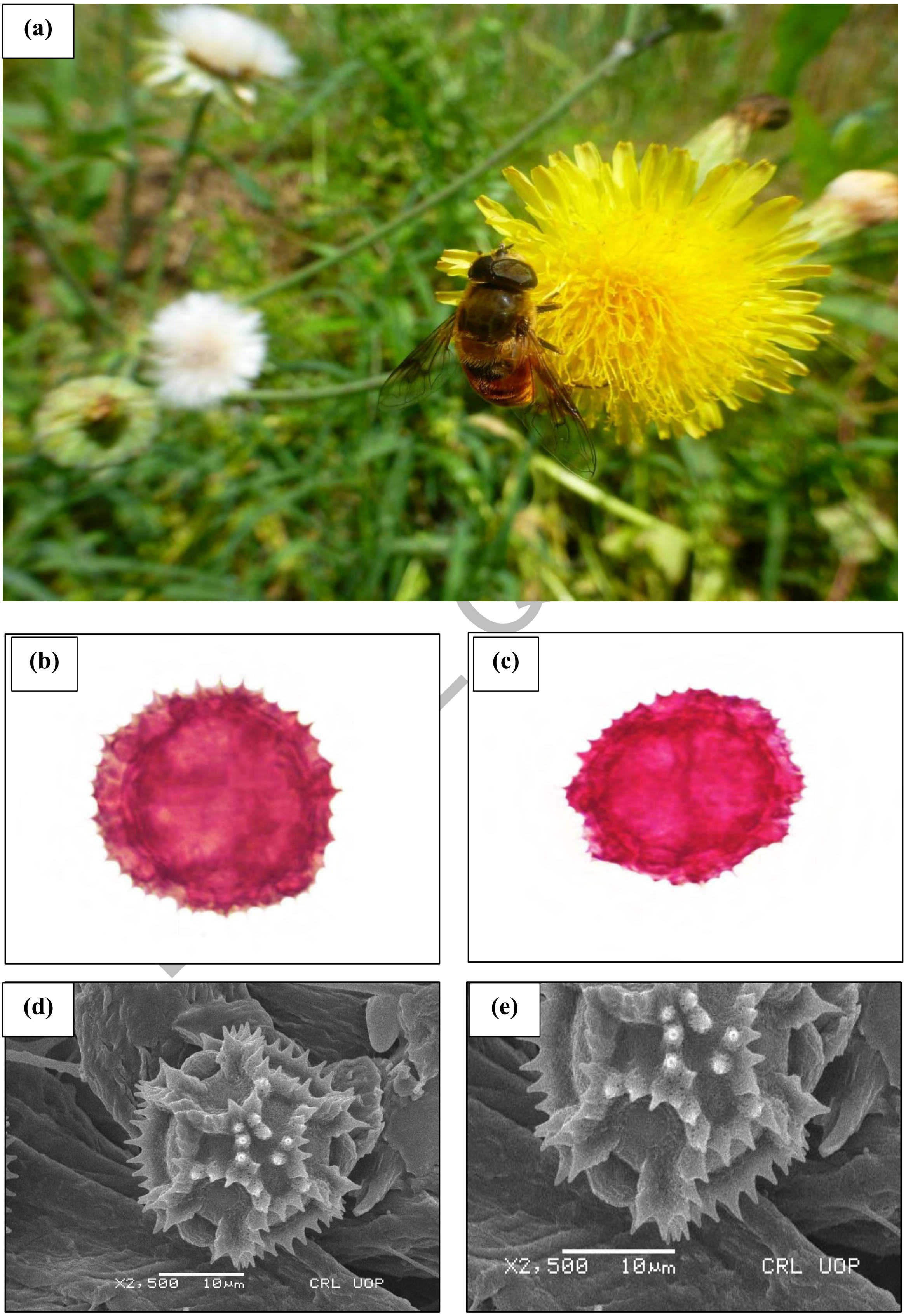

Plate 29: *Sonchus asper* (L.) Hill. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

16.*Taraxacum campylodes* G.E.Haglund

Synonym	*Taraxacum officinale* (L.) Weber ex F.H.Wigg.
Family	Asteraceae
Common Name	Common Dandelion
Habit	Perennial Herb
Habitat	Lawns, degraded meadows, vacant lots, and areas along roads
Flowering period	February to May
Status	Wild
Distribution	Alabama, Portugal, Croatia, Germany, China, Pakistan, Taiwan
Morphology	Herbaceous, 3 to 45 cm and branched taproots. Stems; ascending, purplish, glabrous, sparsely villous and distally. Leaves: horizontal erect, petioles winged; blades oblong, 6 to 40 × 2–12 cm, shallow margins, deeply lobed and broadly triangular, lanceolate and acuminate, Calyculi; 10–22, reflexed, glaucous, 4–14 × 2–4.2 mm, Involucres; dark green, tips dark gray, campanulate. Phyllaries; 10–21, lanceolate, 1.5–2.4 mm wide, apices acuminate and erose scarious. Florets; 20 to 80; corolla yellow and 12–25 × 1.5–2.5 mm. Cypselae; olivaceous, straw-colored, oblanceolate, 2 to 3 mm, cones shortly terete, 0.3–1.2 mm and beaks slender (Plate 30a).
Melissopalynology	Pollen are monad, medium sized, fenestrate and tricolporate. Triangular polar view and oblate-spheroidal equatorial view shape. Aperture slightly bulged; echini regular with short narrow bases. Lacunas trigonal, narrow inter-lacunar gap, and small to moderate polar region. Exine sculpturing echino-perforated. Polar diameter 26.9(24.0-30.0)±1.12 µm and equatorial view distance 27.9(24.7-32.2)±1.23 µm. P/E ratio 0.96. Colpi length 10.5(8.00-12.7)±0.98 µm and colpi width 13.7(11.7-15.2) ±0.69 µm, spine length 3.00(2.25-4.0)±0.30 µm, spine width 1.10(0.25-1.75)±0.26 µm and mesocolpium 19.1(17.0-22.5)±0.99 µm. Exine thickness 5.15(2.50-6.75)±0.72 µm. Pollen fertility 89.5% and sterility 10.4% (Plate 30b,c,d & e).

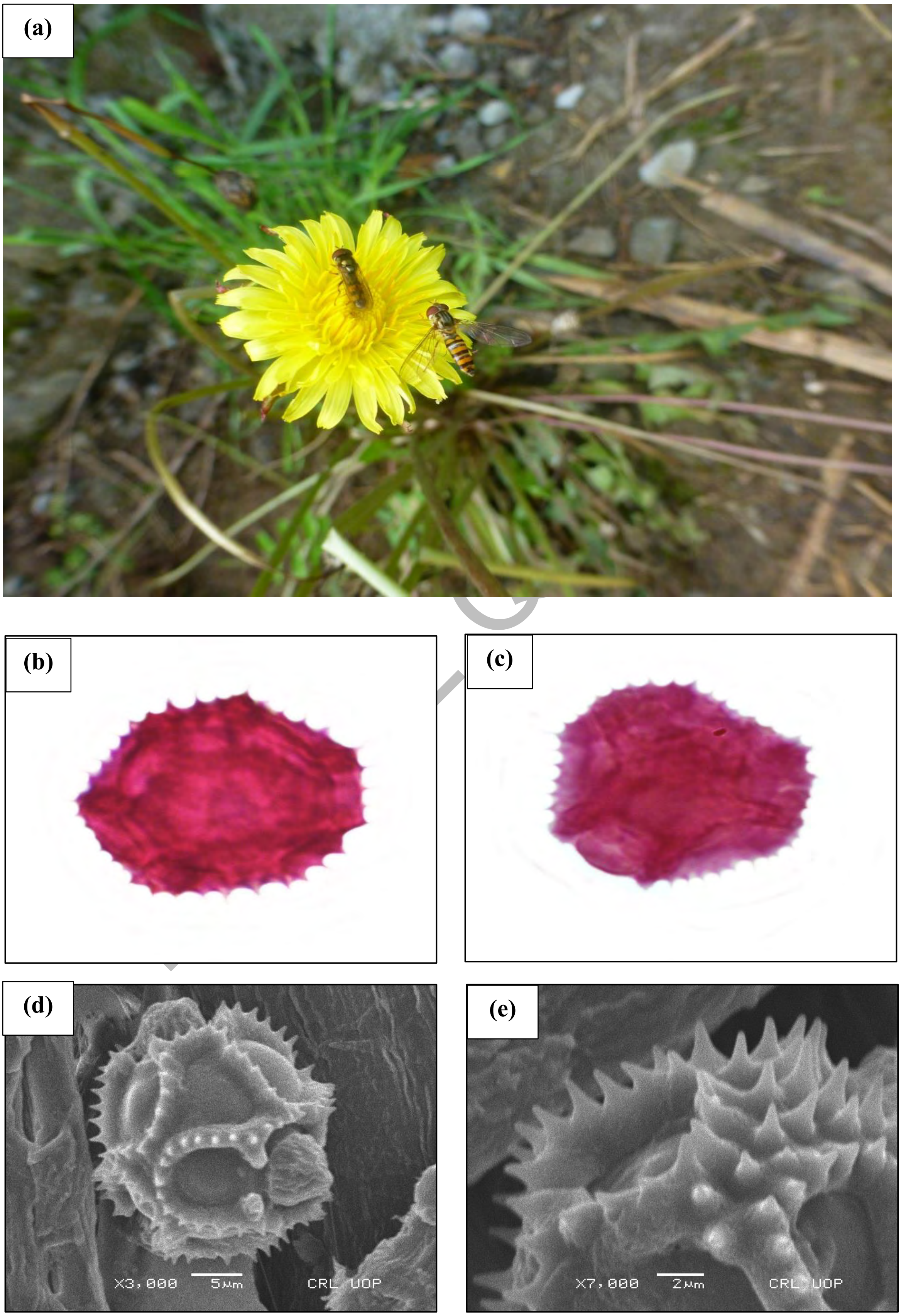

Plate 30: *Taraxacum campylodes* G.E.Haglund (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

17.*Tripleurospermum caucasicum* (Willd.) Hayek

Synonym	*Tripleurospermum caucasicum* var. *caucasicum*
Family	Asteraceae
Common Name	Mayweed
Habit	Annual Herb
Habitat	Found in nurseries and gardens
Flowering period	March to May
Status	Ornamental
Distribution	North America, Argentina, Pakistan, Sudan, India, China
Morphology	Annual or perennial herb, glabrous to sparsely hairy herbs with alternate, 1 to 3 pinnatisect leaves. Capitula discoid, radiate or disciform, homogamous, pedunculate, solitary. Involucre hemispherical, phyllaries 2-5 seriate, imbricate, scarious margined. Receptacle glabrous, convex to elongate conical or hemispherical. Ray-florets female, mostly white or pale pink, ligulate, Disc-florets bisexual, with 5 lobed corolla tube, each lobe with a reddish or sometimes brown-black gland-like resin sac at tip (Plate 31a).
Melissopalynology	Pollen grains are monad, medium sized and tricolpate. Rounded polar view and prolate-spheroidal equatorial view shape. Exine sculpturing echinate-scabrate. Polar diameter 29.1(30.0-27.5)±1.03 µm and equatorial view distance 27.2(30.0-25.0)±2.23 µm. P/E ratio 1.06. Colpi length 5.6(6.25-5.00)±0.60 µm, colpi width 7(10.0-5.25)±1.83 µm, spine length 1.95(1.15-2.65)±0.22 µm, spine width 0.84(0.6-1.2)±0.36 µm and mesocolpium distance 18.9(21.2-17.2)±1.69 µm. Exine thickness 3.7(4.75-2.50)±0.87 µm. Pollen fertility 71.4% and sterility 28.5% (Plate 31b,c,d & e).

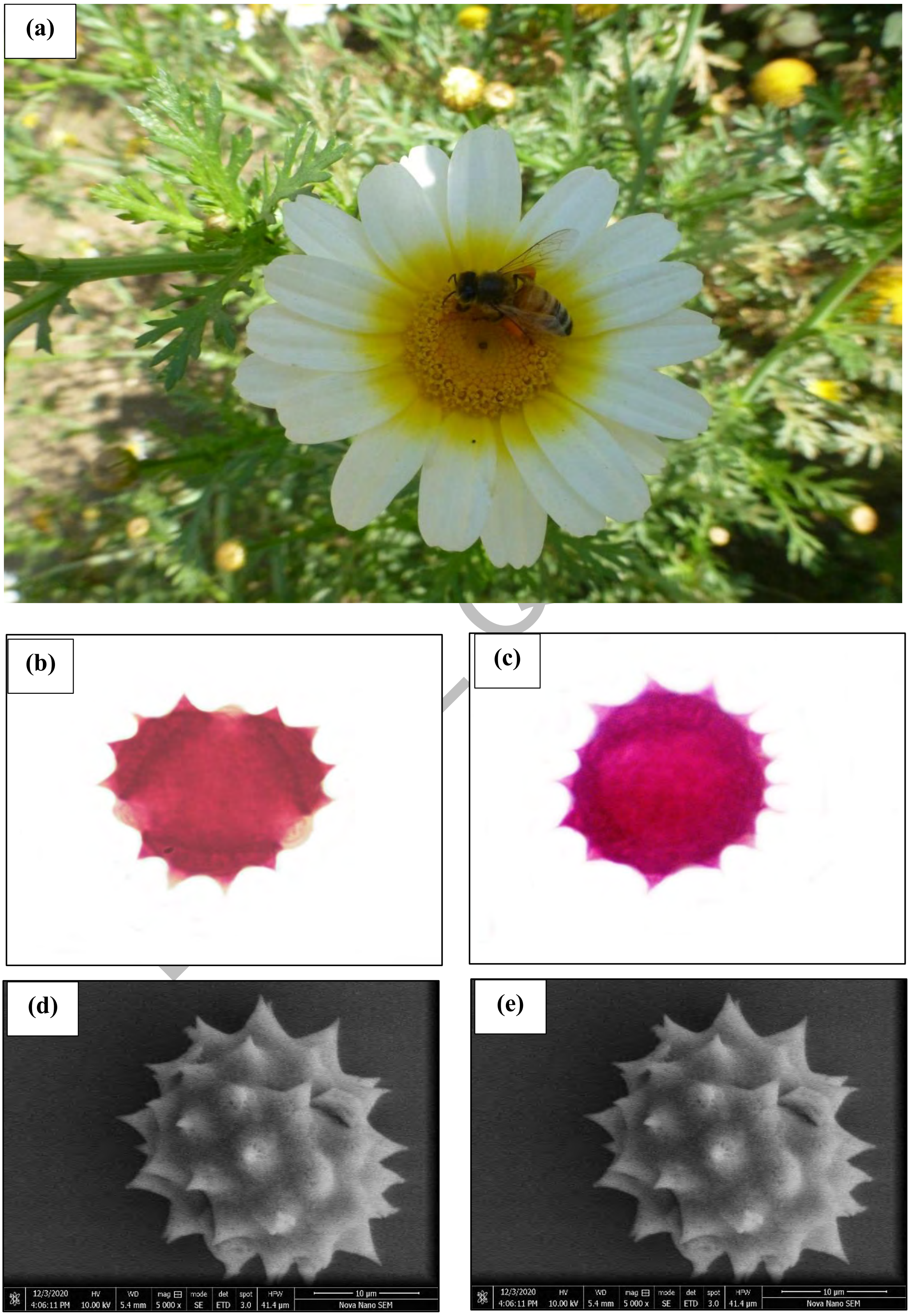

Plate 31: *Tripleurospermum caucasicum* (Willd.) Hayek (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

18. *Verbesina encelioides* (Cav.) Benth. & Hook. f. ex A.Gray

Synonym	*Verbesina encelioides* subsp. *encelioieds*
Family	Asteraceae
Common Name	Wild sunflower/Gold weed
Habit	Annual Herb
Habitat	Pastures, grasslands, dry and plain areas.
Flowering period	August to October
Status	Wild
Distribution	South America, Pakistan, Australia, Mexico, India, Pakistan
Morphology	Annual herbaceous plant; 10-51 cm in diameter. Leaves are mostly alternate or proximal generally opposite; blades deltate, ellipsoid, ovate to lanceolate, 3-9 x 2-5 cm, bases approximately cuneate to truncate, margins coarsely, toothed to subentire, apices acute to attenuate, faces strigoso-scabrellous to sericeous. Heads usually borne singly, 2 to 3 in loose, cymiform or corymbiform arrays. Involucres, hemispheric to saucer like, 11–22 mm in diameter (Plate 32a)
Melissopalynology	Pollen are monad, radically symmetrical, medium size and tricolporate. Circular polar view and prolate-spheroidal equatorial view shape. Regular long echini, narrow bases and pointed tips. Pollen region small to moderate and aperture sunken orientated Exine sculpturing echinate. Polar diameter 26.2(19.7-34.0)±4.67 µm and equatorial view distance 25.8(17.7-35.2)±5.89 µm. P/E ratio 1.01. Colpi length 5.05(2.00-8.00)±2.56 µm, colpi width 6.37(4.00-8.50)±1.73 µm, spine length 4.85(3.25-6.75)±1.13 µm, spine width 3.42(2.25-4.75)±0.89 µm and mesocolpium distance 20.9(19.5-23.0)±1.48 µm. Exine thickness 3.47(2.25-4.75)±0.80 µm. Pollen fertility 97.2% and sterility 2.77% (Plate 32b,c,d & e).

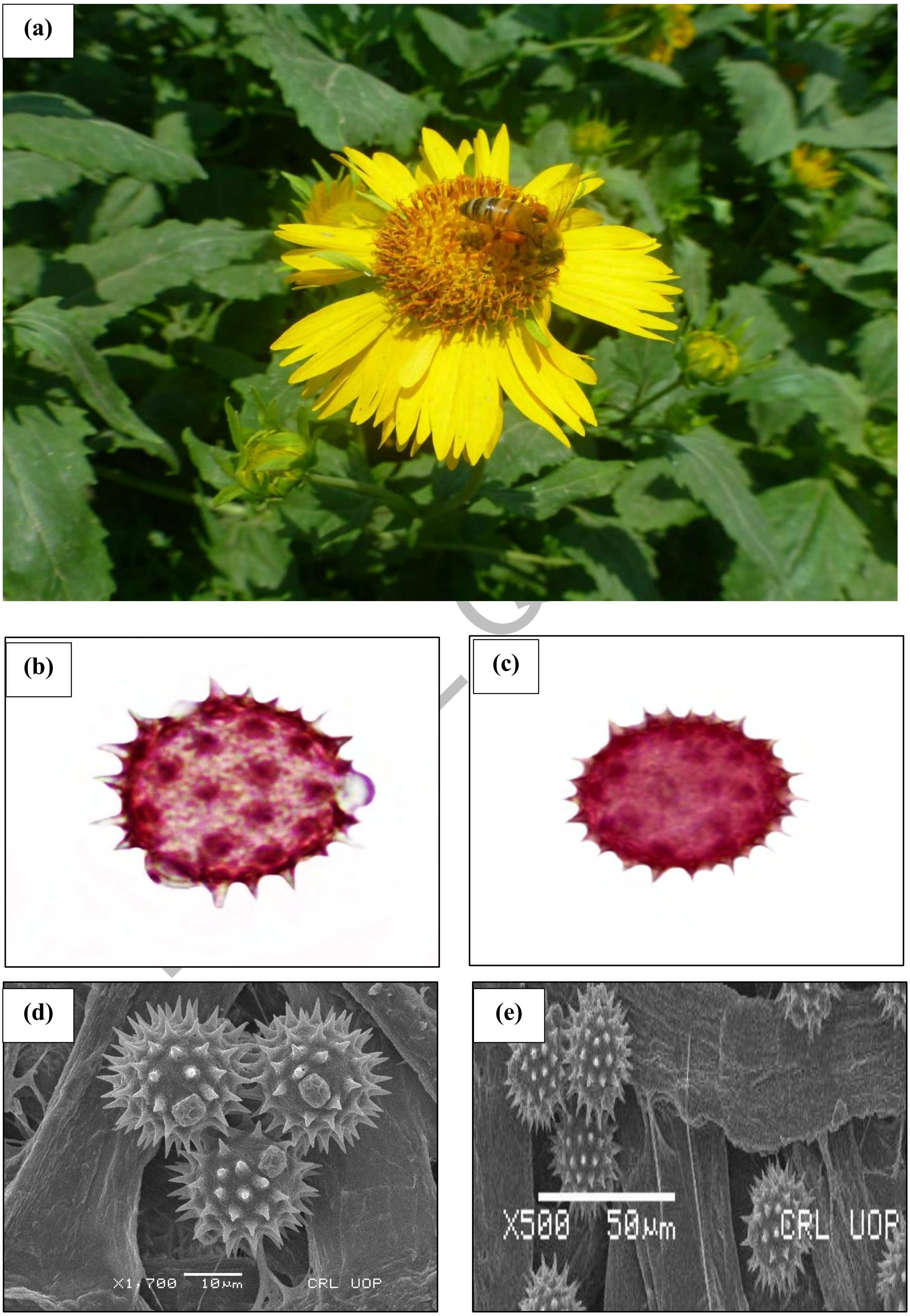

Plate 32: *Verbesina encelioides* (Cav.) Benth. & Hook. f. ex A.Gray (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

19.*Youngia japonica* (L.) DC.

Synonym	*Chondrilla japonica* (L.) Lam.
Family	Asteraceae
Common Name	Oriental false hawksbeard
Habit	Annual Herb
Habitat	On slopes, valleys, grasslands, stream banks, roadsides, curbs
Flowering period	March to May
Status	Wild
Distribution	Florida, Spain, China, North Korea, Srilanka, Pakistan
Morphology	Herbs; 12-125 cm tall. Stems; solitary erect, basally branched, glabrous. Basal leaves; oblanceolate, 11×6 cm, pinnatisect, glabrous, base attenuate, margin dentate, lateral lobes few, rhombic, smaller toward leaf base, terminal lobe ovate-lanceolate. Synflorescence; corymbiform and numerous capitula. Capitula; 8-20 florets and peduncle capillaceous. Involucre; cylindric, 3-9 mm. Phyllaries; abaxial glabrous, ovate to triangular, less than 1.7 mm, apex acute, inner phyllaries; adaxially pubescent and margin white scarious. Anther tube; dark green. Style; branches yellow upon drying, Achene; light brown, fusiform, 1.2-2.3 mm, ribs finely spiculate, apex strongly attenuate. Pappus white (Plate 33a).
Melissopalynology	Pollen are monad**,** radically symmetrical, fenestrate, medium sized and tricolporate. Moderate polar region. Hexagonal polar view, and oblate-spheroidal equatorial view shape. Sunken aperture, echini regular with broad bases. Pentagonal lacunaes with narrow gap. Exine sculpturing echino-perforate. Polar diameter 30.0(25.2-34.00)±3.25 µm and equatorial view distance 30.6(24.7-35.2)±4.13 µm. P/E ratio 0.98. Colpi length 7.45(7.00-8.50)±0.41 µm, colpi width 7.95(7.25-8.50)±0.48 µm, spine length 5.75(4.75-6.75) ±0.79. µm, spine width 3.40(2.25-4.25)±0.85 µm and mesocolpium distance 20.9(19.5-23.00)±1.57 µm. Exine thickness 3.55(2.25-4.75)±1.03 µm. Pollen fertility 6.97% and sterility 93 % (Plate 33b,c,d & e).

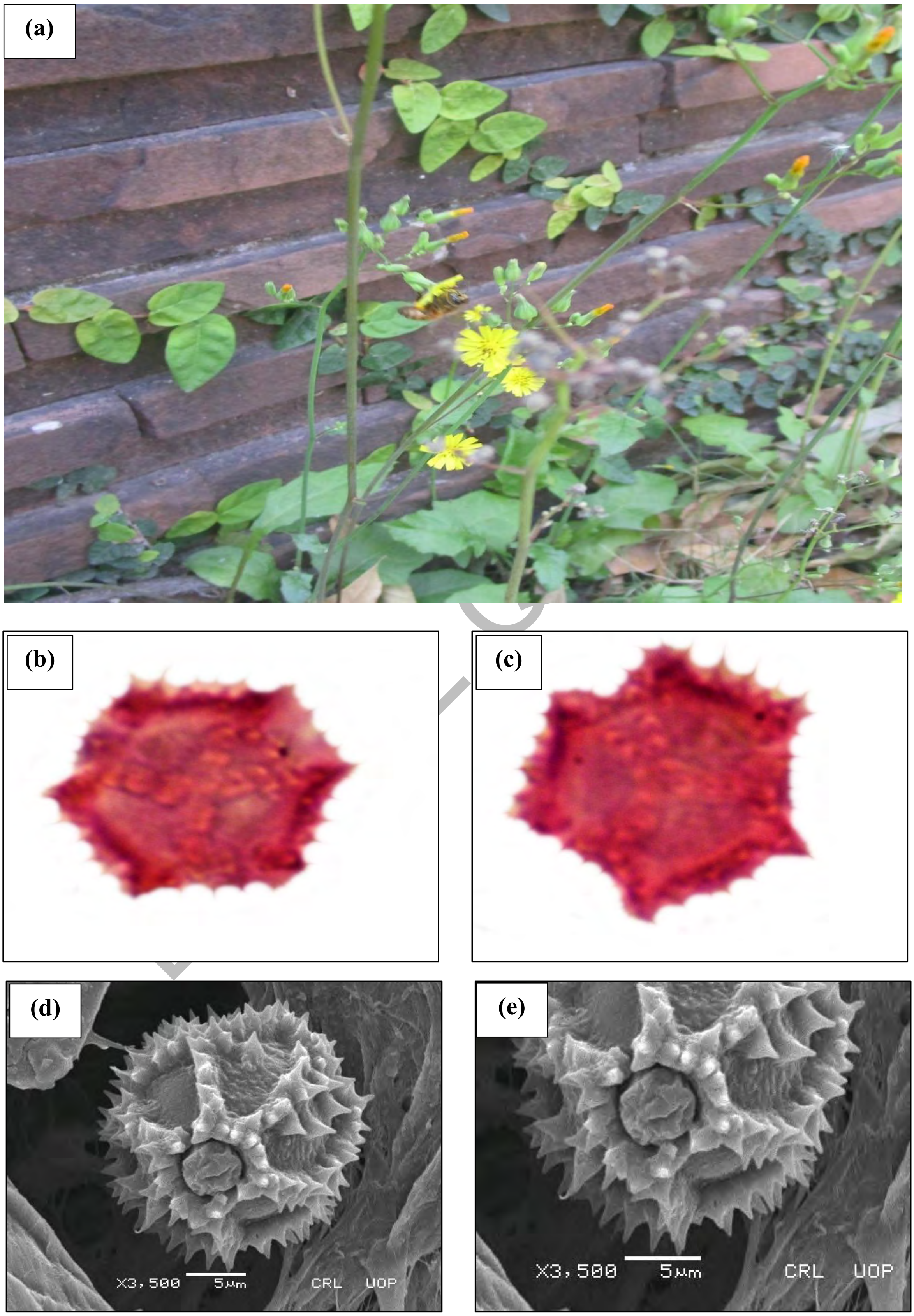

Plate 33: *Youngia japonica* (L.) DC. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.2 Melisso-palynomorphs description of Asteraceous taxa

This section focused on the palynology of 19 honeybee Asteraceous species belonging to 8 different tribes were providing detailed pollen qualitative and quantitative morphological features were summarized.

The palyno-morphological investigation of Asteraceous bee floral species revealed small to medium, medium and large size pollen of dominant shape Prolate-spheroidal in 9 species and 8 species have oblate-spheroidal shape and 2 species have sub-oblate. Pollen sculpturing: echino-lophate perforate, echino-lophate, fenestrate, echinate perforate, micro-reticulate, echinate-scabrate, spinulate types were observed. The maximum pollen diameter (54.2±25 µm) and equatorial view distance (56.1±23.1 µm) was measured in *Carthamus oxyacantha* while minimum polar diameter (21.4±1.31 µm) and equatorial view distance (20.4±2.46 µm) examined in *Coreopsis tinctoria* as shown in (Figure 5). Pollen shape was determined by polar to equatorial diameter ratio (P/E) ranging from maximum 1.09 in *Erigeron canadensis* to minimum 0.87 in *Bidens pilosa* (Figure 6).

Asteraceous honeybee floral species having colpi and pore present on pollen surface uniformly. Sunken pores and orientated outwards colpus has been reported in examined species. Number of apertures (pore and colpi) observed in various species is tricolporate, trizonocolporate and tetracolporate. Colpi length and width was calculated maximum in *Cirsium arvense* (10.9±15.49 µm) and *Taraxacum campylodes* (13.7±0.69 µm) respectively. Whereas minimum colpi length (2.80±0.79 µm) and width (2.80±0.37 µm) was noted in *Biden pilosa* as shown in (Figure 7). Echinate pollen with regular, irregular and slightly regular arrangement of spines was observed. Largest echini length and width was observed in *Yongia japonica* (5.75±0.79 µm) and *Verbesina encelioides* (3.42±0.89 µm) respectively. While shortest length of echini was examined in *Launaea procumbens* (1.3±0.48 µm) and width in *Biden pilsoa* (0.45±0.20 µm) as illustrated in Figure 9. The echinate pollen surface have lacunas of tetragonal, pentagonal and hexagonal shapes with fenestrated perforate and fenestrated type of sculpturing.

Exine thickness studied was found to be maximum in *Coreopsis tinctoria* (3.90±1.91 µm) and minimum in *Cichorium intybus* **(**2.47±0.36 µm) as mentioned in

Figure 8. Mesocolpium distance was also measured largest in *Cirsium arvense* (26.2±4.70 µm) and shortest in *Aster squamatus* (7.6±0.09 µm) as shown in Figure 10.

a) Statistical Cluster Analysis

The dendrogram distributed the Asteraceous species into three major clusters (Fig. 11). Cluster 1 (C1) includes species *Carthamus oxyacantha* and *Silybum marianum* which entirely distinct from other species. C2 (cluster II) contained *Cirsium arvense* and *Gazania rigens* whereas third cluster (C3) divided into two clades; *Aster squamatus*, *Coreopsis tinctoria* and *Taraxacum campylodes* in clade 1 while clade 2 further divide into sub-clusters I *Bidens Pilosa*, *Centaurea iberica, Helianthus annuus, Launaea procumbens*, and. *Tripleurospermum caucasicum* while sub-cluster II with (*Calendula arvensis*, *Parthenium hysterophorus, Verbesina encelioides*, *Yongia japonica*, *Sonchus asper*, *Erigeron canadensis*, and *Cichorium intybus*). The highest similarities were observed among *C. arvensis* and *P. hysterophorus* in sub-cluster II, and *H. annuus* and *C. iberica* in sub-cluster II.

In our current study PCA was used to investigate pollen variability of nineteen (19) honeybee floral species belonging to Asteraceae family. Variable loadings for the first five components have been illustrated in Table. Eigenvalues were found higher than 1 in PC1, PC2, PC3, PC4 and PC5 hence, are considered as significant in the PCA analysis. Variable loadings analysis illustrated that PC1 holds about 41.485%of total data variation and differentiated pollen of Asteraceous species. Exine thicknessfollowed by polar and equatorial diameter was the most significant variables in PC1. *Centaurea iberica, Cirsium arvense* and *Helianthus annuus* with higher values of polar and equatorial diameter were located on the positive side of the first axes whereas, *Bidens Pilosa, Calendula arvensis, Coreopsis tinctoria, Taraxacum campylodes, Verbesina encelioides* and *Youngia japonica* on the negative side of the first axes (Figure 12). Second axis (PC2) of PCA explained 29.75% variability in the original responses separating pollen of selected plant species. Most significant variables in PC2were polar and equatorial diameter followed by colpi width and spinal length. *Carthamus oxyacantha, Gazania rigens, Launaea procumbens* and *Silybum marianum*was found on the positive side of the second axis while *Helianthus annuus*, *Calendulaarvensis*, *Erigeron canadensi*, *Verbesina encelioides*, *Parthenium hysterophorus* and *Sonchus asper* was found on negative side of the second axis.

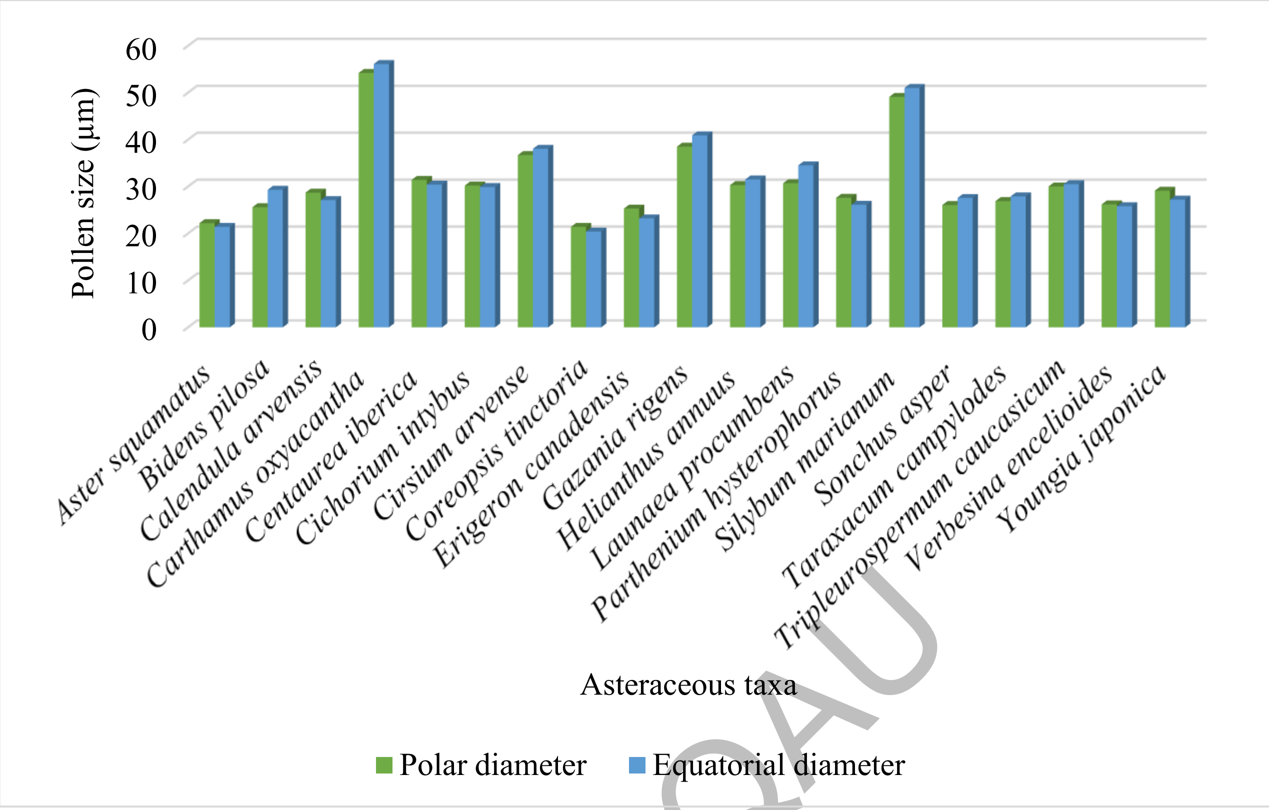

Figure 5. Variations in mean values of pollen diameter among Asteraceous bee flora

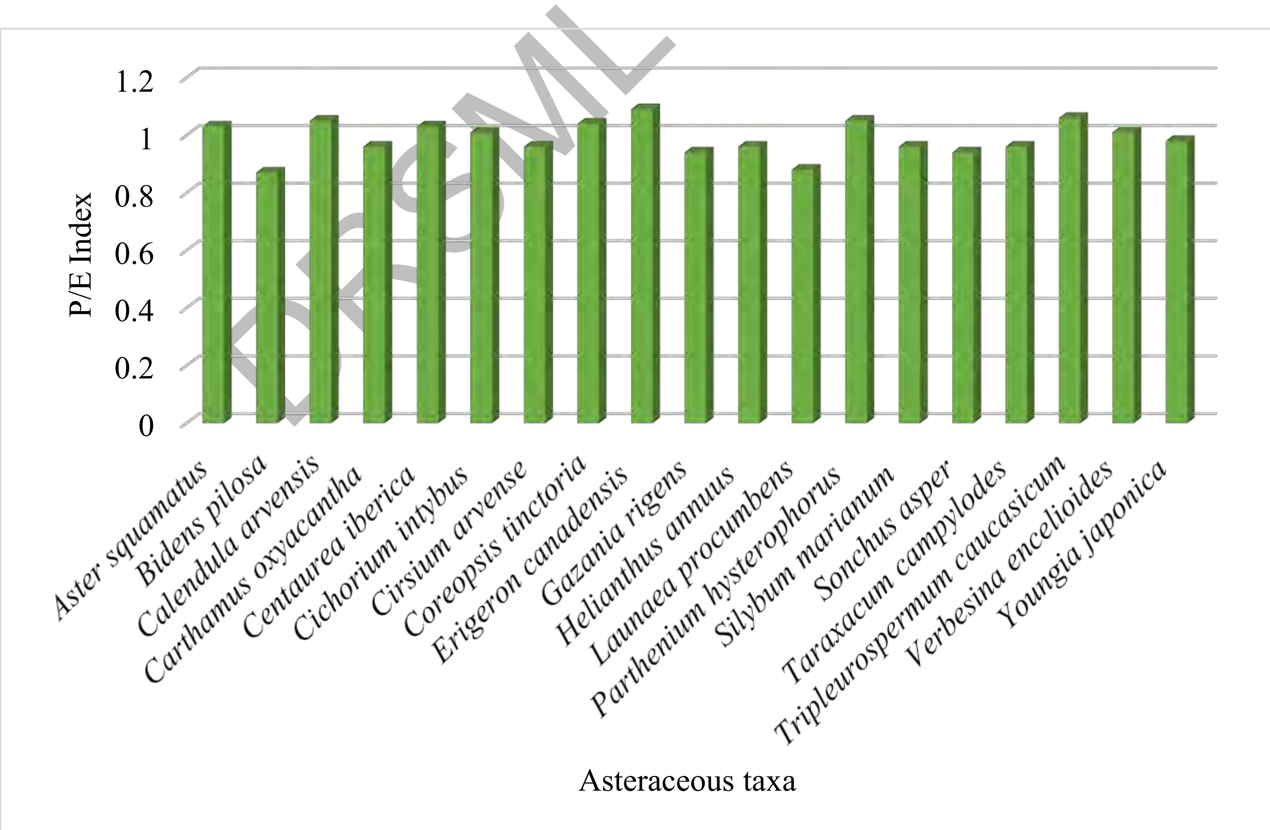

Figure 6. Variation in P/E ratio of Asteraceous honeybee floral plants

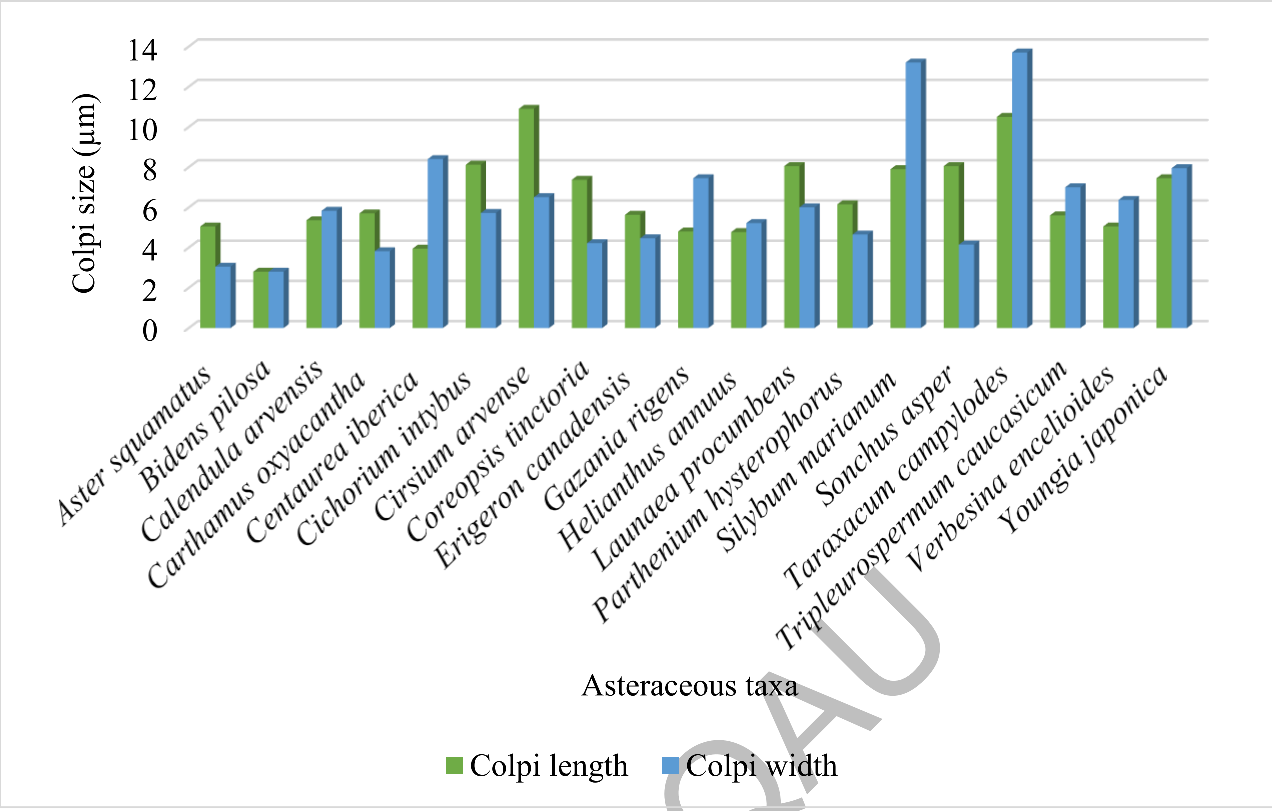

Figure 7. Average data variations of colpi length and width in Asteraceous bee flora

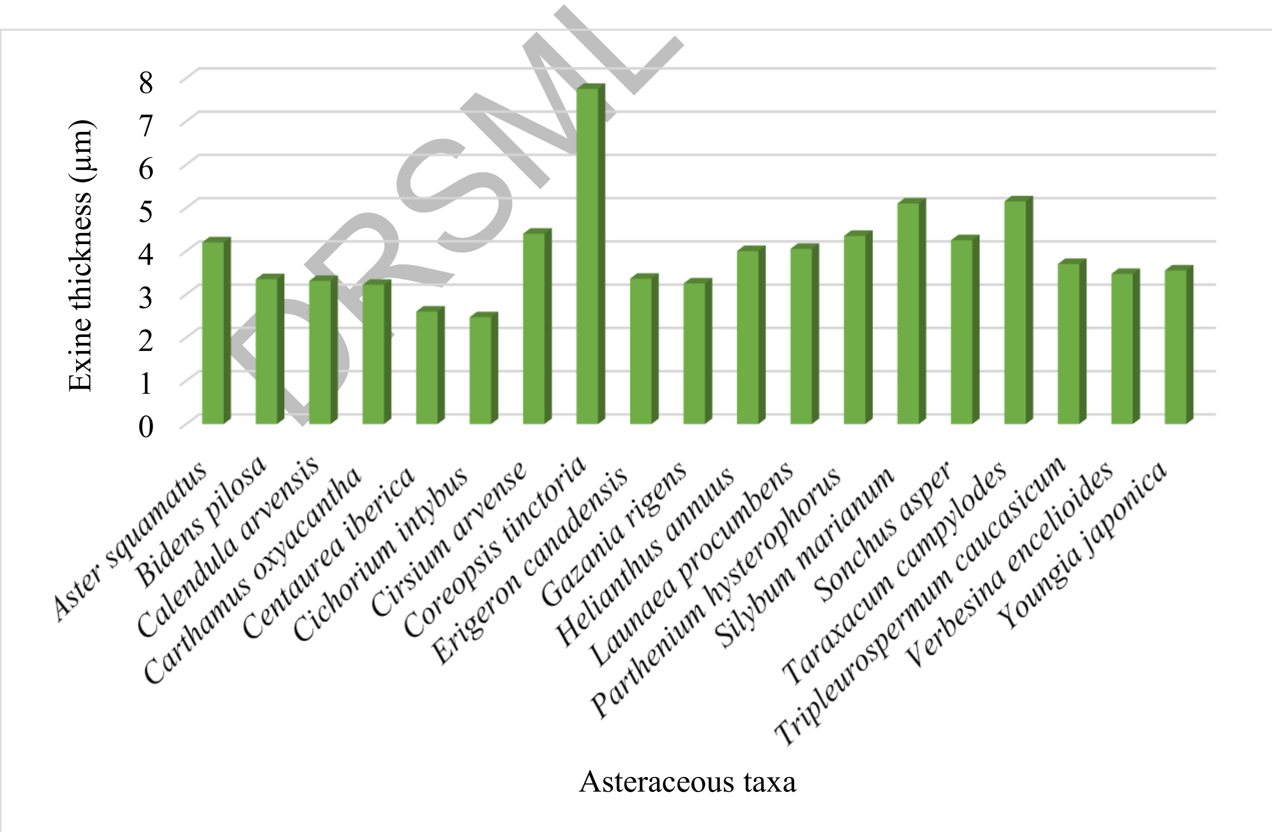

Figure 8. Mean exine thickness variations in Asteraceous bee floral species

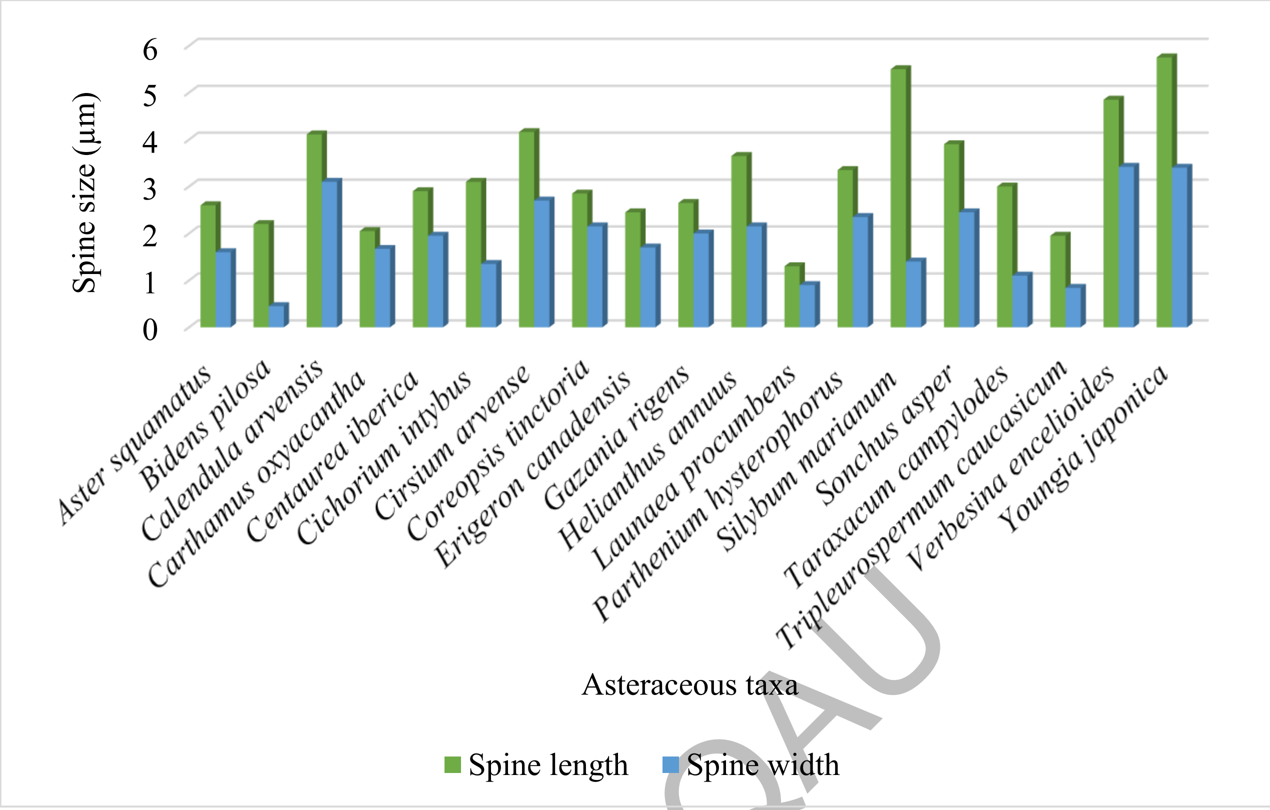

Figure 9. Mean spine size measurement variations in Asteraceous bee floral species

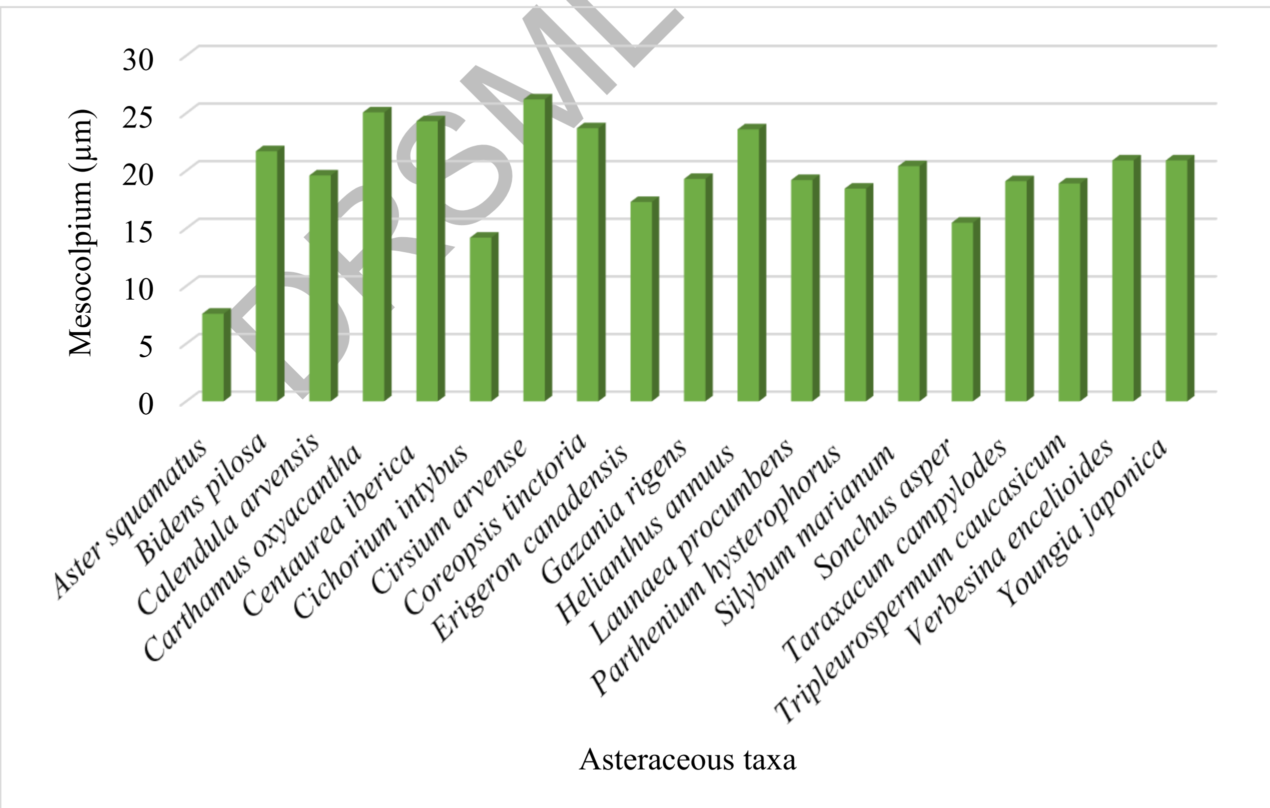

Figure 10. Graphical mean mesocolpium distance of Asteraceous bee floral species

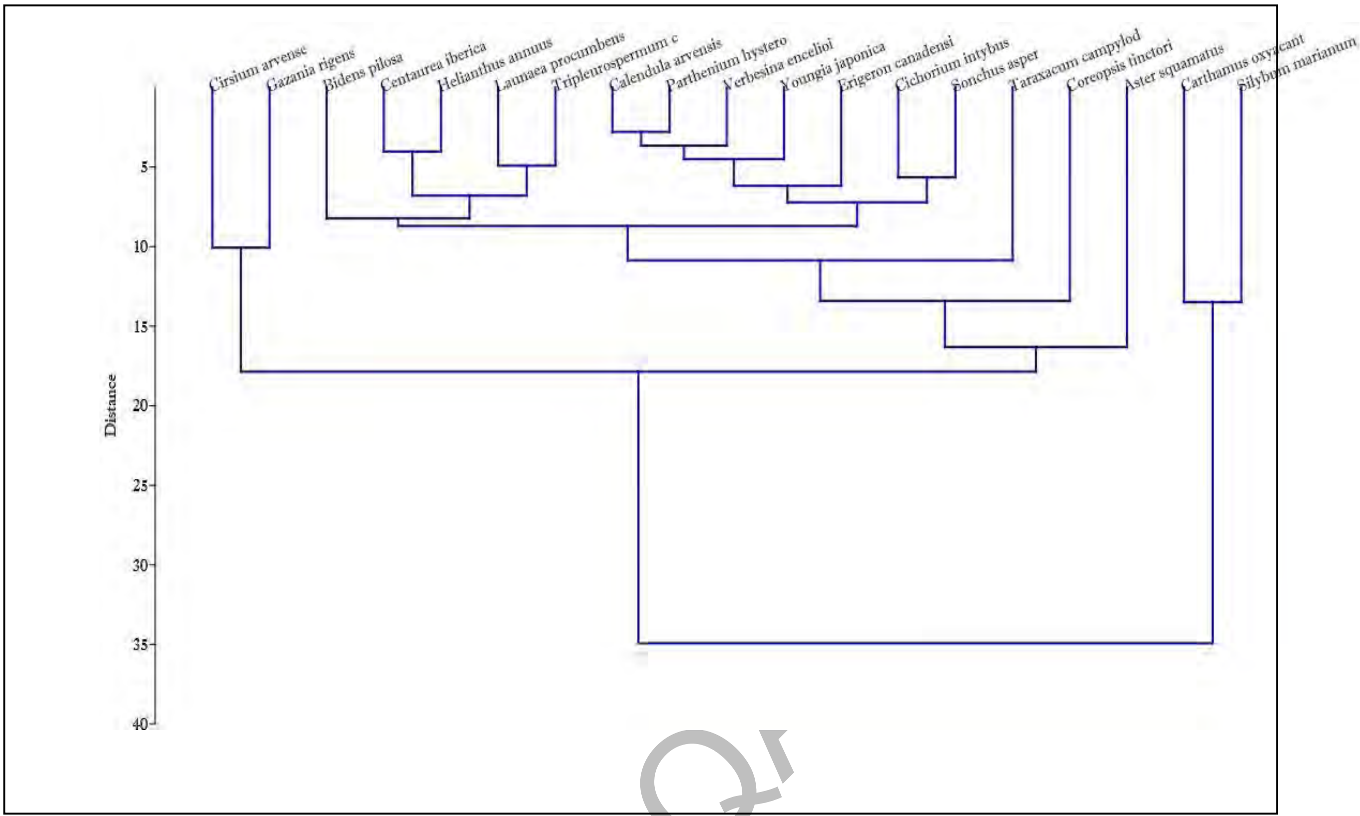

Figure 11. Cluster groupings dendrogram of Honeybee Asteraceous species

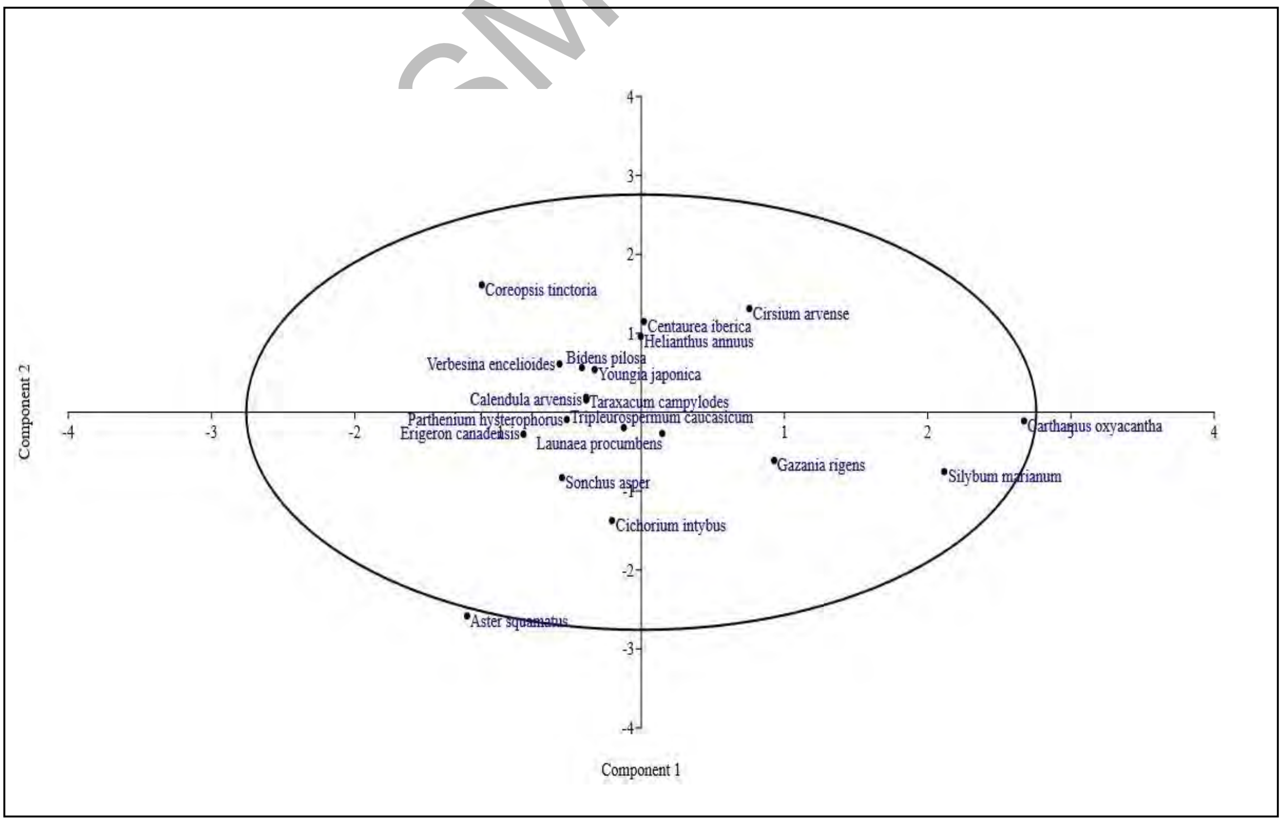

Figure 12. Principal component analysis (PCA) biplot of active variables

3.2.3 Fabaceous Honeybee flora

1. *Acacia modesta* Wall.

Synonym	*Mimosa dumosa* Roxb.
Family	Fabaceae
Common Name	Phulai
Habit	Deciduous Tree
Habitat	Waste places,
Flowering period	March to October
Status	Wild
Distribution	Afghanistan, India, Nepal, Burma, Pakistan
Morphology	Medium sized tree, young shoot; glabrous, bark brownish, rough, compressed, recurved, dark brown, shining, 3-7 mm long, prickles absent. Stem; erect, glabrous and subglabrous, branched. Leaves are compound, bipinnate. Rachis; 1.5-4 cm long. Pinnae; 2-4 pairs, leaflets 2-6 pairs, petiolate, 0.6 to 1 mm long, lamina 3-12 mm long, 2.5-6 mm broad, obovate, and glaucous. Flowers; creamish, fragrant are about 2.1-2.6 mm long, borne in staked spike. Inflorescence; pedunculate spike, 3-6 cm long, peduncle. Pedicel; 1-1.5 mm long. Calyx; 1.3 mm long, campanulate, and glabrous. Corolla; 1.5-2.2 mm long. Stamens; indefinite, filaments 4 mm long. Pod; stipitate, pod proper 3.5-6 cm long, 7-12 mm broad, flat, glabrous and mucronate. Seeds 2-6 (Plate 34a).
Melissopalynology	Pollen are polyad, medium-sized, heteropolar and radically symmetrical. Polar view semicircular and Prolate- spheroidal equatorial view. Colpi and pores absent. Exine thicker than nexine and sculpturing regulate to fossulate. Polar diameter 41.0(36.2-47.2)±1.92 µm and equatorial distance 39.7(34.7-43.7)±1.62 µm. P/E ratio 1.03. Exine thickness is 10.6(8.12-13.12)±0.88 µm. Pollen fertility 82% and sterility 17.9% (Plate 34b,c,d & e).

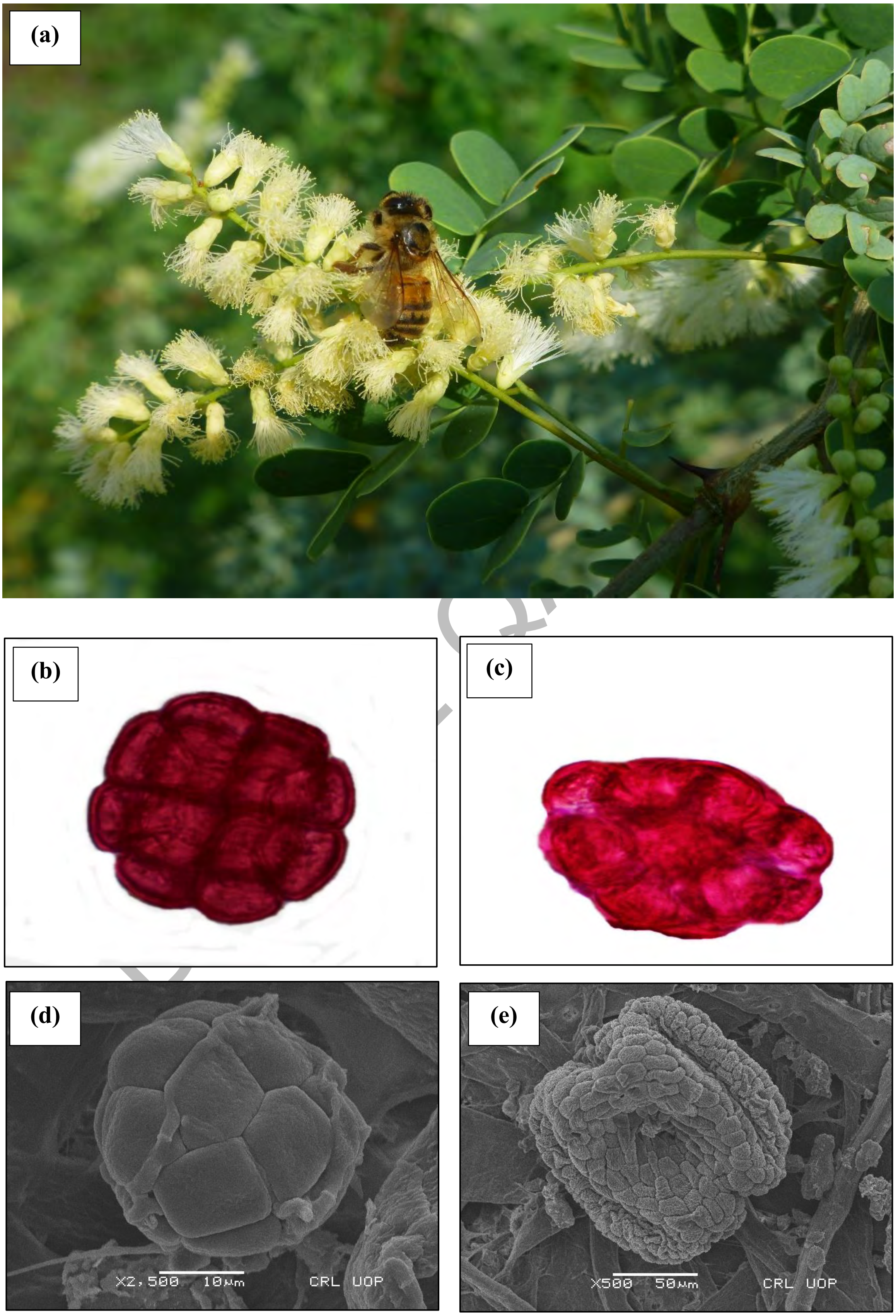

Plate 34: *Acacia modesta* Wall. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Acacia nilotica* (L.) Delile

Synonym	*Acacia arabica* (Lam.) Willd.
Family	Fabaceae
Common Name	Prickly Acacia
Habit	Evergreen Tree
Habitat	Fast growing on arid sites, Sandy soil and loamy soil
Flowering period	February to May
Status	Wild
Distribution	Iraq, Zambia, Nepal, Oman, India, Pakistan
Morphology	Erect, Perennial, Tree, 1.5-20 m high, bark rough, blackish, young branches sub-tomentose. Bark on stem; blackish grey in color and fissured rough. Branches are glabrous later become rough. Stipule present and spinescent. Stipules; spinescent, up to 10 cm long. Leaf; 1-2 petiolar glands, leaflets; 5-22 pairs, 2-8.5 mm long, 0.8-1.4 mm wide, glabrous. Inflorescence; axillary, pedunculate heads, 8-20 mm diameter. Flowers; bright yellow, involucel; near base to halfway. Calyx; 1.5-2.5 mm long, pubescent. Corolla; 2-3.8 mm long, glabrous. Fruit; indehiscent, variable, curved, velvety, 3-20 cm long, 1.5-2.5 cm wide. Seed; blackish brown, smooth, 5-11 mm long, 4-9 mm wide, sub-circular, compressed, areole 4-8 mm long, 3.5-6 mm wide (Plate 35a).
Melissopalynology	Pollen are 32 celled polyad, radically symmetrical, medium-sized and heteropolar. Polar view shape circular and oblate-spheroidal equatorial view shape. Exine ornamentation sub-psilate. Colpi, pores and spines absent. Exine thicker than nexine, tectum sub-Psilate, perforate or foveolate. Polar view diameter 36.0(30.2-40.2)±1.64 µm and equatorial view distance 36.9(26.2-45.2)±3.14 µm. P/E ratio 0.97. Exine thickness 2.50(1.75-3.00)±0.22 µm. Pollen fertility 90.4% and sterility 10.5% (Plate 35b,c,d & e).

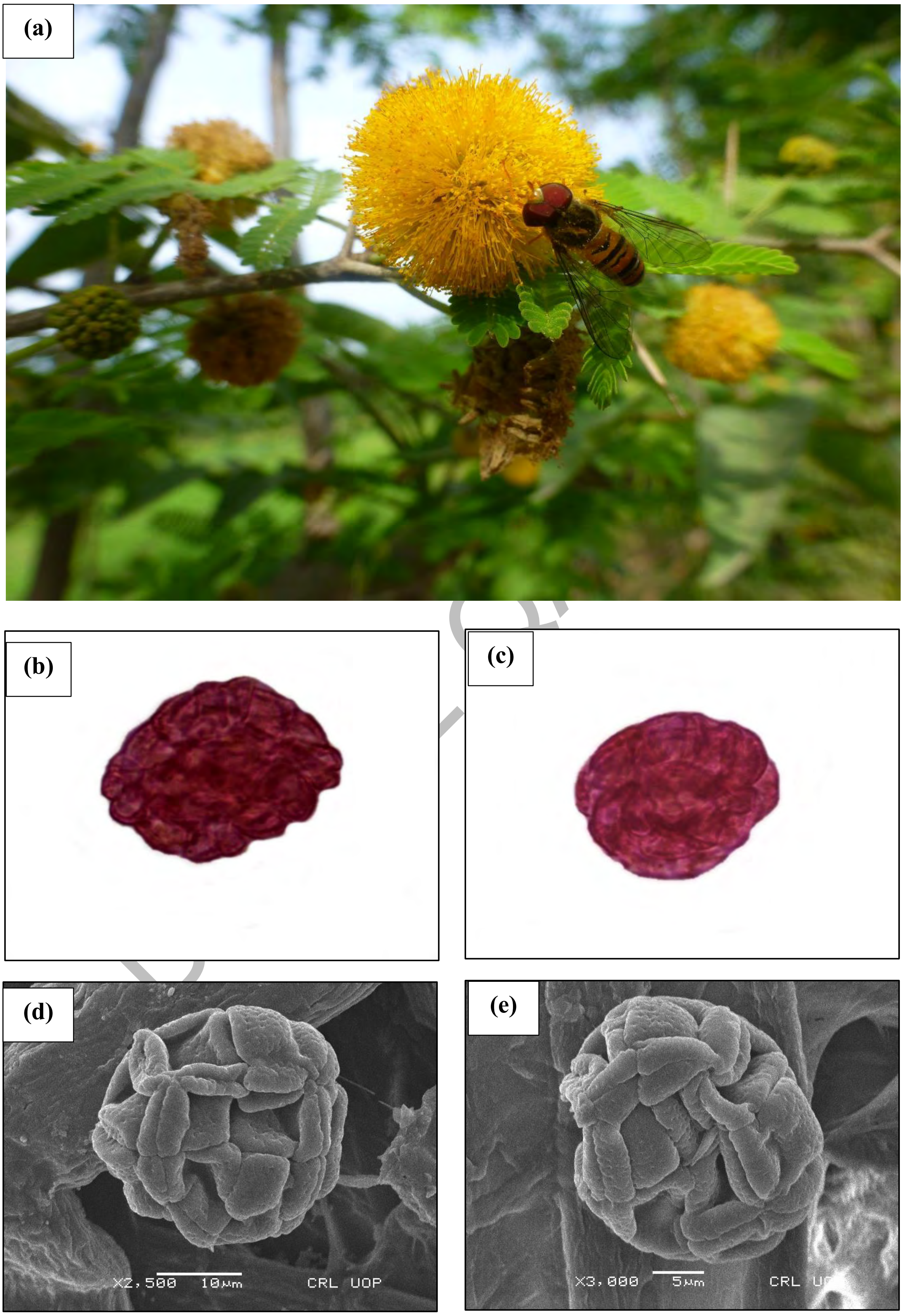

Plate 35: *Acacia nilotica* (L.) Delile (a) Floral part; (b & c) LM polar view and equatorial view of pollen; (d & e) SEM polar view and Exine sculpturing

3. *Dalbergia sissoo* DC.

Synonym	*Amerimnon sissoo* (Roxb.) Kuntze
Family	Fabaceae
Common Name	Indian rosewood
Habit	Perennial Tree
Habitat	Colonizer of landslips, hillsides, roadsides and grasslands
Flowering period	March to June
Status	Wild
Distribution	Nigeria, India, Oman, Victoria, Texas, Pakistan
Morphology	Medium to large, deciduous tree, with light crown, reproduces through seeds and suckers. Grow up to 20-25 m in height, and 2 to 4 m in diameter. Trunks; crooked when grown in open. Leaves; leathery, alternate, pinnately compound, about 12-18 cm long. Flowers; whitish to pink, fragrant, sessile, up to 1.6 cm long and dense clusters of 4-13 cm long. Pods; oblong, flat, thin, strap like, 3–7 cm long, 1.5 cm wide and light brown, Contain 1 to 5 flat bean shaped seeds, 7–11 mm long (Plate 36a).
Melissopalynology	Pollen are monad, medium-sized and trizonocolporate. Semi-angular polar view and equatorial view shape oblate-spheroidal. Exine sculpturing psilate. Polar diameter 25.9(21.7-30.2)±1.67 µm and equatorial view distance 26.1(22.7-31.2)±1.65 µm. P/E ratio 0.99. Colpi length 4.40(2.75-5.50)±0.50 µm and colpi width 6.75(5.75-7.75)±0.35 µm. Exine thickness 2.45(1.75-3.25)±0.25 µm. Mesocolpium measurement 14.9(14.0-15.7)±0.34 µm. Pollen fertility 95.2% and sterility 4.71% (Plate 36b,c,d & e).

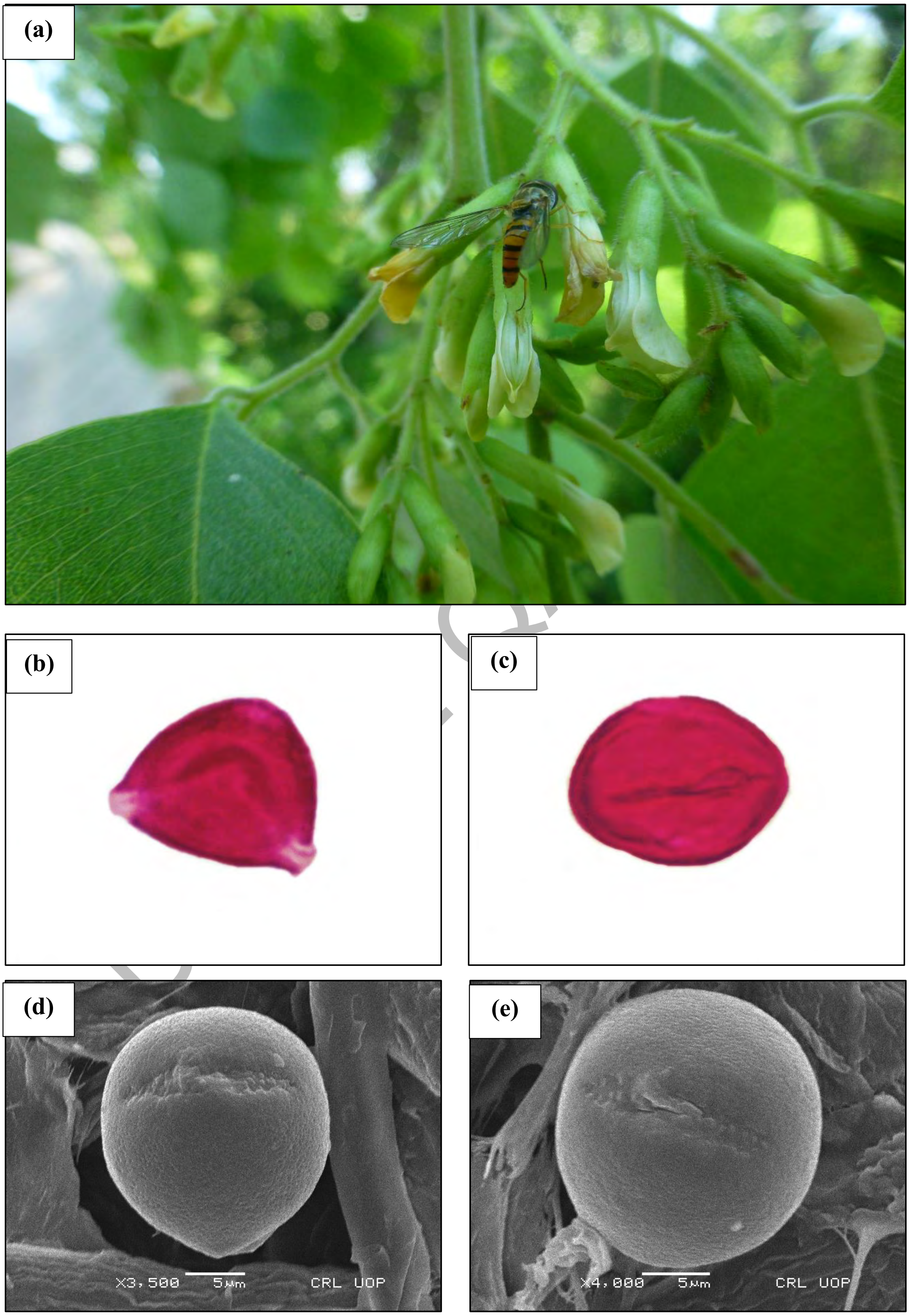

Plate 36: *Dalbergia sissoo* DC. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Indigofera heterantha* Brandis

Synonym	*Indigofera gerardiana* Baker
Family	Fabaceae
Common Name	Himalayan indigo
Habit	Shrub
Habitat	Along dry slopes and in most well drained soils
Flowering period	June to October
Status	Wild
Distribution	Tibet, Nepal, China, Bhutan, Afghanistan, Pakistan
Morphology	Shrub, 35-56 cm tall, young branches white and canescent. Stem: brown, terete, rounded lenticels, young branches; angular. Stipules; linear, caducous and 1.6-3.5 mm. Leaf; imparipinnate compound, leaflets; 10-29, 4.5-7 mm long, elliptic, obovate, oblanceolate, mucronate, pubescent both sides, hairs white, petiolate, 1.3 mm long; stipel small and stipules setaceous. Petiole: adaxial grooved. Inflorescence; raceme and nearly sessile. Pedicel short. Bract minute. Calyx; campanulate, pubescent, teeth as long as the tube. Corolla; purple to pale red. Stamens: 5.5-10 mm, anthers; ovoid-globose and base hairy. Ovary: hairy and 10 ovules. Fruit; 1-1.8 cm long, straight, cylindrical glabrous, 12-14 seeded (Plate 37a).
Melissopalynology	Pollen are monad, iso polar, medium-sized and tricolporate. Triangular polar view and equatorial view shape prolate-spheroidal. Exine sculpturing micro-reticulate. Aperture sunken oriented. Polar diameter 37.6(30.7-43.7)±2.18 µm and equatorial view distance 35.0(27.7-40.5)±2.20 µm. P/E ratio 1.07. Colpi length 0.70(0.25-1.75)±0.18 µm and colpi width 1.45(0.75-1.75)±0.18 µm and mesocolpium distance 30.4(23.7-38.0)±2.83 µm. Exine thickness 2.35(2.00-2.75)±0.16 µm. Pollen fertility 80.7% and sterility 19.2% (Plate 37b,c,d & e).

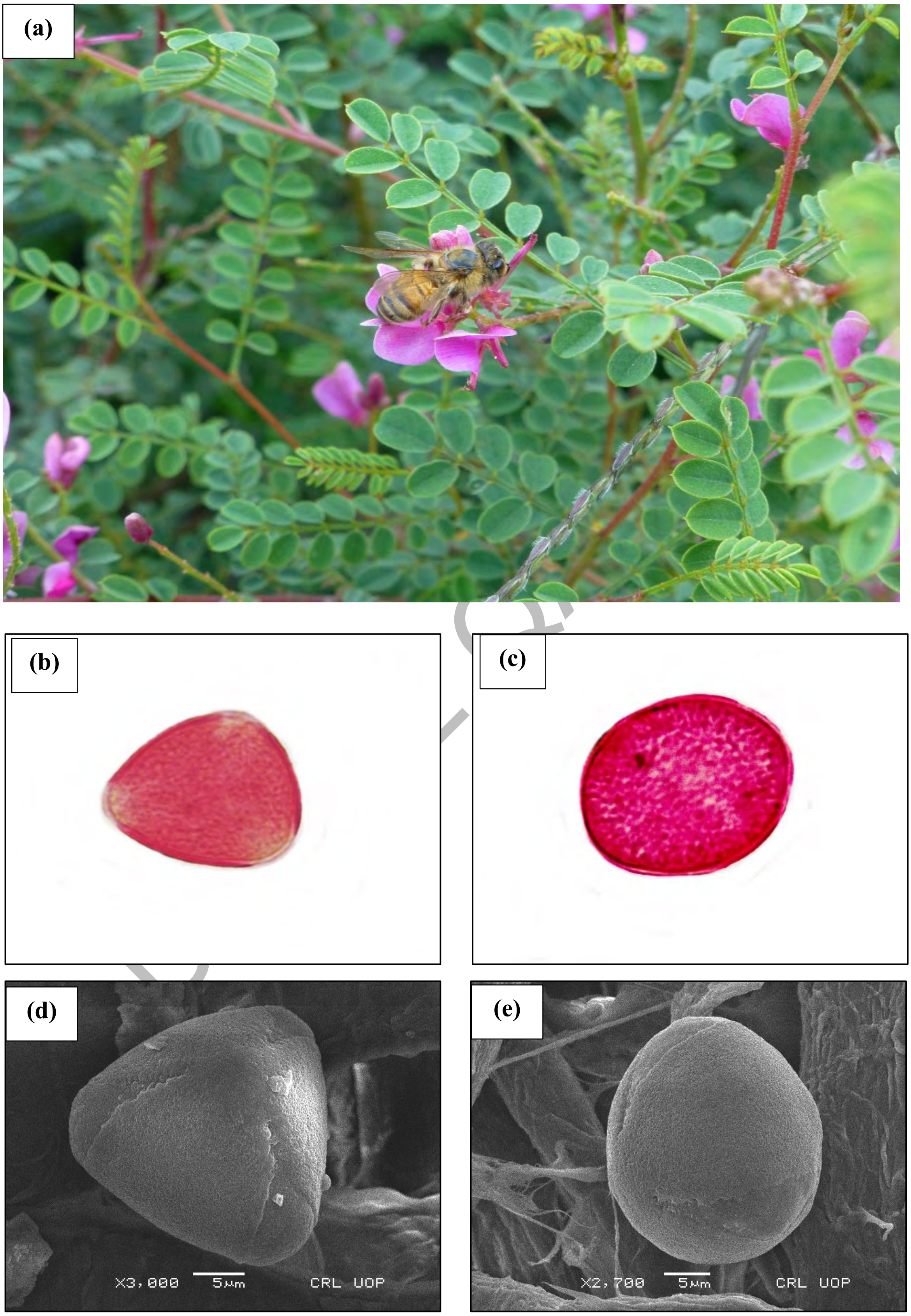

Plate 37: *Indigofera heterantha* Brandis (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Medicago minima* (L.) L.

Synonym	*Medicago hirsuta* (L.) All.
Family	Fabaceae
Common Name	Small medik
Habit	Annual Herb
Habitat	On dry sandy areas and in open sandy or gravelly places
Flowering period	April to June
Status	Wild
Distribution	North Africa, South America, Florida, Kashmir, Pakistan
Morphology	Annual, pubescent, hairs simple and glandular hairs. Stem: diffuse, prostrate, ascending and basally branched. Stipules; ovate, round base, margin entire serrate and apex acute. Petiole; up to 8-10 mm long, leaflets; 3-12 mm long, 1.5-6 mm broad, obovate, oblanceolate, pubescent, retuse to emarginate, toothed, stipules entire and toothed. Inflorescence; 2 to 6 flowered, raceme and peduncle longer than the petiole. Calyx; 1.5-2 mm long, finely pubescent, teeth as long as the tube. Corolla; up to 3-4.5 mm long. Fruit; 2-5 coils, spines variable, from short tubercles, hooked spines, inserted from the marginal border (Plate 38a).
Melissopalynology	Pollen are monad, small sized, isopolar, and tricolporate. Trilobed polar view and oblate-spheroidal equatorial view shape. Exine sculpturing regulate-striate. Polar diameter 19.2(16.2-22.2)±1.11 µm, and equatorial view distance 19.8(16.7-23.2)±1.07 µm. P/E ratio 0.96. Colpi length 2.35(1.75-3.00)±0.23 µm, colpi width 2.60(2.00-3.25)±0.76 µm and mesocolpium distance 14.1(12.2-16.0)±0.76 µm. Exine thickness 5.25-2.25=3.37±0.91 µm. Pollen fertility 81.8% and sterility 18.1% (Plate 38b,c,d & e).

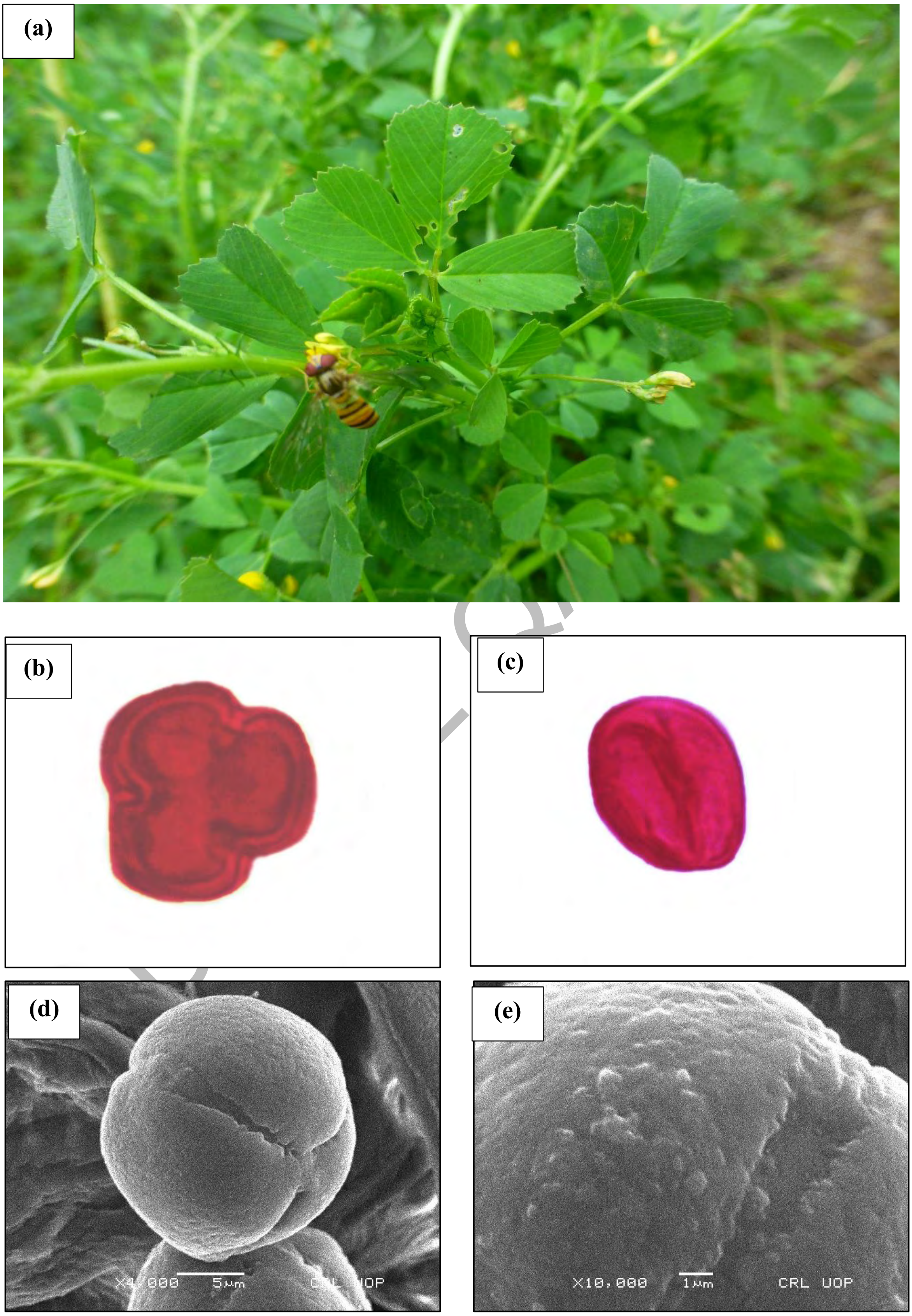

Plate 38: *Medicago minima* (L.) L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

6. *Melilotus indicus* (L.) All.

Synonym	*Melilotus indicus* subsp. *permixtus* (Jord.)
Family	Fabaceae
Common Name	Sweet clover
Habit	Annual Herb
Habitat	Found in cultivated lands along with other crops
Flowering period	March to May
Status	Wild
Distribution	Egypt, Ethiopia, Kenya, Namibia, Pakistan, Sudan, China
Morphology	Annual herbaceous plant to erect stems is 21-51 cm long, and simple or branching from base. Stipules lanceolate, 3-5 mm, base auriculate with 2 or 3 teeth , have margin membranous: leaflets obovate-cuneate to nar-rowly oblong, 10-25 × 8-10 mm, lateral veins 7-9 pairs, parallel running into teeth, base cuneate, margins serrulate toward apex, apex obtuse, sometimes retuse. Racemes slender, dense, 1.7-4.1 cm; peduncle long; flowers 14-24; 1.2 mm. Corolla yellow, 2.4-2.9 mm; standard broadly ovate, equal to wings and keel, or sometimes keel slightly longer (Plate 39a)
Melissopalynology	Pollen are monad, small-sized, and tricolpate. Slightly rounded polar view and oblate-spheroidal equatorial view shape. Exine sculpturing micro-reticulate-foveolate. Polar diameter 23.7(27.5-20)±2.82 µm and equatorial view distance 20.9(25-18.7)±2.4 µm. P/E ratio 0.88. Colpi length 4.95(5.25.4.75)±0.2 µm, colpi width 8.5(10-7.25)±1.06 µm and mesocolpium 19.6(20.2-18.7)±0.67 µm. Exine thickness 4(5-2.75)±0.87 µm. Pollen fertility 91.2% and sterility 8.7% (Plate 39b,c,d & e).

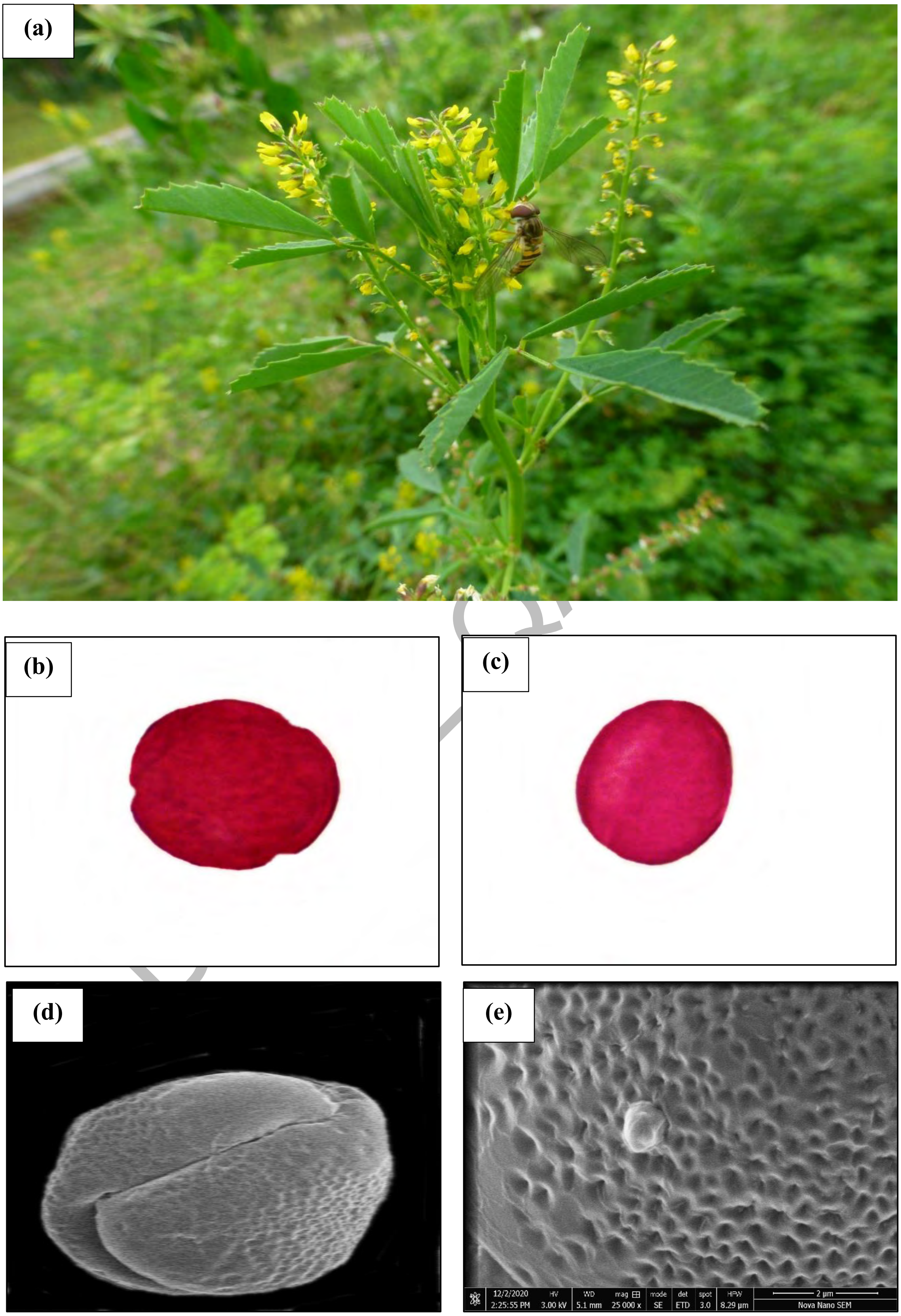

Plate 39: *Melilotus indicus* (L.) All. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

7. *Prosopis juliflora* (Sw.) DC.

Synonym	*Mimosa piliflora* Sw.
Family	Fabaceae
Common Name	Ironwood
Habit	Evergreen Shrub
Habitat	Saline soils and marginal soil and compete with grasses
Flowering period	June to November
Status	Wild
Distribution	Colombia, Cuba, Pakistan, Netherlands, Indonesia, Qatar, Srilanka
Morphology	Large shrub or tree, 5 m tall, generally armed with stipular spines. Leaves alternate, bipinnate, with 1-3 pairs of pinnae, rachis 1-8 cm long, prolonged beyond the last pinnae as a soft bristle. Leaflets 10-20 pairs, 7-17 mm long, 2-3 mm broad, entire, oblong, obtuse, and mucronate. Stipules spiny, generally 1.0 cm or less long, in pair. Inflorescence dense axillary pedunculate spikes 4-8.5 cm long, peduncle 6-12 mm long. Flowers greenish yellow, pedicel 1 mm. Calyx; 1 mm long, cup-shaped, 5 toothed, teeth small. Petals 5, free, 3 mm long, tip and margin hairy. Stamens 10, free, exerted, 4 mm long, anthers tipped with deciduous glands. Pod pedicellate, 16-23 cm long, 10-12 mm broad, almost straight to semi-circular, light yellow, glabrous, pedicel 5-7 mm long. Seeds 10-18, oblong (Plate 40a).
Melissopalynology	Pollen are monad, radially symmetrical, isopolar, medium-sized, and tricolporate. Circular polar view and sub-prolate equatorial view shape. Colpi long or short sized, broad at base. Exine sculpturing scabrate-granulate. Polar diameter 32.9(24.7-48.7) ±4.60 µm and equatorial view distance 27.2(22.2-38.2)±2.92 µm. P/E ratio 1.20. Colpi length 5.75(4.75-6.75)±0.35 µm, colpi width 3.50(3.00-4.25)±0.23 µm, and mesocolpium distance 17.9(15.2-20.2)±0.83 µm. Exine thickness 3.80(3.00-4.75)±0.32 µm. Pollen fertility 91.3% and sterility 8.6% (Plate 40b,c,d & e).

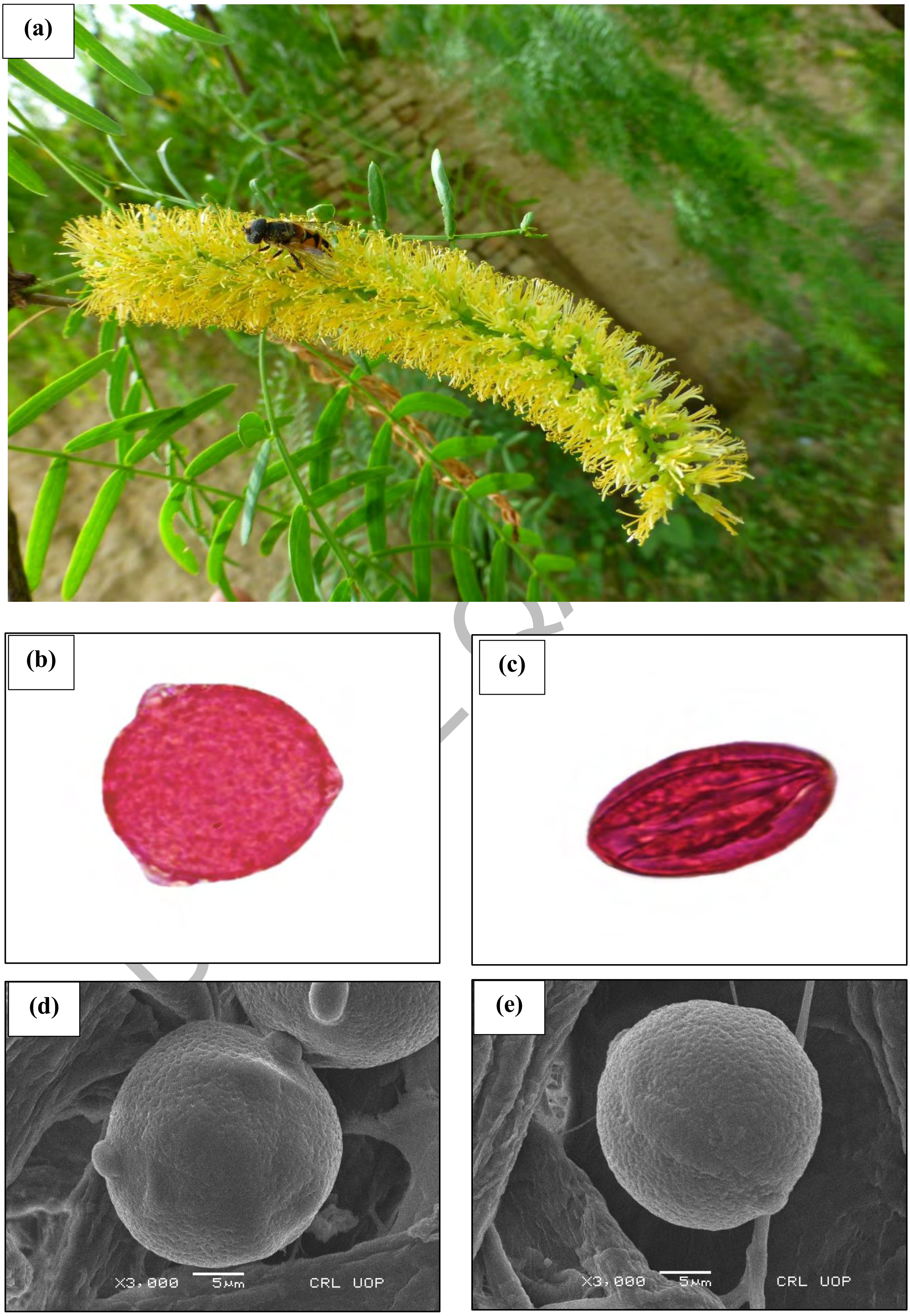

Plate 40: *Prosopis juliflora* (Sw.) DC. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

8. *Sesbania sesban* (L.) Merr.

Synonym	*Aeschynomene sesban* L.
Family	Fabaceae
Common Name	Sesbane
Habit	Tree
Habitat	Common along streams, swamp banks and moist lands
Flowering period	September to January
Status	Wild
Distribution	Australia, India, Egypt, Pakistan, Nigeria, Bhutan
Morphology	Tree, soft wooded, short-lived, 2 to 7 m tall, young stem pubescent. Leaf; paripinnate, rachis 5-12 cm long; leaflets; 16-51, 6-20 mm long, 3.5-6 mm wide, linear to oblong, obtuse, apiculate, glabrous, stipules 4 to 6 mm long. Inflorescence; axillary raceme, 2-22 flowered, up to 12 cm long. Bract and bracteoles; up to 4 mm long and caducous. Pedicel; up to 10-14 mm long, Calyx; glabrous, 4-5 mm long, teeth 0.8-1.4 mm or less and broadly triangular. Corolla; yellow, tinged with or spotted purple. Vexillum; 10-16 mm long. Fruit; 14-31 cm long, up to 7 mm wide, 24-45 seeded (Plate 41a).
Melissopalynology	Pollen are monad, iso-polar, medium-sized, and radially bilaterally symmetrical and tricolporate. Semi-angular polar view and sub-prolate equatorial view shape. Exine sculpturing psilate-reticulate. Polar diameter 36.6(30.2-42.7)±2.14 µm and equatorial view distance 30.8(26.2-35.7)±1.83 µm . P/E ratio 1.18. Colpi length 4.05(3.25-5.25)±0.33 µm, colpi width 7.65(6.75-8.50)±0.30 µm and mesocolpium distance 21.5(18.5-23.7)±0.90 µm. Exine thickness 44(3.25-5.25)±0.38 µm. Pollen fertility 87.3% and sterility 12.6% (Plate 41b,c,d & e).

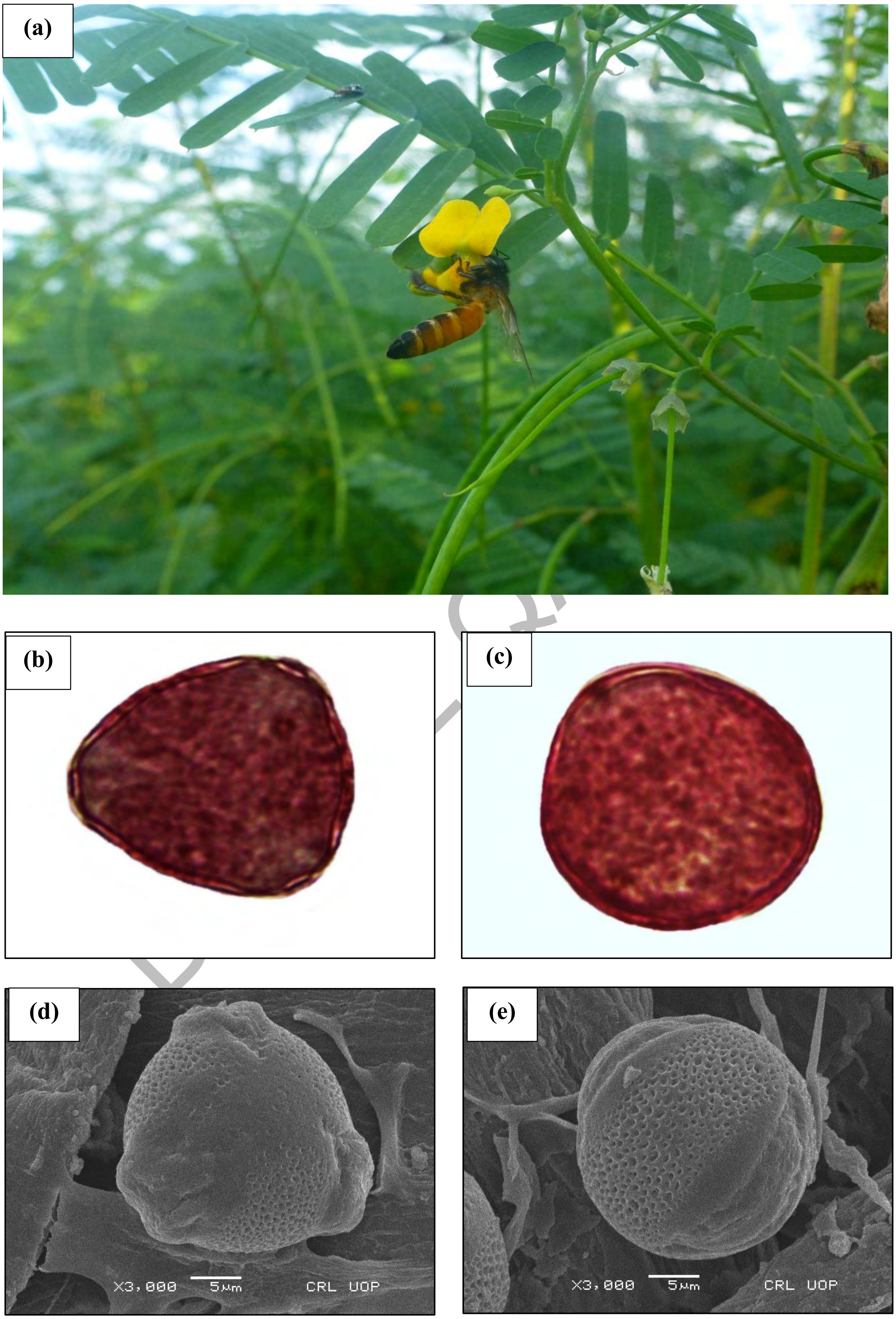

Plate 41: *Sesbania sesban (L.) Merr.* (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

9. *Thermopsis montana* Torr. & A.Gray

Synonym	*Thermopsis angustata* Greene
Family	Fabaceae
Common Name	Golden pea
Habit	Herb
Habitat	Moist meadows, thickets, forest and often along streams
Flowering period	April to August
Status	Wild
Distribution	Columbia, Washington, New Mexico, Pakistan
Morphology	Perennial herb, thick woody rhizome; stems erect to ascending, 10-40 cm tall, mostly unbranched, appressed hairy to nearly glabrous. Leaves: Alternate, palmately compound, stalked; leaflets 3, oblanceolate to elliptic, 1.5-3 cm long, short-hairy on both surfaces or glabrous above; lowest stipules papery, sheathing, the upper ones large, egg-shaped, resembling leaflets, joined to the leaf-stalk at the base. Flowers: Inflorescence a dense, stalked, erect, terminal raceme, 5-10 cm long, of 10 to 30 erect, pea-like flowers; corollas bright yellow, 17-25 mm long; calyces bell-shaped, 8-13 mm long, 2-lipped, the upper lip 2-toothed, the lower 3-toothed, the teeth triangular. Fruits: Pods, linear, flattened, 4-8 cm long, spreading and curved, stiff-papery (Plat 42a).
Melissopalynology	Pollen are monad, medium medium-sized tricolporate. Triangular polar view and prolate-spheroidal equatorial view shape. Colpi orientation bulged and rounded. Exine sculpturing reticulate. Polar diameter 35.7(28.7-40.2)±1.91 µm and equatorial view distance 33.1(28.7- 38.7)±1.88 µm. P/E ratio 1.07. Colpi length 6.90(4.50-9.2)±0.55 µm, colpi width 3.30(1.75-4.25)±0.19 µm and mesocolpium distance 14.2(12.5-15.7)±0.34 µm. Exine thickness 4.90(4.25-5.75)±0.26 µm. Pollen fertility 85.7% and sterility 14.2% (Plate 42b,c,d & e).

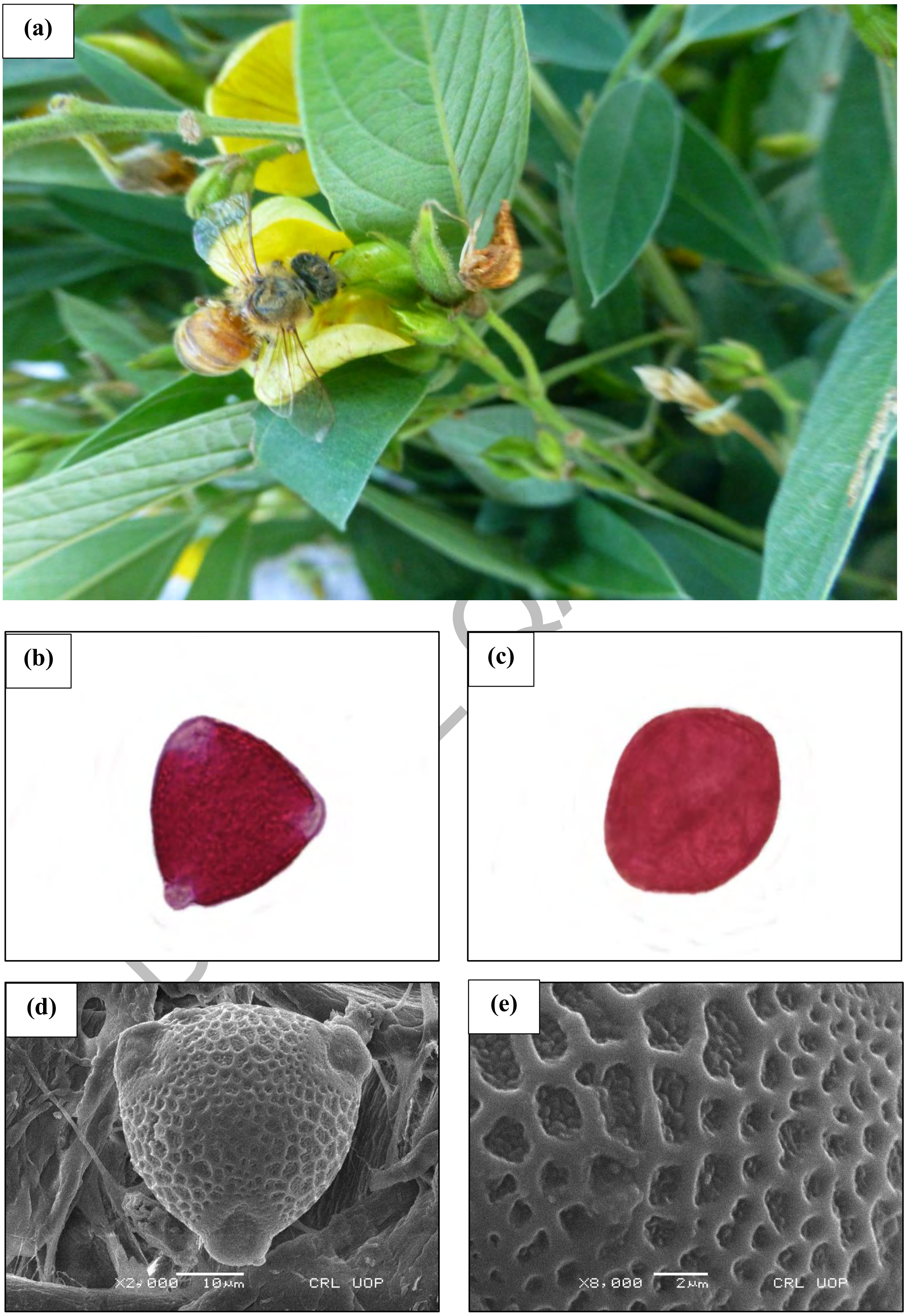

Plate 42: *Thermopsis montana* Torr. & A.Gray (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

10. *Trifolium alexandrinum* L.

Synonym	*Trifolium alexandrinum* sensu auct.
Family	Fabaceae
Common Name	Egyptian clover
Habit	Annual/Perennial Herb
Habitat	Found in cultivated lands
Flowering period	March to May
Status	Wild
Distribution	Ethiopia, Algeria, Kenya, Mali, Pakistan, South Africa, Sudan
Morphology	Annual or perennial herb, pubescent and glabrescent. Stem: erect, ascending, 15-55 cm, striate and branched base. Leaf trifoliate, rarely, digitately 5-9 foliolate, leaflets mostly dentate; stipules adnate to petiole. Leaflets: broadly elliptic, oblong-lanceolate, 12-40 × 5-20 mm. Inflorescence; sessile or pedunculate head or short raceme or solitary. Bracts absent and present. Calyx variable, accrescent or inflated, teeth equal or unequal. Corolla red, pink, purple, pink, white, persistent. Stamens diadelphous, 9+1, vexillary stamens free, anthers uniform. Ovary with few ovules, style incurved, stigma capitate. Fruit usually included in calyx, often indehiscent, 1-2 seeded (Plate 43a).
Melissopalynology	Pollen are monad, small to medium-sized and tricolpate. Circular polar view and spheroidal equatorial view shape. Colpi orientation sunken and tapering at end. Exine sculpturing Papillate-striate. Polar diameter 22.2(23.7-20.0)±1.38 µm and equatorial view distance 22.0(25-18.7)±2.59 µm. P/E ratio 1.0. Colpi length 13.8(15-12.5)±0.92 µm, colpi width 7.85(8.7-7.25)±0.57 µm and mesocolpium 21.1(23.7-18.7)±1.97 µm. Exine thickness 5.5(7.75-4.25)±1.32 µm. Pollen fertility 87.6% and sterility 12.3% (Plate 43b,c,d & e).

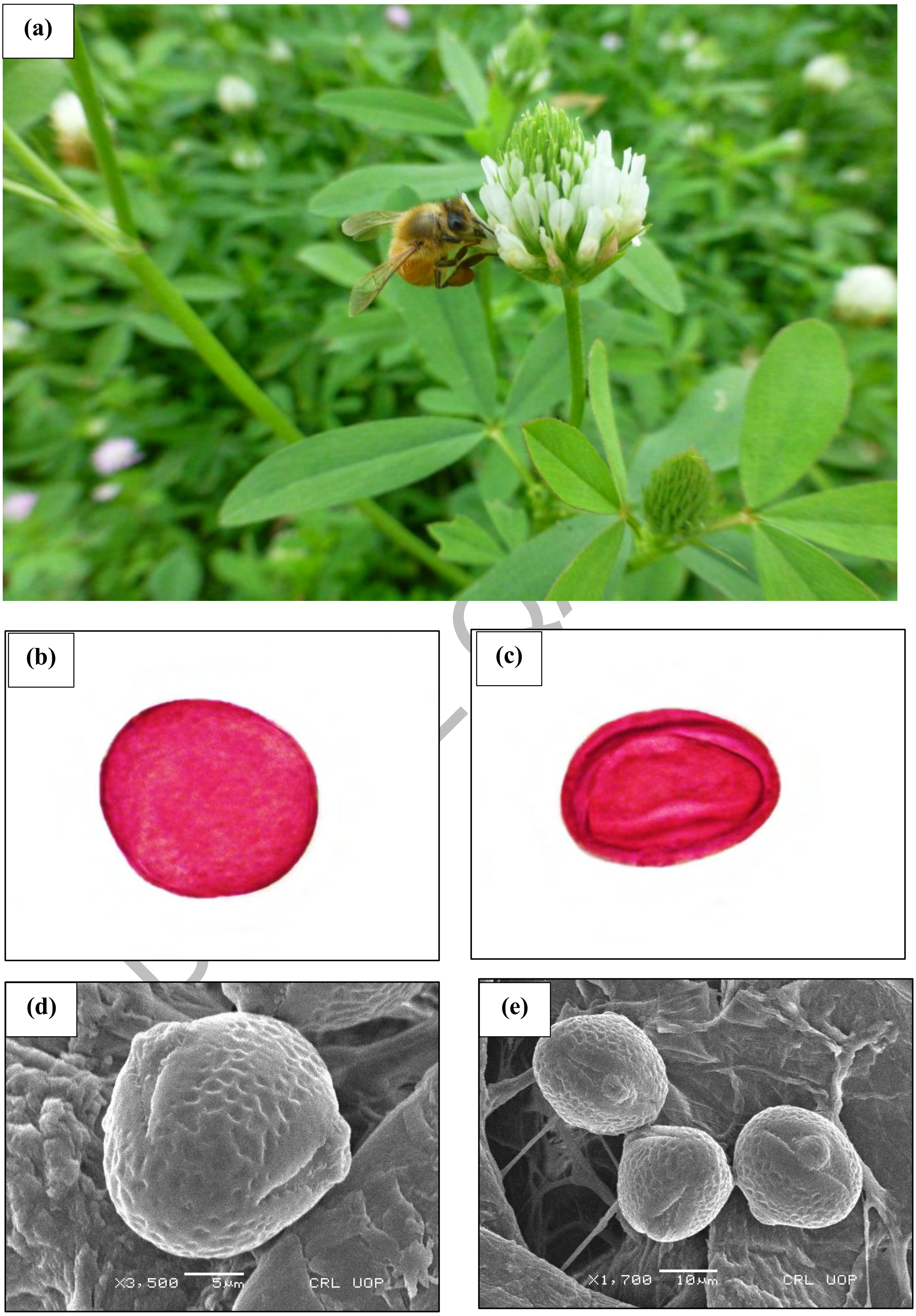

Plate 43: *Trifolium alexandrinum* L. a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

11. *Trifolium tomentosum* L.

Synonym	*Amoria tomentosa* (L.) Roskov
Family	Fabaceae
Common Name	Woolly Clover
Habit	Annual Herb
Habitat	Along grassland and roadside
Flowering period	March to June
Status	Wild
Distribution	Turkey, Portugal, France, Italy, Pakistan, Western Asia
Morphology	Annual, glabrous and hairy. Stem; 6-30 cm, decumbent and erect. Leaf; alternate, cauline, free part, lance triangular, petiolate; stipules ovate acuminate, membranous, petiole of lower leaves 80-90 mm; leaflets; 16 × 13 mm, obcordate, sub seated, serrulate, spiny obtuse, truncate and emarginated teeth. Inflorescence: heads 5-13 mm, sessile, 2 bract like leaves, peduncle, woolly fruit, bracts small and cup shaped. Flower; calyx hairy, lobes short, linear inflating fruit, corolla; 2.5-6 mm, pink and reflexed. Seed; 1 to 3, 1.2-1.8 mm, smooth, greenish yellow and olive-green streaks (Plate 44a).
Melissopalynology	Pollen are monad, medium-sized and tricolporate. Lobate polar view and oblate-spheroidal equatorial view shape. Colpi orientation sunken. Exine sculpturing perforate reticulate. Polar diameter 38.9(36.2-42.7)±1.22 µm and equatorial view distance 39.8(36.2-43.7)±1.39 µm. P/E ratio 0.97. Colpi length 7.50(5.75-9.25)±0.66 µm, colpi width 10.6(8.75-13.5)±0.84 µm and mesocolpium distance 28.0(24.0-33.5)±1.78 µm. Exine thickness 2.75(2.25-3.25)±0.176 µm. Pollen fertility 95.8% and sterility 4.18% (Plate 44b,c,d & e).

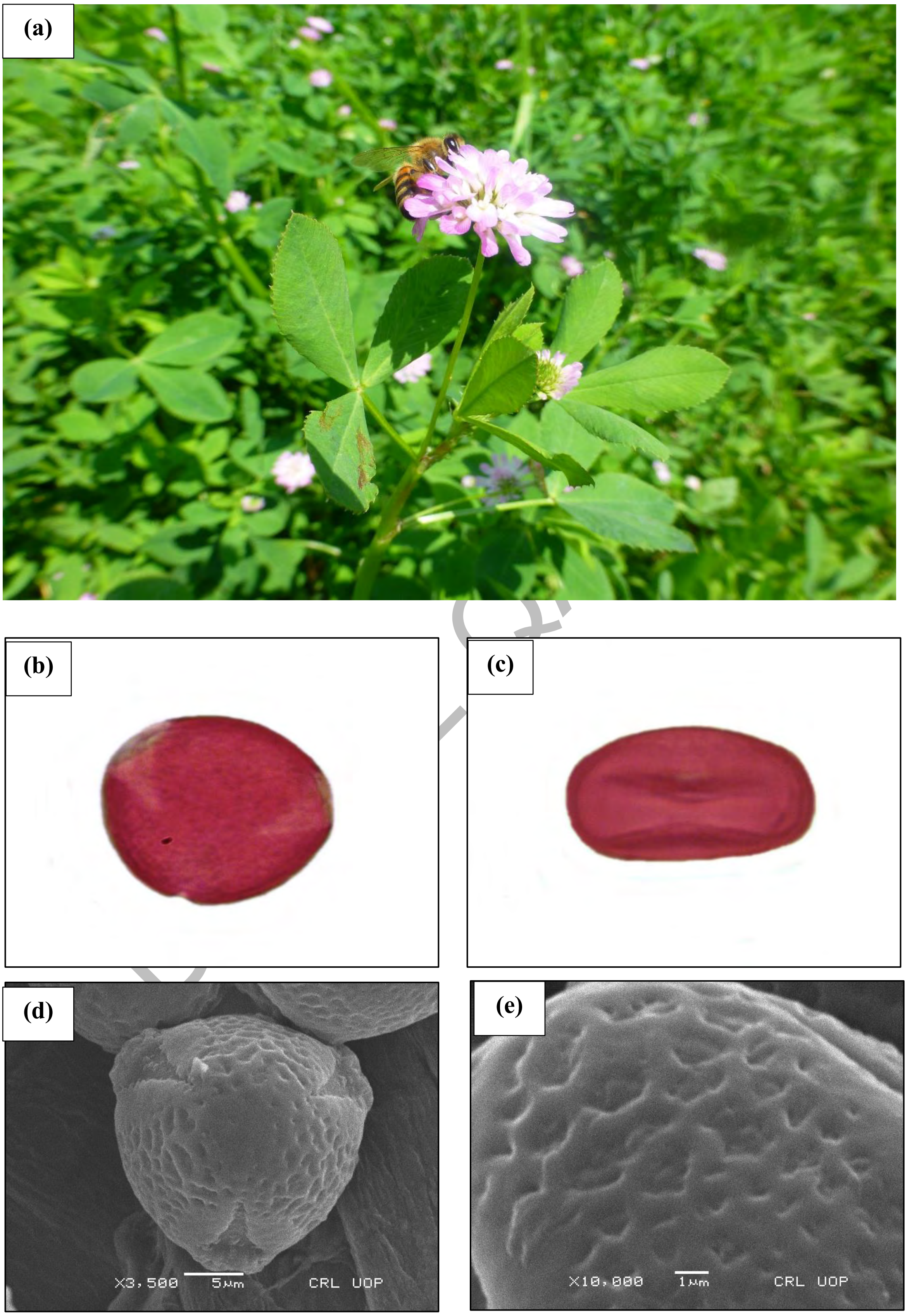

Plate 44: *Trifolium tomentosum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.4 Melisso-palynomorphs description of Fabaceous taxa

In the present study the result demonstrated the pollen morphology of 11 honeybee floral species of Fabaceae. The pollen grains of the studied taxa show little variations among the quantitative features. Pollen features were also described for the investigated taxa such as size, shape, symmetry and polarity of pollen, aperture condition, surface sculpturing, and ornamentation based on scanning microscopy.

The measurement of quantitative features of pollen were taken on LM examination. The maximum average polar diameter and equatorial diameter (38.9±1.22 µm) and (39.8±1.39 µm) was measured in *Trifolium tomentosum*, while minimum polar diameter 19.2±1.11 µm and equatorial distance (19.8±1.07 µm) noted in *Medicago minima* (Figure 13). The average ranged of P/E index ratio from (0.96) in *Medicago minima* to (1.20) in *Prosopis juliflora* (Figure 14). The largest average length and width of colpi was (7.50±0.66 µm) and (10.6±0.84 µm) in *Trifolium tomentosum* respectively. Similarly, shortest colpi length (0.70±0.18 µm) and colpi width (1.45±0.18 µm) was calculated in *Indigofera heterantha* (Figure 15). Further, mesocolpium is found at a range of (14.1±0.76 µm) in *Medicago minima* to (30.4±2.83) µm in *Indigofera heterantha* (Figure 17). Furthermore, exine thickness ranging from (1.60±0.38 µm) in *Medicago minima* to (4.90±0.26 µm) in *Thermopsis montana* (Figure 16).

Pollen grains were small to medium sized (PD=38.9 µm to 19.2 µm, ED= 39.8 µm to 19.8 µm) and oblate-spheroidal to sub-prolate in shape (P/E= 0.96 to 1.20). Thus, the symmetry of pollen is radially symmetrical, polarity (iso polar), aperture condition (trizonocolporate to tricolporate), while the surface sculpturing varies such as regulate fossulate, tectum sub-psilate, psilate, micro reticulate, scabrate-granulate, regulate-striate, scabrate reticulate, perforate-reticulate papillate-striate and reticulate. Pollen was stained perfectly and examined. Among the studied taxa, grains which retain the stain were regarded as fertile, whereas the unstained and rupturepollen were counted as sterile. We found that the *Trifolium tomentosum* had the highestpollen fertility (95.8%), whereas the *Indigofera heterantha* had the lowest (80.7%). Similarly, the *I. heterantha* had the highest pollen sterility (19.2%), while the *T. tomentosum* had the lowest (4.18%) as shown in Figure 18.

a) Statistical Cluster Analysis

The cluster analysis performed by the Euclidean distance method, based on pollen micro-morphological characters. Analyzing dendrogram reveled major cluster divided to two sub-cluster, in which sub-cluster (C1) is further subdivided into two sub-clades. Sub-clade I outgroup difference is attributed to the presence of regulate-striate type exine in *Medicago minima*. Whereas sub-clade II comprised *Dalbergia sissoo, Melilotus indicus* and *Trifolium alexandrinum*. Sub-cluster (C2) consisted of two further subgroups: *Prosopis juliflora, Sesbania sesban* and *Thermopsis montana* comprised the first sub-group (C2b1), whereas species of *Acacia modesta, Acacia nilotica, Indigofera heterantha* and *Trifolium tomentosum comprised* the second sub-group (C2b2). Cluster C2b2 group *A. nilotica* and *I. heterantha* has similar prolate-spheroidal type pollen shape (Figure 19).

PCA of sample data is envisaged in the form of two dimensional or three-dimensional plans with two axes principal components (PC). Eleven honeybee plant species belonging to family Fabaceae were investigated for their variability in pollen using factors like exine thickness, polar view diameter, equatorial view distance, length and width of colpi and mesocolpium distance. PCA illustrated maximum contribution to accumulative variability at each PCA axis as shown in figure. Eigenvalues of PC1, PC2, PC3, PC4, PC5 and PC6 were found higher than 1 and therefore, are considered as the most significant components in PCA analysis (Figure 20). Results of variable loadings analysis revealed that PC1 has about 75.62% of accumulative variation and distinguishing pollen of Fabaceous honeybee plant species. Polar diameter followed by equatorial diameter was the most significant variables in PC1. *Indigofera heterantha, Sesbania sesban* and *Trifolium tomentosum* with higher values of equatorial and polar diameter were positioned on the positive side of the 1st axis. While *Acacia modesta* and *Thermopsis montana* were located on the negative side of the 1st axis. Variable loading along 2nd axes of Principal component tool PC2 exhibited 12.93% variability of accumulative variation. Colpi length followed by colpi width and polar diameter were the most significant variables in PC2. *Acacia niloticaa* was found on the +ve side of second axes. However, *Dalbergia sissoo, Medicago minima, Melilotus indicus, Prosopis juliflora* and *Trifolium alexandrinum* were observed on -ive side of 2nd axes.

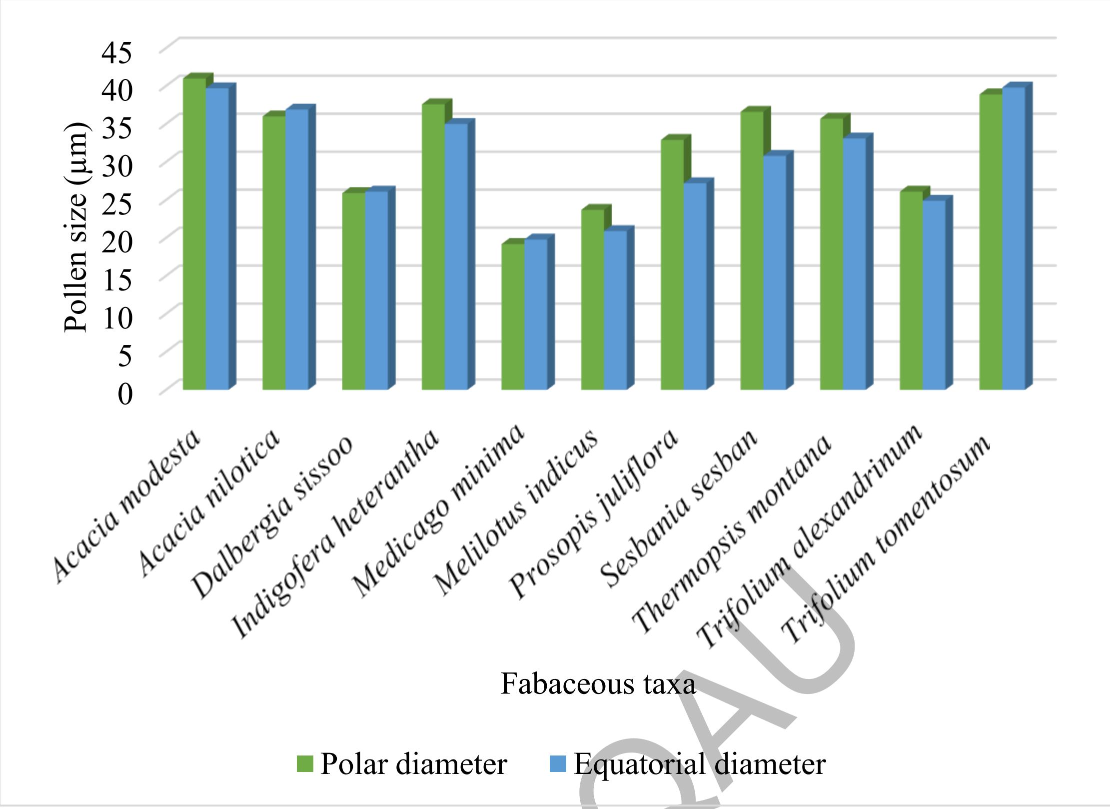

Figure 13. Variations in mean values of pollen diameter among Fabaceae bee flora

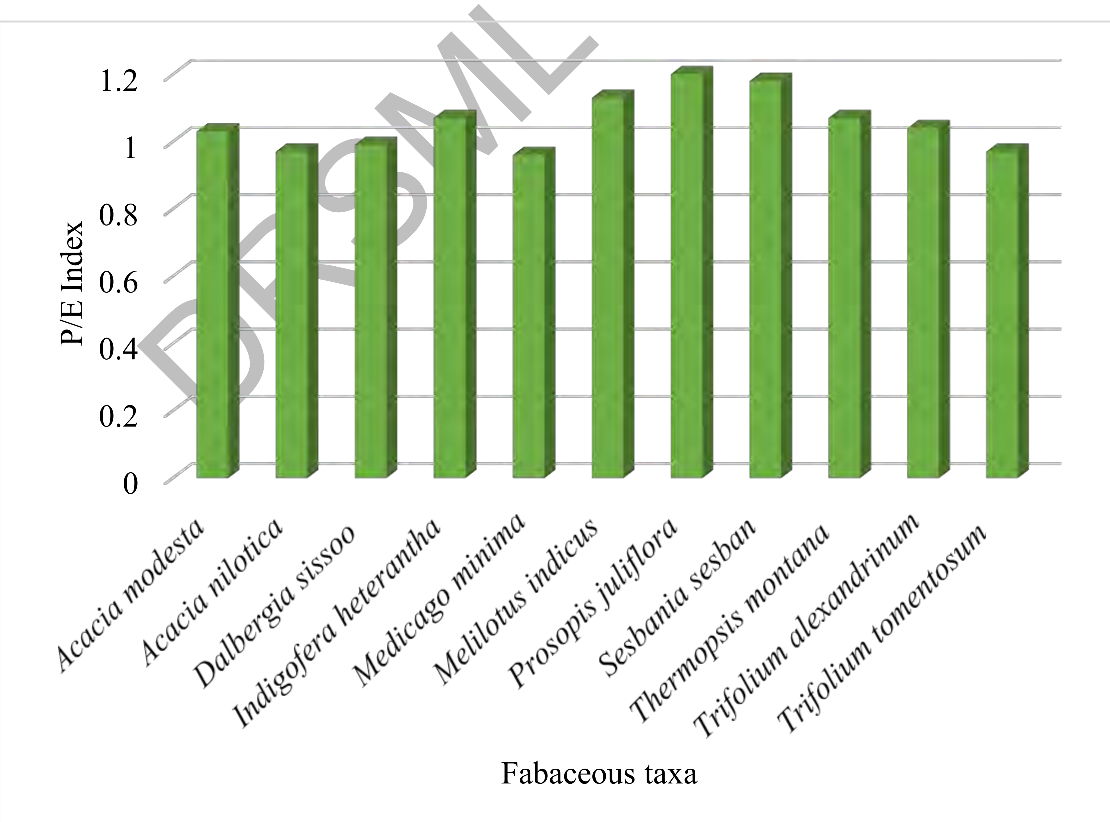

Figure 14. Variation in P/E ratio of Fabaceae honeybee floral plants

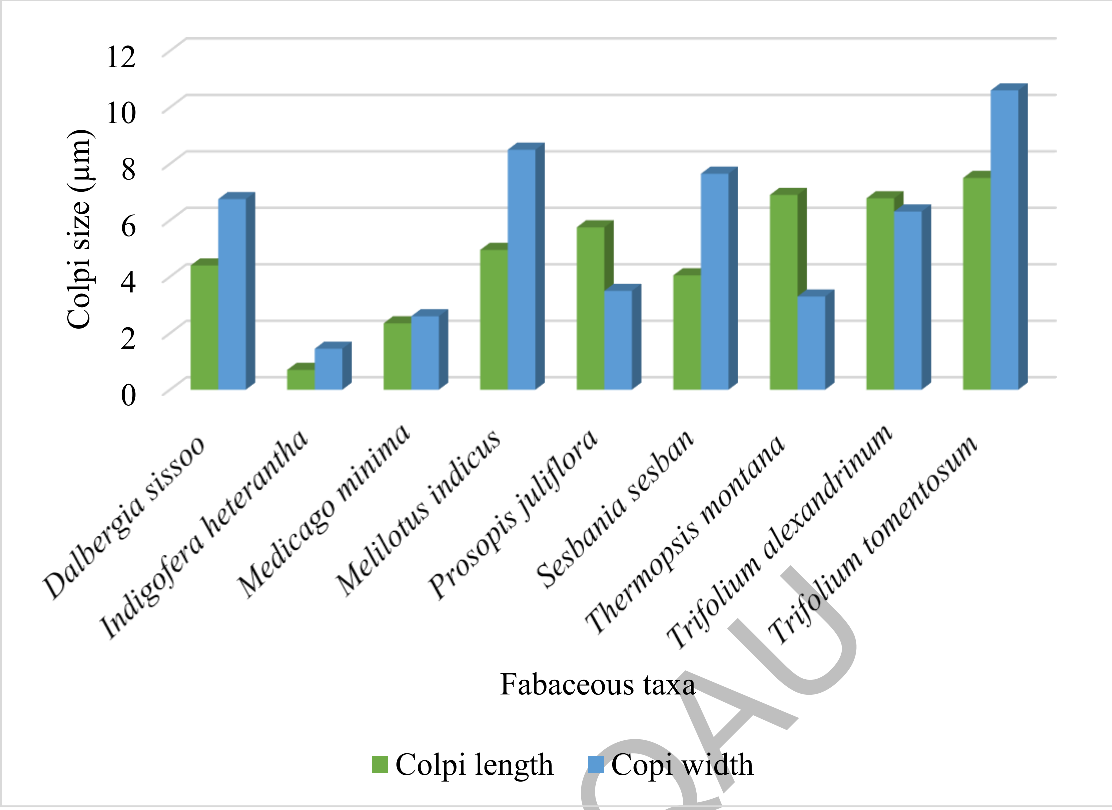

Figure 15. Average data variations of colpi length and width in Fabaceae bee flora

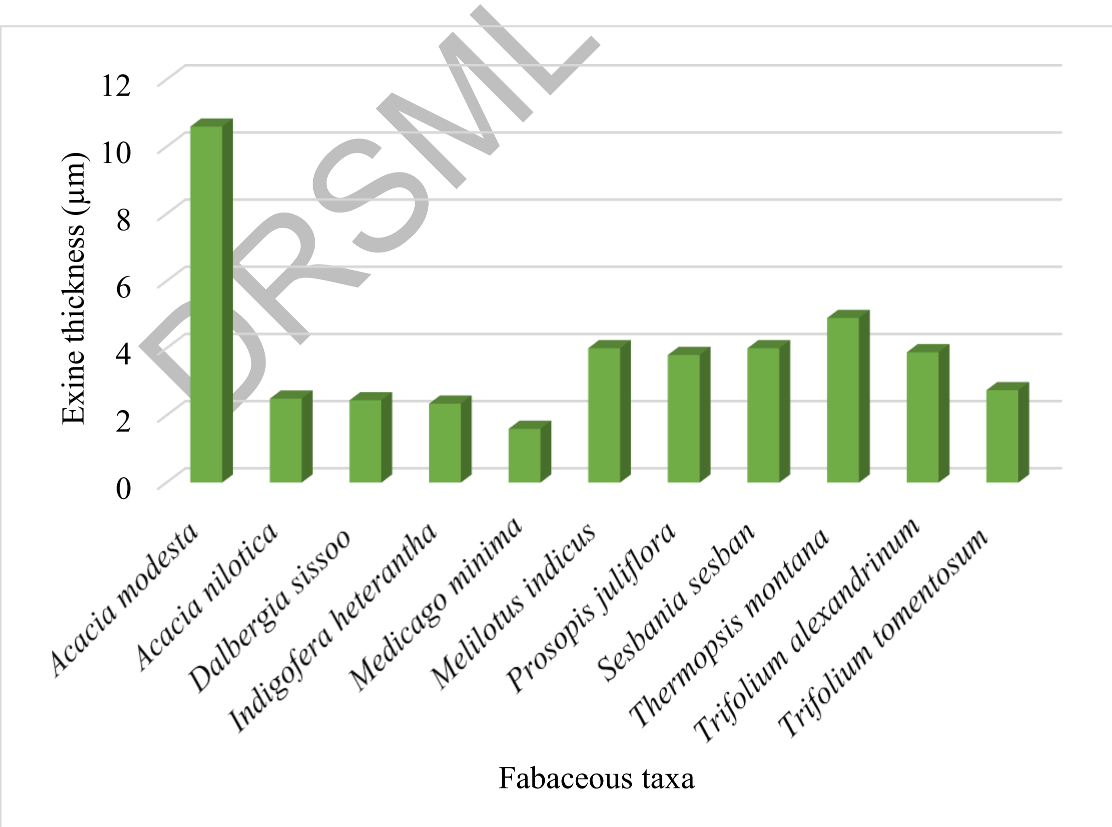

Figure 16. Mean exine thickness variations in Fabaceous bee floral species

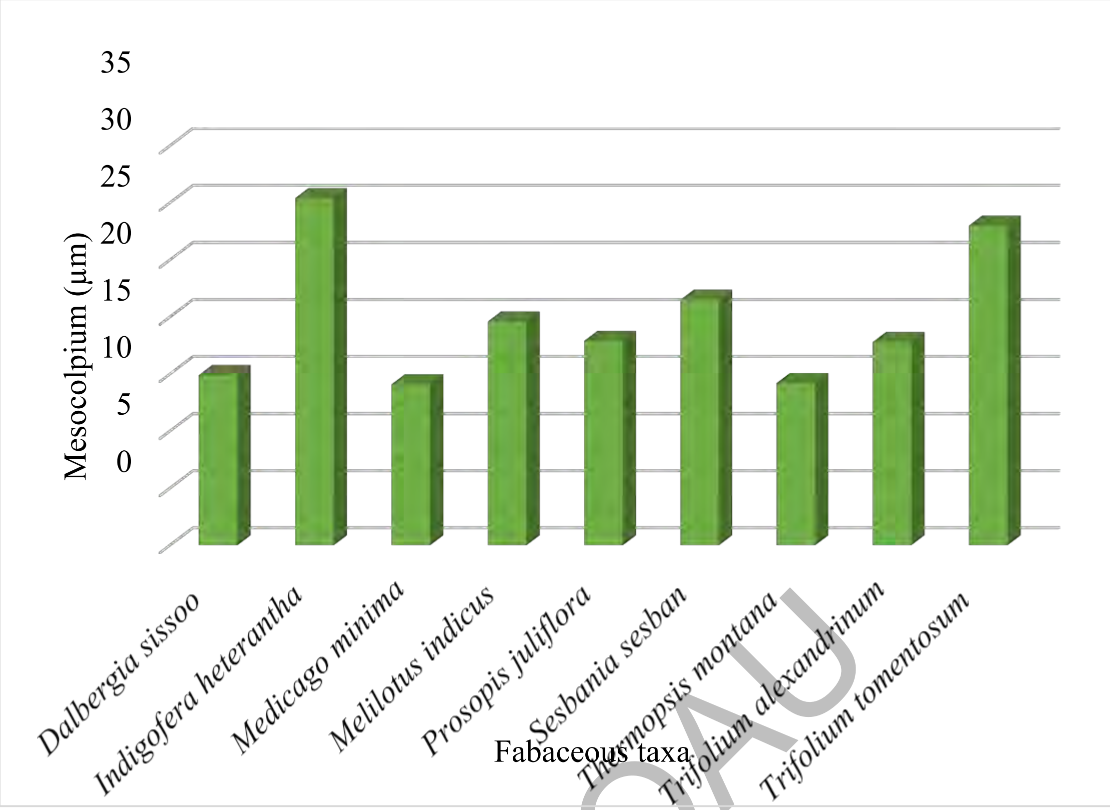

Figure 17. Graphical mean mesocolpium distance of Fabaceous bee floral species

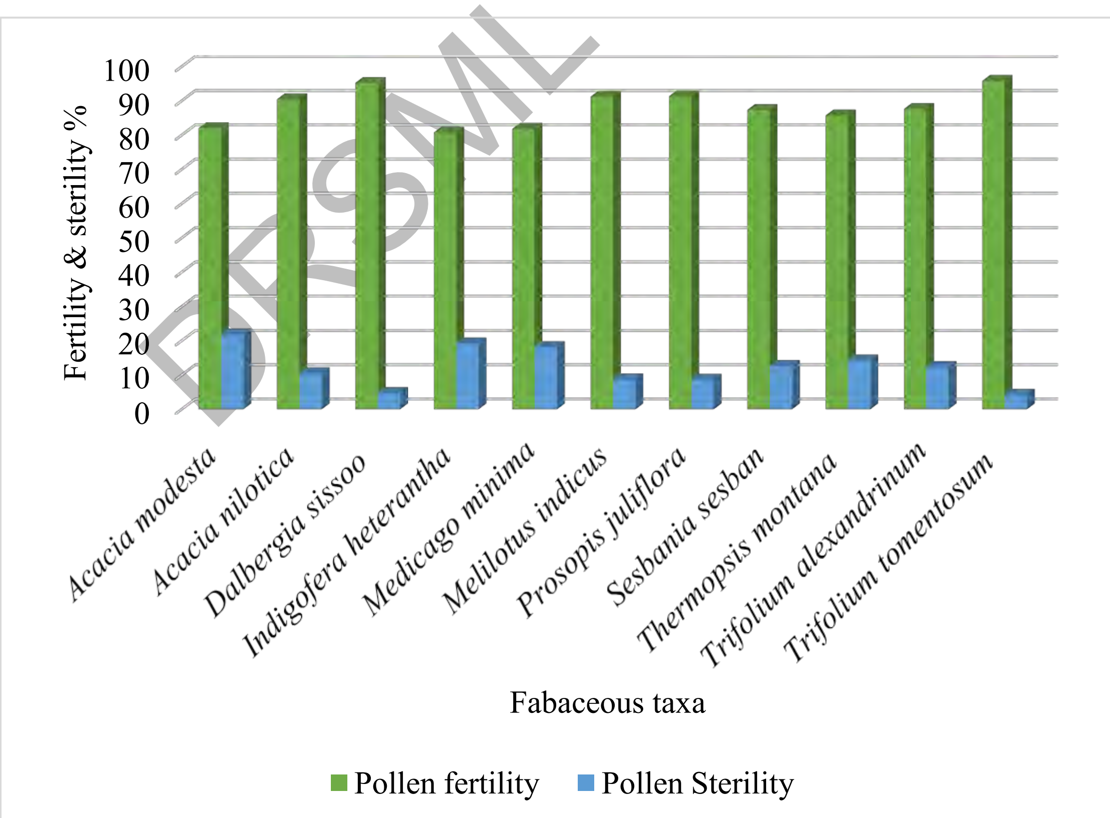

Figure 18. Graphical illustration of pollen fertility and sterility of Fabaceae bee flora

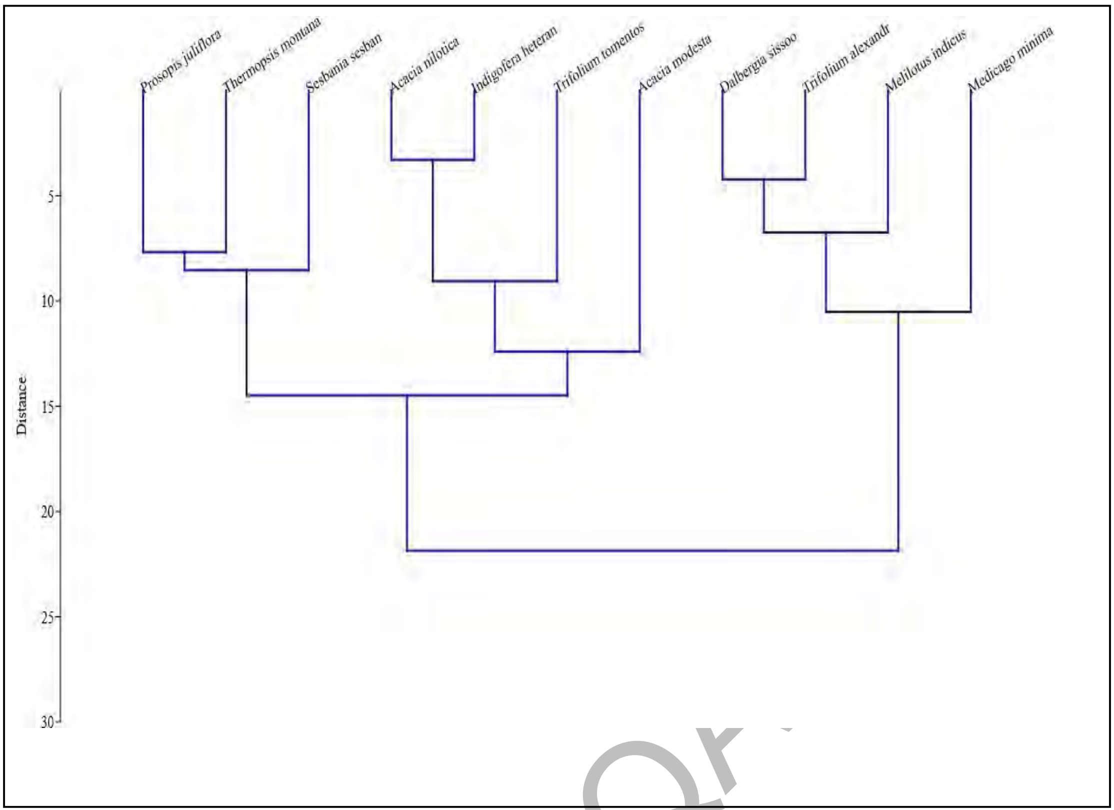

Figure 19. Cluster groupings dendrogram of Honeybee Fabaceous species

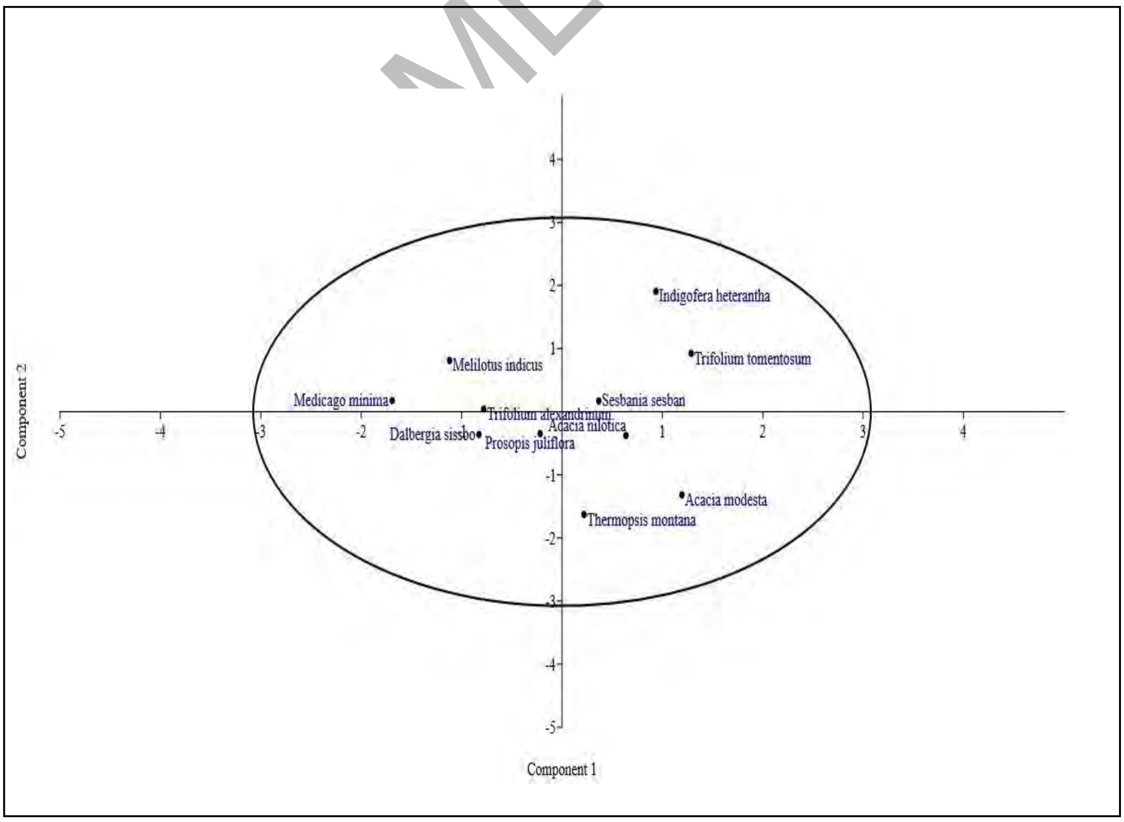

Figure 20. Principal component analysis (PCA) biplot of active variables

3.2.5 Amaranthaceous Honeybee flora

1. *Achyranthes aspera* L.

Synonym	*Achyranthes australis* R.Br.
Family	Amaranthaceae
Common Name	Devil horsewhip
Habit	Herb
Habitat	In crops, grasslands, forestry, disturbed areas and waste places.
Flowering period	August to November
Status	Wild
Distribution	Malaysia, Philippines, Pakistan, Sri Lanka, Thailand, Vietnam
Morphology	Herbs, perennial, 15-90 cm tall. Stem; quadrangular, pubescent, nodes inflated and opposite branches. Petiole; 0.6-1.2 cm, hairy; leaf blade broadly obovate, elliptic to oblong, 1.2-6 × 0.6-3.5 mm, papery, both surfaces hairy, base cuneate, margin entire, undulate, apex obtuse. Spikes; terminal, erect, reflexed, 12-34 cm; rachis angular, stout, densely hairy. Bracts; lanceolate, 2.5-6 mm, apex acuminate, bracteoles spiny, shiny, 2-4.2 mm, rigid, base 2 winged; wings; 1-2.5 mm, membranous and entire margin. Tepals; lanceolate, 3-5 mm. Stamens; 2-3.3 mm; pseudo-staminodes, truncate at apex, fimbriate and ciliate. Utricles; ovoid, 2-4.5 mm. Seeds; brown, ovoid, 1.4-2 mm (Plate 45a).
Melissopalynology	Pollen are monad, small sized and pantoporate. Round shape polar view and prolate spheroidal equatorial view. Aperture membrane ornamented and pantoaperturate type. Exine ornamentation micro-echinate perforate. Polar diameter 17.2(16.2-18.2)0.37 µm and equatorial diameter 16.05(13.2-18.0)0.78 µm. P/E ratio 1.07. Pores circular, numbers vary per pollen (19 to 26). Pore length 1.55(0.75-2.25)0.28 µm and pore width 2.05(1.50-2.75)0.21 µm. Exine thickness 4.35(4.00-4.75)0.12 µm. Pollen fertility 85.4% and sterility 14.5% (Plate 45b,c,d & e).

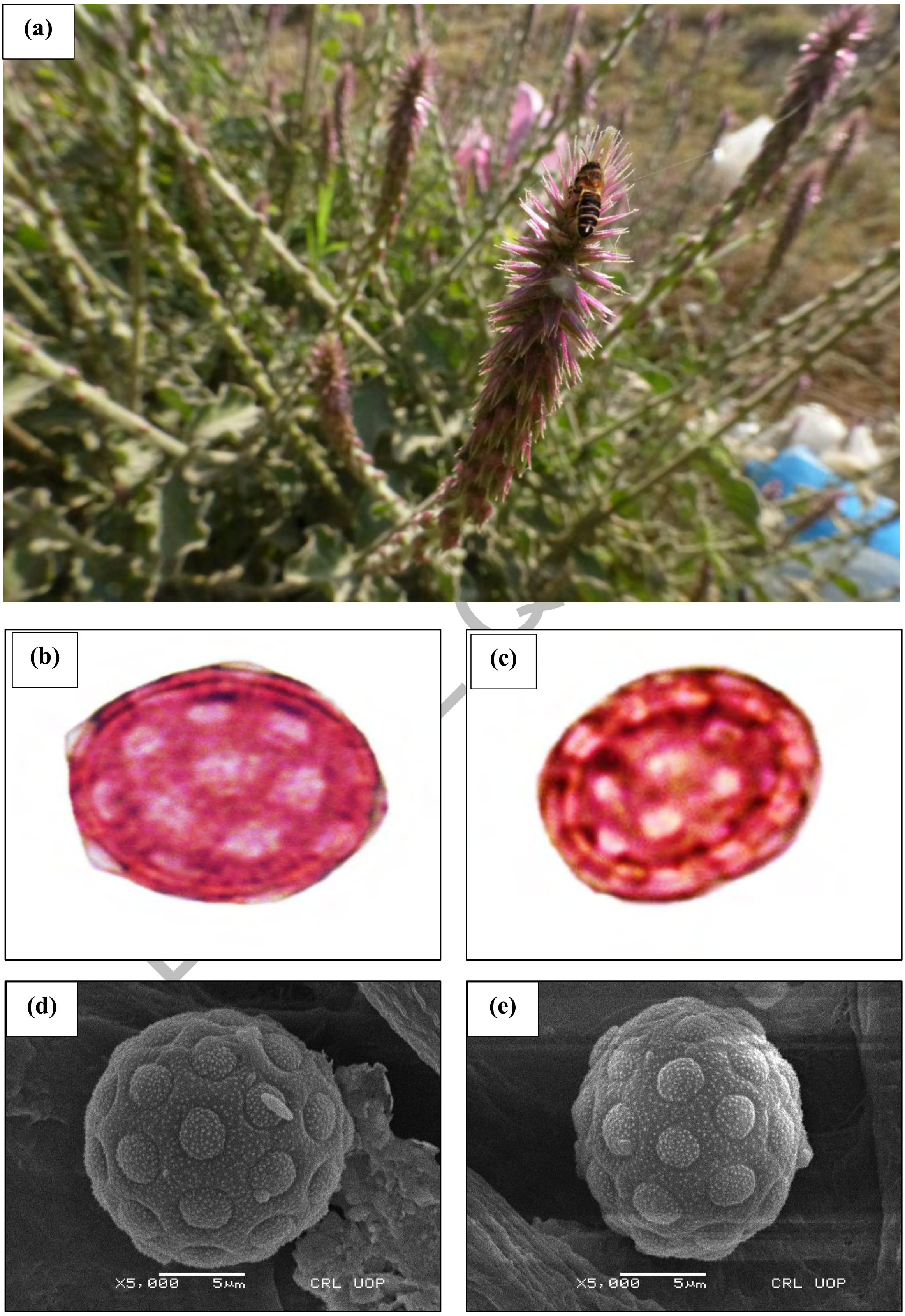

Plate 45: *Achyranthes aspera* L. (a) Floral part; (b & c) LM polar view and surface pattern of pollen along with spines, (d & e) SEM polar view and Exine sculpturing

2. *Amaranthus spinosus* L.

Synonym	*Galliaria spitosa* (L.) Nieuwl.
Family	Amaranthaceae
Common Name	Spiny amaranth
Habit	Annual Herb
Habitat	In cultivated fields, waste places, roadsides, garbage heaps
Flowering period	July to October
Status	Wild
Distribution	Peru, Guyana, Newzeland, Pakistan, Texas, France
Morphology	Annual herb, erect, much-branched and bushy, up to 2 m in height. Stem; stout, reddish, branched, angular, glabrous, multicellular and flocculent hairs. Leaves; glabrous, thinly pilose, long-petiolate 6.5-8 cm, lamina rhomboid-ovate, elliptic, lanceolate-oblong, 1.2-10 x 1.2-5 cm, subacute, fine, cuneate at the base; each leaf-axil bearing a pair of spines; 1.2-2 cm long. Flowers green, 4-14 mm diameter; Lower clusters; entirely female, spikes; upper flowers male spikers. Bracts and bracteoles; deltoid-ovate, pale-membranous, pale or reddish awn bracteoles shorter. Perianth; 5 segments, 1.3-3 mm, spathulate-oblong, obtuse, mucronulate, with greenish dorsal vitta, male flowers; broadly lanceolate, lanceolate-oblong, acuminate, only the midrib green. Stigmas 3, flexuose or reflexed, 0.8-1.6 mm (Plate 46a).
Melissopalynology	Pollen are monad, small sized and pantoporate. Round shape polar view and prolate-spheroidal equatorial view. Exine ornamentation micro-echinate perforate. Polar view diameter is 15.6(14.0-17.7) ±0.65 μm and equatorial diameter 14.9(13.7-17.2) ±0.69 μm respectively. P/E ratio 1.04. Pore length 0.80(0.25-50) ±0.24 μm and pore width 0.65(0.25-125) ±0.20 μm. Exine thickness 2.45(2.00-3.0) ±0.18 μm. Mesocolpium measurement 13.8(12.315.2) ±0.43 μm. Pollen fertility 95.1% and sterility 4.83% (Plate 46b,c,d & e).

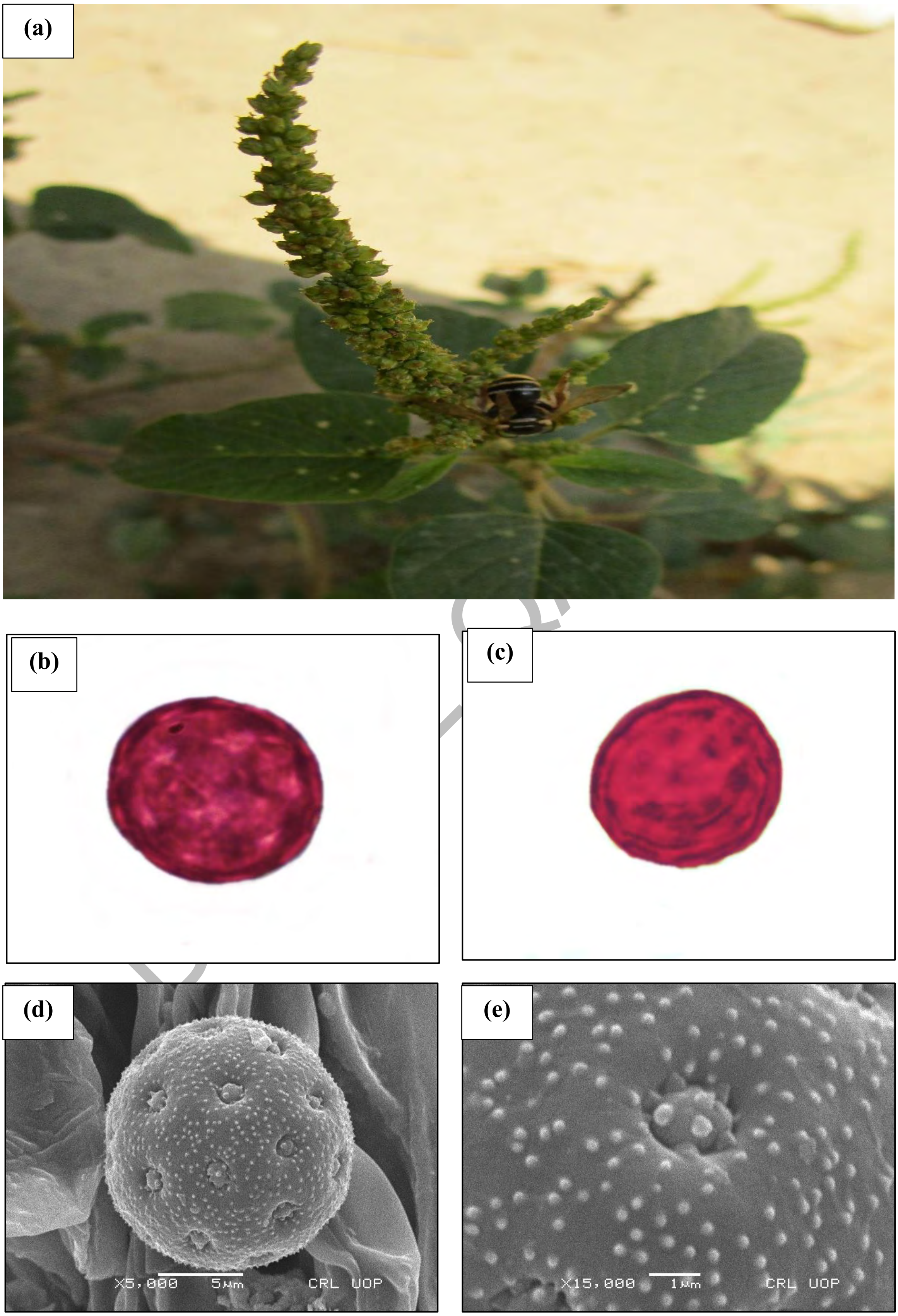

Plate 46: *Amaranthus spinosus* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Amaranthus viridis* L.

Synonym	*Albersia caudata* (Jacq.) Boiss.
Family	Amaranthaceae
Common Name	Slender Amaranth
Habit	Annual Herb
Habitat	Grows in heavy organic, sandy soils and muck soils
Flowering period	July to October
Status	Wild
Distribution	Kenya, Pakistan, Senegal, Cambodia, Iraq, Chile, Florida
Morphology	Slender, sparingly branched, angular, glabrous, hairy upwards, with longer floccose multicellular hairs. Leaves; glabrous, pilose on the lower surface, long petiolate, petioles; 7-10 cm long, lamina deltoid to ovate, 1.5-6 x 2-5 cm, margins obviously sinuate, shortly cuneate, sub-truncate, and obtuse and narrowly to clearly emarginated. Flowers; green, slender, axillary, paniculate spikes; 1.5-10 cm long and 3-7 mm wide, stem in dense axillary clusters to 5-8 mm in diameter. Bracts and bracteoles deltoid ovate to lanceolate ovate, whitish membranous bracteoles shorter than the perianth. Perianth segments 3, male flowers oblong to oval, 2.2 mm, mucronate; female flowers narrowly oblong to narrowly spathulate, finally 1.75-2.25 mm, minutely mucronate midrib green and often thickened above. Stigmas; 2-3, short, erect (Plate 47a).
Melissopalynology	Pollen are monad, small sized and pantoporate. Round shape polar view and prolate-spheroidal equatorial view. Exine sculpturing micro-echinate perforate. Polar view diameter 17.7(16.5-19.7)0.56 μm and equatorial view distance 15.6(14.0-17.7)0.60 μm. P/E ratio 1.13. Pore length 1.15(0.25-2.25)0.36 μm and pore width 0.70(0.25-2.0)0.32 μm. Exine thickness 2.9(2.25-3.50)0.21 μm. Pollen fertility 95.5% and sterility 4.47% (Plate 47b,c,d & e).

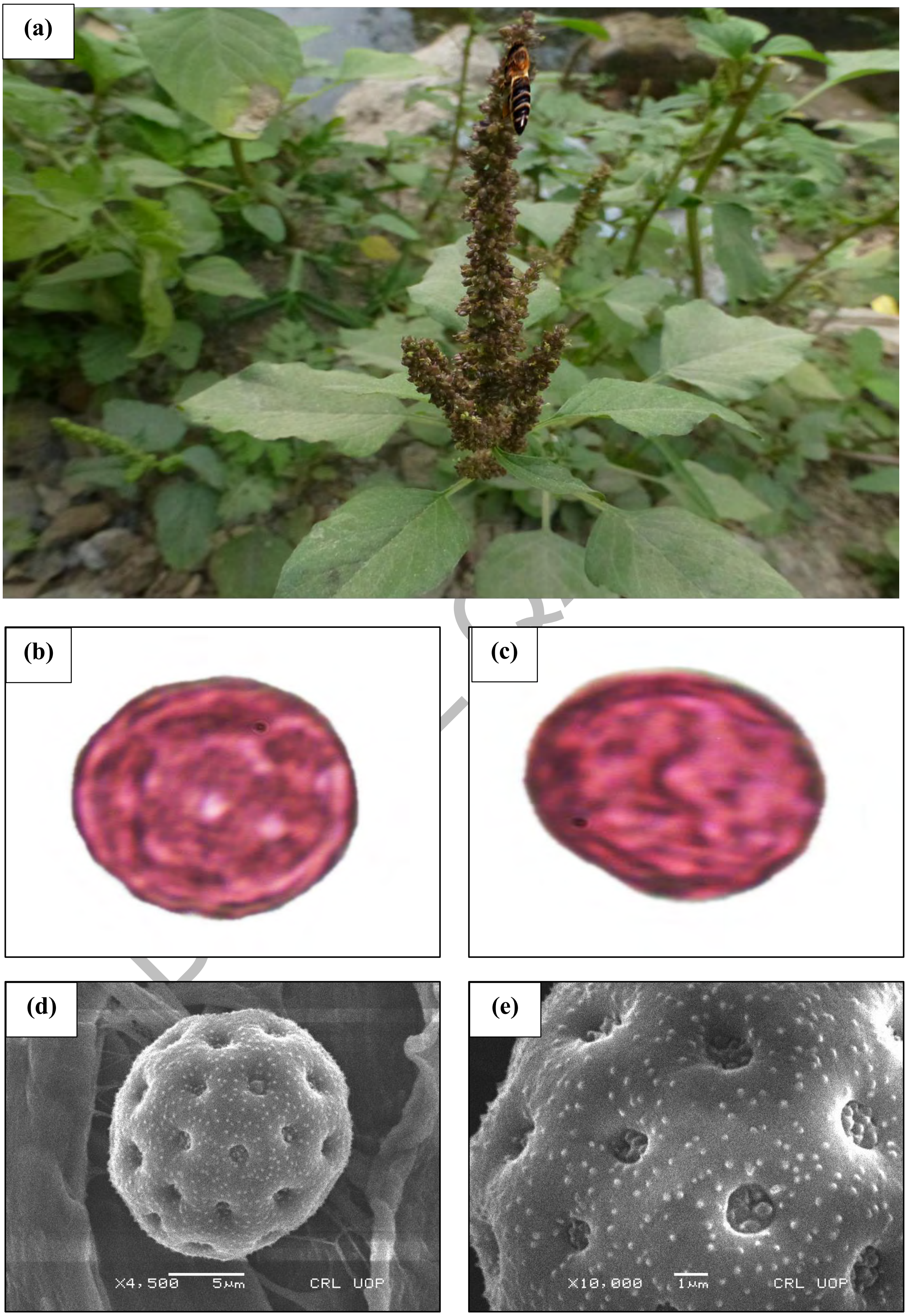

Plate 47: *Amaranthus viridis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Celosia argentea* L.

Synonym	*Celosia cristata* L.
Family	Amaranthaceae
Common Name	Silver cock's comb
Habit	Annual Herb
Habitat	In open locations, harvested fields, hill slopes and arable land
Flowering period	May to September
Status	Wild
Distribution	Ethiopia, Sudan, Hong Kong, Vietnam, Brazil, Pakistan
Morphology	Erect, 0.5-2.5 m, with ascending branches. Stem; strongly ridged, and sulcate, glabrous. Leaves; lanceolate, obtuse, mucronate, excurrent midrib, glabrous; 1.5-12x0.5-3 cm. Petiole; smaller, markedly reducing and sterile shoots. Inflorescence; dense spike, 2-18x1.4-2.5 cm, pink, conical, terminal stem and branches, sulcate peduncle. Bracts and bracteoles; lanceolate 2.5-6 mm, hyaline. Perianth segments; 5-12 mm, elliptic oblong, acute, mucronate, excurrent midrib, 2 to 4 lateral nerves and margins hyaline. Filaments; delicate, free part, sinuses rounded, anthers and filaments; ovary; 3-8 ovulate. Capsule; 2.2-4 mm and almost globular. Seeds; 1.3-1.4 mm, lenticular, black, shining, testa very finely reticulate (Plate 48a).
	Pollen are monad, iso diametric, isopolar, small sized and pantoporate. Circular polar view, prolate-spheroidal equatorial view. Aperture orientation sunken. Exine sculpture echinate, micro perforate. Polar diameter 23.1(18.75-30.25) ±1.98 µm and equatorial diameter 22.8(20.2-27.7) ±1.56 µm. P/E ratio 1.01. Pore length 0.90(0.25-1.75) ±0.26 µm, pore width 2.40(1.75-3.25) ±0.26 µm. Exine thickness 2.4(1.75-3.25) ±0.26 µm. Pollen fertility 82.4% and sterility 17.3% (Plate 48b,c,d & e).

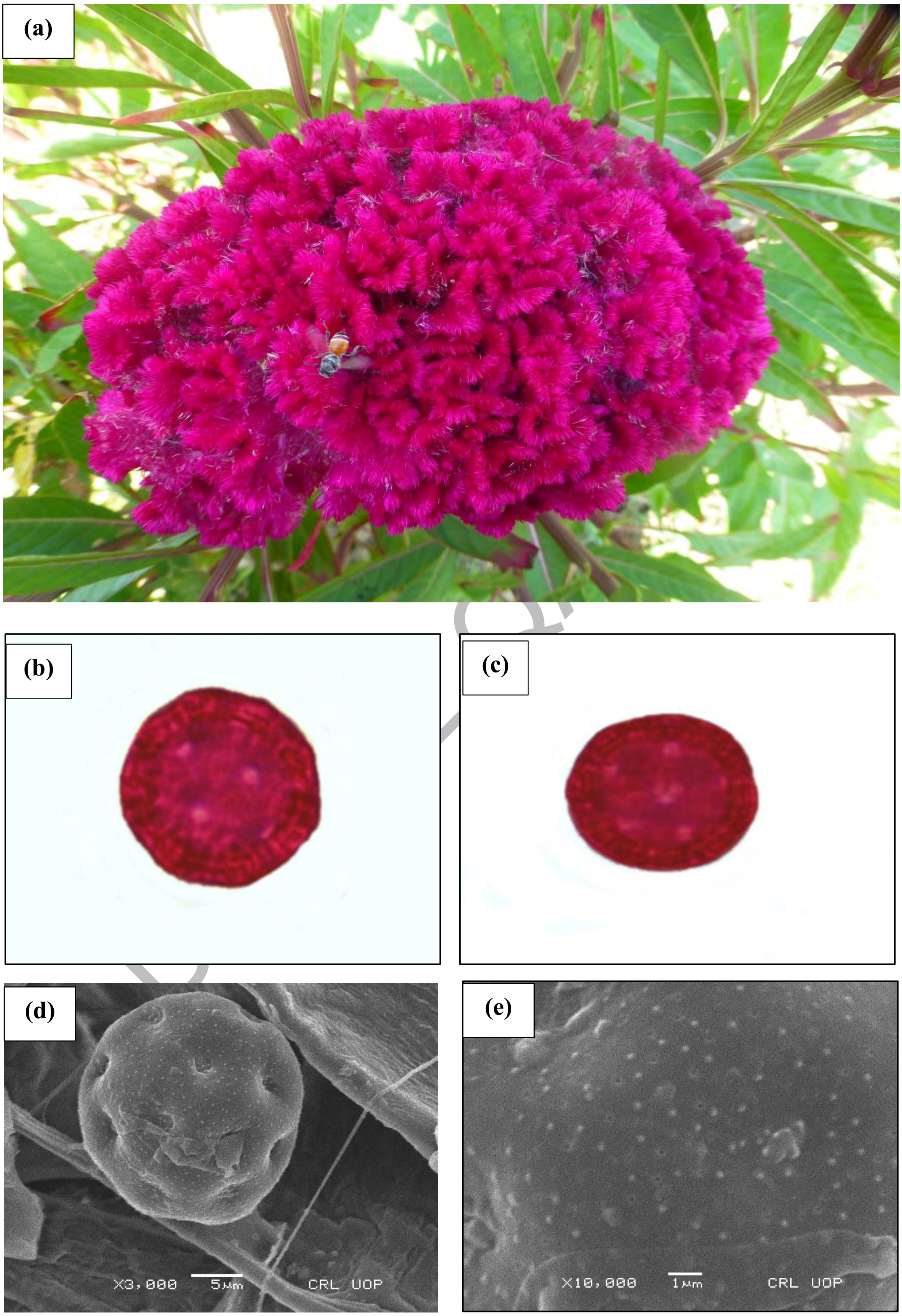

Plate 48: *Celosia argentea* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Chenopodium album* L.

Synonym	*Chenopodium album var. album*
Family	Amaranthaceae
Common Name	Goose foot
Habit	Herb
Habitat	found on wasteland, in pastures and strips of uncultivated land
Flowering period	February to April
Status	Wild
Distribution	Kenya, Bangladesh, South Korea, Pakistan, Germany
Morphology	Annual, 8-120 cm, erect, branched and grey farinose. Stem; yellowish green, sometimes reddish. Lower and medium leaves; petiolate, blade usually 3-8 cm, rhombic to ovate, clearly longer than broad, base broadly cuneate, margins irregularly serrate and somewhat trilobed, teeth acute, unequal in size; uppermost leaves lanceolate and entire. Inflorescence; a variable spiciform, cymosely branched panicle, mostly terminal. Perianth; segments 5, dorsally keeled. Pericarp thin and adherent. Seeds; horizontal, black, 1-1.8 mm in diameter, ovate, margin weakly acute, testa with faint radial striae and almost smooth (Plate 49a).
Melissopalynology	Grains are monad, small sized, and pantoporate. Circular polar view, and prolate-spheroidal equatorial view shape. Aperture orientation slightly sunken. Exine sculpturing micro-echinate perforate. Polar diameter 22.0(21.7-22.2) ± 0.11 μm and equatorial view distance 21.1(20.2-22) ±0.32 μm. P/E ratio calculated 1.04. Pore length 4.00(3.25-5.75) ±0.35 μm, pore width 1.95(0.75-2.7) ±0.41 μm. Exine thickness 3.15(2.75-3.50) ±0.28 μm. Pollen fertility 91.7% and sterility 8.23% (Plate 49b,c,d & e).

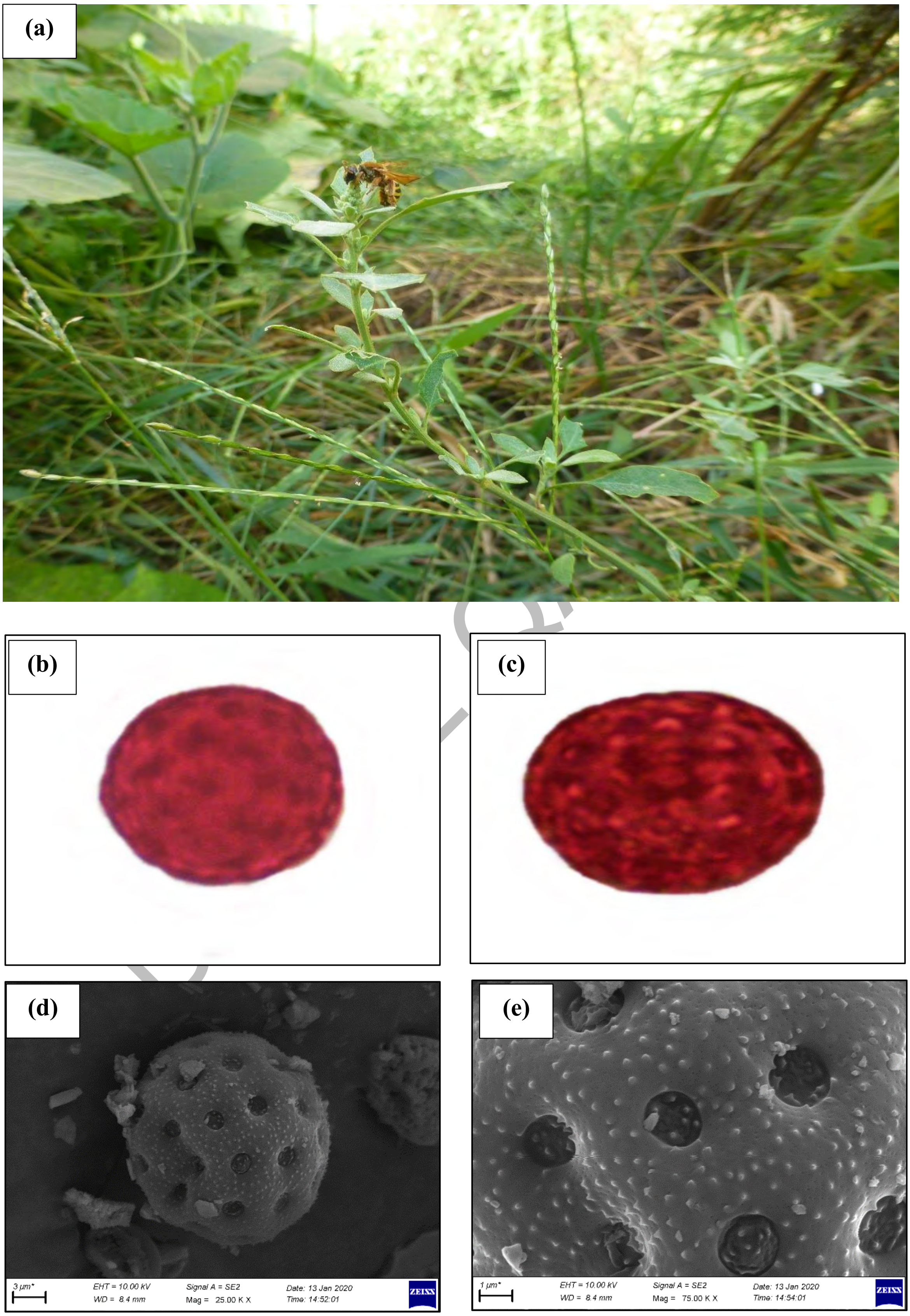

Plate 49: *Chenopodium album* L.(a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

38.*Digera muricata* (L.) Mart.

Synonym	*Achyranthes alternifolia* L.
Family	Amaranthaceae
Common Name	False amaranth
Habit	Annual Herb
Habitat	On disturbed and waste ground, but occurs in semi desert localities
Flowering period	April to August
Status	Wild
Distribution	Afghanistan, Yemen, India, Malaysia, Pakistan, Kenya
Morphology	Annual herb, 22-55 cm, simple, ascending branches, stem; glabrous, very sparingly pilose and pale ridges. Leaf-blade; narrowly linear, broadly ovate and rarely subrotund, 16-65 x 5-38 mm, glabrous, hairy, acute, acuminate apically, Flowers; glabrous, white tinged, pink to carmine, greenish white fruit, axillary racemes, long-pedunculate, up to 25 cm long, peduncles slender and inflorescence axis glabrous, sparingly spreading hairy, bracts persistent and deltoid lanceolate. Central flower; fertile, 2 membranous, navicular outer perianth, 2.5-5.2 mm long, oblong, acute, hyaline, style; 1.4-4.5 mm. Lateral flowers; appressed, 1-bracteolate, modified into accrescent, antler shaped scales. Fruit; sub-globose, compressed, 2.1-2.8 mm and bluntly keeled (Plate 50a).
Melissopalynology	Grains are monad, small to medium sized, and pantoporate. Circular polar view and equatorial view shape oblate-spheroidal. Pore orientation slightly bulged. Polar area small to moderately extensive. Exine sculpturing micro-echinate scabrate. Polar diameter 22.4(20.2-25.5) ±0.92 µm and equatorial view distance 25.0(22.2-28.0) ±1.08 µm. P/E ratio 0.89. Pore length 3.15(2.75-4.1) ±0.25 µm and pore width 2.5(1.85-3.3) ±0.62 µm. Exine thickness 3.50(3.00-4.00) ±0.17 µm. Pollen fertility 82.05% and sterility 17.9% (Plate 50b,c,d & e).

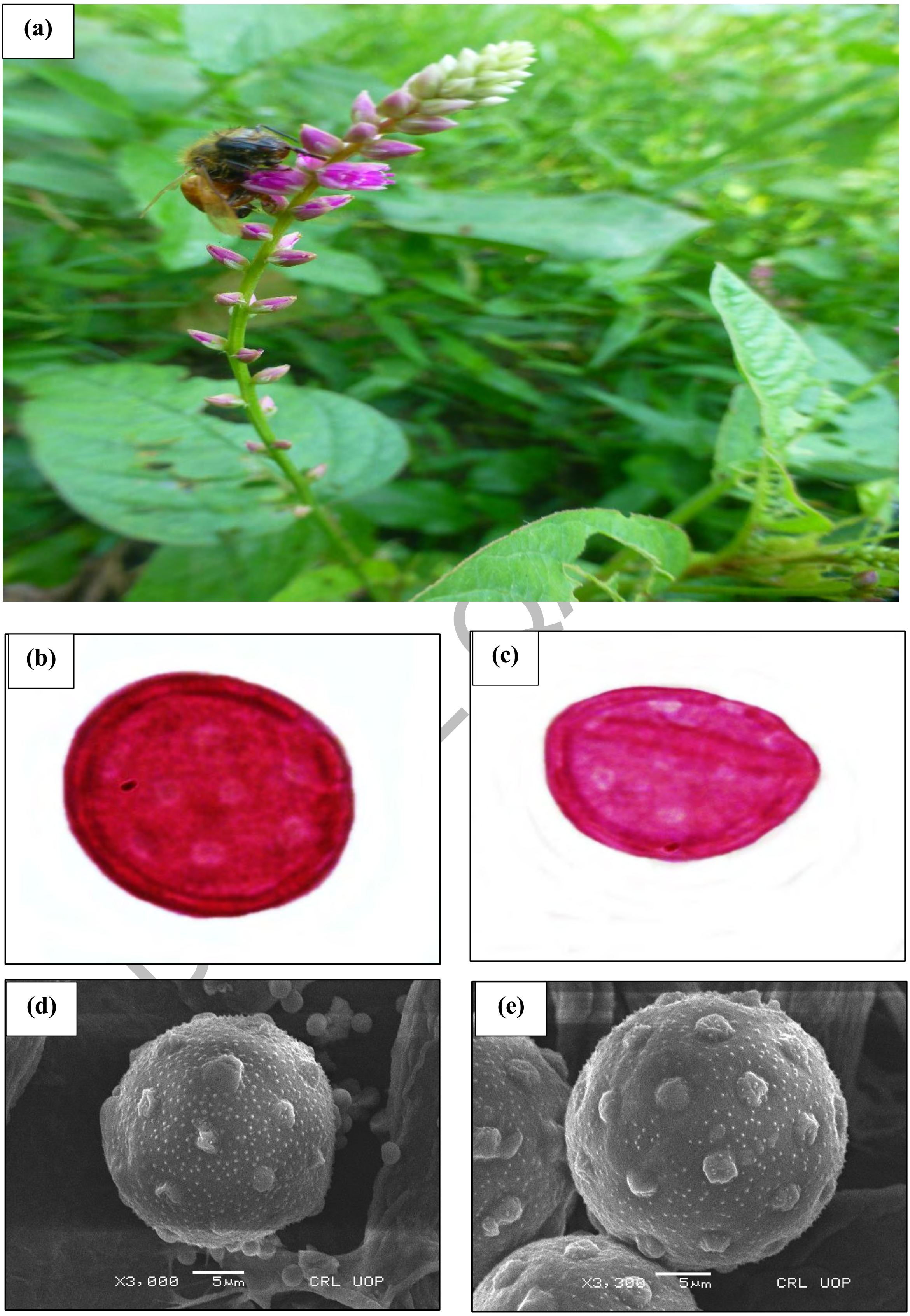

Plate 50: *Digera muricata* (L.) Mart. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.6 Melisso-palynomorphs description of Amaranthaceous taxa

The characterization of palynomorph was carried through LM and SEM techniques on six Amaranthaceous species, which were examined both quantitatively and qualitatively. Palynological diversity among Amaranthaceous species were revealed variations in pollen shape and size have been observed in most species ranging from small to medium.

Amaranthaceous species pollen had a wide diversity in shape, size, and sculpturing, indicating a wide range of diversity in micro-morphology which has implications for taxonomic validity. Pollen was monad, mostly small to medium size and pantoporate. Circular polar view and spheroidal, prolate-spheroidal and oblate-spheroidal equatorial view shapes. The polar and equatorial diameter of the largest grain was recorded in *Celosia cristata* (23.1±1.98 µm) and *Digera muricata* (25±1.08 µm) respectively. Whereas minimum polar diameter (15.6±0.65 µm) and equatorial diameter (14.9±0.69 µm) was calculated for *Amaranthus spinosus* (Figure 21). Highest P/E Index was measured in *Amaranthus viridis* (1.13), whereas lowest *Digera muricata* (0.89) as illustrated in Figure 22.

Pore length was noted maximum for Chenopodium album (4.00±0.35 µm), whereas the minimum for *Amaranthus spinosus* (0.80±0.24 µm). While largest colpi width measured for *Digera muricata* (2.5±0.62 µm), and shortest for *Ricinus communis* (0.4±0.32 µm) (Figure 23).

Exine surface observed through optical microscopy was scabrate type. Exine sculptured elements observed via scanning microscopy revealed diverse types: micro-echinate perforate, echinate and micro-echinate scabrate. Exine thickness was recorded highest *Achyranthes aspera* (4.35±0.12 µm), whereas lowest for *Celosia cristata* (2.4±0.26 µm) as shown in (Figure 24).

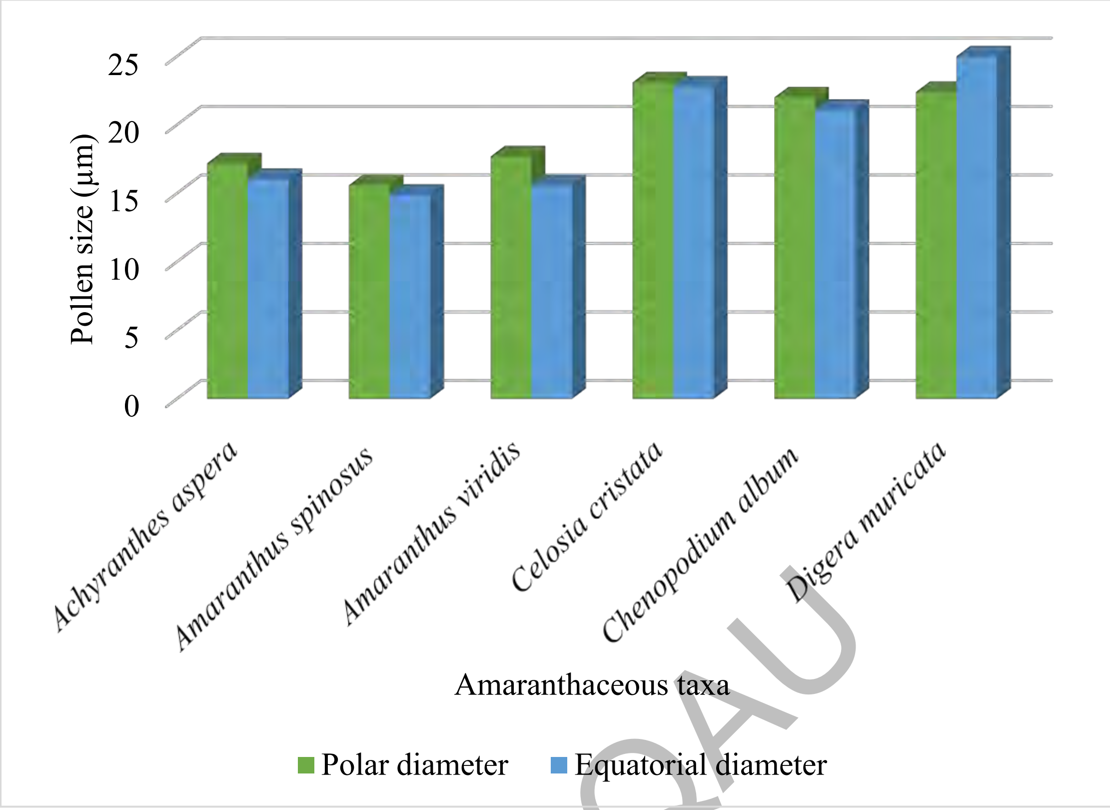

Figure 21. Mean values of pollen diameter among Amaranthaceous bee flora

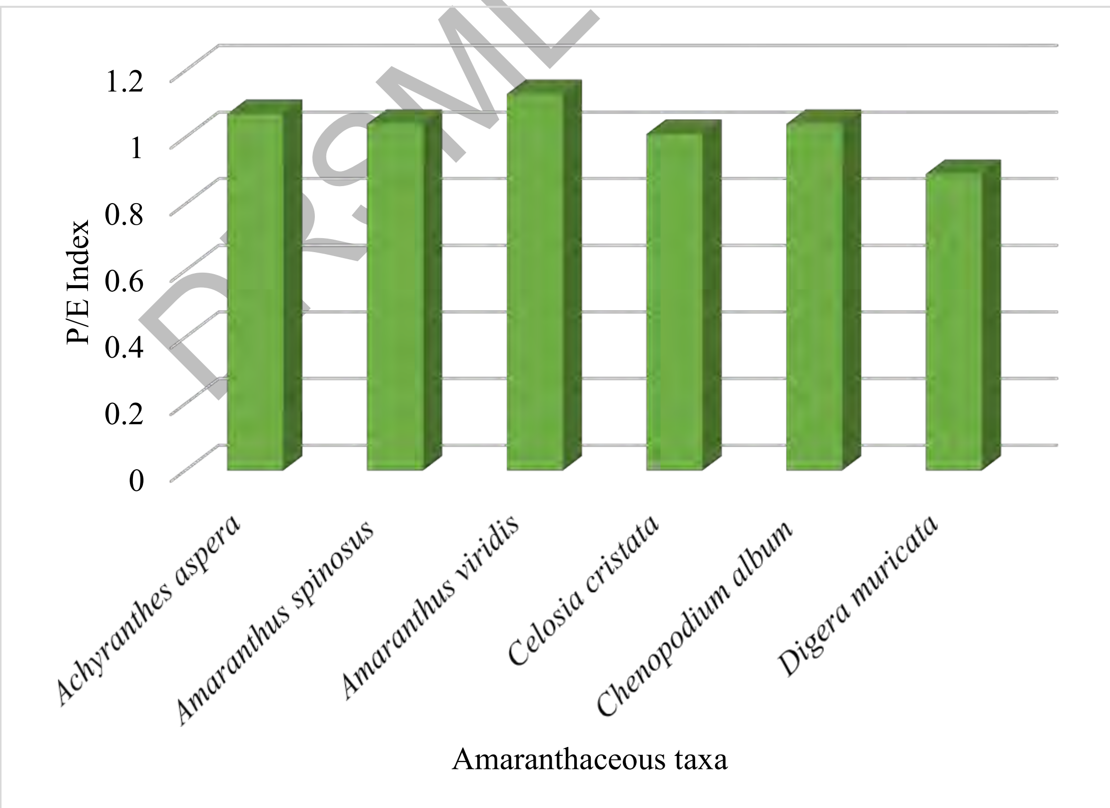

Figure 22. Variation in P/E ratio of Amathaceous honeybee floral plants

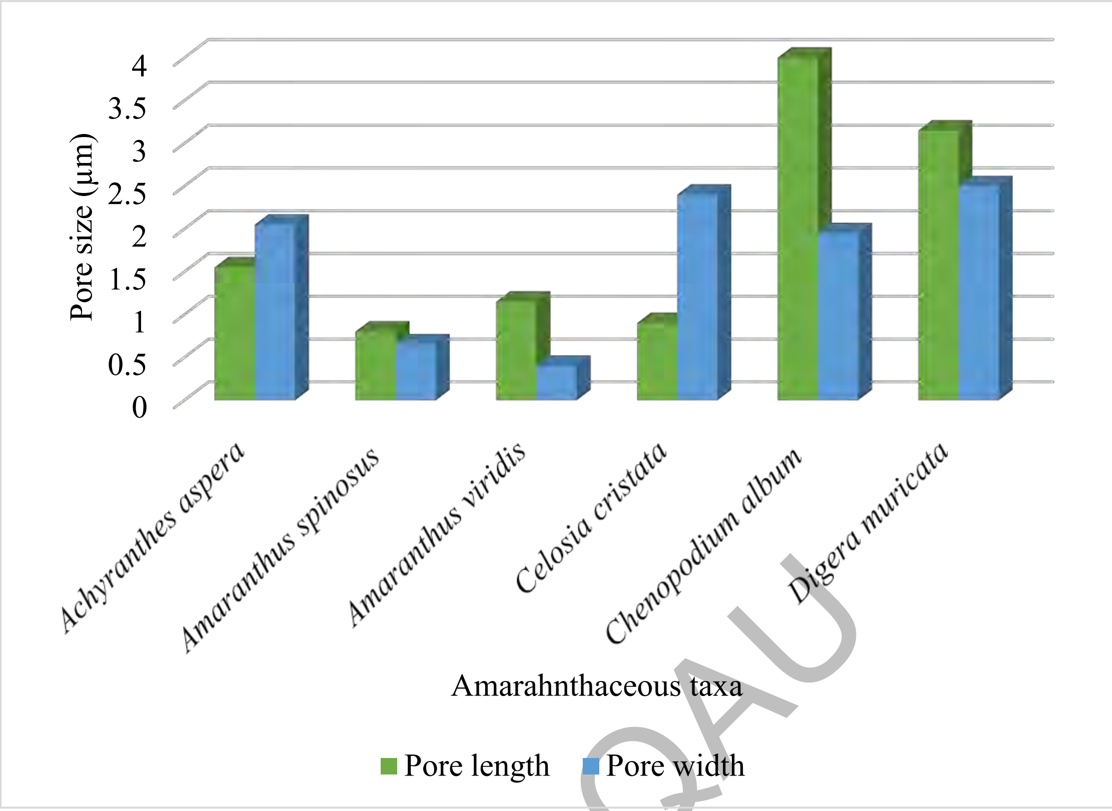

Figure 23. Average variations of pore length and width in Amaranthaceous bee flora

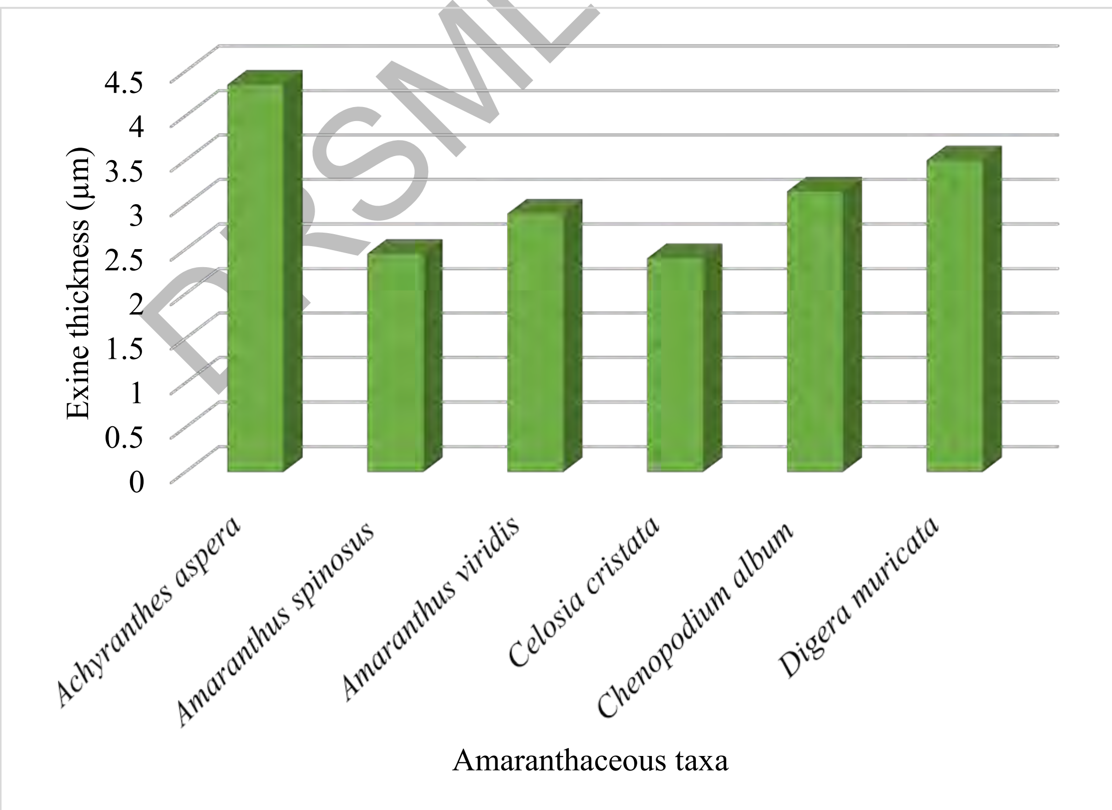

Figure 24. Mean exine thickness variations in Amaranthaceous bee floral species

3.2.7 Solanaceous Honeybee flora

1. *Datura stramonium* L.

Synonym	*Datura bernhardii* Lundstr.
Family	Solanaceae
Common Name	Jimsonweed
Habit	Annual Herb
Habitat	In temperate areas and found in almost any summer crop.
Flowering period	May to June
Status	Wild
Distribution	Chile, Brazil, Pakistan, New York, Cuba, Iran
Morphology	Plant; 45-110 cm tall, branched and pubescent, branches; purplish. Leaves; 6-18 x3-15 cm, ovate, sinuately dentate, minutely puberulose and cuneate Petiole; 2.2-6 cm long. Calyx; 3-6.5 cm long, tubular, dentate, puberulous and persistent. Lobes; 4.5-8 mm long, strongly reflexed and apiculate. Corolla; 6-11 cm long, white purplish suffused and limb up to 7 cm broad. 5 lobed, with the lobes, triangular and acuminate. Anthers; 4-5.5 mm long, narrow oblong and white. Capsule; erect, 2.75-4 cm long, ovoid, spiny, densely pubescent, splitting by 4 valves, spines up to 4.5 mm long. Seeds; 2.5-3 mm long, reniform, reticulate and black (Plate 51a).
Melissopalynology	Grains monad, large sized and tricolpate. Rounded polar view and equatorial view shape prolate-spheroidal. Aperture orientation brevicolpus. Exine ornamentation regulate striate. Polar diameter 44.4(36.2-55.2)±3.65 µm and equatorial view distance 43.6(37.7-50.7)±02.85 µm. P/E ratio 1.01. Colpi length 5.10(4.50-5.75)±0.23 µm and colpi width 4.70(3.75-5.50)±0.32 µm. Exine thickness 2.50(2.50-2.50)±0.01 µm. Mesocolpium measurement 37.9(33.7-42.7)±1.48 µm. Pollen fertility 80.8% and sterility 19.1% (Plate 51b,c,d & e).

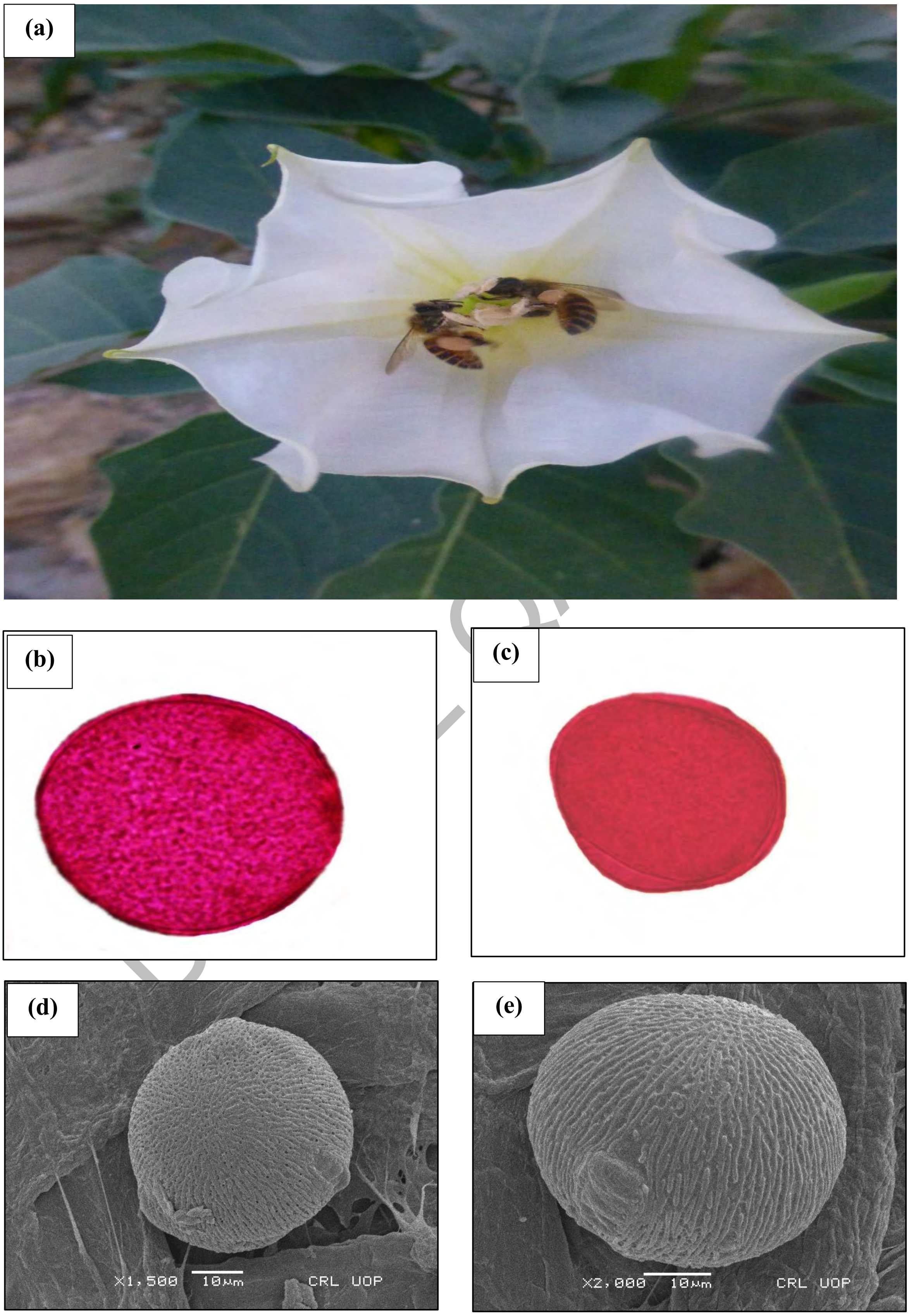

Plate 51: *Datura stramonium L.* (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Nicotiana tabacum* L.

Synonym	*Nicotiana alba* Mill.
Family	Solanaceae
Common Name	Tabacoo
Habit	Shrub
Habitat	Alongside plains, mountains, wetlands and Savannahs
Flowering period	April to June
Status	Wild
Distribution	China, Pakistan, Tunisia, Finland, Zimbabwe
Morphology	Plant 1-1.5 m tall and viscid pubescent. Leaves; cauline, 22-44 × 12-25 cm, oblong, broadly elliptic-ovate, cuneate and texture thin. Flowers pink, corymboid panicles. Calyx; 8-12 mm long, oblong, persistent in fruit; unequal lobes. Corolla: tube, 3.2-4.8 cm long, glandular-hairy, limb 11-15 cm broad, lobes acute, and apiculate. Anthers; 3.4 mm long, oblong, filaments 2.8 cm long. Capsule; 17-20 mm long, oblong-ovoid. Seeds; 0.6-1.2 mm long, angled, minutely ruminate and brown (Plate 52a).
Melissopalynology	Pollen grains are monad, medium sized, iso polar, and tricolporate. Circular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing regulate-perforate. Polar diameter 27.2(21.2-33.0)±2.12 µm and equatorial distance 25.0(19.7-28.7)±1.72 µm. P/E ratio 1.08. Colpi length 7.15(5.25-8.75)±0.64 µm, colpi width 9.15(8.00-10.5)±0.51 µm and mesocolpium distance 27.9(20.2-37.7)±3.18 µm. Exine thickness 3.35(1.25-5.25)±0.64 µm. Pollen fertility 73.5% and sterility 27.45% (Plate 52b,c,d & e).

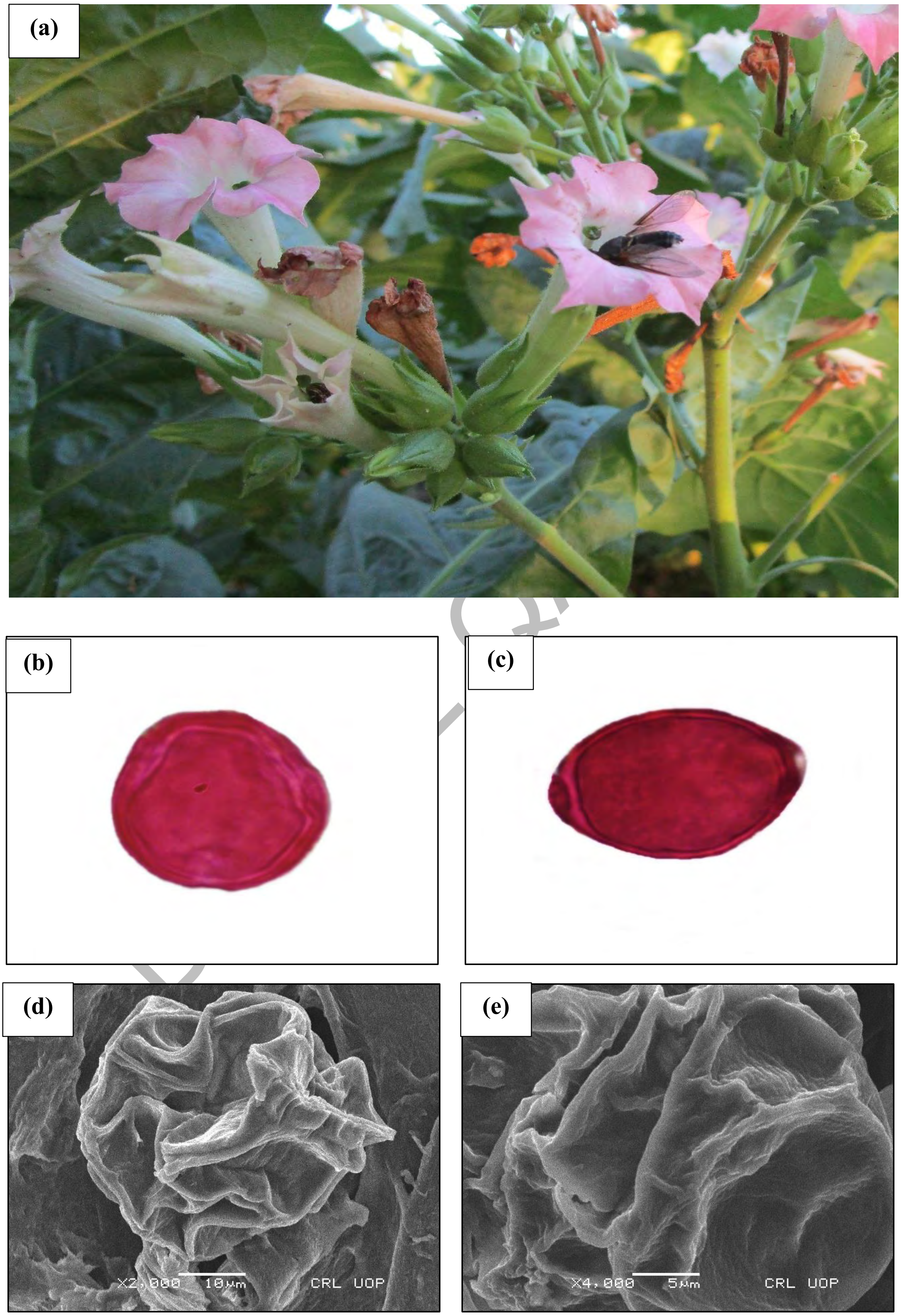

Plate 52: *Nicotiana tabacum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Physalis minima* L.

Synonym	*Physalis angulata var. angulata*
Family	Solanaceae
Common Name	Goose beery
Habit	Herb
Habitat	Along with bunds of fields, wastelands, around houses, roadsides
Flowering period	March to May
Status	Wild
Distribution	Australia, Europe, Pakistan, Afghanistan, Nepal
Morphology	Herbs annual. Roots fibrous. Stems prostrate or erect, pubescent with long many-celled hairs. Petiole 2-2.5 cm; leaf blade ovate or ovate-lanceolate, 2.5-3 × 1.5-2 cm, pubescent along veins, base cuneate, often oblique, margin entire, sinuate, or with a few coarse teeth, apex acuminate. Pedicel 6 mm, pubescent. Calyx campanulate, 3-5 mm, pubescent; lobes deltate, short acuminate, densely ciliate. Corolla yellow, 5 mm. Anthers light yellow, 1.5-2 mm. Fruiting pedicel less than 1 cm, pendulous. Fruiting calyx green, sub-globose or ovoid, 2-2.5 cm. Berry globose, 7 mm in diameter (Plate 53a).
Melissopalynology	Pollen grains are monad, iso-polar, small to medium sized, and tricolporate. Semi angular polar view and sub-prolate equatorial view shape. Exine sculpturing micro-echinate scabrate. Polar diameter 27.9(25.2-30.2)±0.96 µm and equatorial view distance 24.1(20.2-28.2)±1.34 µm. P/E ratio 1.15. Colpi length 4.90(4.50-5.50)±0.20 µm, colpi width 4.85(4.25-5.50)±0.23 µm, and mesocolpium distance 19.4(18.0-20.7)±0.54 µm. Exine thickness 35.50(5.75-5.25)±0.11 µm. Pollen fertility 90.9% and sterility 9.09% (Plate 53b,c,d & e).

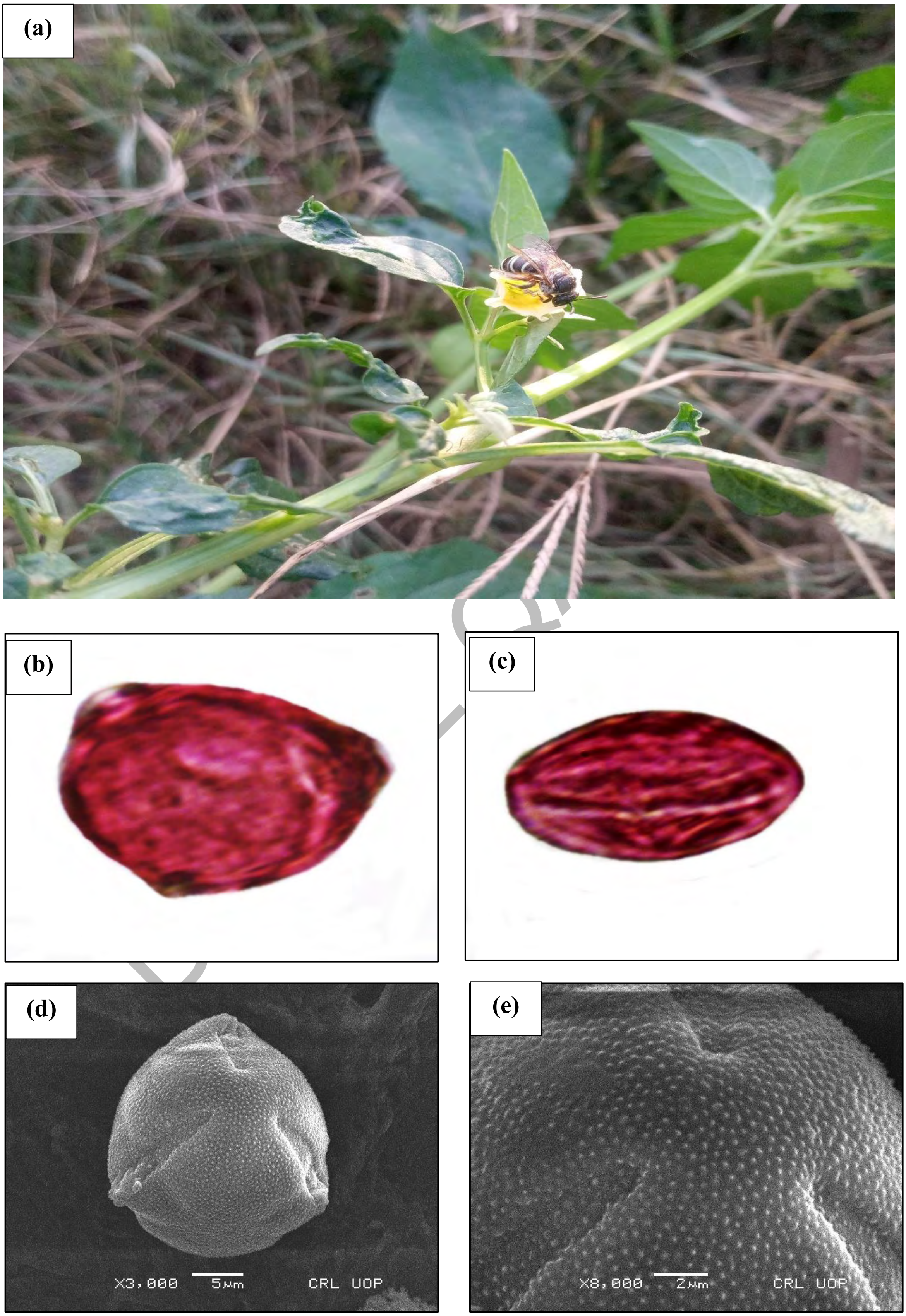

Plate 53: *Physalis minima* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Solanum melongena* L.

Synonym	*Solanum esculentum* Dunal
Family	Solanaceae
Common Name	Egg plant
Habit	Herb
Habitat	From mountain slopes high above treeline
Flowering period	August to October
Status	Cultivated
Distribution	India, Pakistan, Spain, Italy, Romania
Morphology	Perennial, suffruticose, annual, up to 70-85 cm tall. Stem; branches stellate, hairy, with few prickles. Leaves; 4-22 x 2-13 cm, ovate to rhomboid, sinuate to lobed. Flowers; solitary, up to 3-5 in number, pale violet, pedicel; recurved, up to 3.5 cm in fruit. Calyx; campanulate, 12-19 mm long, sparsely prickled, enlarging in fruit. Corolla; limb 2-7 cm broad; lobes triangular, stellate tomentose to the outside. Anthers; 4-8 mm long. Filaments; 2-4 mm long. Berry; ovoid to sub-globose or elongated, 7-17 cm long, usually dark purple. Seeds; sub-reniform, 2.3 mm long, minutely rugose (Plate 54a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Circular polar view and sub-prolate equatorial view shape. Exine sculpturing scabrate-granulate and mesocolpium densely Verrucate and gemmate surface. Polar diameter 44.4(39.2-47.7)±1.52 μm and equatorial view distance 37.1(28.0-41.7)±2.40 μm. P/E ratio 1.19. Colpi length 6.40(4.75-8.00)±0.65 μm, colpi width 3.70(2.75-23.7)±1.67 μm and mesocolpium distance 18.6(13.7-23.7)±1.67 μm. Exine thickness 2.65(2.00-3.75)±0.35 μm. Pollen fertility 92.3% and sterility 7.69% (Plate 54b,c,d & e).

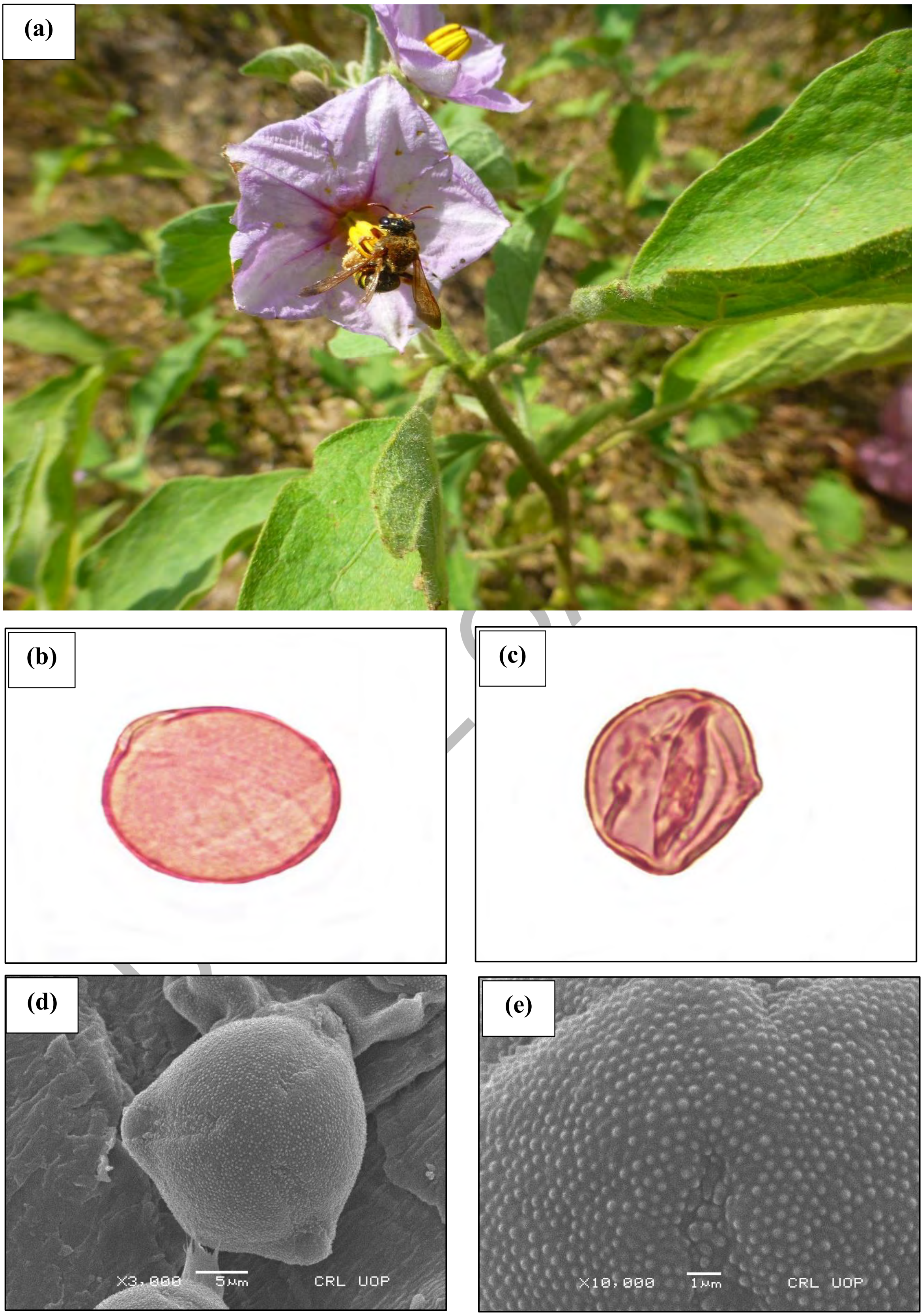

Plate 54: *Solanum melongena* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Solanum nigrum* L.

Synonym	*Solanum americanum* Mill.
Family	Solanaceae
Common Name	Black nightshade
Habit	Herb
Habitat	In cultivated land, roadsides, wasteland and uncompetitive pastures
Flowering period	July to November
Status	Wild
Distribution	Morocco, Iran, Belgium, Pakistan, Hungary, Mexico
Morphology	Annual, 12-65 cm tall, erectt base, branches and shoots sub-glabrous, pubescent to glandular villous, hairs appressed. Leaves; 2-13 x 2-5 cm, sinuate, irregularly dentate, glabrous pubescent or glandular. Lamina decurrent. Petiole; 6-42 mm long, appressed pubescent. Peduncle; 14-29 min long, shorter than the pedicel length. Calyx; lobes 1-1.7 mm long, glabrous to pubescent. Corolla; lobes triangular acute, 3-9 mm long; anthers yellow. Filaments; shorter than anthers and pilose. Style; included and pubescent at the base. Stigma; capitate. Ovary; glabrous. Berry; globose to sub-ovoid, 3.5-9 mm broad, black. Seeds; discoid, minutely reticulate-foveolate (Plate 55a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Lobate circular view and spheroidal equatorial view shape. Aperture membrane ornamented. Exine sculpturing micro-echinate scabrate. Polar diameter 28.8(25.7-32.7)±1.24 µm and equatorial view distance 28.7(26.0-31.0)±0.85 µm. P/E ratio 1.00. Colpi length 6.90(5.75-7.75)±0.33 µm, colpi width 10.1(9.50-10.7)±0.23 µm and mesocolpium distance 22.2(18.7-25.7)±1.15 µm. Exine thickness 3.05(2.25-3.75)±0.24 µm. Pollen fertility 88.4% and sterility 11.5% (Plate 55b,c,d & e).

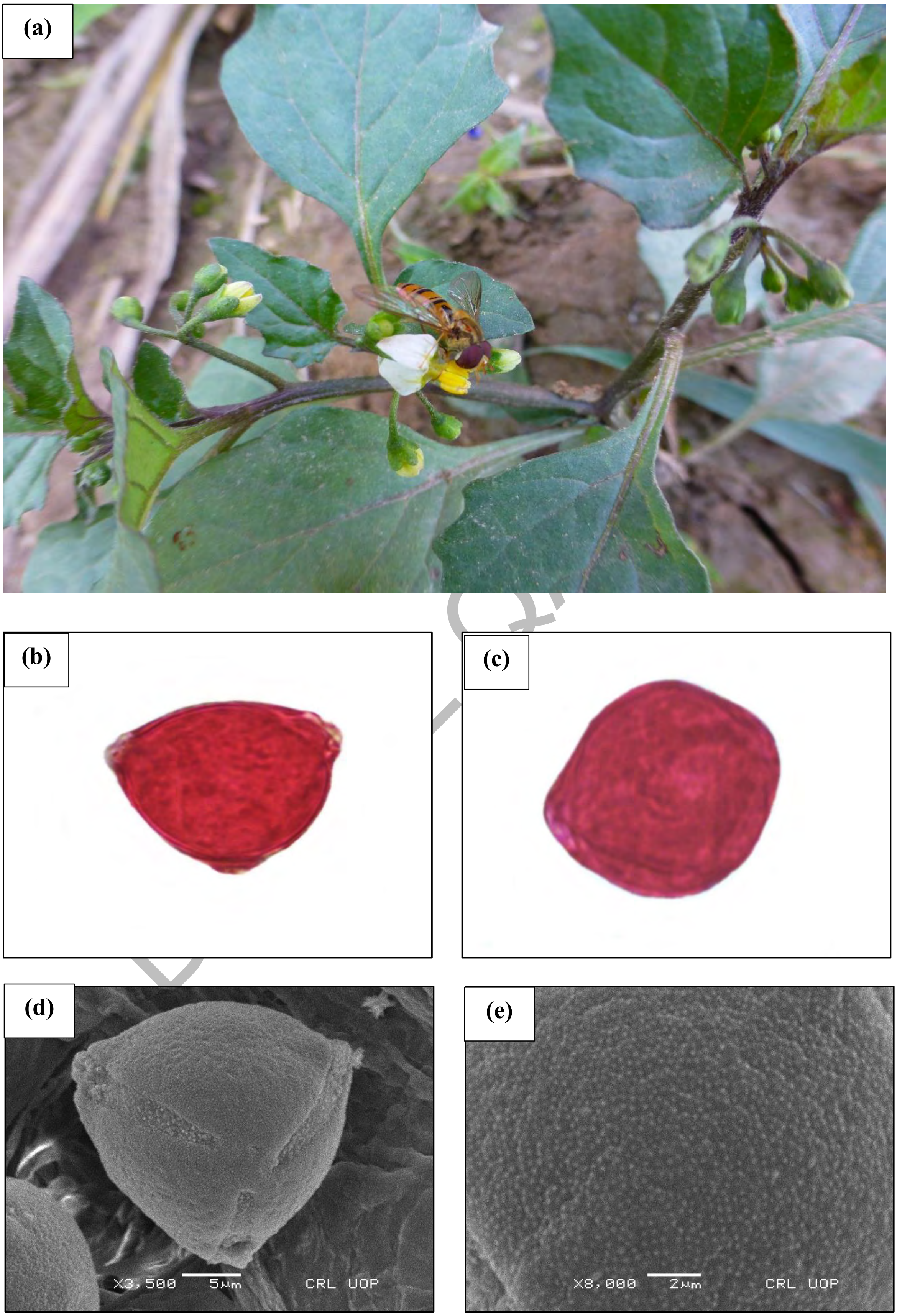

Plate 55: *Solanum nigrum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

6. *Solanum surattense* Burm. f.

Synonym	*Solanum jacquini* Willd.
Family	Solanaceae
Common Name	Wild eggplant
Habit	Annual Herb
Habitat	In dry situation abundant by road sides and wastelands
Flowering period	March to August
Status	Wild
Distribution	Iran, Afghanistan, North Africa, China, Burma, Pakistan, Australia.
Morphology	Prostrate, diffuse prickly herb; prickles up to 15 mm long, yellow. Stem and branches glabrous to stellate pubescent. Leaves 30-80 x 25-50 mm, elliptic-oblong, sinuate to deeply lobed, dark-green above; lobes unequal, obtuse or acute, often toothed or lobulate. Flowers 2-4, purple; on peduncle cymes. Peduncle 10-20 mm long. Calyx lobes 5 mm long, acute, prickly. Corolla limb 2-2.8 cm broad; lobes 10-12 mm long, ovate-triangular. Anthers 7.5 mm long, elongated. Berry globose, 15-20 mm broad. Seeds discoid, smooth to faintly reticulate (Plate 56a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Triangular polar view and oblate-spheroidal equatorial view shape. Colpi longer in length and broad at base. Exine sculpturing Psilate. Polar diameter 23.6(21.2-25.5)±0.79 µm and equatorial view distance 24.7(20.5-27.7)±1.18 µm. P/E ratio 0.95. Colpi length 4.85(3.75-5.25)±0.29 µm, colpi width 6.45(5.25-7.75)±0.47 µm and mesocolpium distance 19.1(17.2-21.2)±0.79 µm. Exine thickness 2.10(1.50-2.75)±0.21 µm. Pollen fertility 88.03% and sterility 11.9% (Plate 56b,c,d & e).

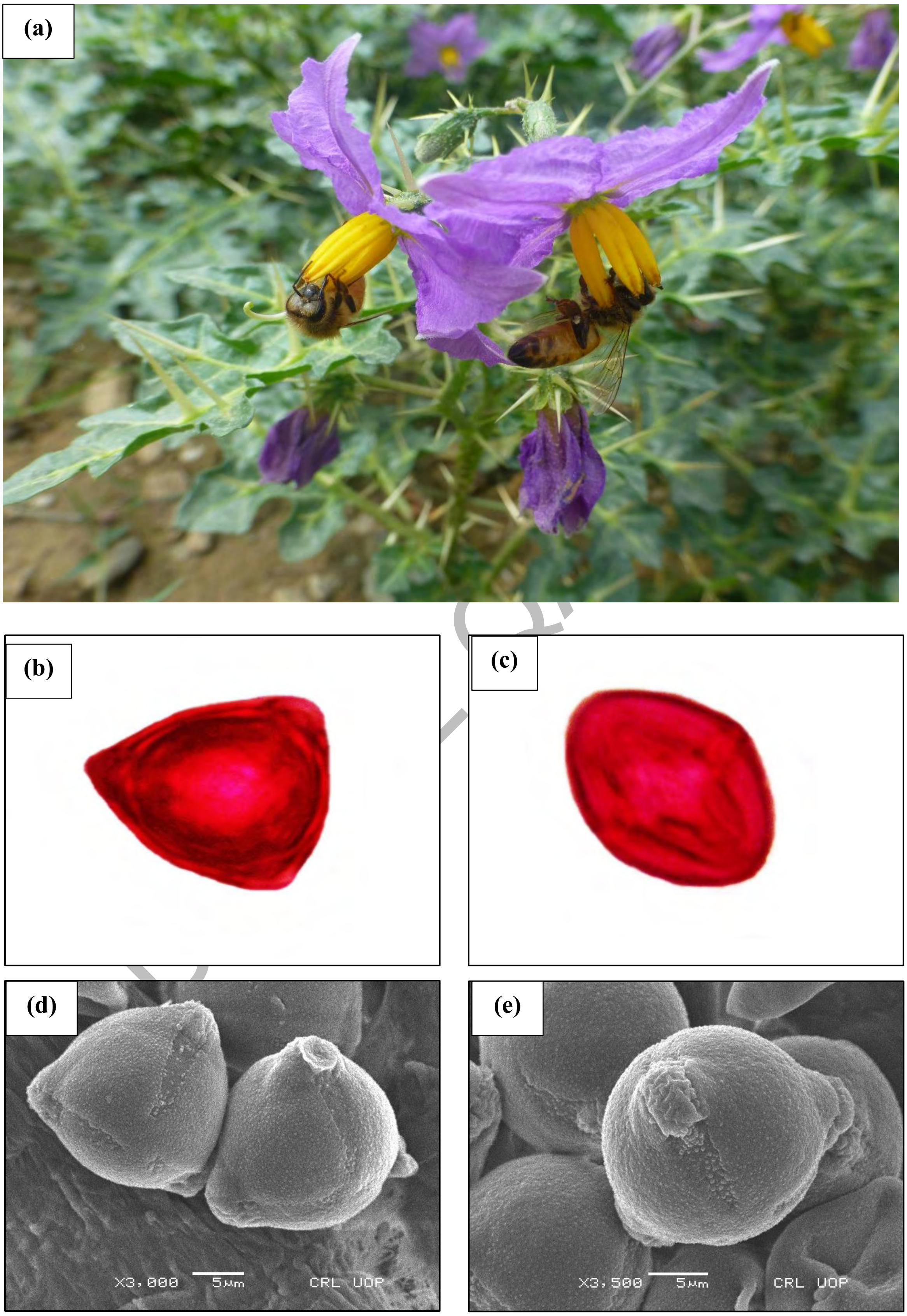

Plate 56: *Solanum surattense* Burm. f. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.8 Melisso-palynomorphs description of Solanaceous taxa

Micro-morphological features both qualitative and quantitative among Solanaceous honeybee floral species were examined using light and scanning microscopy. Grains were monad, triangular to oblate and tricolporate. Shape in equatorial view was prolate-spheroidal, sub-prolate, spherical and oblate-spheroidal. Aperture orientation varies from deeply sunken to bulged.

Solanaceous species were prolate-spheroidal (*Datura stramonium* and *Nicotiana tabacum*), sub-prolate, (*Physalis minima* and *Solanum melongena*), Oblate-spheroidal (*Solanum surattense*), and Spheroidal (*Solanum nigrum*). As far size of pollen is concerned maximum polar and equatorial axis diameter was found in *Datura stramonium* (44.4±3.65 µm) and (43.6±2.85 µm) respectively. Minimum pollen diameter of polar axis was calculated in *Solanum surattense* (23.6±0.79 µm) and equatorial distance was recorded for *Physalis minim* (24.1±1.34 µm) as illustrated in Figure 25. On the basis of polar diameter to equatorial distance ratio to determine pollen shape, highest value of P/E index was calculated in *Solanum melongena* i.e. 1.19 while lowest P/E value was calculated for *Solanum surrattense* (0.95) (Figures 26).

The maximum length of colpi was shown by *Nicotiana tabacum* (7.15±0.64 µm) and minimum was noted in *Physalis minima* (4.90±0.20 µm). The highest value for colpi width was observed in *Solanum nigrum* (10.1±0.23 µm) as far as lowest value concerned it was noted for *Solanum melongena* 3.70±1.67 µm (Figure 27). *Datura stramonium* has shown the highest value of mesocoplium (37.9±1.48 µm) and minimum was noted in *Solanum melongena* (18.6±1.67 µm) (Figure 29).

Exine ornamentation showed a great variation among Solanaceous honeybee floral species. Variation of exine surface peculiarities showed regulate-perforate, scabrate gemmate, regulate striate, micro-echinate scabrate, verrucate gemmate and scabrate ornamentation. Exine thickness was measured maximum in *Datura stramonium* (6.25±0.57 µm) and minimum (2.10±0.21 µm) for *Solanum surattense* (Figure 28).

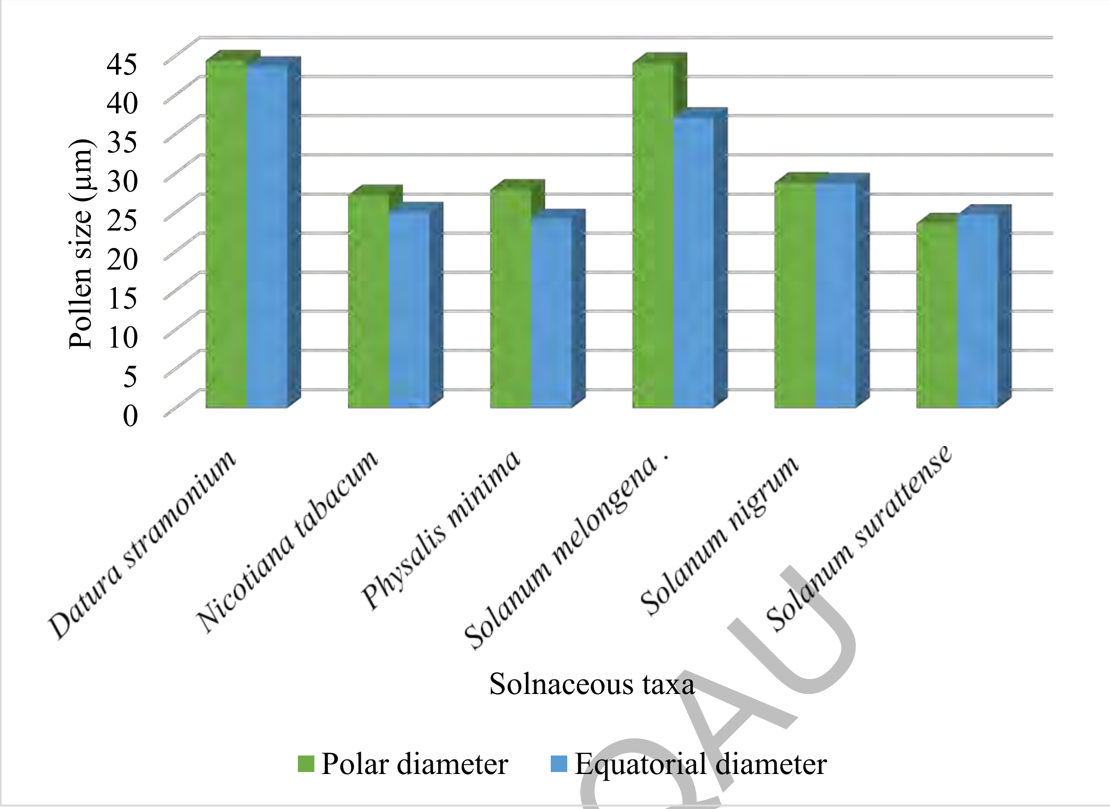

Figure 25. Variations in mean values of pollen diameter among Solanaceous bee species

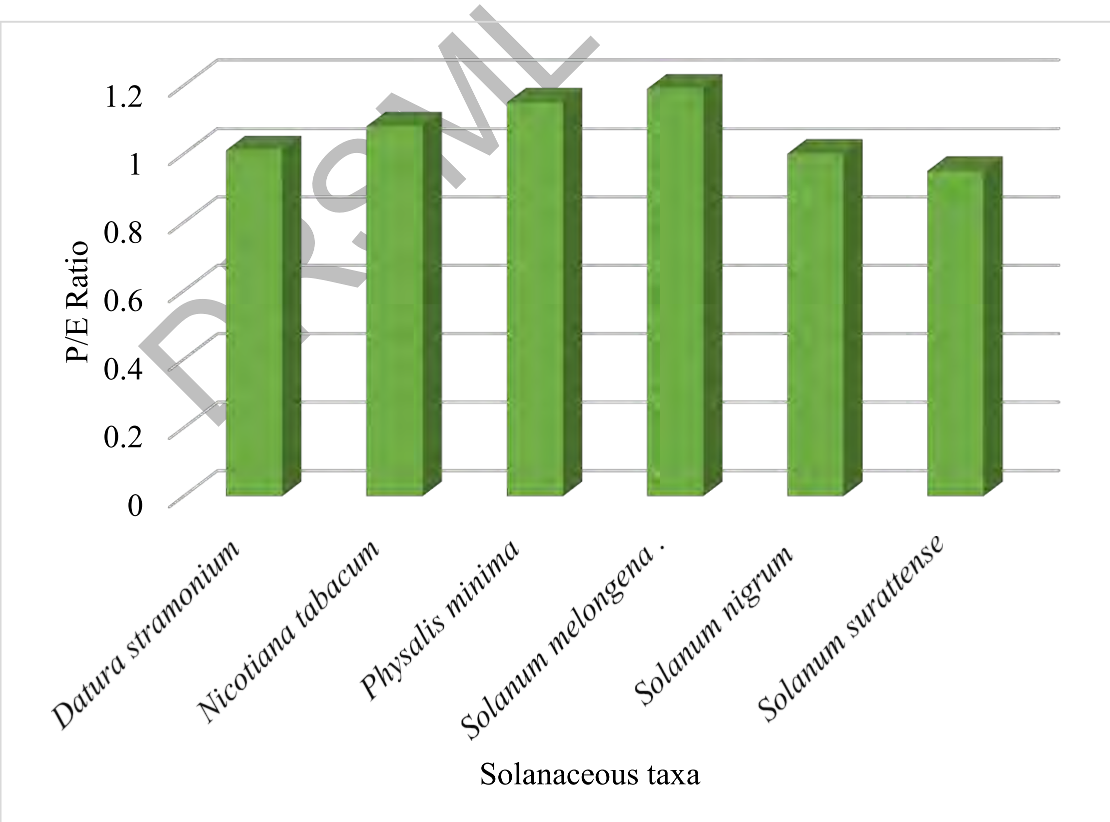

Figure 26. Variation in P/E ratio of Solanaceous honeybee floral plants

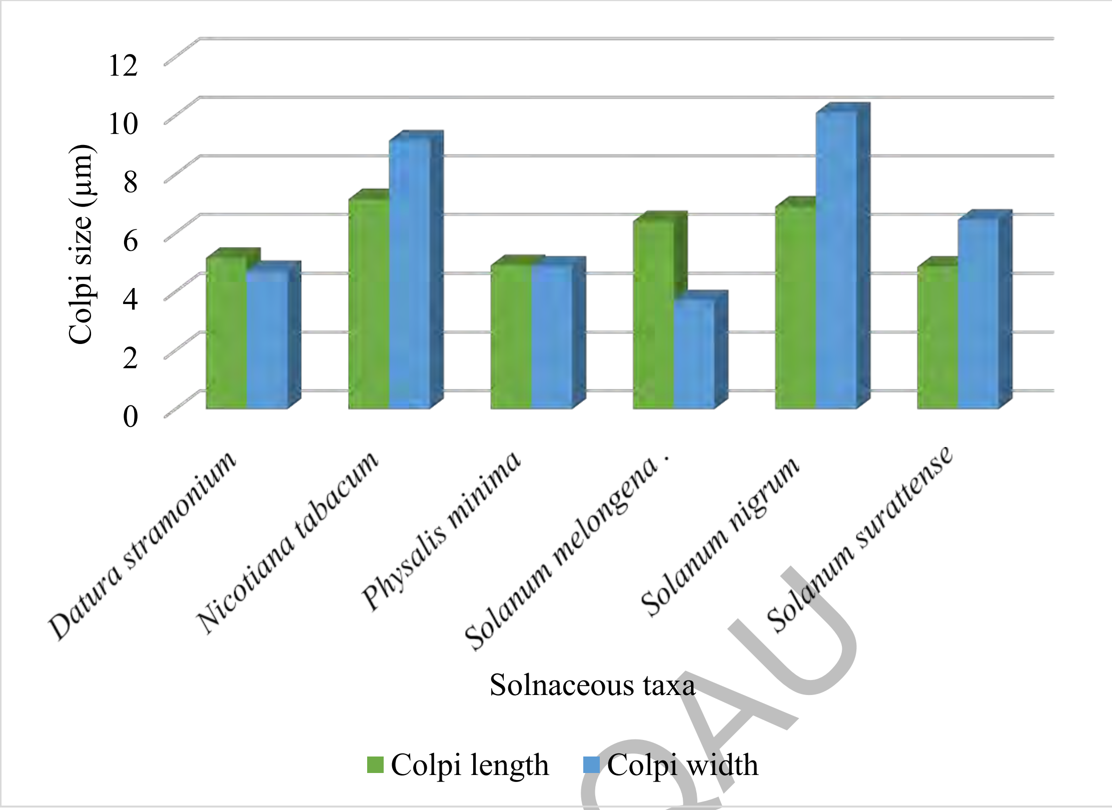

Figure 27. Average data variations of colpi length and width in Solanaceous bee flora

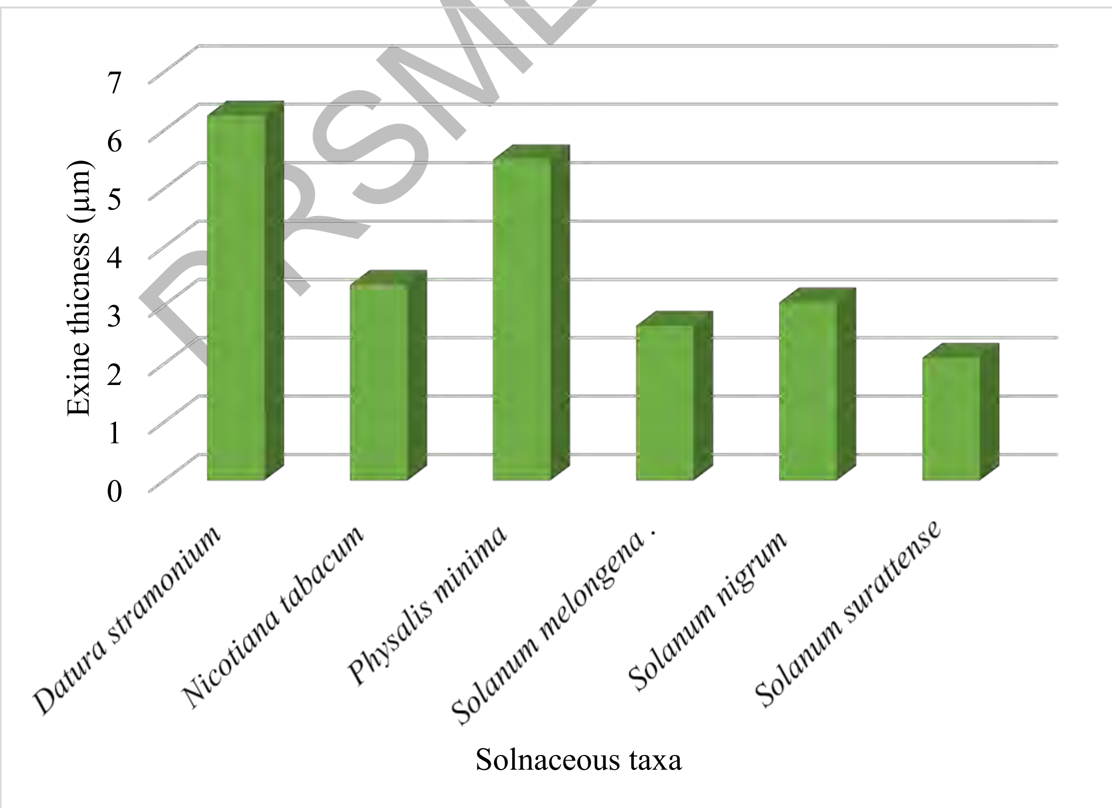

Figure 28. Mean exine thickness variations in Solanaceous bee floral species

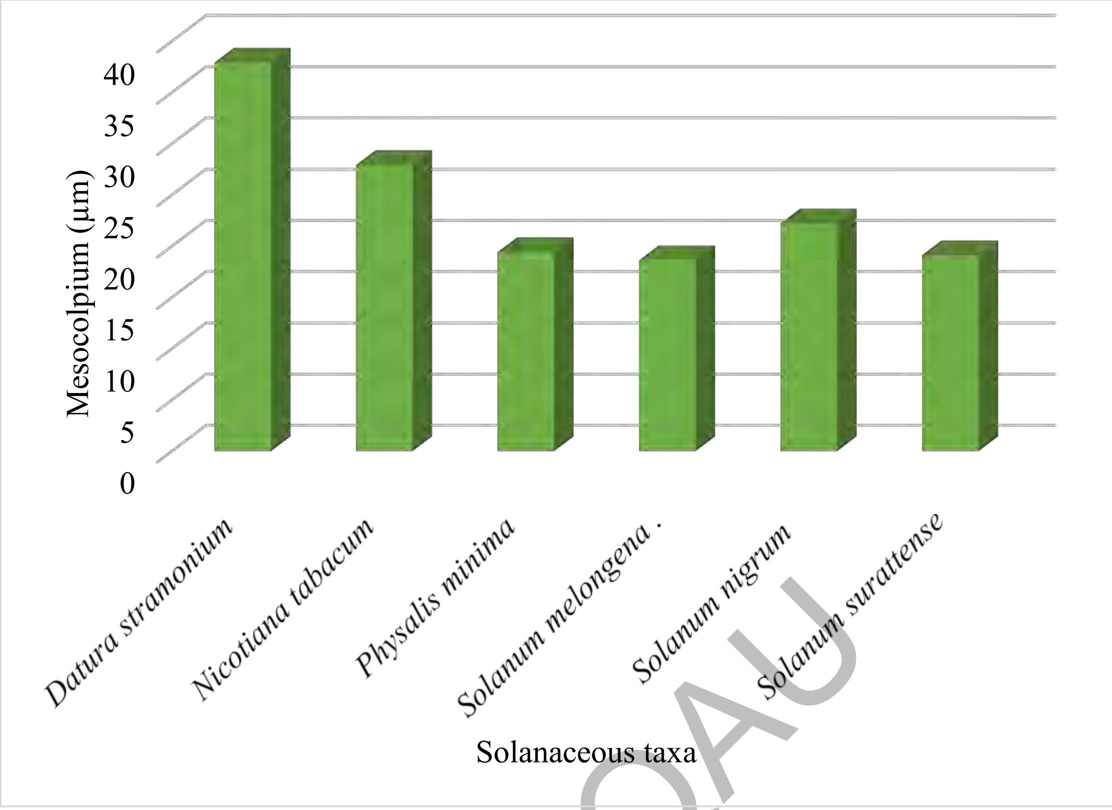

Figure 29. Graphical mean mesocolpium distance of Solanaceous bee floral species

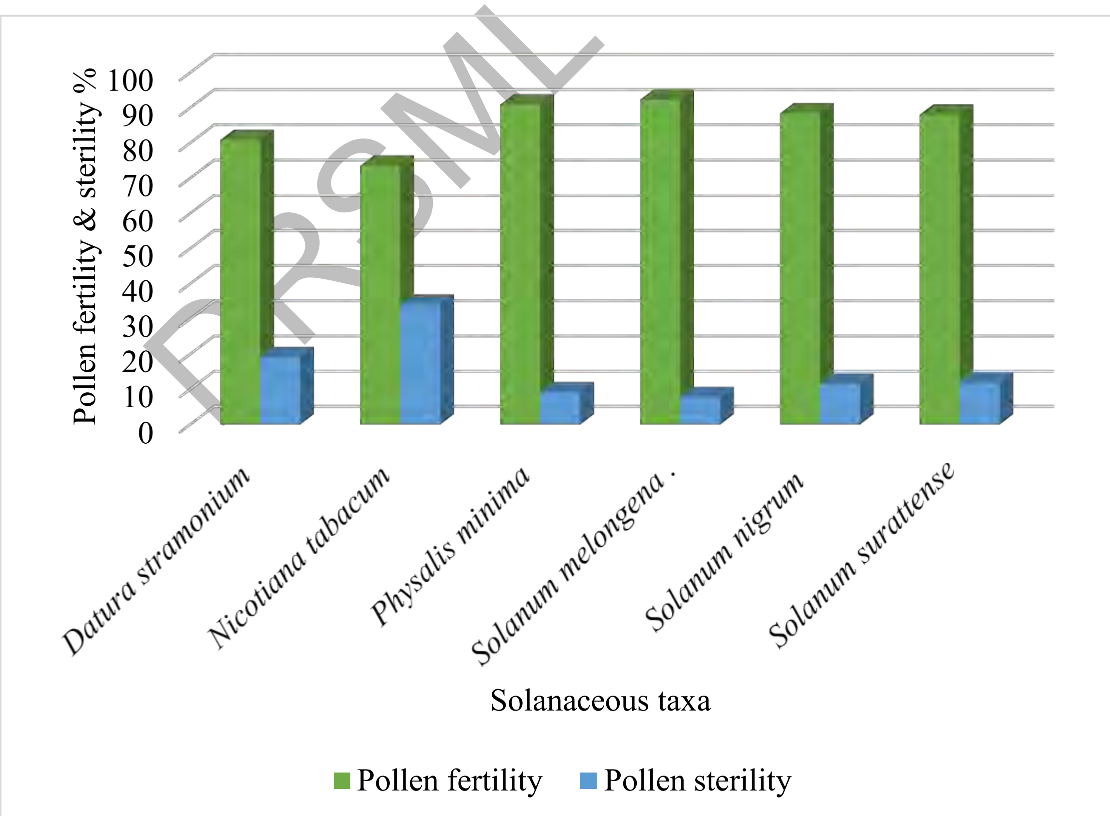

Figure 30. Pollen fertility and sterility % variations among Solanaceous beeflora

3.2.9 Brassicaceous Honeybee flora

1. *Brassica campestris* L.

Synonym	*Brassica rapa* L.
Family	Brassicaceae
Common Name	Field mustard
Habit	Annual Herb
Habitat	Cropland, weedy fields, roadsides, along railroads, and waste areas
Flowering period	January to May
Status	Cultivated
Distribution	Central Asia, Russia, Canada, India, Bhutan, Pakistan
Morphology	Annual or biennial, 1.5-3.5 m tall, branched minutely, stem grey-green, glabrous, glaucous, basal and lower leaves are up to 10mm long, oblanceolate, strongly pinnatifid with undulate or bluntly dentate margins, terminal lobes longest, stout petioles, middle to upper leaves smaller in size, lanceolate oblong in shape, margins usually smooth or bluntly dentate, leaves either clasps stem or are sessile, leaves just like stem are greyish-green, glaucous, glabrous. Upper stem form racemes of bright yellow flowers ,growth of flowers is towards apex ,seed pods grow below flowers 1/3 (8-10mm) across, 4 yellow petals, 4 green to yellow sepals, several stamens and a pistil with a single style, sepals lanceolate and hairless, tape root is present and reproduce by reseeding itself (Plate 57a).
Melissopalynology	Pollen grains are monad, medium sized and tricolporate. Polar view shape spherical, equatorial view shape sub-prolate. Exine sculpturing pattern reticulate. Polar diameter 37.9(37.0-39.0) ±0.39 µm, equatorial view distance 31.7(29.7-34.75) ±0.90 µm. P/E ratio 1.19. Colpi length 2.55(0.25-3.75) ±0.60 µm and colpi width 7.30(6.75-7.75) ±0.20 µm. Exine thickness 4.75(3.75-5.25) ±0.27 µm, mesocolpium distance 23.5(22.2-25.2) ±0.50 µm. Pollen fertility 95.1% and sterility was 4.89% (Plate 57b,c,d & e).

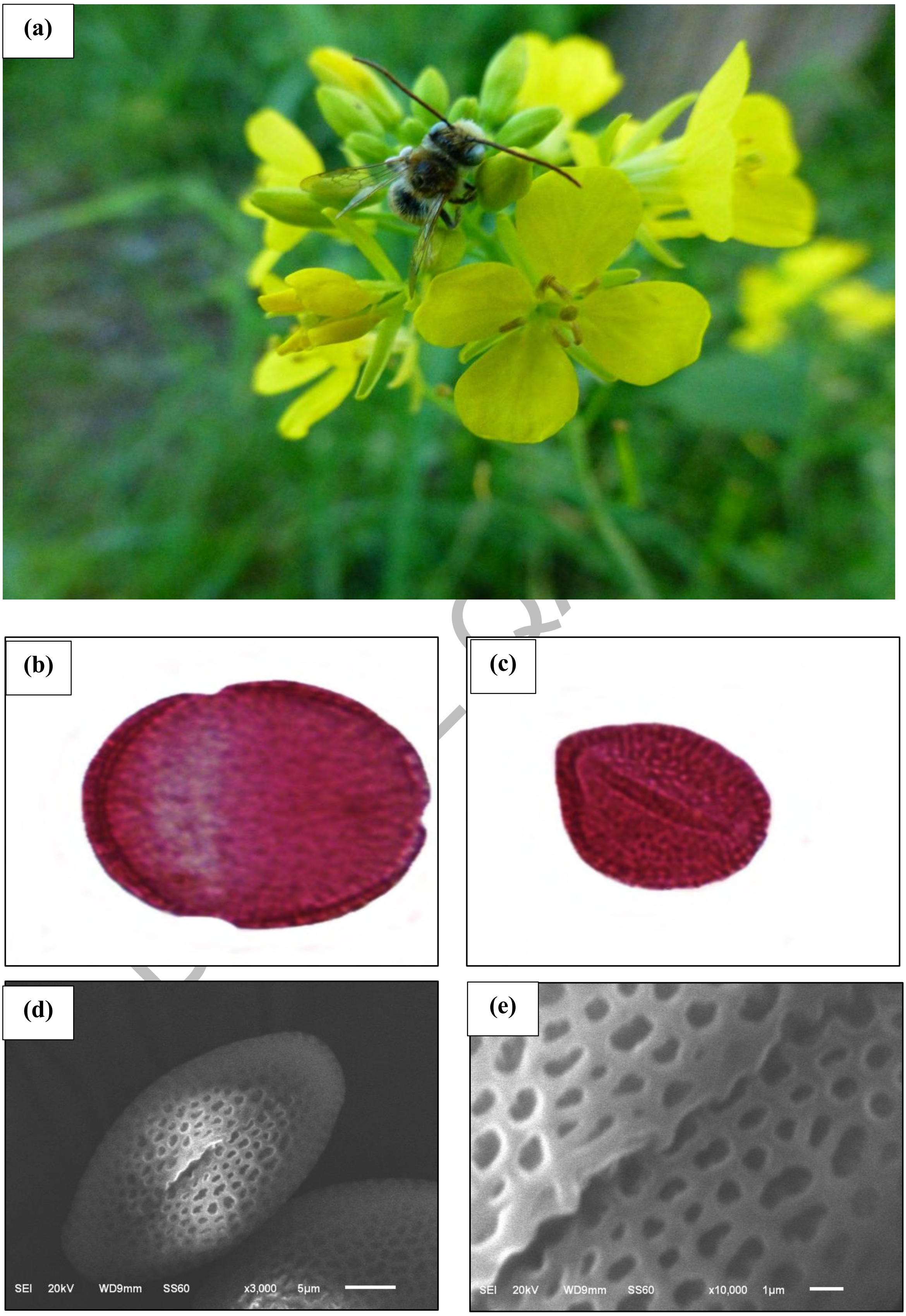

Plate 57: *Brassica campestris* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Capsella bursa-pastoris* (L.) Medik.

Synonym	*Bursa abscissa* (E.G.Almg.) Druce
Family	Brassicaceae
Common Name	Shepherd's purse
Habit	Herb
Habitat	Areas along railroads and roadsides, gardens and lawns
Flowering period	March to June
Status	Wild
Distribution	Ethiopia, Iraq, Japan, Bulgaria, Russia, Pakistan, California
Morphology	Annual or biennial, up to 40 cm tall, erect, glabrous or hairy with simple or branched hairs. Basal leaves rosulate, very variable, usually pinnatifid, 5-8-jugate, shortly stalked, usually up to 8 cm long, 2 cm broad; cauline leaves smaller, sessile. auricled and clasping the stem. Racemes many flowered, up to 30 cm long in fruit. Flowers 2.5 mm across, white; pedicels up to 18 mm long in fruit, spreading. Sepals 1.5 mm long, 1 mm broad. Petals 2.5 mm long, 1 mm broad, obovate-oblong, cuneate. Stamens 1.5, each 2 mm long. Siliculae obcordate-triangular, 5-9 mm long, 4-6 mm broad; valves usually with straight margins; apical notch wide, V-shaped; style 0.5 mm long, hardly or not exceeding the notch; septum; 1-2 mm broad, seeds 4-10 in each locule, 1 mm long, oblong-elliptic and pale brown (Plate 58a).
Melissopalynology	Pollen are monad, iso-polar, medium sized, and trip orate. Circular polar view, prolate-spheroidal equatorial view. Exine sculpturing reticulate. Polar view diameter 30.0(15.7-42.7) ±1.88 µm and equatorial view distance 27.5(15.2-38.5) ±1.63 µm. P/E ratio 1.09. Colpi length 3.71(0.75-5.50)±0.31 µm, colpi width 5.46(2.00-8.50)±0.45 µm, and mesocolpium length 17.8(11.2-23.7)±0.76 µm. Exine thickness 4.26(1.75-7.25)±0.35 µm. Pollen fertility 92.1% and sterility 7.8% (Plate 58b,c,d & e).

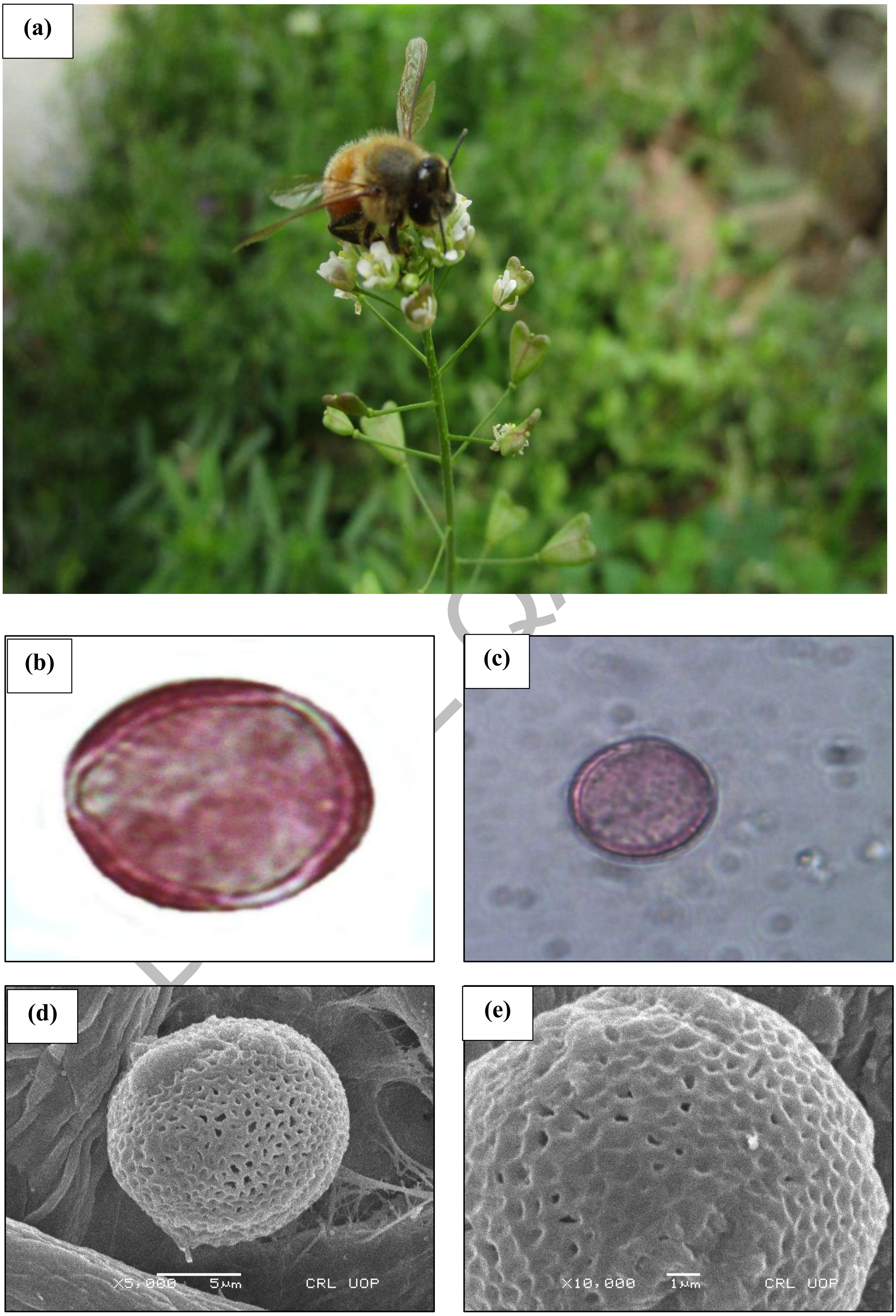

Plate 58: *Capsella bursa-pastoris* (L.) Medik. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Eruca vesicaria* (L.) Cav.

Synonym	*Eruca sativa* Mill.
Family	Brassicaceae
Common Name	Rocket plant
Habit	Herb
Habitat	Grow in sandy soil, loamy soil and marginal lands
Flowering period	December to April
Status	Wild
Distribution	Iran, Afghanistan, Brazil, Pakistan, Italy, Australia, Hong Kong
Morphology	Diploid, annual herb, 10 to 100 cm tall, and having a slender tap root and erect, stiff, and elongated branching system. The roots are of spindle form with few secondary roots, stem is branched, and leaves are compound. Lower leaves are stalked, upper leaves more or less sessile, and all are lyrate pinnatisect, with a long oblong or obovate terminal lobe coarsely toothed, rarely glabrous and slightly fleshy with a characteristic pungent smell. The flowers are 2 to 4 cm in diameter, bisexual, large, few and in small terminal racemes. Petals are 15 to 20 mm, sepals 8 to 10 mm long, pale yellow or whitish with deep violet veins. Fruits are cylindrical siliquae 3 to 4 mm long, erect and with a flattened beak. Seeds are 1.5 to 2 mm, yellow-brown, spherical or ovoid in two rows in each cell (Plate 59a).
Melissopalynology	Pollen are monad, medium sized and tricolpate. Circular polar view and equatorial view shape prolate spheroidal. Colpi sunken with acute ends, exine surface semi-tectate. Sexine thicker like exine. Exine sculpturing reticulate. Polar diameter 27.1(22.2-30.2) ±1.38 µm and equatorial diameter 25.1(21.2-28.0) ±1.29 µm. P/E ratio 1.07. Colpi length 3.35(2.25-4.75) ±0.43 µm and width of colpi 4.30(3.00-6.25) ±0.56 µm. Exine thickness 6.35(5.25-7.75) ±0.43 µm. Mesocolpium distance 16.2(14.7-17.7) ±0.5 µm. Pollen fertility 82.3% and sterility 17.6% (Plate 59b,c,d & e).

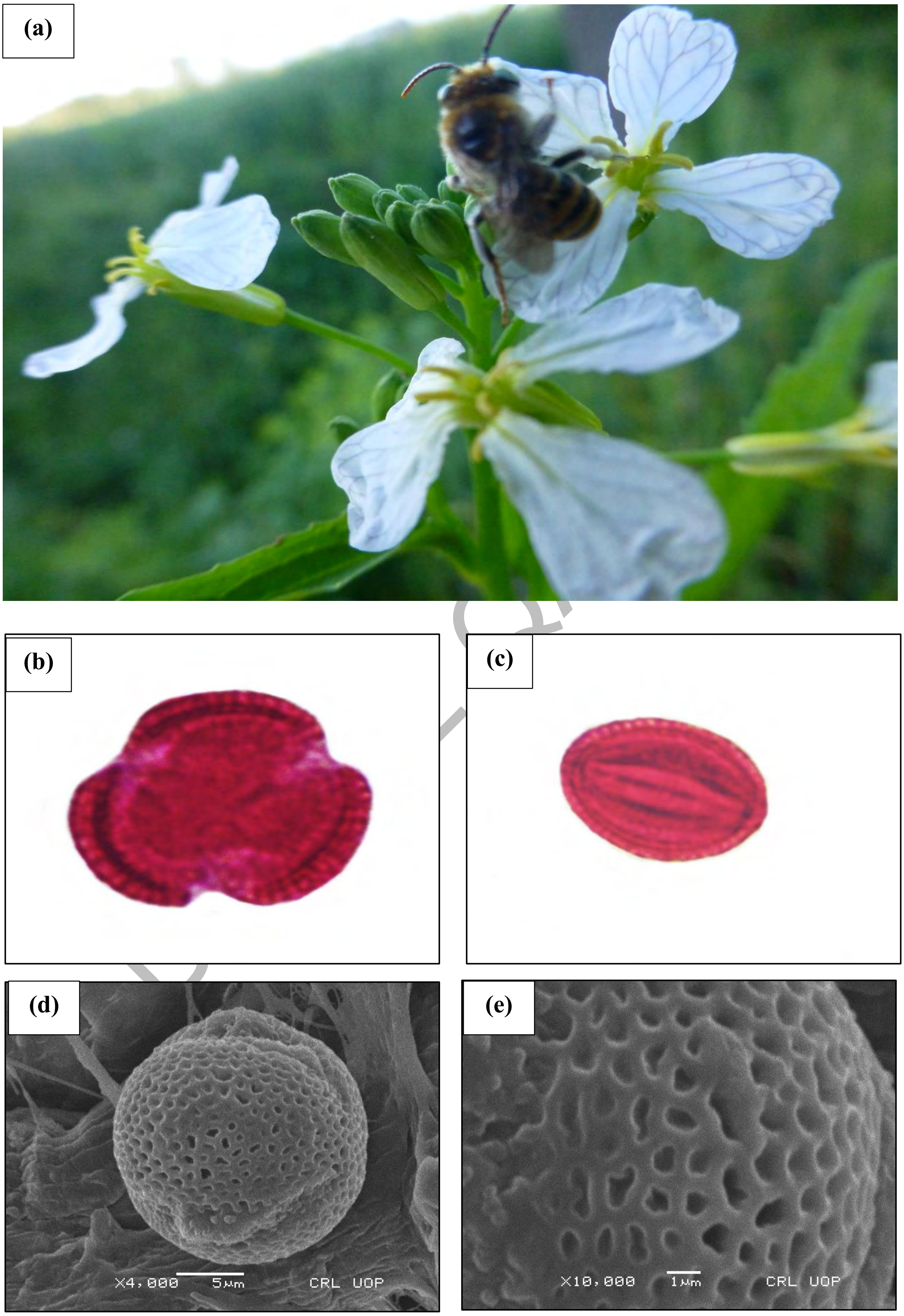

Plate 59: *Eruca vesicaria* (L.) Cav. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Lepidium didymum* L.

Synonym	*Carara didyma* (L.) Britton
Family	Brassicaceae
Common Name	Lesser swine-cress
Habit	Annual Herb
Habitat	In sandy soils of waste places, roadsides and cultivated fields
Flowering period	March to May
Status	Wild
Distribution	India, Brazil, Kenya, Pakistan, South America, South Africa
Morphology	Small annual herb, with offensive smell, stems; creeping, ascending, up to 35 cm long, strongly branched and finely hairy. Leaves; alternate, stipules absent; rosette, bipinnate, pinnately cleft, 1.2–4 cm × 0.8–1.5 cm, lanceolate, incised lobes and glabrous. Inflorescence; leaf opposed raceme, 5-6 cm long. Flowers; bisexual, regular, tetramerous, minute and greenish. Pedicel; 1.5–3 mm long; sepals elliptical, petals shorter, narrow, reduced small scales, stamens 2; ovary superior, flat, sessile stigma and flat. Fruit; heart shaped, flattened silique, 1.9 mm × 2.3 mm, notched, wrinkled and 1 seeded halves. Seeds; 1.2–1.7 mm long, finely reticulate and reddish brown (Plate 60a).
Melissopalynology	Pollen grains are monad, small sized, and tricolpate. Circular polar view and oblate-spheroidal equatorial view shape. Exine ornamentation reticulate. Polar diameter 19.1(16.2-20.7) ±0.79 µm and equatorial view distance 20.3(19.5-21.7) ±0.42 µm. P/E ratio 0.94. Colpi length 4.70(4.25-5.25) ±0.16 µm, colpi width 5.20(4.50-5.75) ±0.25 and mesocolpium distance 11.9(11.2-13.5) ±0.42 µm. Exine thickness 1.60(1.00-2.25) ±0.23 µm. Pollen fertility 92.04% and sterility 7.95 % (Plate 60b,c,d & e).

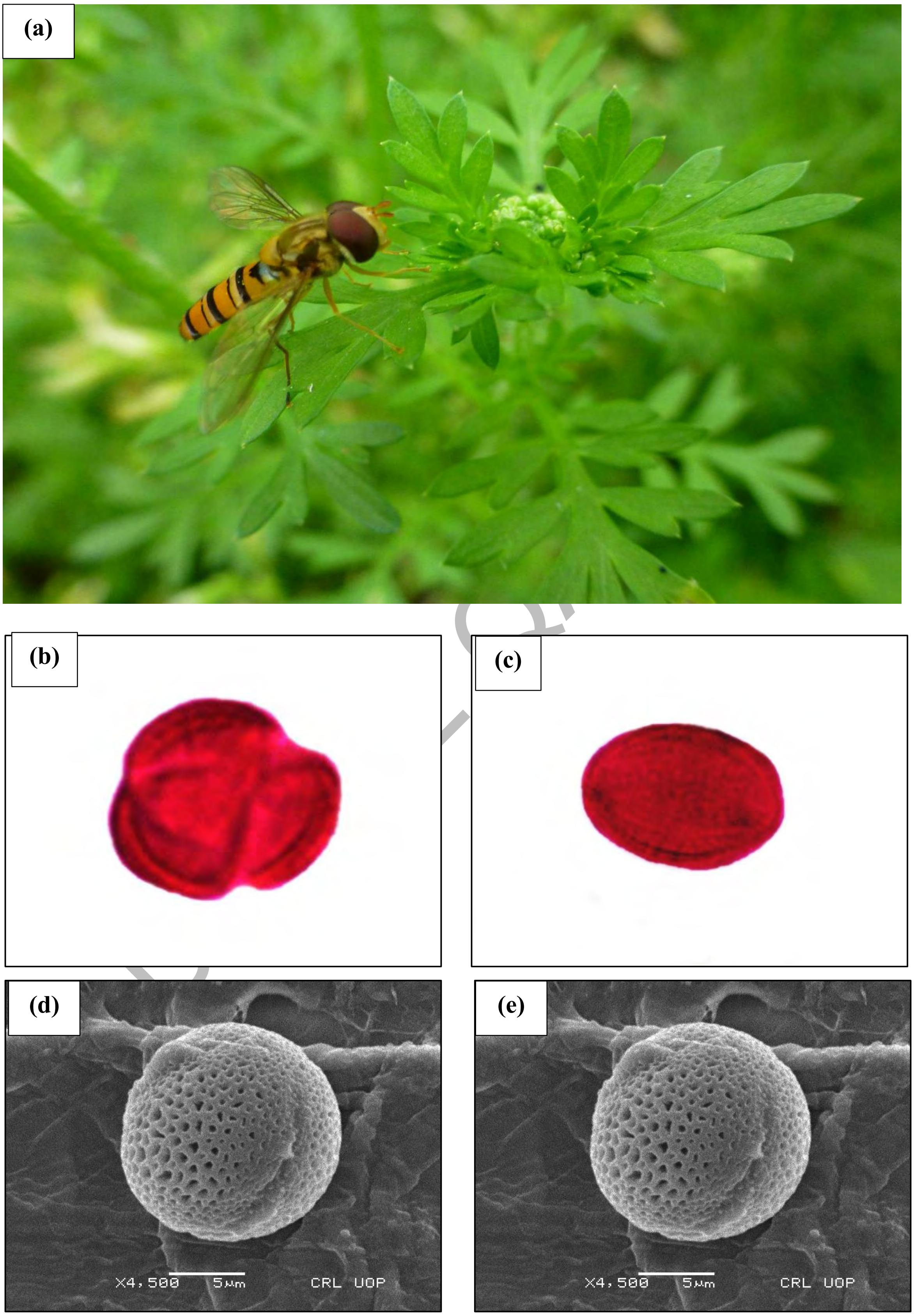

Plate 60: *Lepidium didymum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Sisymbrium irio* L.

Synonym	*Sisymbrium irio* var. *gallicum* (Willd.) DC.
Family	Brassicaceae
Common Name	Desert mustard
Habit	Annual Herb
Habitat	Found in disturbed and undisturbed areas
Flowering period	March to June
Status	Wild
Distribution	North Africa, Pakistan, Southern Europe, North Africa, India
Morphology	Annual, erect, herbaceous, 21-60 cm tall, branched, glabrous or sparsely hairy with simple hairs. Stem: erect, branched below, sparsely pubescent basally. Lower and basal leaves petiolate, pinnately lobed with a hastate terminal lobe larger than the laterals, cauline leaves similar. Racemes up to 50 flowers, up to 31 cm long in fruit with siliquae overtopping young flowers and buds. Flowers 3.3 mm across, yellow; pedicels 11 to 16 mm long in fruit, filiform, ascending, rarely spreading. Sepals 2-2.6 mm long. Petals 3.1-4.2 mm long, 1.2 mm broad, usually slightly longer than the sepals. Stamens; 1.5-3 mm long; anthers 0.5 mm long. Filaments: yellowish, erect, 2-4.5 mm. Anthers: oblong, 0.4-1.1 mm. Ovules: 30-80 per ovary. Fruit: slender, terete, 2.2-5.4 cm × 0.6-1.3 mm, slightly curved, valves glabrous and slightly torulose. Style: 0.4-0.7 mm; stigma bi-lobed. Seeds: oblong, 0.7-1.3 × 0.4-0.8 mm (Plate 61a).
Melissopalynology	Pollen grains are monad, small sized and tricolpate. Semicircular polar view an oblate-spheroidal equatorial view shape. Exine sculpturing reticulate. Polar diameter is 22.4(27.5-20)±2.04 µm and equatorial view distance 24.8(28.7-20.0)±2.8 µm. P/E ratio 0.90. Colpi length 4.8(7.50-2.25)±2.25 µm, colpi width 4.97(6.75-2.75)±1.13 µm and mesocolpium distance 14.5(17.5-12.5)±1.74 µm. Exine thickness 3.22(4.75-2.25)±0.91 µm. Pollen fertility 88.8% and sterility 11.1% (Plate 61b,c,d & e).

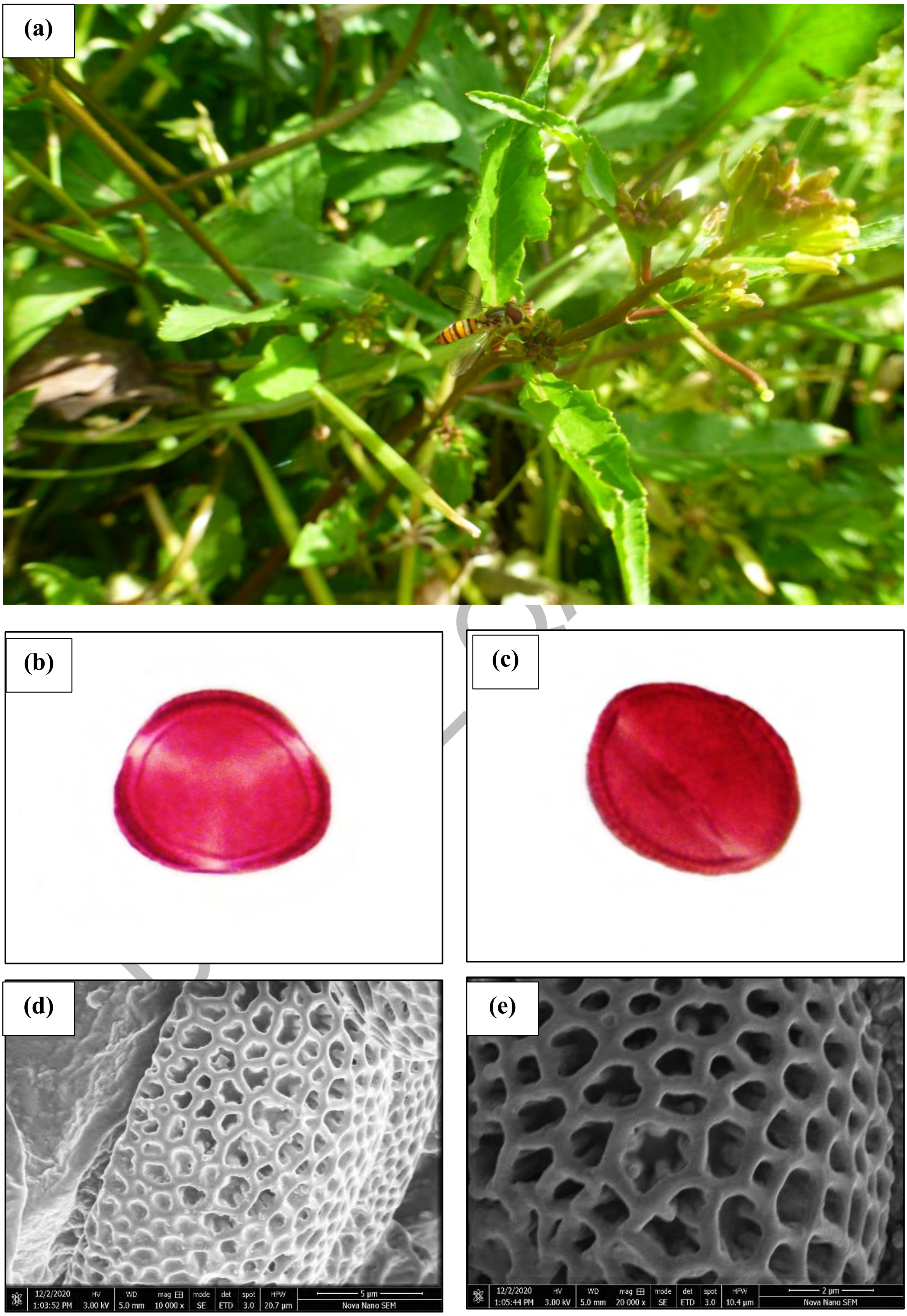

Plate 61: *Sisymbrium irio* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.10 Melisso-palynomorphs description of Brassicaceous taxa

Micro-morphological investigation of five Brassicaceous honeybee floral pollen were examined under optical and scanning electron microscope (SEM) to reveal the ultra-picture of pollen of this family. We found some of outstanding observation after the study these selected melliferous plants species, pollen was shown in (Plate 54, 55, 56). Grains were monad, small to medium sized and tricolpate to tricolporate. Aperture orientation was bulged and slightly sunken. Shape in polar view (triangular) and oblate-spheroidal, prolate-spheroidal and sub-prolate in equatorial view.

Pollen diameter in polar and equatorial view was calculated maximum for *Brassica campestris* (37.9±0.39 µm) and (31.7±0.9 µm) respectively. Whereas minimum polar diameter was measured in *Lepidium didymum* (19.1±0.79 µm) as shown in Figure 31. Colpi size varies among species; highest value of colpi length in *Sisymbrium irio* (4.8±2.25 µm) and lowest value in *Brassica campestris* (31.7±0.6 µm). However, the maximum width of colpi was measured for *Brassica campestris* (7.30±0.20 µm) while minimum in *Eruca sativa* (4.30±0.56 µm) (Figure 33). Mesocolpium distance ranged from highest in *Brassicacampestris* (23.5±0.5 µm) to lowest were recorded in *Lepidium didymum* 11.9±0.42 µm (Figure 35).

Exine surface peculiarities were semi-tectate and reticulate type. The maximum exine thickness was recorded in *Eruca sativa* (6.35±0.43 µm) while minimum in *Lepidium didymum* (1.60±0.23 µm) as shown in Figure 34. Highest pollen fertility was estimated for *Brassicacampestris* (95.1%) while lowest for *Eruca sativa* (82.3%). Similarly, the sterility percentage was recorded maximum for *Eruca sativa* (17.6%) and minimum for *Brassica campestris* (4.89%) as mentioned in Figure 36.

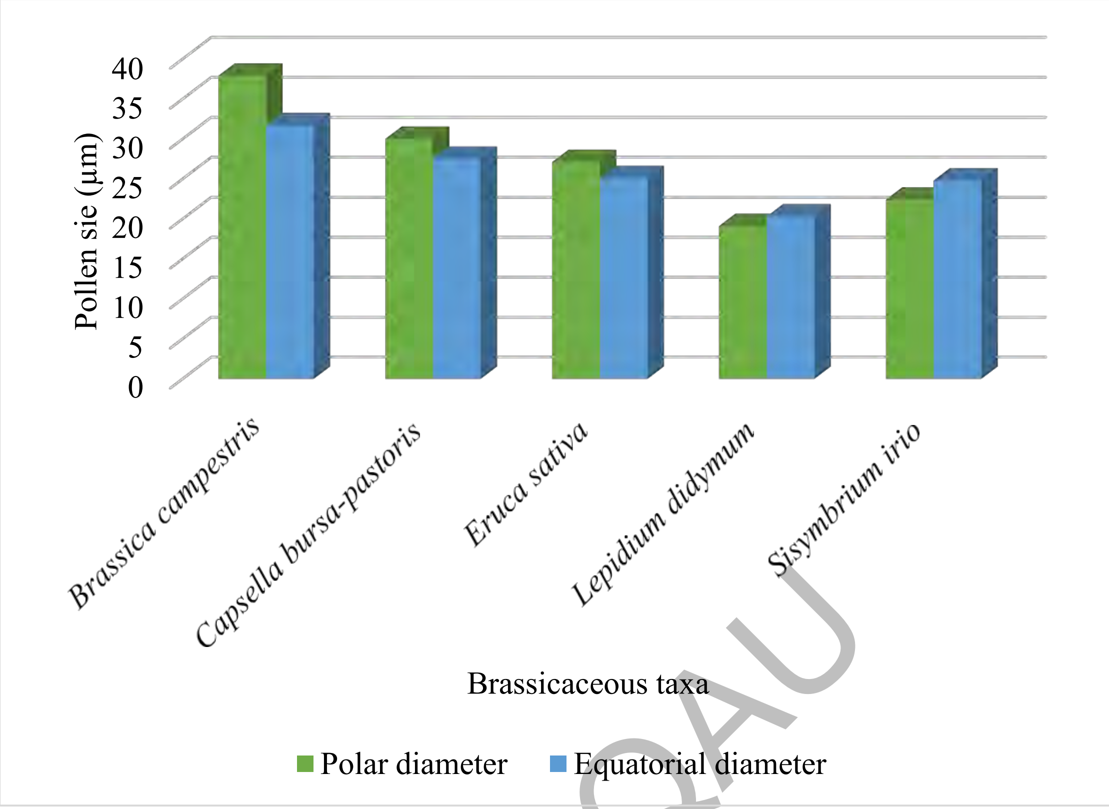

Figure 31. Variations in mean values of pollen diameter among Brassicaceae bee flora

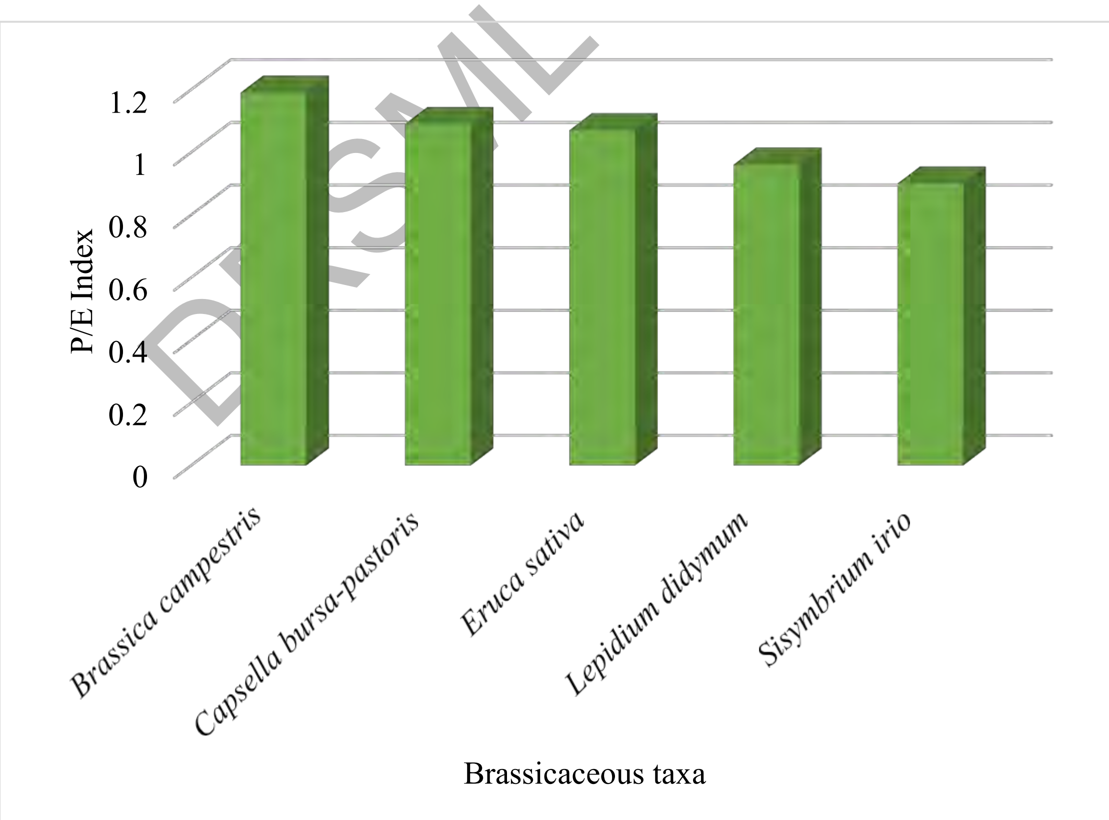

Figure 32. Variation in P/E ratio of Brassicaceae honeybee floral plants

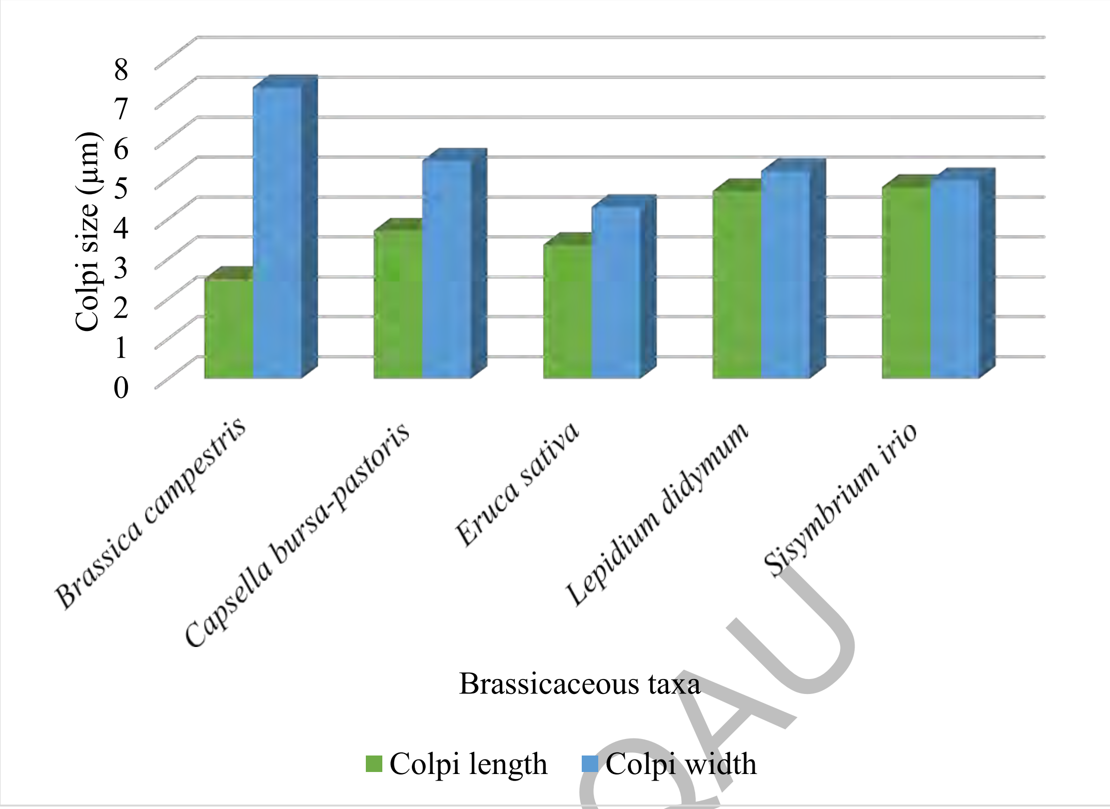

Figure 33. Average data variations of colpi size in Brassicaceous bee flora

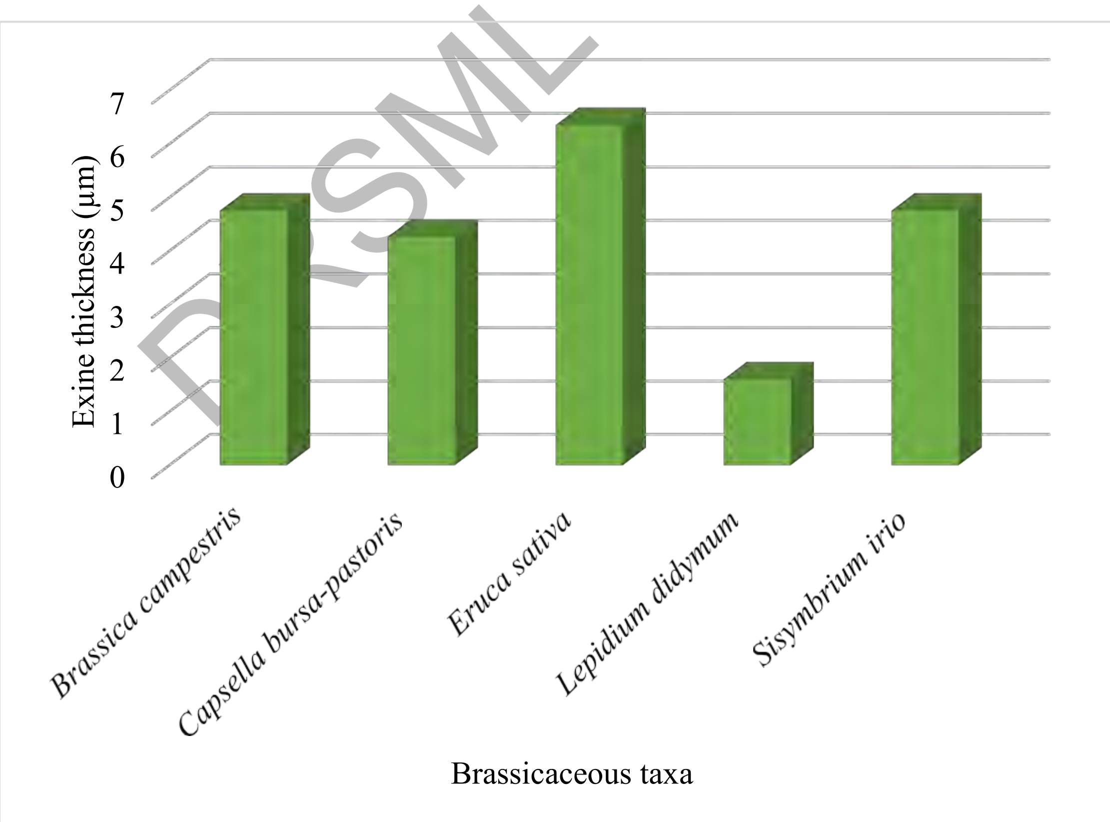

Figure 34. Mean exine thickness variations in Brassicaceous bee floral species

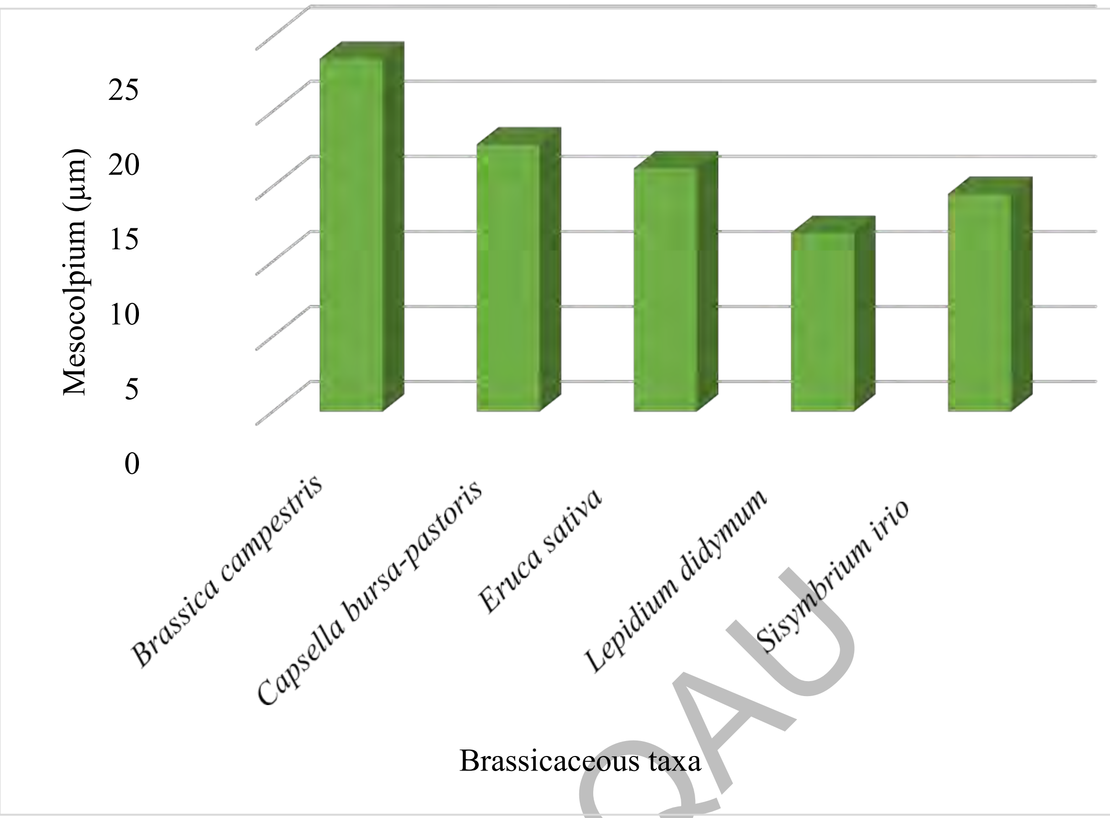

Figure 35. Graphical mean mesocolpium distance of Brassicaceous bee floral species

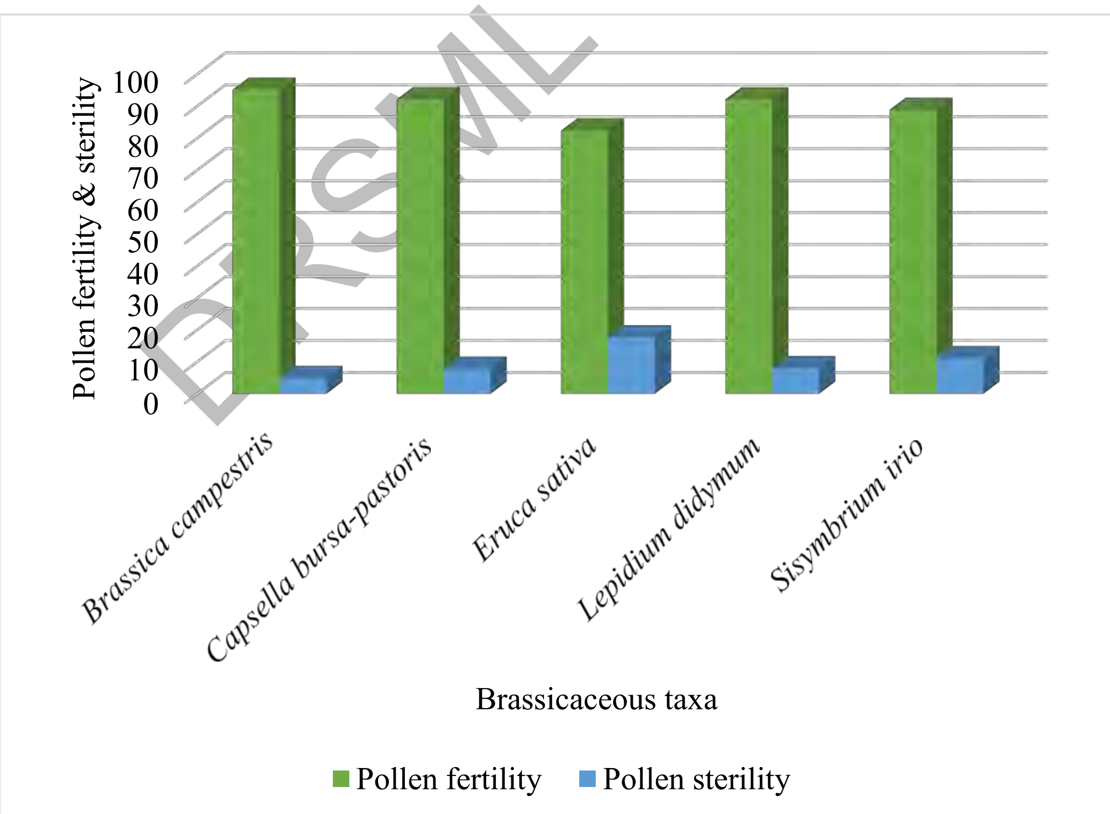

Figure 36. Graphical illustration of pollen fertility and sterility of Brassicaceae bee flora

3.2.11 Lamiaceous Honeybee flora

1. *Clinopodium vulgare* L.

Synonym	*Acinos vulgaris* (L.) Pers.
Family	Lamiaceae
Common Name	Wild basil
Habit	Perennial Herb
Habitat	In agricultural settings and home gardens
Flowering period	March to August
Status	Wild
Distribution	India, China, Barbados, Kenya, Thailand, Pakistan
Morphology	Perennial, herb and slender woody root. Stem; 25-50 cm, erect, ascending, simple branches, retrorse, white e-glandular and indumentum. Leaves; thin textured, ovate, 1.5-3 x 1.4-2.8 cm, crenulate-denticulate, rounded base, pilose, without sessile oil globules, petiole up to 15 mm. Verticillasters axils, densely globose, up to 33-35 flowered, remote, and axillary. Bracts; 6-15 mm, filiform and ciliate. Pedicels; erect, spreading, 2.5 mm. Calyx; 5-13 mm, purplish, without capitate glandular hairs; teeth upper lip; 2.2-3.5 mm, subulate; throat with long e-glandular hairs. Corolla; rose to purple, 10-16 mm, deciduous and calyx teeth. Thecae; glabrous, parallel and diverging. Nutlets; pale brown, smooth and sub-globose (Plate 62a).
Melissopalynology	Pollen grains are monad, small sized, isopolar, and hexacolpate. Circular polar view and spheroidal equatorial view shape. Aperture orientation sunken. Exine sculpturing micro-reticulate. Polar diameter 18.0(16.2-21.2)±0.93 μm and equatorial distance 18.0(16.2-20.2)±0.64 μm. P/E ratio 1.00. Colpi length 3.30(2.75-4.00)±0.25 μm, colpi width 4.90(4.50-5.25)±0.15 μm and mesocolpium 15.4(13.7-21.25)±1.46 μm. Exine thickness 5.55(4.75-6.25)±0.30 μm. Pollen fertility 89.2% and sterility 10.7% (Plate 62b,c,d & e).

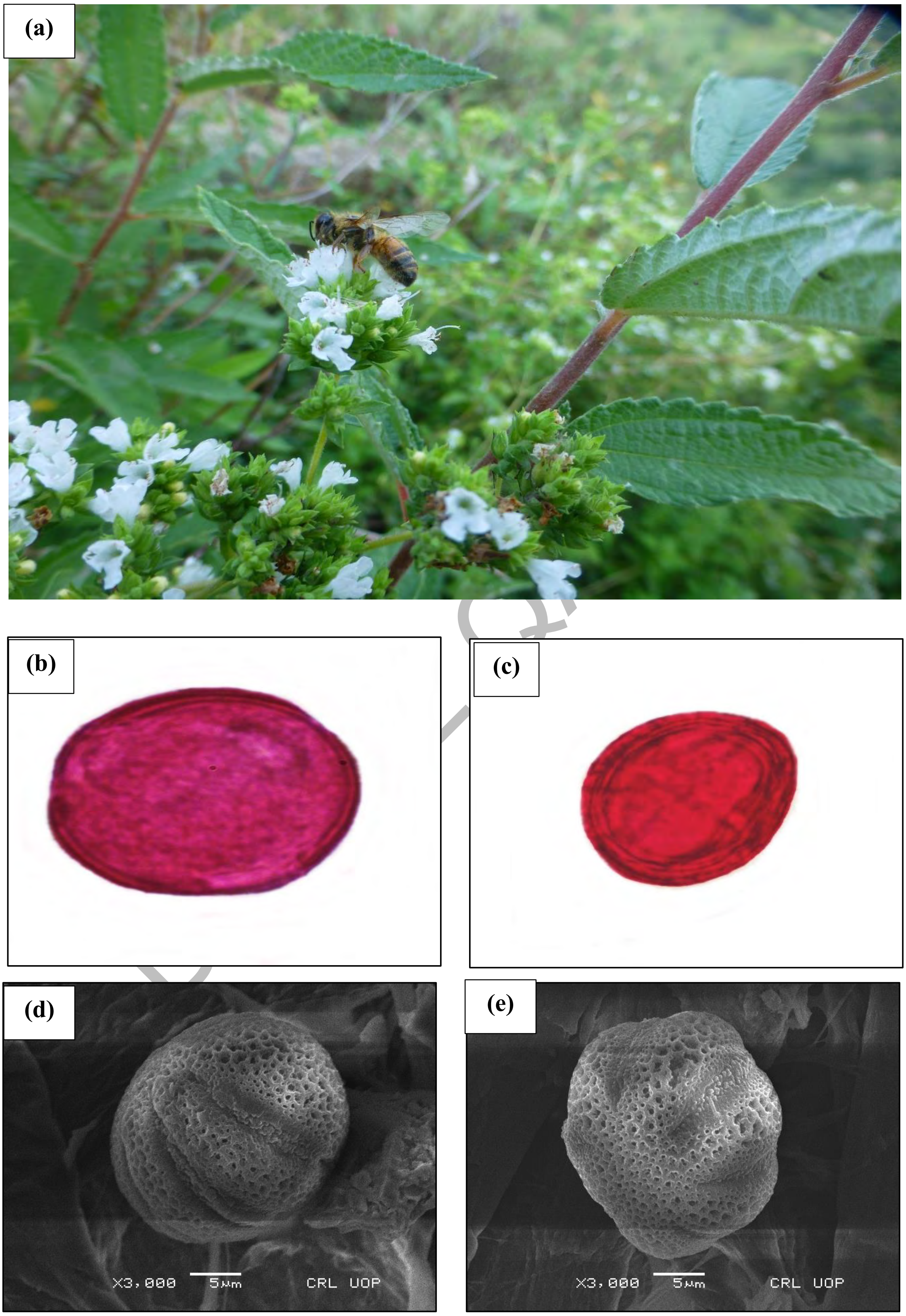

Plate 62: *Ocimum tenuiflorum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Mentha arvensis* L.

Synonym	*Mentha parietariifolia* Becker ex Steud.
Family	Lamiaceae
Common Name	Field Mint
Habit	Herb
Habitat	In moist places, shorelines, in wet meadows, prairies, and ditches,
Flowering period	August to September
Status	Wild
Distribution	Italy, Sweden, Germany, Spain, Pakistan, Cuba
Morphology	Perennial white creeping rhizomes. Stems; erect, branched above, often purplish below, quadrangular, leafy, with a sparse indumentum of e-glandular simple, usually retrorse, hairs. Leaves; ovate to elliptic, 2.1-6 × 1.6-2.5 cm, serrulate to serrate, acute, cuneate, on both surfaces with adpressed e-glandular hairs, gland dotted below; petiole up to 12-14 mm on lower leaves. Flowers; all in axils of middle and upper leaves, verticillasters, man flowered, sub-globose, 1.3 cm in diameter. Bracts; linear-lanceolate, longer than the 3 mm erect-spreading pedicels. Calyx; tubular-campanulate, 1.5-4 mm, pilose with e-glandular hairs. Corolla; pale lilac, 3-5.5 mm; tube rather broad, as long as calyx or slightly exerted; lobes erect, broad, rounded. Nutlets; 4, globose 1.2 × 1.3 mm, smooth and rounded (Plate 63a).
Melissopalynology	Pollen grains are monad, iso polar, small sized and hexacolpate. Rounded polar view and prolate-spheroidal equatorial view. Aperture membrane stephanoaperturate. Exine sculpturing micro-reticulate. Polar diameter 21.2(17.2-23.0)±1.03 µm and equatorial view distance 18.5(15.7-22.2)±1.05 µm. P/E ratio 1.14. Colpi length 3.40(3.00-3.75)±0.12 µm, colpi width 2.40(1.75-3.25)±0.26 µm and mesocolpium 4.05(2.75-5.25)±0.41 µm. Exine thickness 4.15(2.75-5.25)±0.43 µm. Pollen fertility 91.6% and sterility 8.33% (Plate 63b,c,d & e).

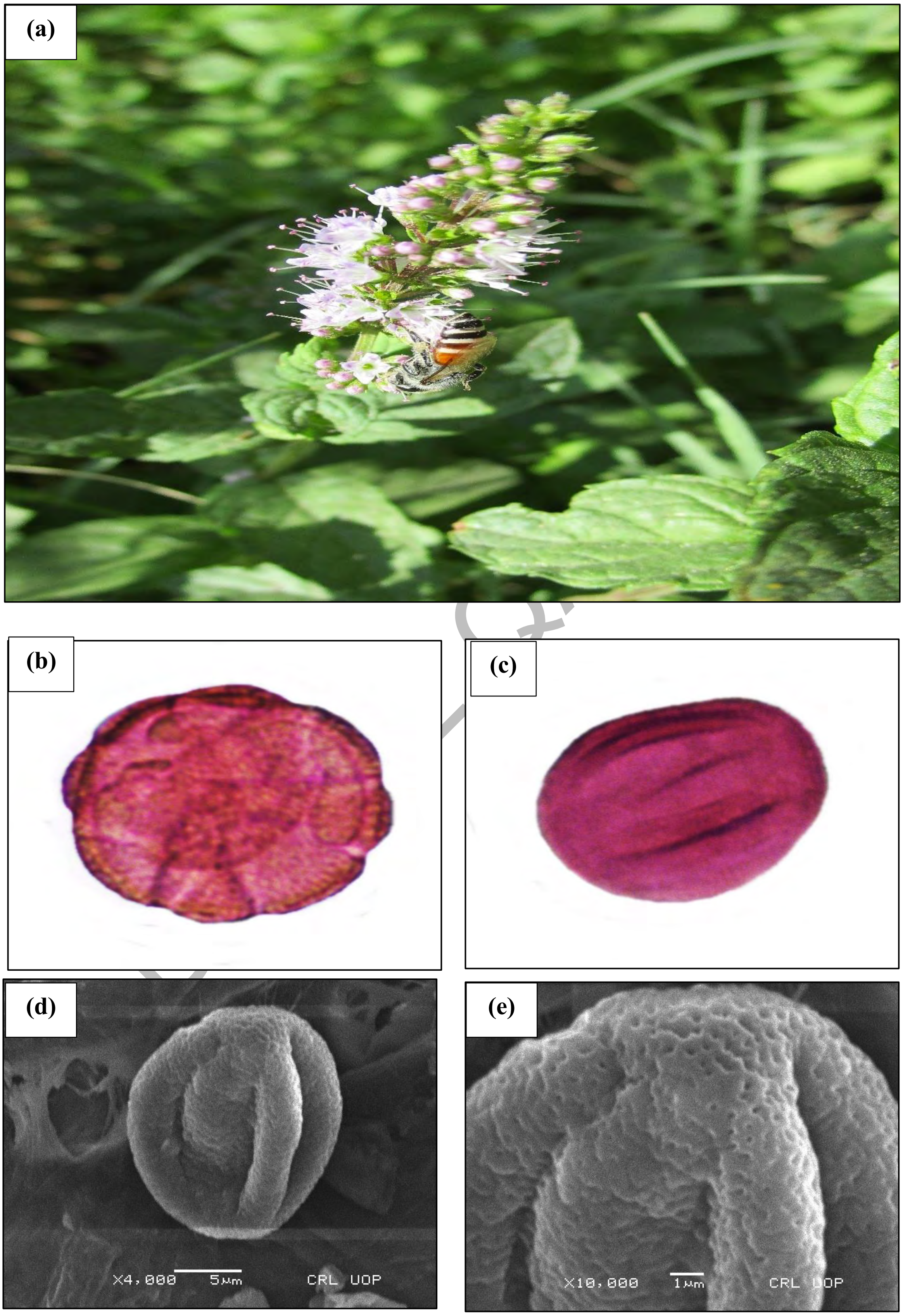

Plate 63: *Mentha arvensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Mentha longifolia* (L.) L.

Synonym	*Mentha acroceraia* (Topitz) Trautm.
Family	Lamiaceae
Common Name	Wild Mint
Habit	Perennial Shrub
Habitat	Marshes and along streams and waste places
Flowering period	May to August
Status	Wild
Distribution	South East Asia, China, Russia, Pakistan
Morphology	Perennial, musty and aromatic smell. Stems; ascending, 32-130 cm, much branched, rarely simple, leafy, range of hair types, soft pilose, crisped, retrorse. Leaves; variable in size, color and indumentum, 1.6-7 × 0.8-3 cm, broadly ovate, lanceolate, narrow oblong-elliptic, green, white, serrulate to coarsely dentate, cordate, cuneate, acute, sessile, shortly petiolate, densely dotted gland, Inflorescence; numerous congested; flowered verticillasters, forming terminal spikes. Bracts; linear to subulate. Calyx; 1.8-3 mm, narrow campanulate, softly pilose, e-glandular hairs, oil globules; teeth sub-equal, narrow triangular, linear subulate Corolla: 2.8-5 mm, light purple, violet, mauve or white (Plate 64a).
Melissopalynology	Pollen grains are monad, iso polar, medium sized, and hexacolpate. Elliptic polar view and prolate-spheroidal equatorial view. Aperture orientation sunken. Exine sculpturing reticulate. Polar diameter 24.2(22.2-27.7)±1.03 µm and equatorial view distance 21.7(18.7-25.2)1.06 µm. P/E ratio 1.11. Colpi length 24.2(22.2-27.7)±1.03 µm, colpi width 8.20(7.25-8.75)±0.30 µm and mesocolpium 4.05(2.75-5.25)±0.41 µm. Exine thickness 3.89(5.25-2.25)±0.95 µm. Pollen fertility 64.2% and sterility 35.7% (Plate 64b,c,d & e).

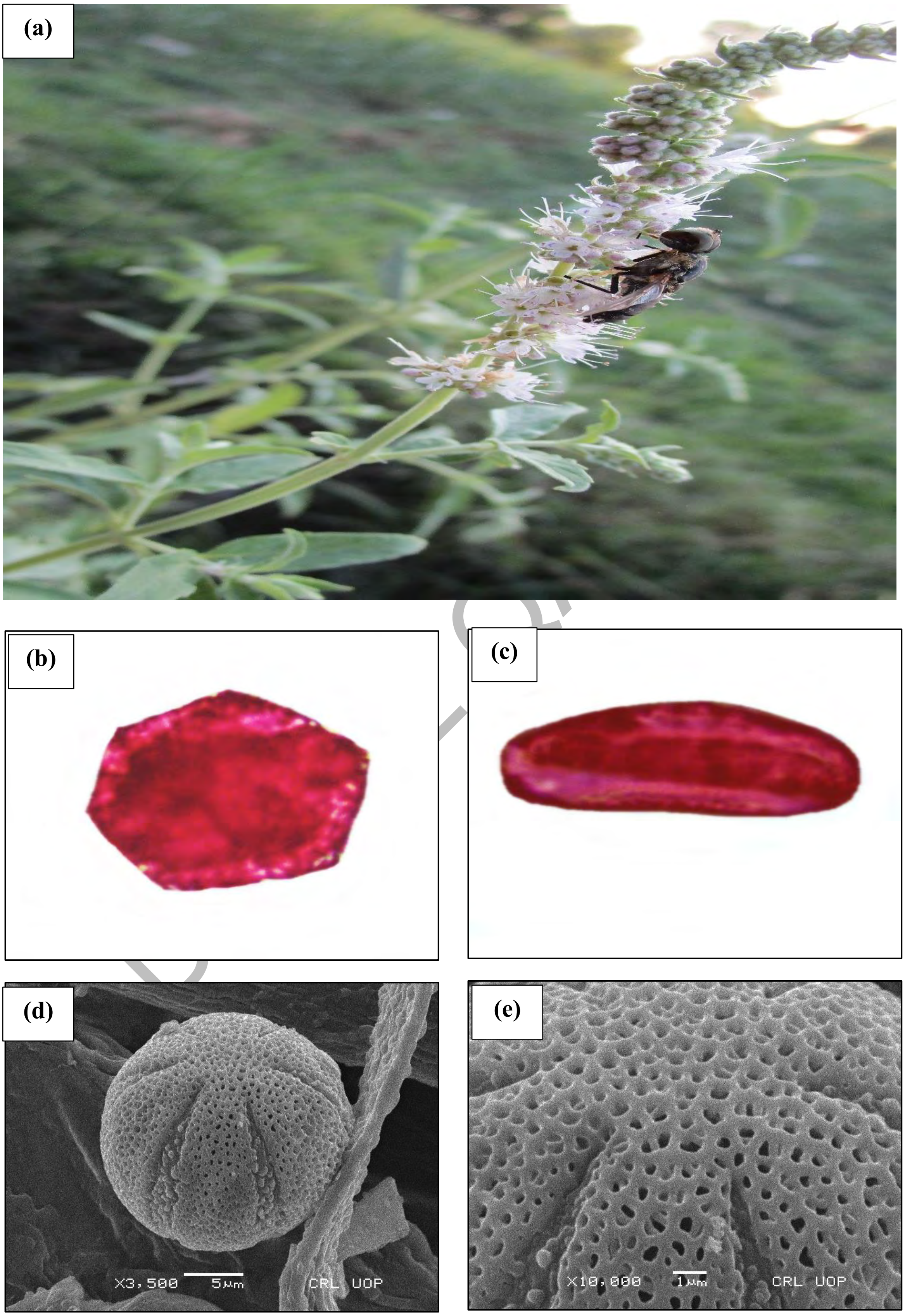

Plate 64: *Mentha longifolia* (L.) L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Mentha spicata* L.

Synonym	*Mentha sepincola* Holuby
Family	Lamiaceae
Common Name	Garden mint
Habit	Herb
Habitat	Grows in moist places such as along shorelines and stream banks
Flowering period	August to October
Status	Wild
Distribution	Ireland, China, Greece, Italy, Pakistan, Russia, India
Morphology	Herb and stoloniferous. Stems; erect, 32-115 cm, glabrous to sub-glabrous and striate. Leaves; sessile or sub-sessile, ovate oblong to oblong lanceolate, 2.5-6 × 0.8-2.2 cm, base broadly cuneate to rounded, margin irregularly serrate and apex acute. Verticillasters, in cylindrical terminal spikes 3-11 cm, spikes interrupted at base, bracteoles linear, 3.5-9 mm. Pedicel; 1.3-2 mm. Calyx; campanulate, 2-3.6 mm, glandular, obscurely 5 veined; teeth triangular to lanceolate, 0.6-1.5 mm. Corolla; purplish, 3.2-4 mm, glabrous, tube 1.5-2 mm; lobes sub-equal, apex emarginated. Ovary; brown and glabrous (Plate 65a).
Melissopalynology	Pollen grains are monad, iso polar, small sized and hexacolpate. Rounded polar view and prolate-spheroidal equatorial view shape. Aperture orientation sunken. Exine sculpturing semi-tectate reticulate. Polar diameter 19.0(17.2-21.2)±0.82 µm and equatorial view distance 17.05(15.7-18.7)±0.62 µm. P/E ratio 1.11. Colpi length 1.95(1.50-2.25)±0.14 µm, colpi width 0.90(0.25-1.75)±0.26 µm and mesocolpium distance 11.2(9.75-12.7)±0.54 µm. Exine thickness 3.35(2.75-4.00)±0.23 µm.. Pollen fertility 89.4% and sterility 10.5% (Plate 65b,c,d & e).

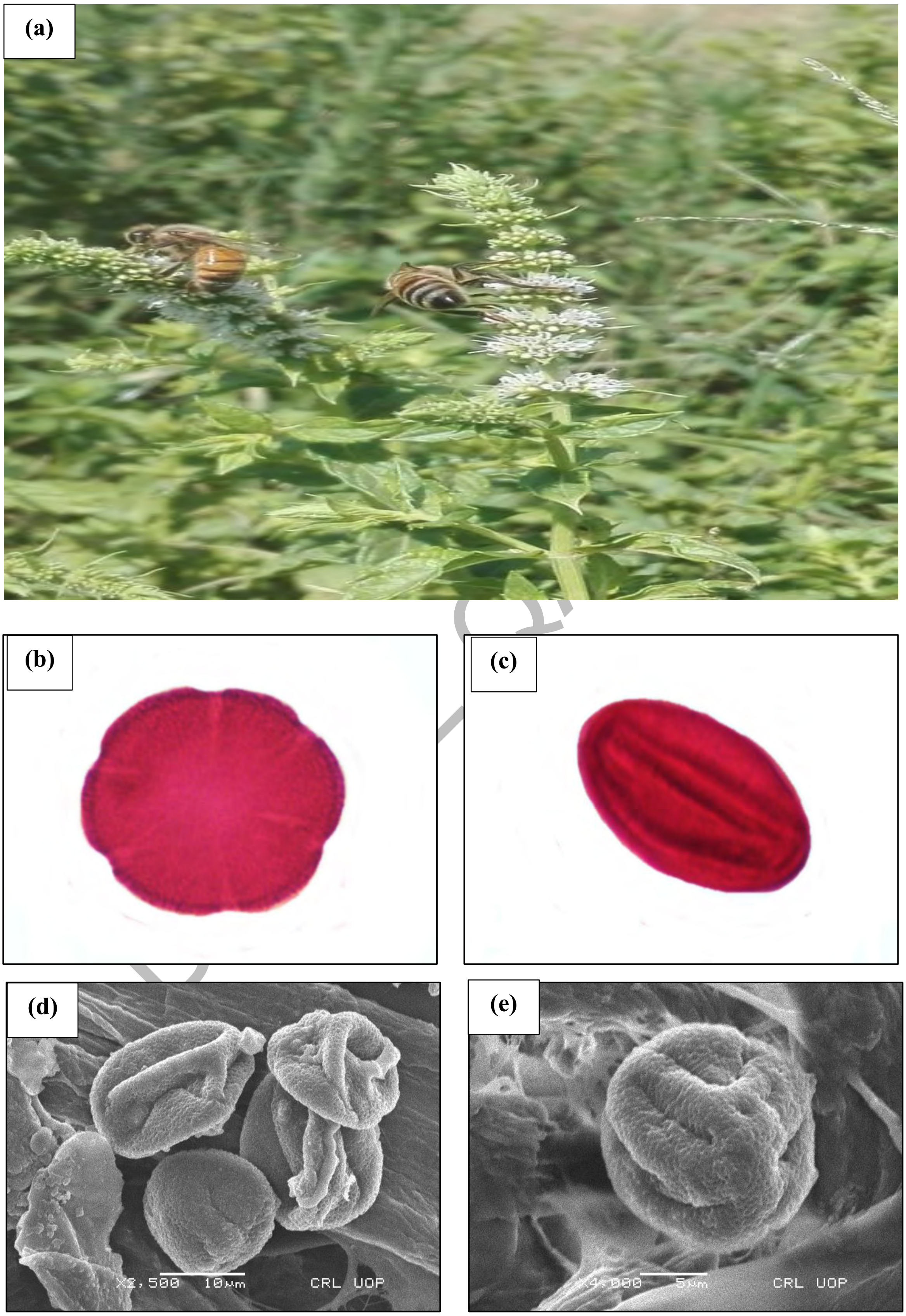

Plate 65: *Mentha spicata* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Vitex negundo* L.

Synonym	*Agnus-castus negundo* (L.) Carrière
Family	Lamiaceae
Common Name	Chinese chaste tree
Habit	Shrub
Habitat	Found near bodies of water, disturbed land and grasslands
Flowering period	June to October
Status	Wild
Distribution	India, Myanmar, Nepal, Pakistan, Kenya, Madagascar
Morphology	Shrubs, 2-4 m tall, whitish to greyish tomentose. Leaves; opposite, decussate, 4-5 foliolate, petiolate; petiole, 4-7 cm long; leaflets; usually lanceolate, 5 to 11 cm long, 1.2-5 cm broad, irregularly denticulate, sub-sessile to petiolate. Terminal inflorescence; 12-28 cm long, cymes; verticillate at nodes and peduncle. Flowers; small, 2-8 mm across, blue or violet, sub-sessile to shortly pedicelled. Calyx; 1.2-2 mm long, increasing up to 4 mm in fruit, persistent, campanulate, 5 toothed. Corolla tube long as calyx; limb slightly bi-lipped, with 5, unequal lobes, densely ciliate, up to 1.6 mm long, largest one orbicular, undulate. Stamens; tetra didynamous, protruding and anther cells divaricating later (Plate 66a).
Melissopalynology	Pollen grains are monad, small to medium sized and tricolporate. Circular lobate polar view and sub-prolate equatorial view shape. Exine sculpturing regulate perforate. Polar diameter 21.5(18.7-25.2)±1.14 µm and equatorial view distance 17.15(13.7-21.2)±1.47 µm. P/E ratio 1.25. Colpi length 2.05(0.50-2.05)±0.04 µm, colpi width 3.60(2.25-4.75)±0.41 µm and mesocolpium 15.3(13.7-16.7)±0.55 µm. Exine thickness 1.30(0.25-2.25)±0.37 µm. Pollen fertility 94.05% and sterility 5.94% (Plate 66b,c,d & e).

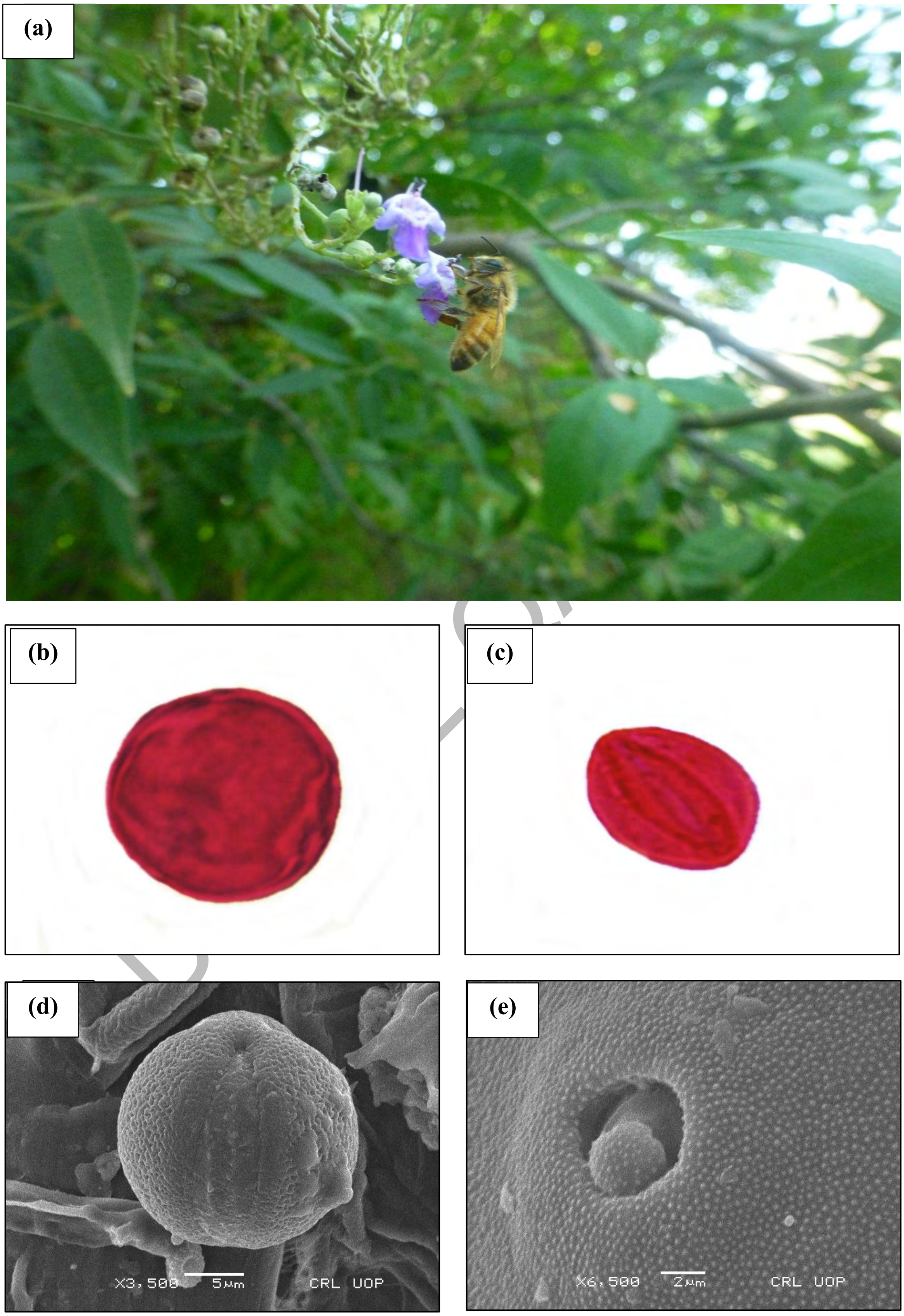

Plate 66: *Vitex negundo* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.12 Melisso-palynomorphs description of Lamiaceous taxa

The pollen grains of the examined Lamiaceous honeybee plant species were monad, tricolporate and hexacolpate, iso polar and radially symmetrical. Based on the Erdmann's classification, Lamiaceous pollen grains were small, small to medium and medium sized. In polar view, the outlines were observed as rounded, circular, circular lobate and elliptical. The pollen grains were mostly prolate-spheroidal, rarely sub-prolate.

The highest mean length of polar axis (P) was 24.2±1.03 µm and equatorial diameter (E) was 21.7±1.06 µm measured for *Mentha longifolia.* Whereas shortest polar diameter (P) was noted for *Clinopodium vulgare* (18.0±0.64 µm) and equatorial diameter (E) for *Mentha spicata* (17.05±0.62 µm) (Figure 37). *Mentha longifolia* had the longest colpi length (5.40±0.18µm) and colpi width (8.20±0.30 µm) respectively. While *Mentha spicata* had the shortest colpi length (1.95±0.1 µm) and width (0.9±0.2 µm) respectively (Figure 39). We determined the broadest (20.1±0.57 µm) mesocolpium for *Mentha longifolia* and narrowest (4.05±0.4 µm) in *Mentha arvensis* (Figure 41).

Four different exine membrane ornamentation of pollen were observed: reticulate, micro-reticulate, semi tectate reticulate and regulate perforate. Exine thickness varies between 1.3±0.37 µm in *Vitex negundo* to 5.15±0.23 µm in *Clinopodium vulgare* (Figure 40). Pollen fertility and sterility estimation was determined maximum in *Vitex negundo* (94.05%) and *Mentha longifolia* (35.7%) respectively. Whereas fertility percentage was determined minimum in *Mentha longifolia* (64.2%) and sterility in *Vitex negundo* (5.94%) as shown in Figure 42.

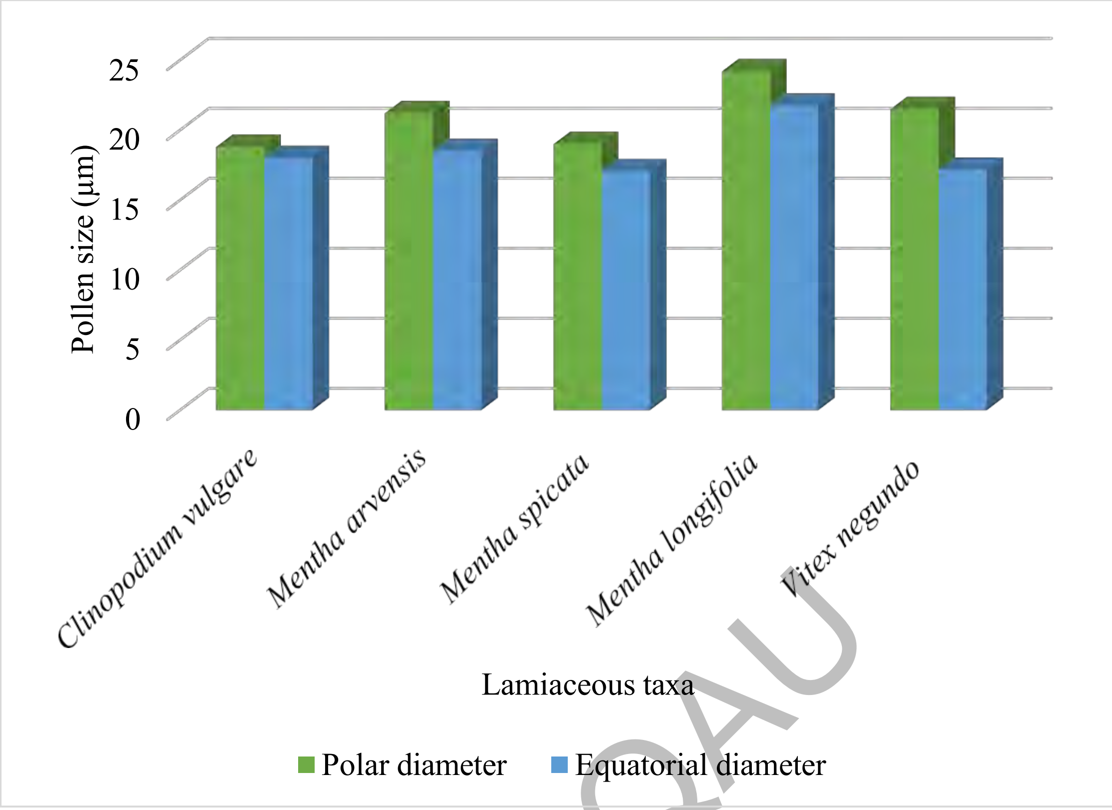

Figure 37. Variations in mean values of pollen diameter among Lamiaceous bee flora

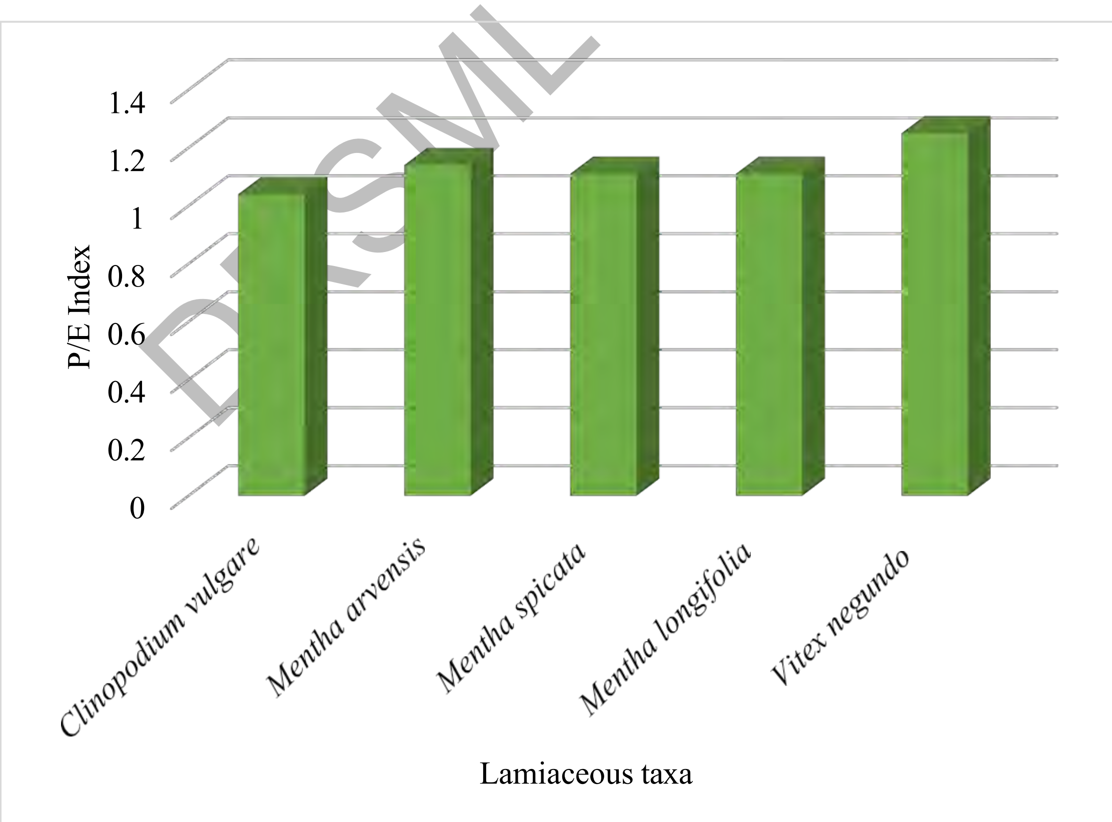

Figure 38. Variation in P/E ratio of Lamiaceae honeybee floral plants

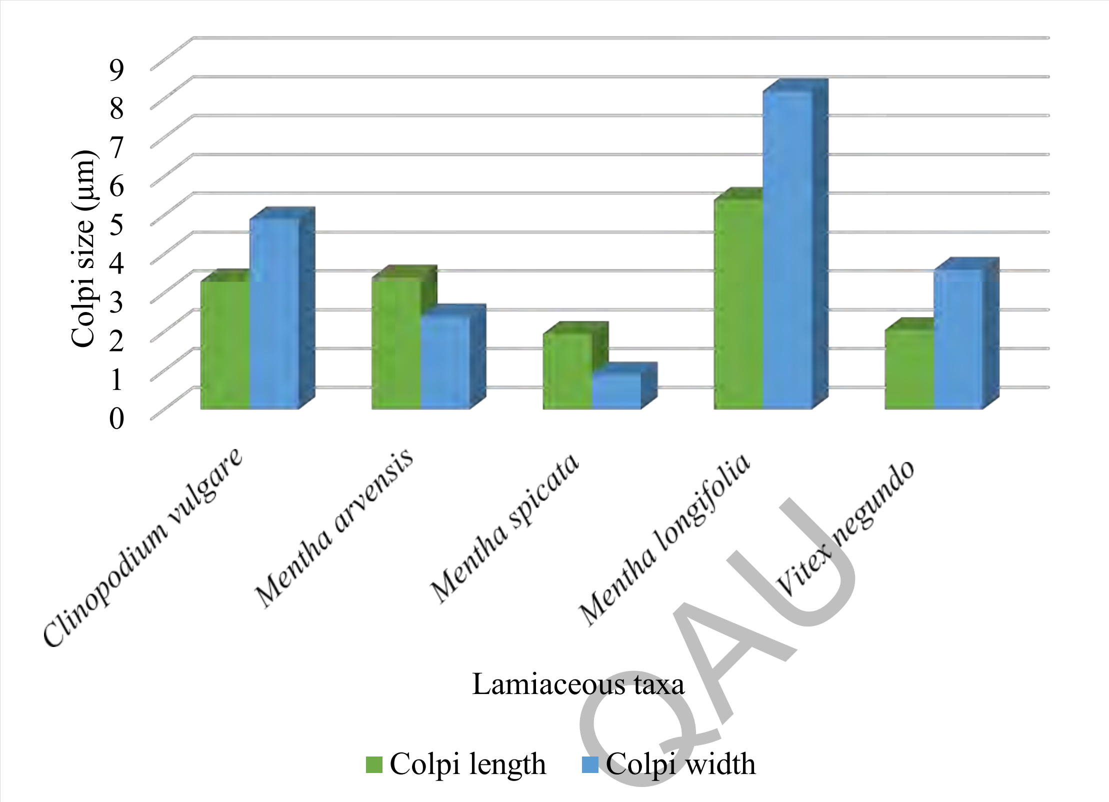

Figure 39. Mean data variations of colpi length and width in Lamiaceous bee flora

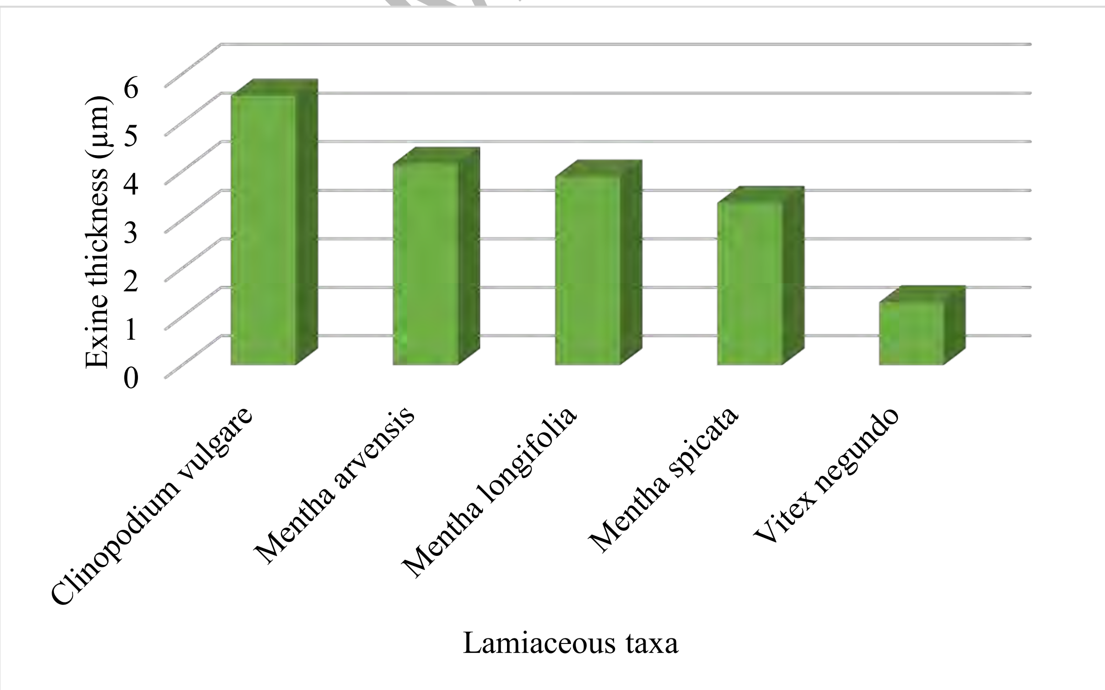

Figure 40. Mean exine thickness variations in Lamiaceae bee floral species

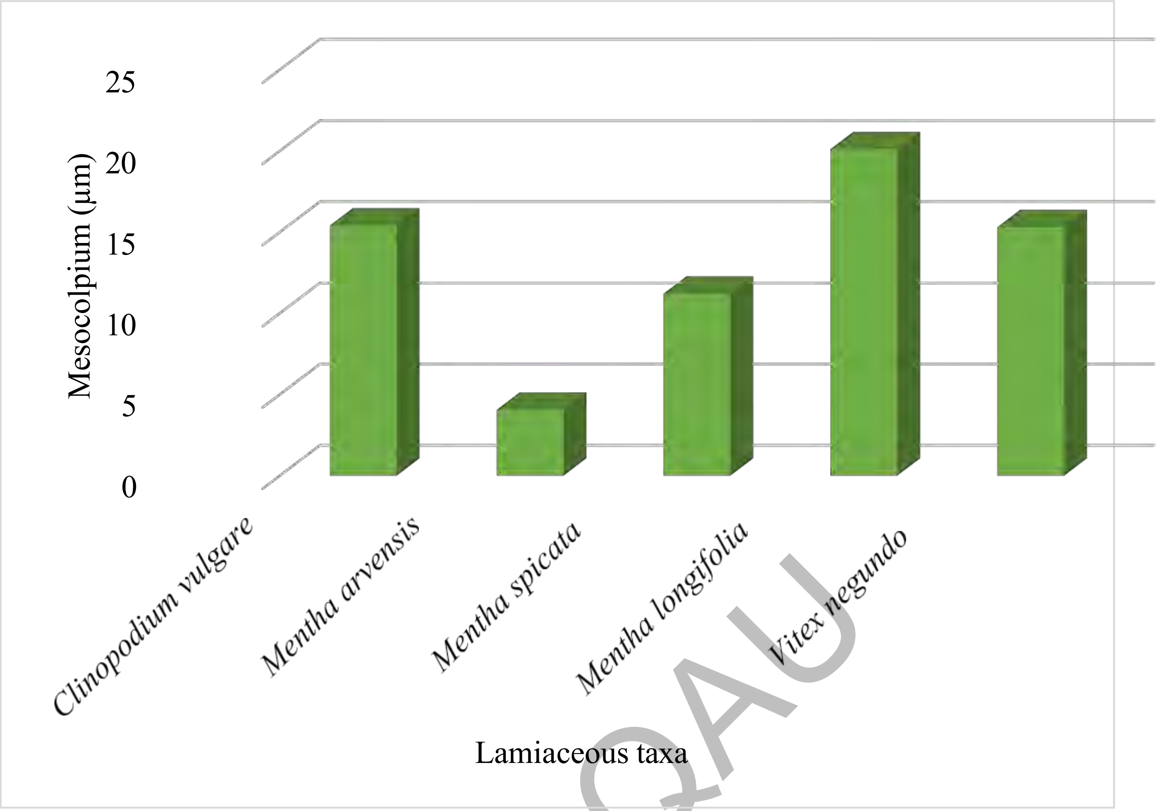

Figure 41. Mean mesocolpium measurement variations in Lamiaceous bee flora

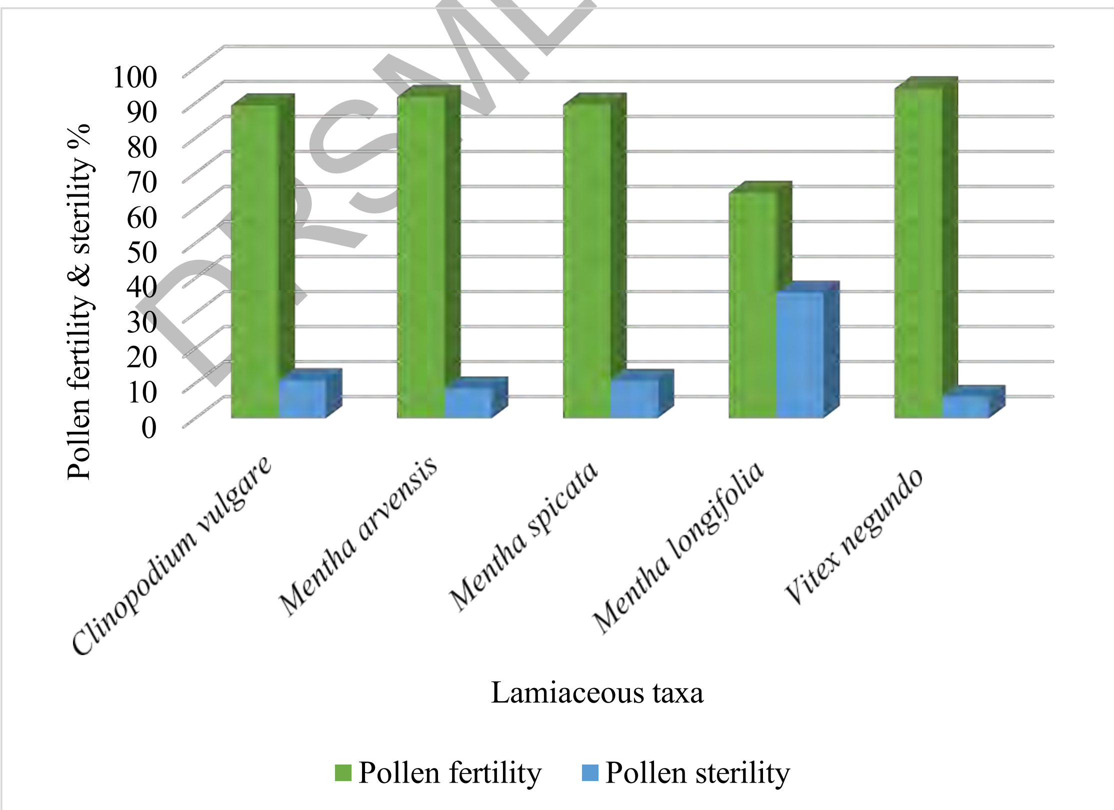

Figure 42. Graphical illustration of pollen fertility and sterility of Lamiaceae bee flora

3.2.13 Malvaceous Honeybee flora

1. *Abelmoschus esculentus* (L.) Moench

Synonym	*Abelmoschus bammia* Webb
Family	Malvaceae
Common Name	Okra
Habit	Annual Herb
Habitat	Along meadows and fields
Flowering period	April to October
Status	Cultivated
Distribution	West Africa, Canada, North America, Pakistan
Morphology	Herb; 0.6-2 m tall. Stem with sparse stellate hairs, glabrescent. Leaves; alternate, palmately lobed, orbicular, 5-14 × 4-15 cm across, base cordate, 4-8 nerved, oblong, 2 to 3 lobules, margins crenate, about 10-14 cm long, filiform stipules, hirsute, 5-13 × 2.5-4 mm across. Inflorescence; terminal and solitary. Flowers; bisexual, yellow, inarticulate, 0.4-1.7 cm long, epicalyx; 9 to 12, connate base, calyx 5 lobed, valvate, stellate pubescent, 1.2-2.4 cm, corolla large, yellow obovate, 1.8-3.2x1.3-1.7 cm across. Stamens; indefinite, monadelphous, filament short, introrse, basifixed anthers. Ovary; superior, 5 locular, style 1, stigma discoid and ovules many. Fruit; capsule, ovoid, beaked apex and hispid. Seed; reniform, globose, 2.5-4 mm across, villous, dark brown (Plate 67a).
Melissopalynology	Pollen are monad, medium sized, and pantoporate. Round shape polar view and equatorial view subprolate. Exine ornamentation echinate. Polar diameter 28.9(23.2- 38.0)±6.03 µm and equatorial diameter 25.05(23.0-27.7)±1.83 µm. P/E ratio 1.15. Colpi length 1.15(0.75-1.50)±0.28 µm and colpi width 1.20(0.75-1.50)±0.27 µm. Mesocolpium distance 15.2(12.7-16.2)±1.41 µm. Spine length 2.70(2.25-3.25)±0.44 µm and spine width 1.35(0.76-3.75)±0.57 µm. Exine thickness 2.20(0.75-3.75)±1.15 µm. Pollen fertility 86.04% and sterility 13.9% (Plate 67b,c,d & e).

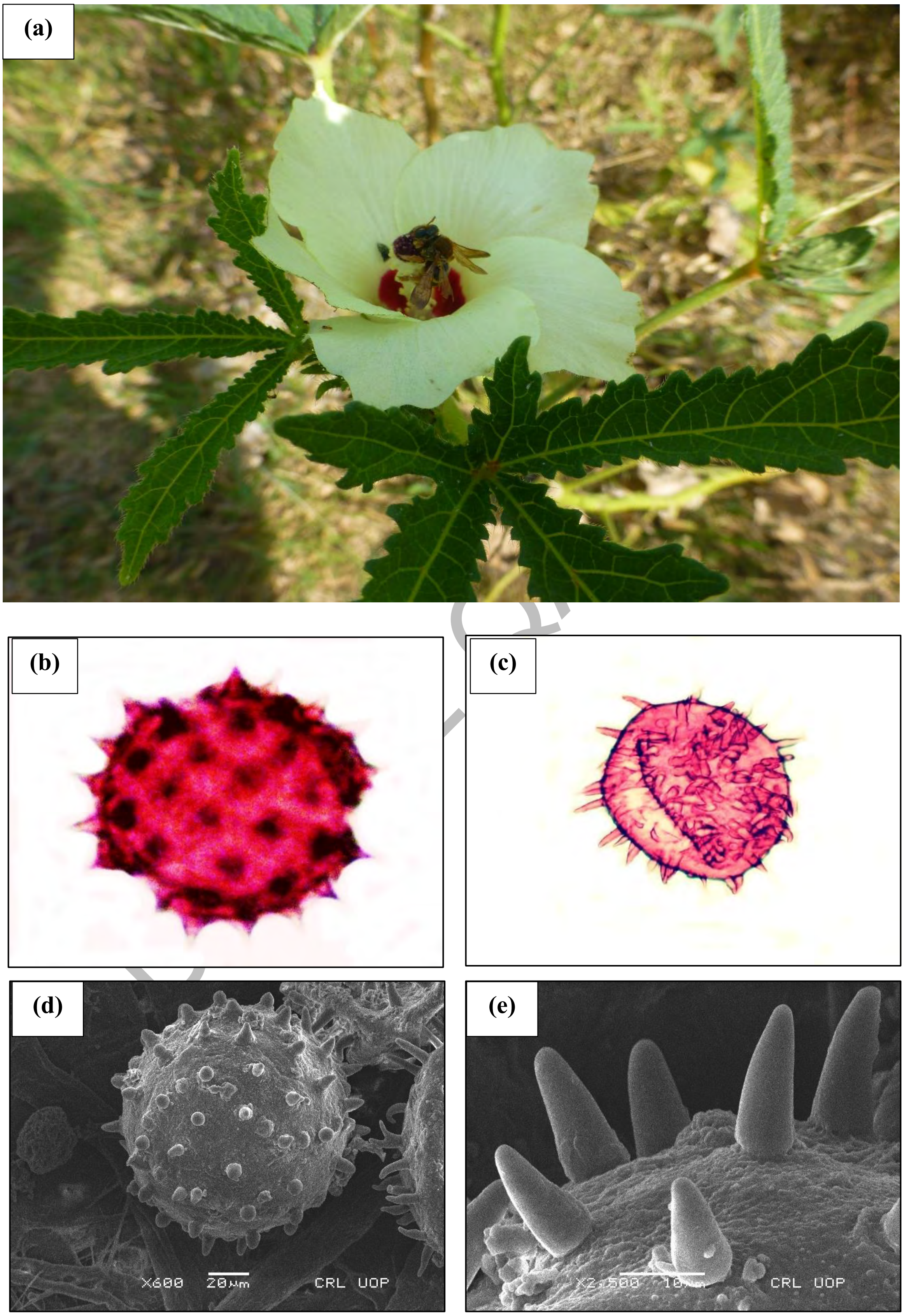

Plate 67: *Abelmoschus esculentus* (L.) Moench (a) Floral part; (b & c) LM polar view and surface pattern of pollen along with spines, (d & e) SEM polar view and Exine sculpturing

2. *Alcea rosea* L.

Synonym	*Alcea biennis* Winterl
Family	Malvaceae
Common Name	Hollyhock
Habit	Annual Herb
Habitat	Terrestrial waste places found near freshwater
Flowering period	Mid to late summer
Status	Cultivated
Distribution	Turkey, India, China, Pakistan, Southern Europe, USA
Morphology	2-3 m tall. Stem terete, green to greenish purple, 5-10 mm across, densely hirsute, more so in the apical region. Stipules green, apically 3-lobed, 7-9 mm long, 4-4.5 mm broad, glabrous in the apical region. Leaves alternate; leaf blade ovate, nearly orbicular to 5-7 lobed 3-8 cm in length, 3 to 9 cm wide; lobes oval shaped, acute; upper surface dark green. Flowers axillary, solitary or aggregated into a terminal spike like inflorescence; pedicels thicker and shorter than petioles, green to light brown, 0.7 to 1.5 cm in length, 2 mm across, densely stellate pubescent. Epicalyx cup-shaped, 7-lobed, 1.5-1.7 cm long, stellate hirsute. Calyx 5-lobed, 2-5 cm across; Corolla pink, white, yellow or purple; petals obovate, length 3.5-4 cm, 2-3 cm broad, apex is notched, clawed. Seeds brown, reniform, elongated, 4 mm long, 2 mm across (Plate 68a).
Melissopalynology	Pollen are monad, apolar, medium sized and pantoporate. Round shape polar view and oblate-spheroidal equatorial view. Exine ornamentation echinate. Polar diameter 12.0(111.2-127.7)±3.32 µm and equatorial diameter 12.1(113.2-127.7)±2.47 µm. P/E ratio 0.99. Pores circular, numbers vary per pollen (13 to 19). Pore length 4.20(3.00-5.50)±0.42 µm and pore width 3.90(2.75-5.25)±0.48 µm. Average spine number per pollen are 30. Spine length 8.75(7.75-9.75) ±0.39 µm and spine width 4.70(4.25-5.25) ±0.37 µm. Exine thickness 6.60(5.25-7.75)±0.0.43 µm. Pollen fertility 88.4% and sterility 11.5% (Plate 68b,c,d & e).

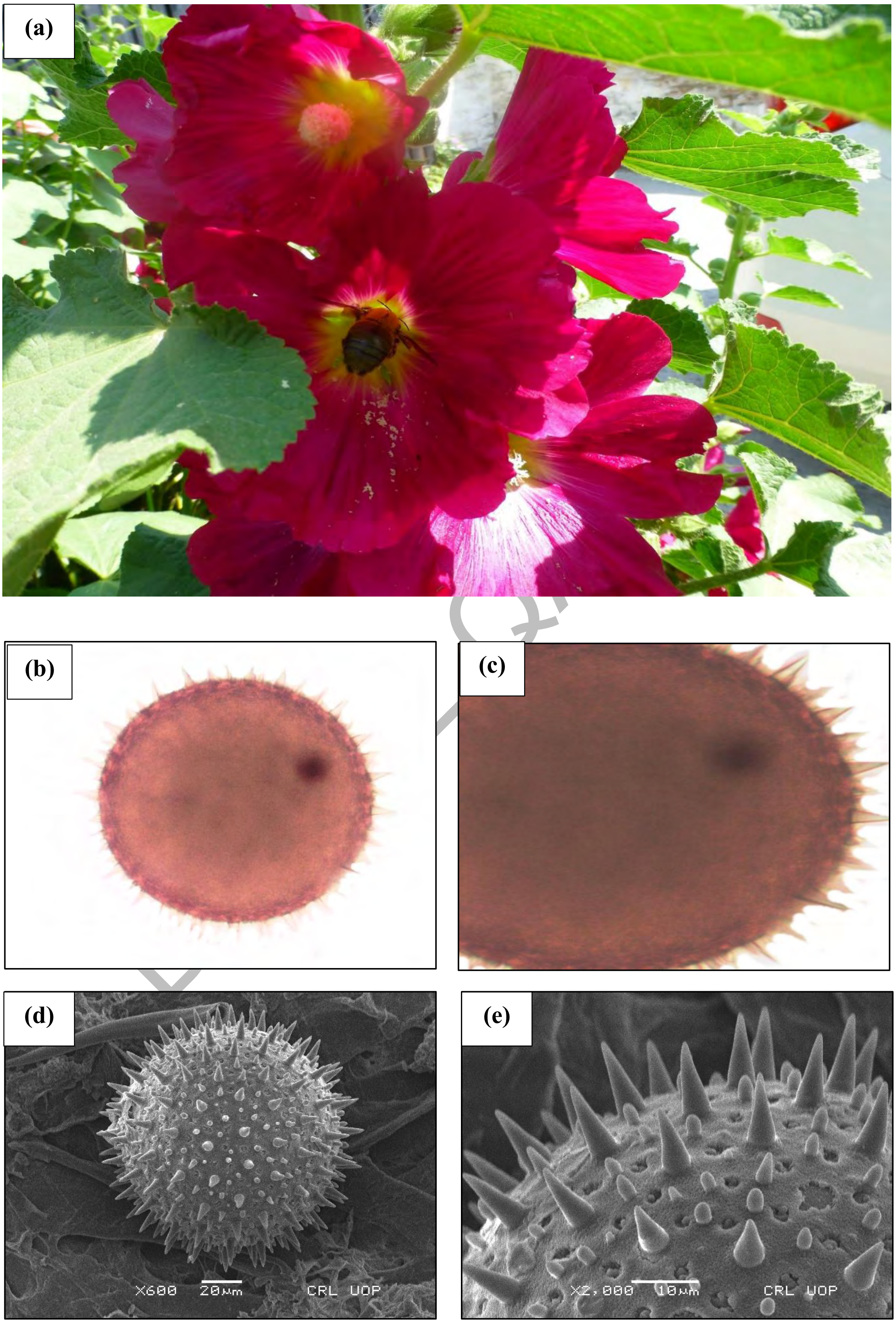

Plate 68: *Alcea rosea* L. (a) Floral part; (b & c) LM polar view and surface pattern of pollen along with spines, (d & e) SEM polar view and Exine sculpturing

3. *Corchorus olitorius* L.

Synonym	*Corchorus catharticus* Blanco
Family	Malvaceae
Common Name	Jute mallow
Habit	Herb
Habitat	Desert, fertile, humus-rich, well drained alluvial soil
Flowering period	August to September
Status	Wild
Distribution	Bangladesh, Australia, Pakistan, Bhutan, Florida, Mexico
Morphology	Erect, sub-glabrous, annual, up to 5 m tall. Stem; basally woody, branched. Leaves; 4-7-costate, ovate lanceolate, 2.5-11 cm long, 1.4-4.5 cm broad, glabrous, serrate, prolonged into filiform deflexed appendages, acuminate, petiole; 2.5-3.8 cm long, hairy, stipules; subulate, 6-13 mm long. Cyme; 2 flowered, pedunculate. Flowers; yellow, 10-14 mm across, subsessile, bracts subulate, 3.2-5.5 mm long. Sepals; linear to oblong, 3-9 mm long, 1-3 mm broad, keeled, caudate, somewhat bullate outside. Petals; oblanceolate, 8 mm long and obtuse. Stamens; numerous, united at base, filaments 5-9 mm long. Carpels; 5, ovary cylindrical, sub-sulcate, 5 loculed, style short, stigma 5 lobed and papillate. Seeds; greenish black, triangular, ovate and 1.3-2.5 mm long (Plate 69a).
Melissopalynology	Pollen are monad, linear symmetrical, medium sized and tricolpate. Circular polar view and equatorial view shape prolate-spheroidal. Exine sculpturing reticulate. Polar diameter 32.9(26.2-42.7)1.71 µm and equatorial distance 28.9(23.5-35.7)1.47 µm. P/E ratio 1.13. Colpi length 4.45(3.25-5.50)0.23 µm and colpi width 6.45(3.25-8.50)0.51 µm. Exine thickness 5.12(3.25-7.12)0.44 µm. Mesocolpium distance 19.5(17.0-23.7)0.78 µm. Pollen fertility 86.3% and sterility 14.69% (Plate 69b,c,d & e).

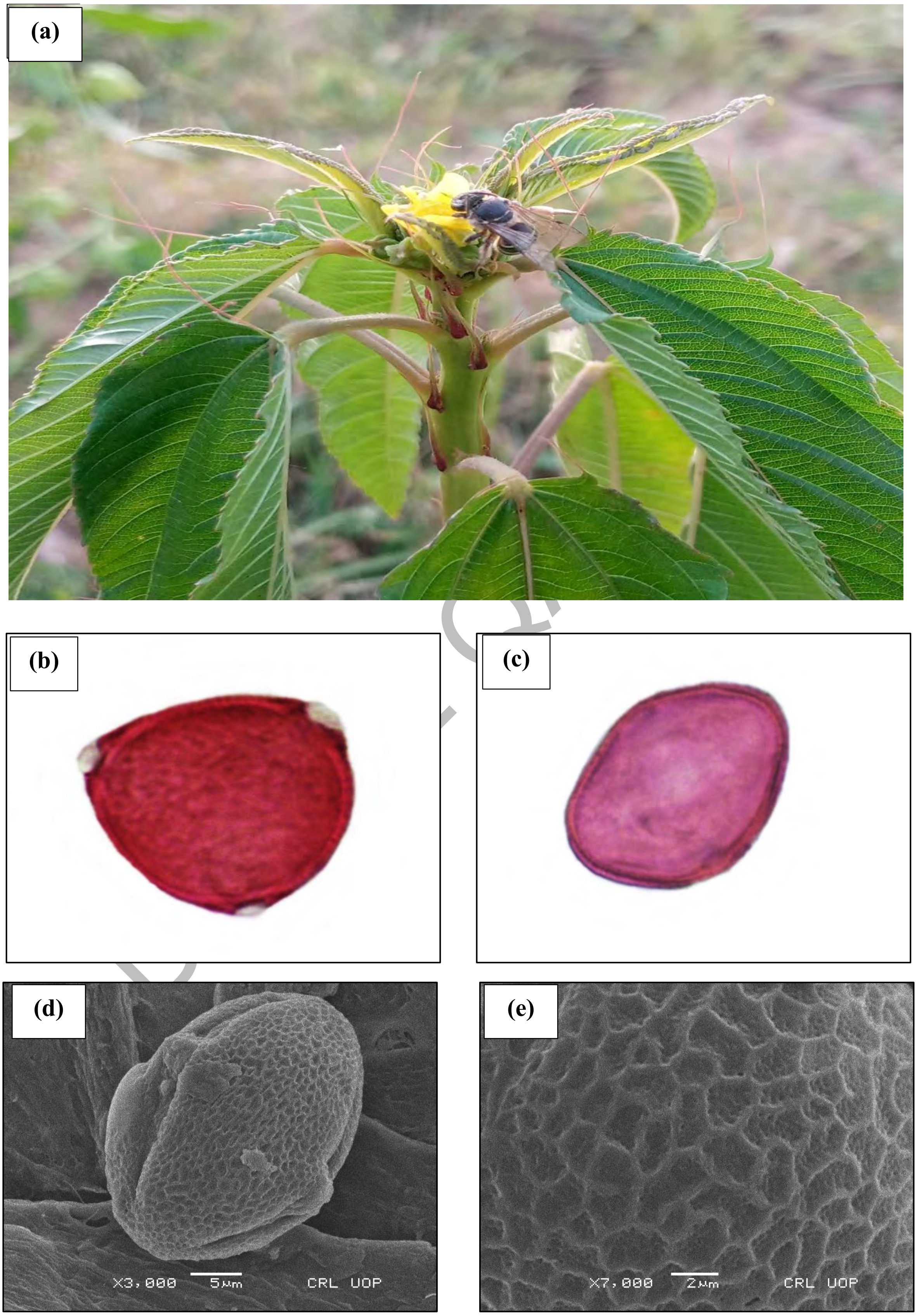

Plate 69: *Corchorus olitorius* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Hibiscus rosa-sinensis* L.

Synonym	*Hibiscus boryanus* DC.
Family	Malvaceae
Common Name	China rose
Habit	Shrub
Habitat	Grow in gardens humid conditions and fertile soil
Flowering period	April to august
Status	Cultivated
Distribution	India, Srilanka , South Africa ,Pakistan, Thailand, Philippines
Morphology	1.5-5 m tall shrub. Branchlets terete, glabrate. Stipules green, linear, 5-11 mm long, 2-3 mm broad. Leaves alternate; leaf blade ovate, 5-8 cm long, 3-5 cm wide, margin dentate-serrate, base cuneate, petiole 0.6-2.1 cm long, green. Flowers solitary, axillary, erect to pendulous, single or double; pedicel 2-8 cm long. Epicalyx; 6-9 sagments, glabrescent, length 5-13 mm, width is 1-3 mm. Calyx campanulate, 5-lobed, 1-3 cm long, lobes ovate and stellate pubescent. Corolla; bell-shaped, pinkish to red or orange, 4-8 cm across; petals obovate, 4-10 cm long, 4-7 cm broad. Staminal column; 4-10 cm long, 5 mm across, glabrescent. Style branches five. Stigmas; 5, capitate. Fruit; capsule, glabrous, ovate, 2-2.5 cm long and 1 cm across, Seeds 2 mm long, reniform (Plate 70a).
Melissopalynology	Pollen are monad, apolar, large sized and pantoporate. Circular polar view and equatorial view shape prolate spheroidal. Exine sculpturing echinate. Polar diameter 81.3(75.2-87.7)±1.98 µm and equatorial view distance 73.2(66.2-87.7)±3.83 µm. P/E ratio 1.11. Pore circular, numbers per pollen 30 to 35. Pore length 2.00(1.25-2.75)±0.25 µm and pore width 3.50(2.00-5.25)±0.72 µm. Average spines number per pollen 17. Spine length 8.90(7.25-10.2)±0.58 µm and spine width 1.95(1.25-2.75)±0.35 µm. Exine thickness 1.75(0.75-2.75)±0.35 µm. Mesocolpium distance 1.75(0.75-2.75)±0.35 µm. Pollen fertility 76.9% and sterility 23% (Plate 70b,c,d & e).

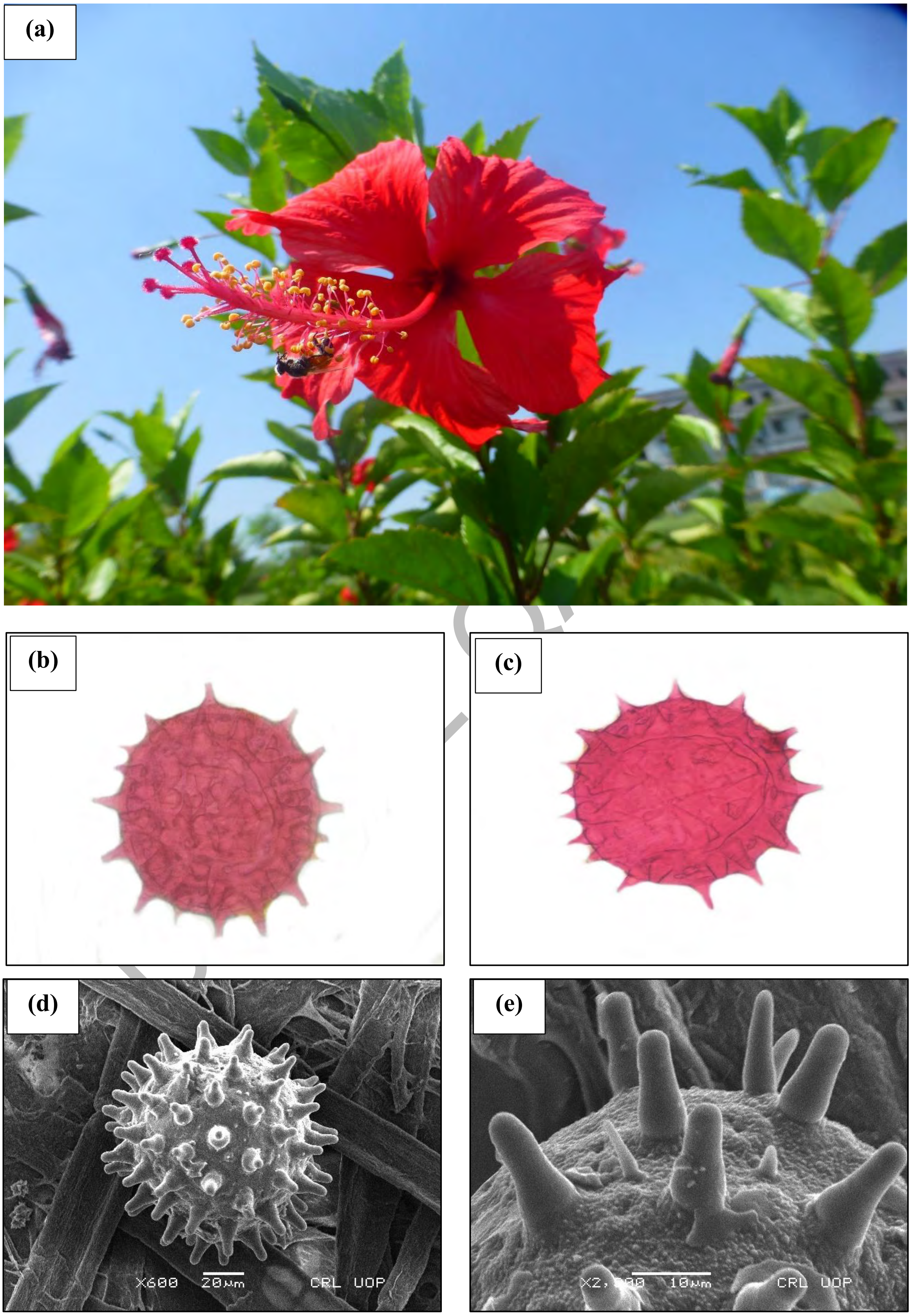

Plate 70: *Hibiscus rosa-sinensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Malvastrum coromandelianum* (L.) Garcke

Synonym	*Malva coromandeliana* L.
Family	Malvaceae
Common Name	Prickly Malvaestrum
Habit	Annual Herb
Habitat	Near moist places, roadsides, and rubbish dumps
Flowering period	July to October
Status	Wild
Distribution	Colombia, Pakistan, China, India , Japan ,South America, Srilanka
Morphology	Erect plant or sub-plant. The main stem is straight and hairy, and root of this plant is tap root. The length of the stem is 9.95cm the width of the stem is 0.3cm .Leaves are simple and hirsute (hair Growth), margins of the leaves are dentate. Length of the leave is 3.5-4cm and the width is 1.9 to 2 cm. Stipules lanceolate, 4-9 mm; petiole; 0.5-3.2 cm, densely pilose; leaf blade; lanceolate, 2-6×0.6-4.5 cm, pilose and stellate, sparsely hairy, base broadly cuneate, margin coarsely dentate, apex obtuse. Flowers axillary, solitary. The flowers are solitary or in small clusters at the terminal or at the base of the leaves (Plate 71a).
Melissopalynology	Pollen monad, apolar, large sized, and pantoporate. Circular in polar view and prolate-spheroidal equatorial view shape. Exine sculpturing echinate. Polar diameter 79.3(61.2-88.7)±4.97 µm and equatorial view distance 75.7(55.2-90.2)±6.72 µm. P/E ratio 1.04. Pore numbers varies (45 to 56). Pore length 4.40(3.75-6.25)±0.47 µm and pore width 4.50(2.75-5.25)±0.46 µm. Average spines number per pollen 33. Spine length 0.25(0.15-0.4)±0.11 µm, spine width 2.8(1.9-3.7)±1.17 µm. Exine thickness 4.25(3.25-5.25)±0.35 µm. Pollen fertility 90.3% and sterility 9.6% (Plate 71b,c,d & e).

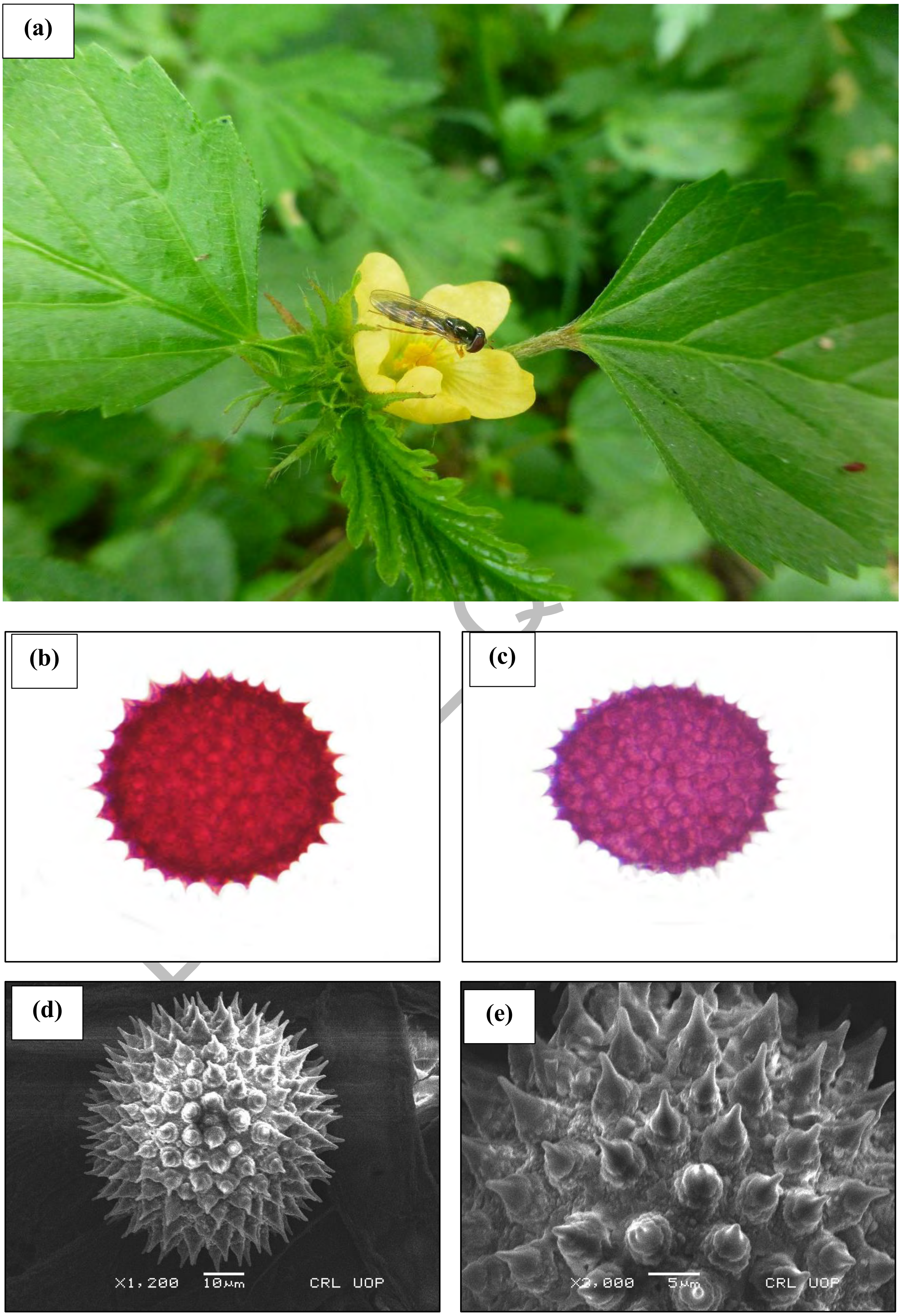

Plate 71: *Malvastrum coromandelianum* (L.) Garcke (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.14 Melisso-palynomorphs description of Malvaceous taxa

The pollen grains of the Malvaceous honeybee floral species studied are monad; iso polar; medium, large, very large; circular, subcircular, rounded polar view; small to large polar area; oblate, prolate-spheroidal, sub-prolate and oblate spheroidal; 3-colpate, pantoporate; short narrow ectoaperturate; pores sometimes with atrium (in pororate condition); exine tectate scabrate; echinate micro-reticulate, reticulate, reticulate and reticulum echinate-reticulate.

The pollen grain diameters of the Malvaceous honeybee plant species analyzed show differences that allow species to be distinguished by metric values. Thereby, based on the measurements performed and comparing the means and the interval of the diameters of the pollen grains studied, we observed that *Alcea rosea* pollen grains have the highest diameter values (PD= 120±3.32 µm and ED = 121±2.4 µm), while those from *Abelmoschus esculentus* have the smallest diameter values in (PD = 28.9±6.03 µm and ED = 25.05±1.83 µm) as mentioned in Figure 43. The ratio of polar axis to equatorial axis varying from 0.71 (*Alcea rosea*) to 1.15 (*Abelmoschus esculentus*) as shown in Figure 44. The maximum average length and width of aperture (L = 4.45±0.23 µm) and (W = 6.45±0.51 µm) respectively. While minimum aperture length (1.15±0.28 µm) and width (1.20±0.27 µm) was noted in *Alcea rosea* (Figure 45). The size range of ET (exine thickness) was ranged from (1.75±0.35 µm) for *Hibiscus rosa-sinensis* and (6.60±0.0.4 µm) for *Alcea rosea* (Figure 46).

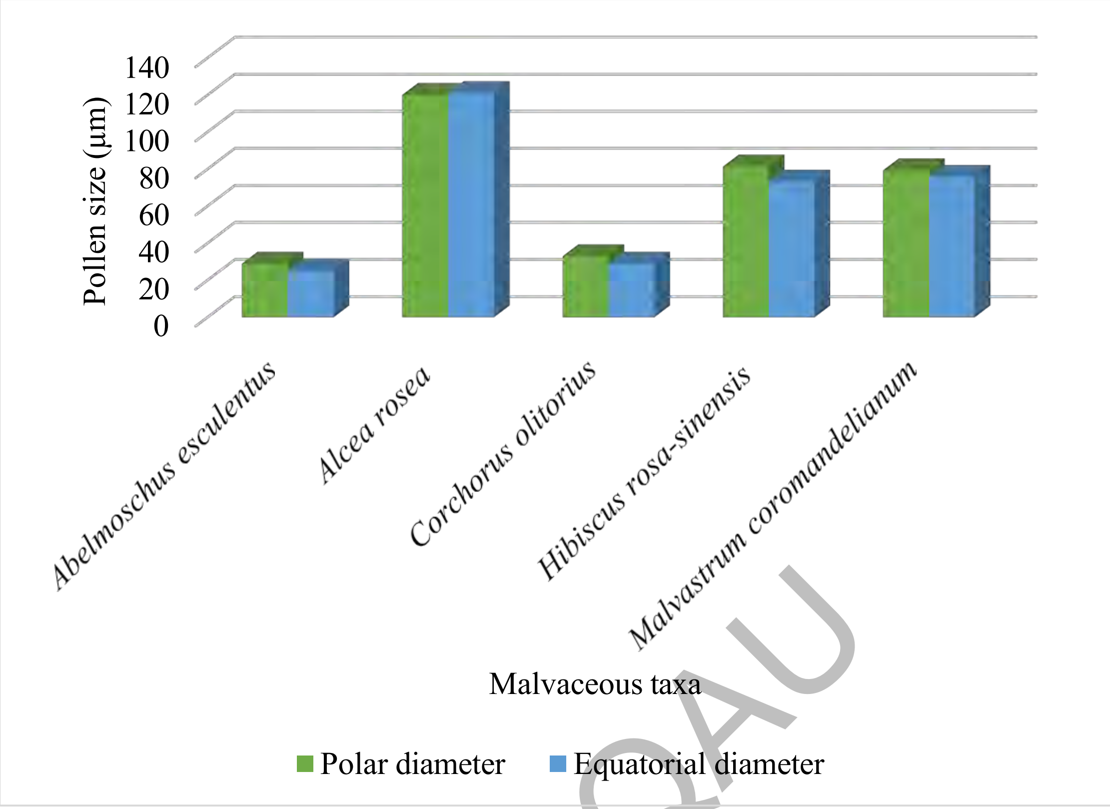

Figure 43. Mean values of pollen diameter among Malvaceous bee flora

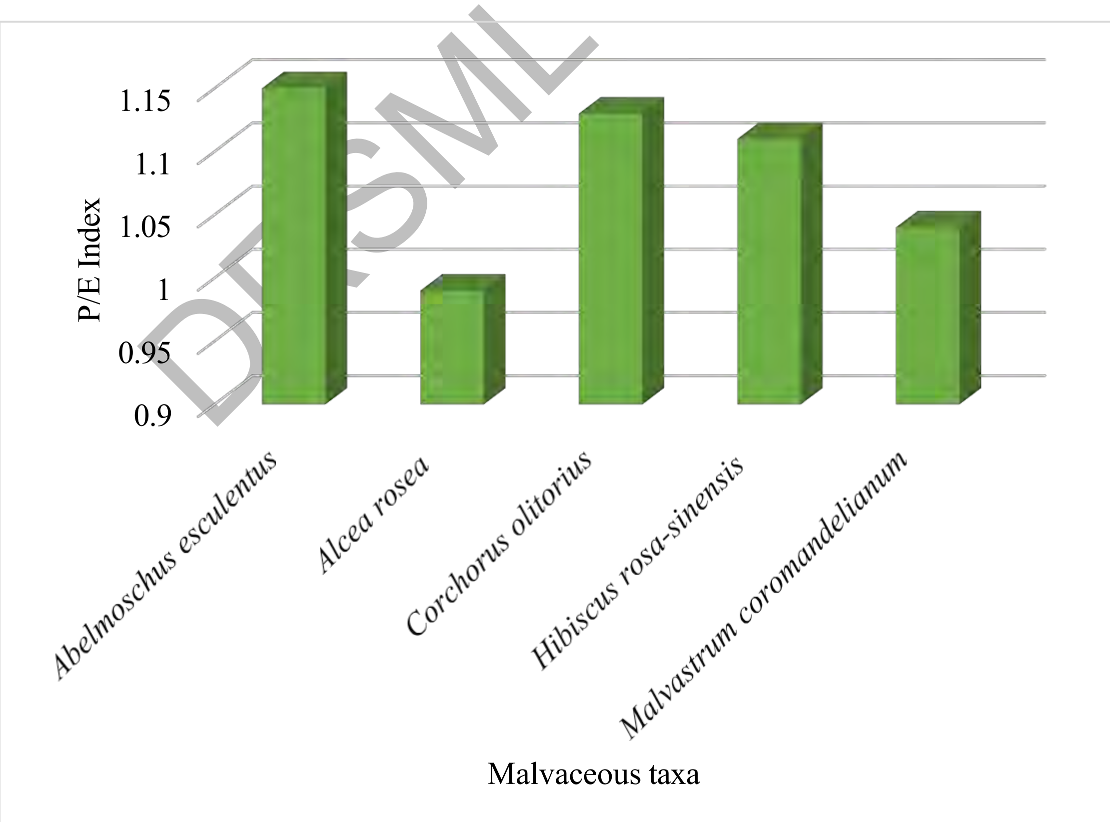

Figure 44. Variation in P/E ratio index of Malvaceous honeybee floral plants

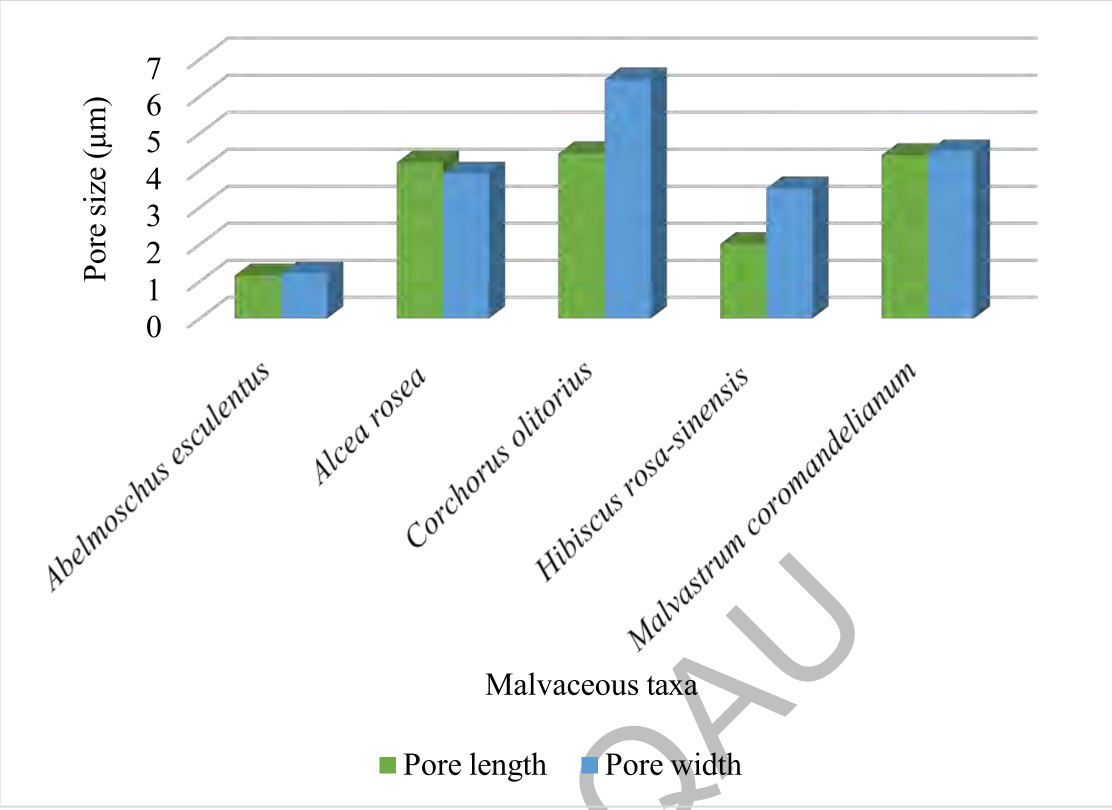

Figure 45. Data variations of pore length and width in Malvaceous bee flora

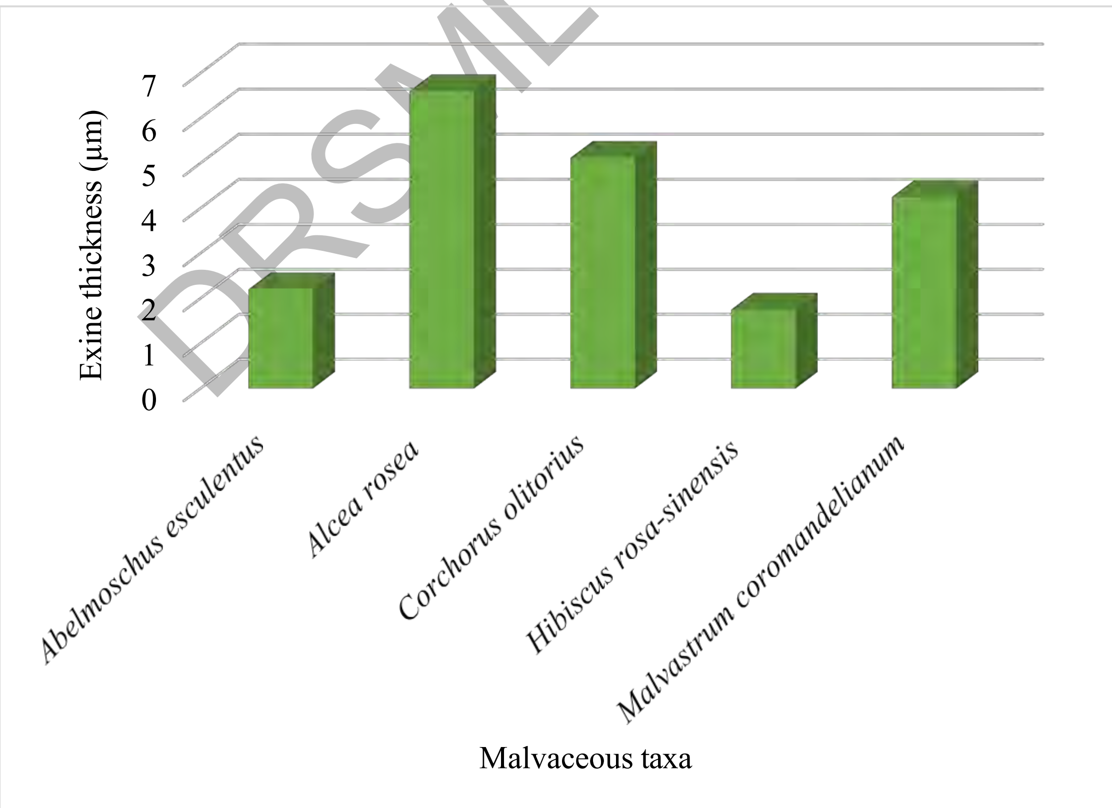

Figure 46. Mean exine thickness variations in Malvaceous bee floral species

3.2.15 Melisso-palynomorphs of Poaceous Honeybee flora

1. *Cymbopogon jwarancusa* (Jones) Schult.

Synonym	*Cymbopogon jwarancusa subsp. jwarancusa*
Family	Poaceae
Common Name	Jawarancusa grass
Habit	Perennial Herb
Habitat	Found on plains at lower elevations to mountains
Flowering period	June to September
Status	Wild
Distribution	Iraq, Nepal, China, Australia. Africa, Pakistan
Morphology	Culms; caespitose. glabrous; persistent; compacted dead sheaths. Culms erect, geniculately ascending; 25 to 130 cm long. Ligule an eciliate membrane; 0.6–4 mm long. Leaf-blades; 15-30 cm long; 3-5.4 mm wide; aromatic. Inflorescence; Synflorescence compound; linear; 15 to 40 cm long and dense; composed of racemes; terminal and axillary and enclosed. Racemes 2; paired; deflexed; 1.3 to 2.2 cm long. Rachis fragile the nodes; semiterete; pilose surface; ciliate margins. Raachis internodes linear. Spikelets in pairs. Fertile spikelets sessile; 1 in the cluster. Spikelets; comprising 1 basal sterile floret; 1 fertile florets; without rhachilla extension. Glumes dissimilar; exceeding apex of florets; firmer than fertile lemma. Basal sterile florets barren; without significant palea. Lemma of lower sterile floret hyaline. Fertile lemma lanceolate; hyaline; without keel (Plate 72a).
Melissopalynology	Pollen are monad, medium sized and monoporate. Slightly circular polar view and equatorial view shape prolate-spheroidal. Colpi absent. Exine sculpturing psilate. Polar diameter 27.9(23.2-31.2)±1.44 µm and equatorial view distance 24.5(22.7-26.2)±0.75 µm. P/E ratio 1.13. Exine thickness 1.55(0.75-2.25)±0.30 µm. Pollen fertility 85.7% and sterility 14.2% (Plate 72b,c,d & e).

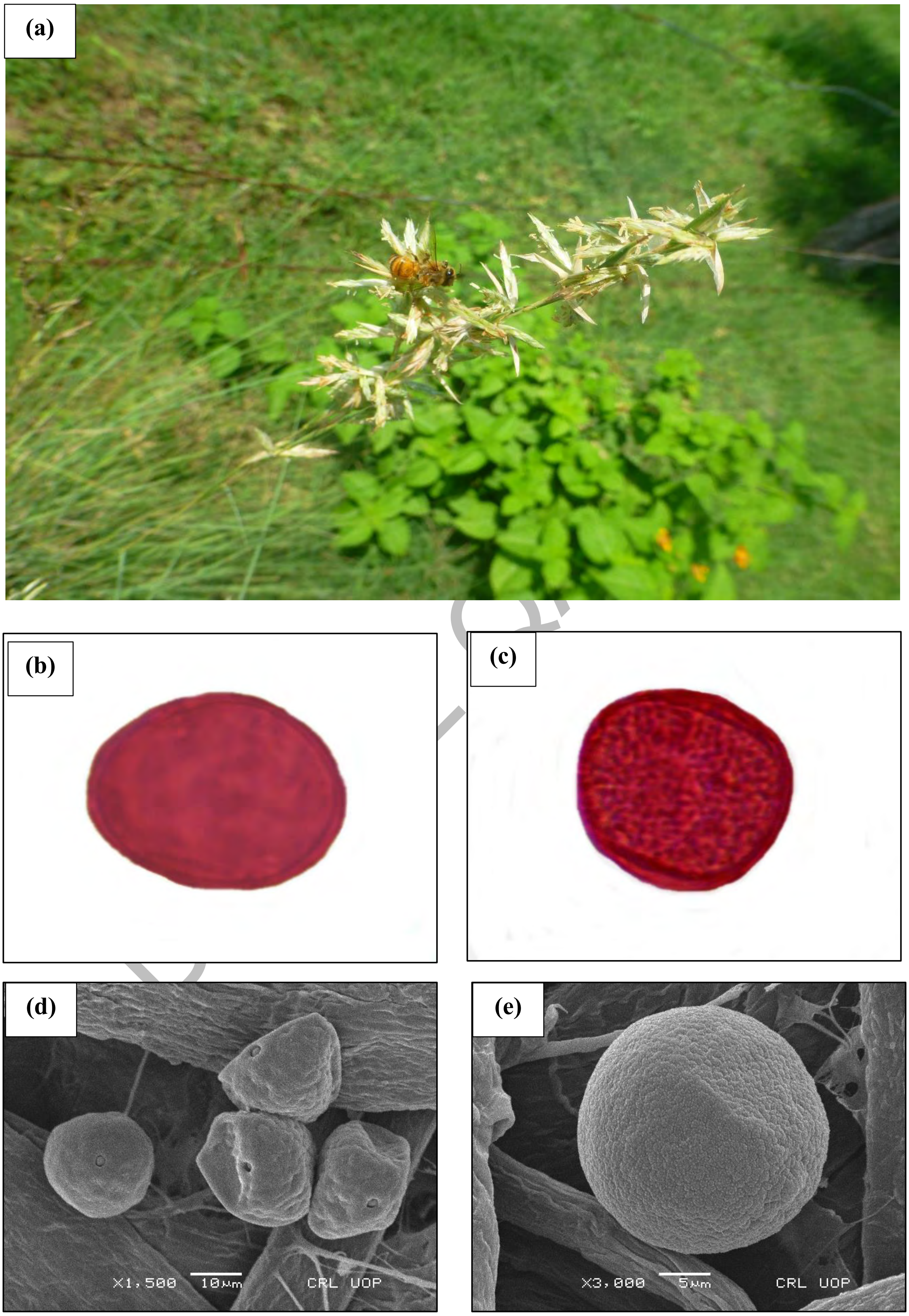

Plate 72: *Cymbopogon jwarancusa* (Jones) Schult. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Pennisetum glaucum* (L.) R.Br.

Synonym	*Alopecurus typhoides* Burm.f.
Family	Poaceae
Common Name	Pearl millet
Habit	Annual Grass
Habitat	Grow along well drained soil and in nutritionally poor soil.
Flowering period	August to October
Status	Wild
Distribution	China, Pakistan, India, West Africa
Morphology	Annual, Culms, robust, up to 3.5 m tall, densely pubescent. Leaf; sheaths loose, smooth; leaf blades 18–115×3–5 cm, surfaces and margins scabrous; base sub-cordate and ligule 2.3–3 mm. Inflorescence; broadly elliptic, dense, 35–52× 1.7–3 cm; axis densely pubescent; involucre persistent, enclosing 1 to 9 spikelets, basal stipe pubescent, 2.5–24 mm; bristles shorter than spikelets, glabrous to densely plumose. Spikeles; obovate, 3.5–4.5 mm; lower glume minute, 0.8-1 mm; upper glume 1.5–2 mm, 3-veined; floret staminate, lemma 2.3 mm, 5 veined, margins membranous, ciliate, palea, puberulous; upper lemma; 3-7.5-veined. Puberulous, margins ciliate, tip obtuse and anthers tuft of short hairs at tip (Plate 73a).
Melissopalynology	Pollen grains are monad, annulate, medium sized and monoporate. Spherical polar view and oblate-spheroidal equatorial view. Exine sculpturing areolate. Polar diameter 25.6(18.7-33.7)±2.52 µm and equatorial view distance 26.7(20.2-36.7)±2.70 µm. Pore length 1.4(0.8-1.85)±0.16 µm and pore width 0.9(0.6-1.4)±0.09 µm. P/E ratio 0.95. Exine thickness 1.25(0.25-2.75)±0.41 µm. Pollen fertility 82.05% and sterility 17.9% (Plate 73b,c,d & e).

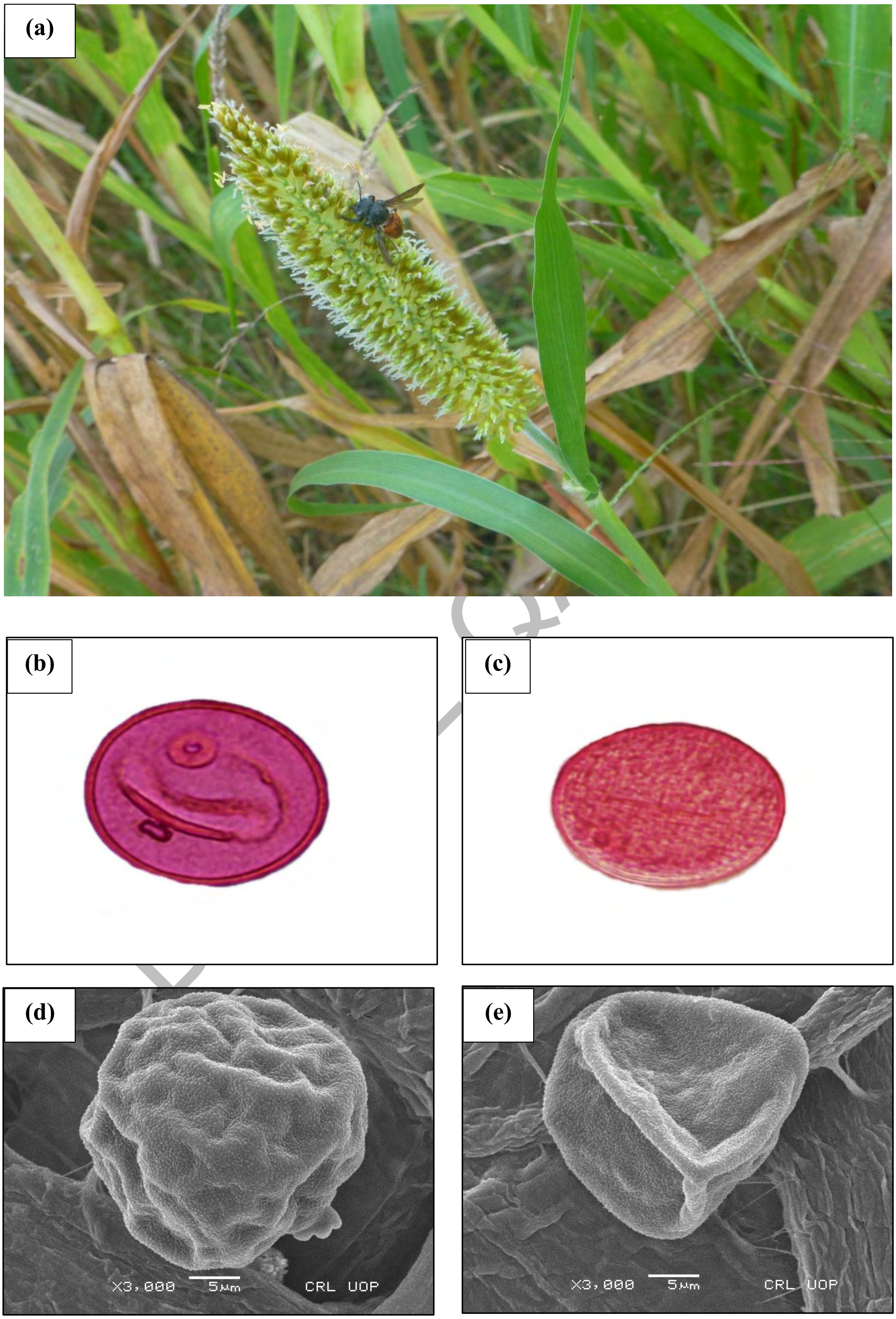

Plate 73: *Pennisetum glaucum* (L.) R.Br. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Setaria viridis* (L.) P.Beauv.

Synonym	*Chaetochloa comosa* (Miq.) Koidz.
Family	Poaceae
Common Name	Green foxtail
Habit	Annual grass
Habitat	Crops annual field, vegetable crops and forestry
Flowering period	May to September
Status	Wild
Distribution	South Africa, Tunisia, India, Iraq, Pakistan
Morphology	Annual, loosely tufted culms, 11-55 cm high, erect and ascending. Leaf blades; broadly linear, narrowly lanceolate, 5.5-23 cm long, 4-14 mm wide, rounded base, flaccid, scaberulous, sheaths glabrous, pubescent, tubercle based hairs. Panicle: dense, cylindrical, tapering upward, 2.5–20 cm, slightly nodding, branchlets bearing spikes; each subtended 2–12 bristles; axis pubescent; bristles green, 3.5-14 mm. Spikelets; ellipsoid, 2-3.5 mm long, lower glume; quarter third length of the spikelet; upper glume; as long as the spikelet and lower floret barren, its plea; half long as the lemma and upper lemma finely rugose (Plate 74a).
Melissopalynology	Pollen grains are monad, medium sized, radially symmetrical and monoporate. Semicircular polar view and sub-oblate equatorial view shape. Exine sculpturing scabrate. Polar diameter 26.4(12.7-33.7)±3.74 µm and equatorial view distance 29.8(22.2-36.1)±2.81 µm. P/E ratio 0.88. Pore length 1.15(0.8-1.5)±0.29 µm and pore width 0.85(0.5-1.1)±0.11 µm. Exine thickness 2.95(2.00-3.75)±0.28 µm Fertility and sterility estimation were 85.7% and 14.2% (Plate 74b,c,d & e).

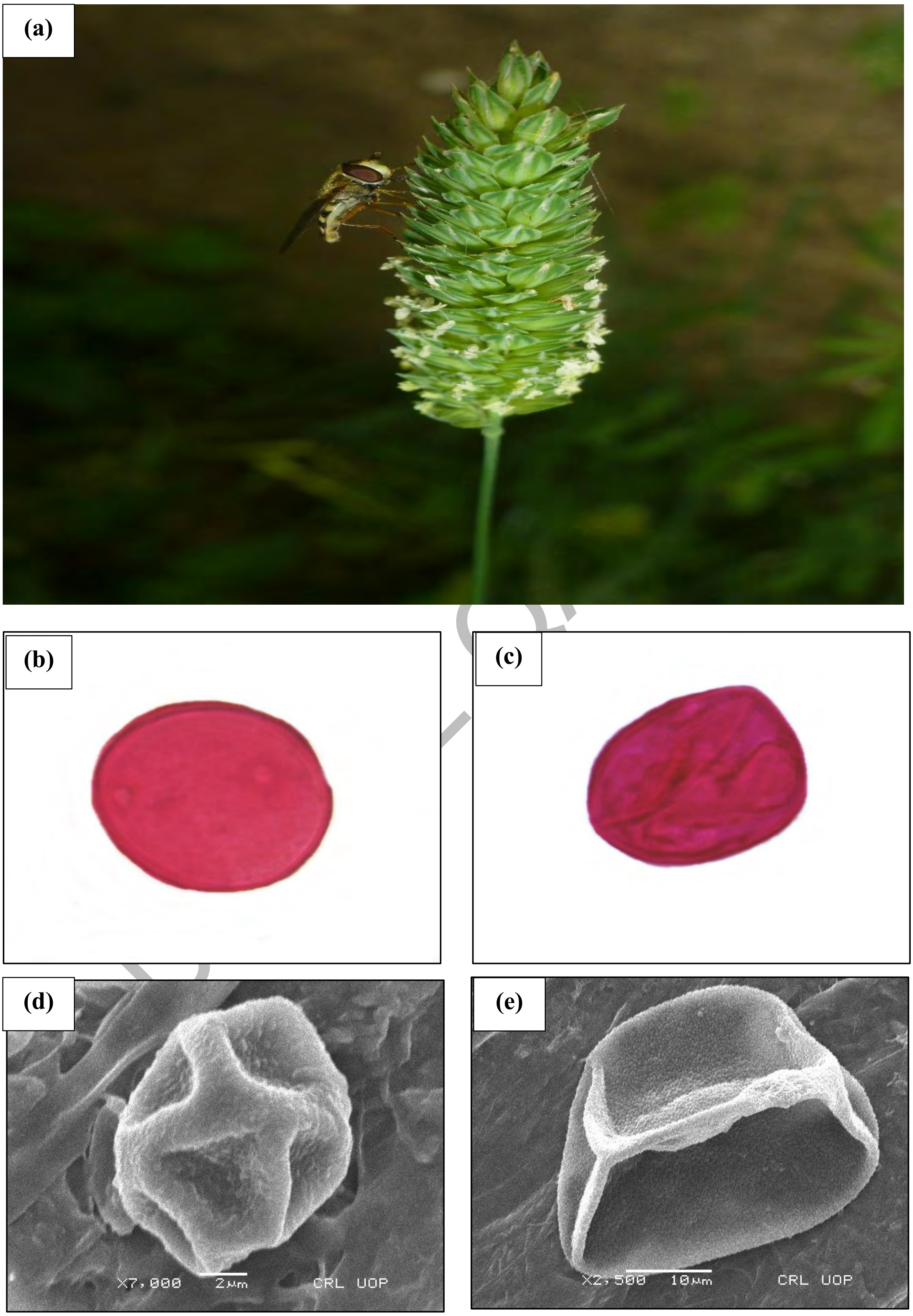

Plate 74: *Setaria viridis* (L.) P.Beauv. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Zea mays* L.

Synonym	*Zea mays* subsp. *acuminata* Golosk.
Family	Poaceae
Common Name	Corn
Habit	Annual Grass
Habitat	Grow in loamy soil cold area.
Flowering period	July to August
Status	Cultivated
Distribution	Mexico, America, Iran, China, India, Pakistan
Morphology	Monoacious, annual grass, culms erect, 1-4 m. Leaf sheaths have transvers veinlets; leaf blade 50-90x3-11 cm, glabrous, margins scabrid, mid vein stout; ligule 1.5 mm. Female inflorescence; cylindrical with 16-30 rows of spikelet's; margins ciliate; florets hyaline. Male inflorescence of many digitate racemes; spikelet's 10 to 14 mm, unequally pedicellate, one pedicel 1-2 mm. Glumes subequal, membranous, lower 10-veined, margins ciliate, upper 7-veined; lower lemma and palea hyaline, subequal; upper lemma smaller than lower. Anthers; orange, 5 mm (Plate 75a).
Melissopalynology	Pollen grains are monad, small sized and monoporate. Circular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing scabrate eutectate. Polar diameter 19.4(21.2-17.2)±0.79 µm and equatorial view distance 17.4(16.2-18.2)±0.38 µm. P/E ratio 1.11. Pore length 0.8(0.50-1)±0.09 µm and pore width 0.55(0.25-0.75)±0.09 µm. Exine thickness 1.95(1.50-2.25)±0.14 µm. Pollen fertility was estimated to be 76.08% and sterility 23.9% (Plate 75b,c,d & e).

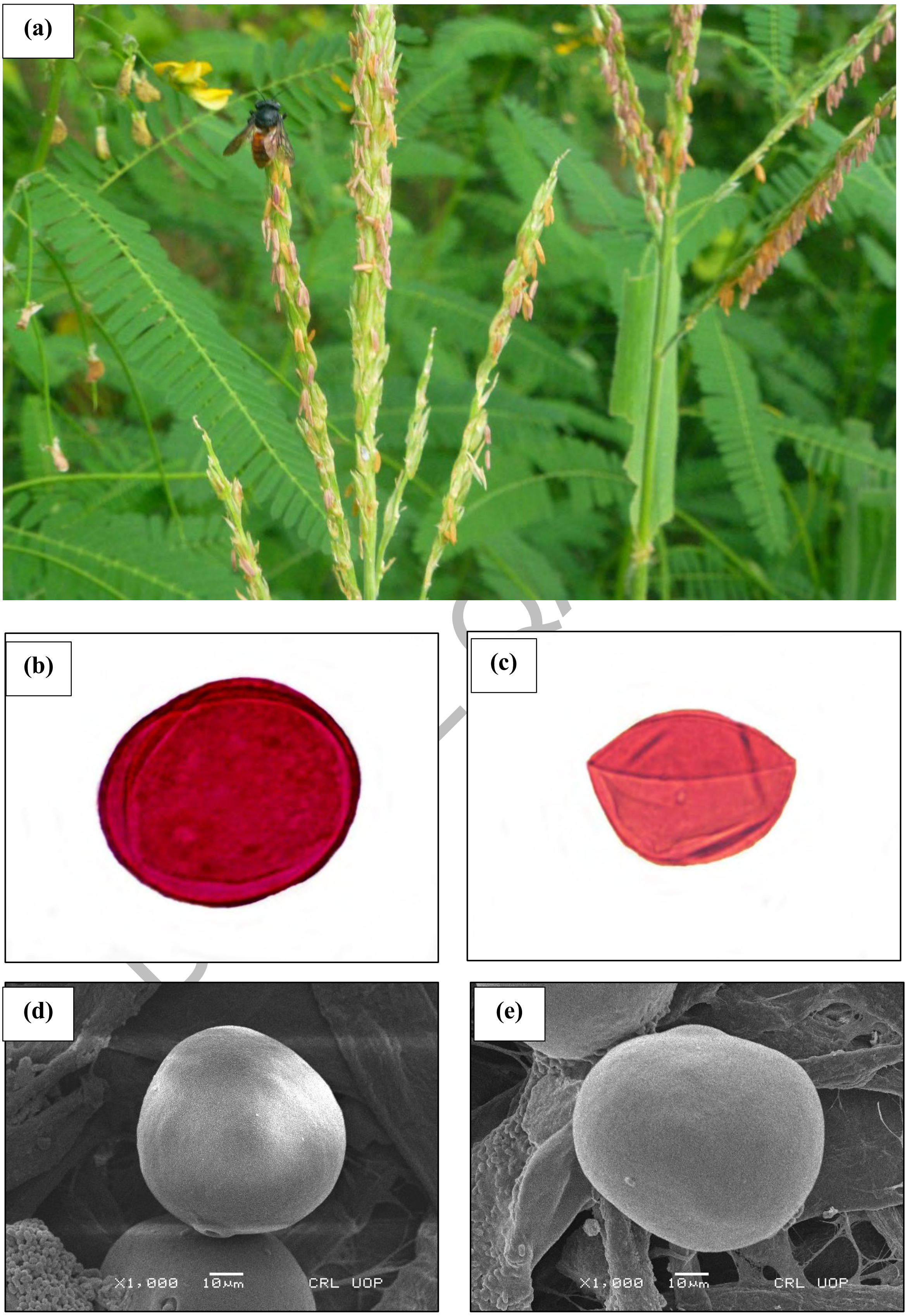

Plate 75: *Zea mays* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.16 Melisso-palynomorphs of Verbenaceae Honeybee flora

1. *Citharexylum spinosum* L.

Synonym	*Citharexylum bahamense* Millsp. ex Britton
Family	Verbenaceae
Common Name	Fiddle wood
Habit	Shrub
Habitat	Drier habitats, forest, coastal areas and moist foothills,
Flowering period	August to November
Status	Wild
Distribution	West Indies, South America, Venezuela, Guyana, Central America
Morphology	Deciduous, large shrub, and small tree. Leaves; simple, entire, spatulate, ovate, oblong elliptic to lanceolate, 5-17 cm long, 3-10 cm broad, glabrous, entire or dentate, subacute. Leaf venation: innate. Petiole: 1.5-4.5 cm long. Branches: tetragonal. Spicate racemes, 13-22 cm long and pendulous. Flowers; trumpet shaped, unisexual, white, 4-9 mm across, subsessile and sweet scented. Calyx: 5 toothed, copular, calyx tube 4.3 mm long, minutely 6 toothed and glabrous. Corolla: white, 5 lobed, corolla tube 4-7 mm long, hairy at the throat; lobes obovate, subequal and spreading. Stamens: 4, didynamous. Anthers: ovoid. Ovary: tetra ocular. Fruits: globose shaped, red when mature, turns black when ripe (Plate 76a).
Melissopalynology	Pollen are monad, medium sized, iso-polar, radially symmetrical, and tricolporate. Triangular polar view and prolate-spheroidal equatorial view shape. Colpi long and sunken, apertures long narrow and circular. Exine sculpturing macro-reticulate psilate. Polar diameter 29.1(26.2-33.7)±1.25 µm and equatorial view distance 27.15(23.5-35.5)±2.18 µm. P/E ratio 1.07. Colpi length 4.85(4.25-5.50)±0.23 µm and width of colpi 5.25(3.25-6.75)±0.61 µm. Exine thickness 6.25(5.25-7.25)±0.35 µm and Mesocolpium distance 17.6(17.0-18.0)±0.20 µm. Pollen fertility 98.2% and sterility 1.79% (Plate 76b,c,d & e).

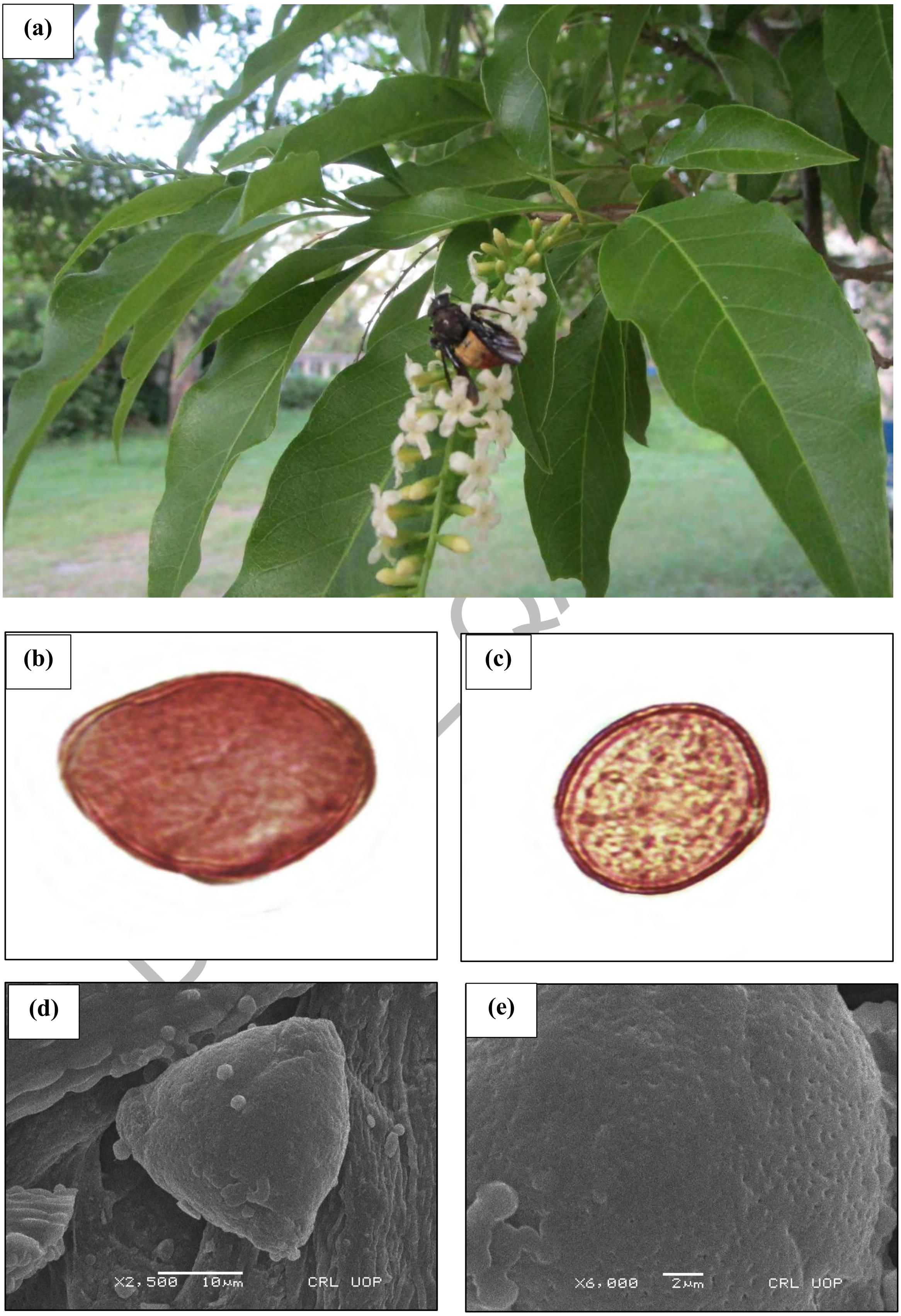

Plate 76: *Citharexylum spinosum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Duranta repens* L.

Synonym	*Duranta erecta* var. *erecta*
Family	Verbenaceae
Common Name	Pigeon berry.
Habit	Shrub
Habitat	Cultivated as ornamental crops on roadside and institutions
Flowering period	August to February
Status	Cultivated
Distribution	Indonesia, Pakistan, Malaysia, Russia and Singapore, Cuba, Peru
Morphology	Erect to sub scandent, usually armed shrub. Leaves 1.5-5 cm long, 1-2 cm broad, obovate-elliptic, rarely oblong-lanceolate, serrate to entire, cuneate, very shortly petiole. Racemes laxly many flowered. Flowers 8-9 mm across, blue or violet, scented; bracts minute; pedicels 2-4 mm long. Calyx-tube 4 mm long, angular, teeth subulate, appressed pubescent. Corolla-tube c. 8 mm long, limb sub equally 5-lobed with lobes 3.5-4.5 mm long, pubescent on both sides. Drupe 6-8 mm in diameter, orange or orange-yellow, enclosed by the accrescent, beaked, persistent calyx (Plate 77a).
Melissopalynology	Pollen are monad, medium sized, iso polar, radially symmetrical and tricolporate. Triangular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing Psilate and Sexine thicker. Polar diameter 32.9(26.2-42.7)1.71 µm, equatorial diameter 28.9(23.5-35.7)1.47 µm. P/E ratio 1.13. Colpi length 4.45(3.25-5.50)0.21 µm and colpi width 6.45(3.25-8.50)0.51 µm. Exine thickness 5.12(3.25-7.25)0.44 µm. Mesocolpium distance 19.5(17.0-23.7)0.78 µm. Pollen fertility 86.1% and sterility 14.8% (Plate 77b,c,d & e).

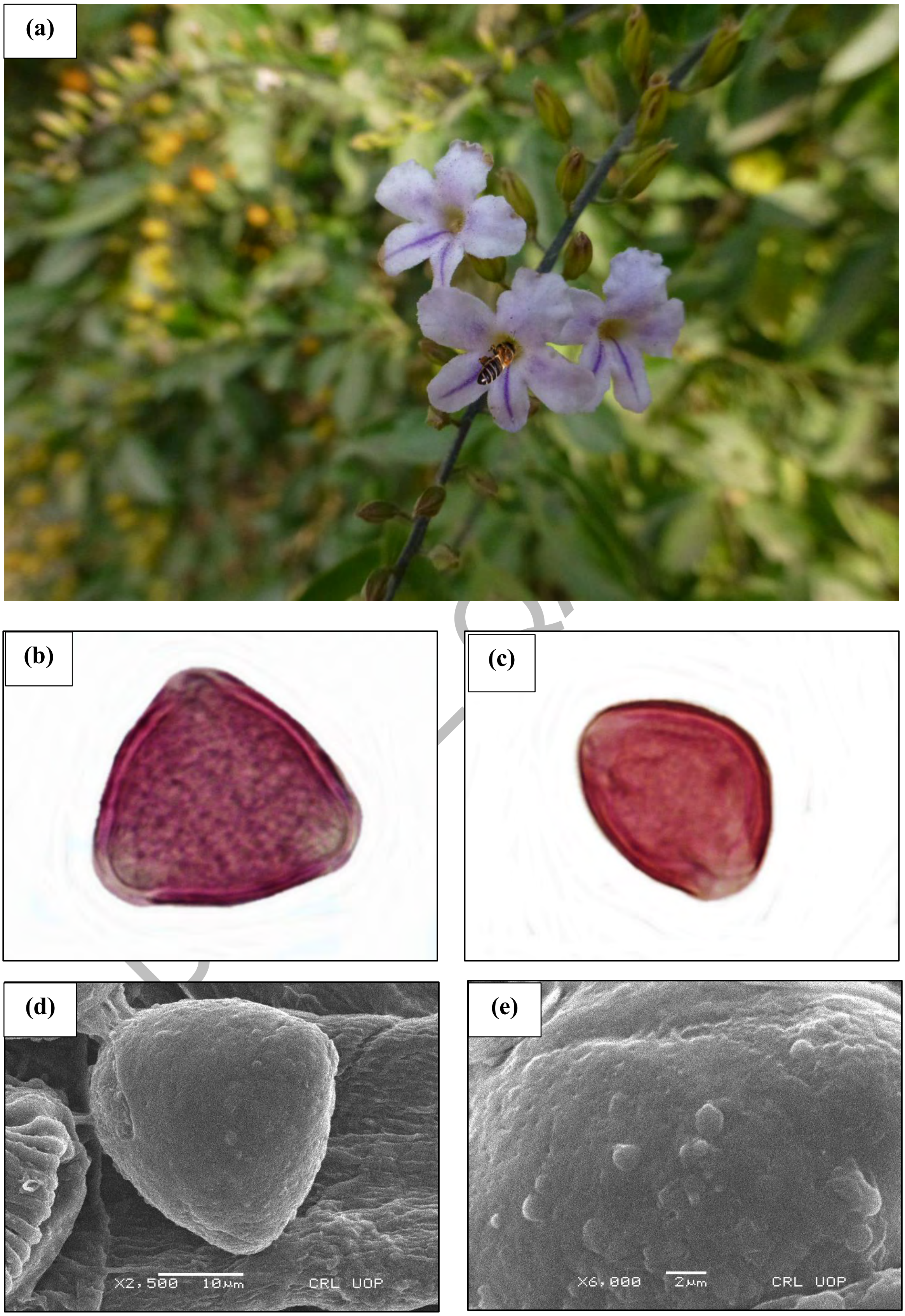

Plate 77: *Duranta repens* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Lantana camara* L.

Synonym	*Lantana antillana* Raf.
Family	Verbenaceae
Common Name	West Indian Lantana
Habit	Shrub
Habitat	Include wastelands, disturbed areas such as roads, railway tracks
Flowering period	Throughout the year
Status	Wild
Distribution	Chile, Fiji, Egypt, Pakistan, Kenya, Sudan
Morphology	Evergreen shrub, rambling branches, 1-3 m tall, branches minutely pubescent, conspicuously prickly and hooked spines. Leaves; opposite, decussate, ovate-oblong, 4-12 cm long, 2.5-7 cm broad, crenate, acute to acuminate, rugose, scabrid, petiole 3-10 mm long. Flowering heads; axillary, peduncled and umbellate flower, subtending leaves, 1.5-4 cm across. Bracts; lanceolate, linear, 3.5-7 mm broad and subulate. Flowers; 4-9 mm across, orange or yellow. Calyx; 3-5 mm long, thin and pubescent. Corolla-tube; 4-12 mm long, pubescent, enlarged and curved. Limb; 4 lobed, spreading and rounded lobes. Drupe; 3-6 mm in diameter, globose, black, shining, fleshy and 2 seeded (Plate 78a).
Melissopalynology	Pollen are monad, isodiametric, medium sized, and tricolporate. Lobed polar view and prolate equatorial view shape. Exine sculpturing psilate-perforate. Aperture sunken oriented. Polar diameter 36.3(23.7-40.7)±3.18 µm and equatorial view distance 25.6(21.2-28.7)±1.29 µm. P/E ratio 1.41. Colpi length 2(0.75-2.75)±0.33 µm, colpi width 1(0.75-1.25)±0.11 µm and mesocolpium distance 18.9(15.2-21.5)±1.16 µm. Exine thickness 2.8(2-3.75)±0.32 µm. Pollen fertility 84.5% and sterility 15.3% (Plate 78b,c,d & e).

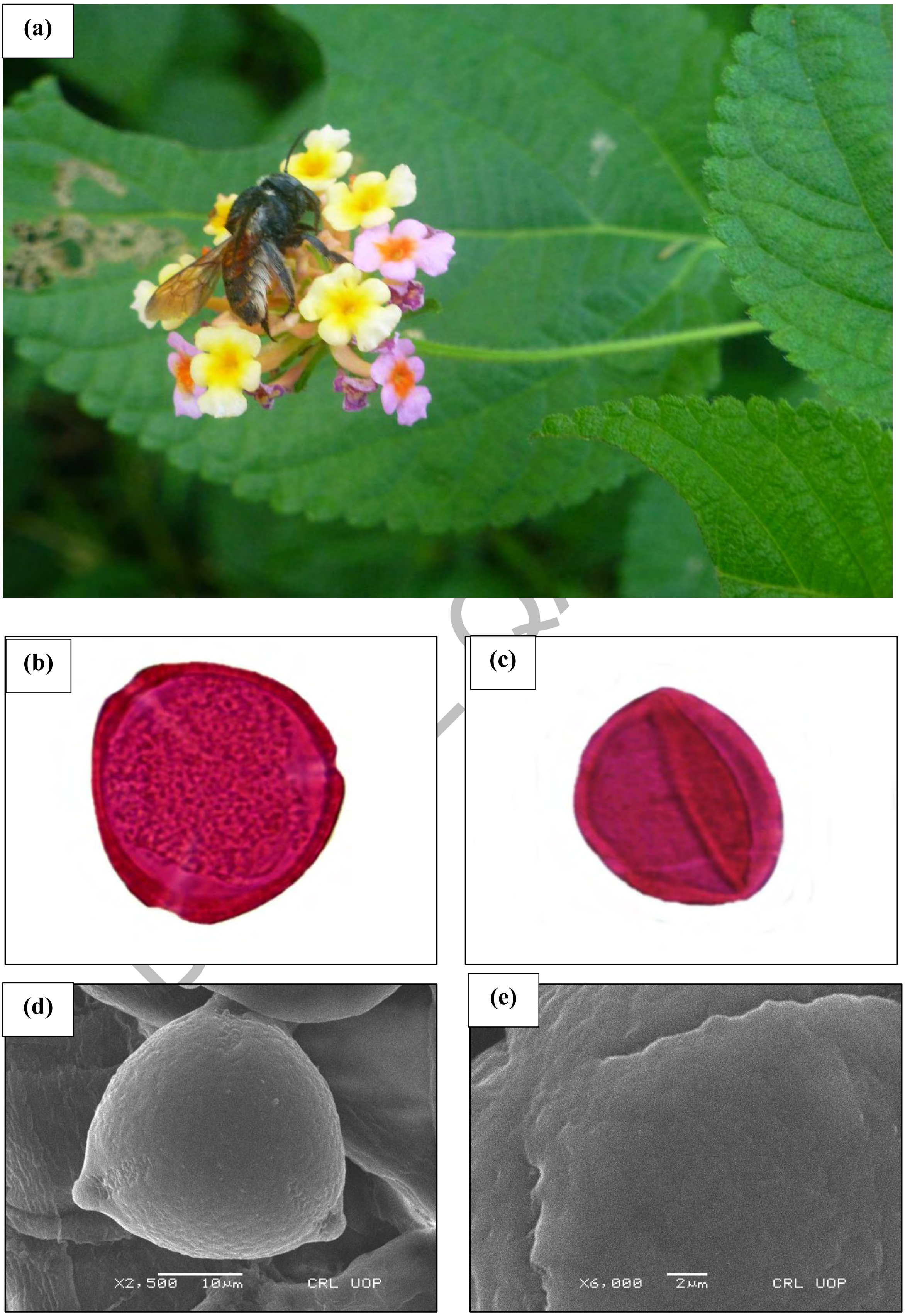

Plate 78: *Lantana camara* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Verbena officinalis* L.

Synonym	*Verbena adulterina* Hausskn.
Family	Verbenaceae
Common Name	Common vervain
Habit	Herb
Habitat	In open areas, waste grounds, roadsides and cultivated fields
Flowering period	July to November
Status	Wild
Distribution	Bermuda, Chile, Newzeland, Pakistan, Cuba, Philippines
Morphology	Erect, perennial, 15-85 cm tall, woody at base, branched above, branches tetra angular and scabrous angles. Leaves; oblong to lanceolate, 3-8.5 cm long, 1.8-4.4 cm broad, deeply serrate, pinnatifid to sub-entire, narrowed at the base; hispid, lower petiolate. Spikes; terminal, paniculate, 12-25 cm long. Flowers; pale pink, 3-4.5 mm across, sub-sessile; bracts oblong, 2-3.5 mm long, acuminate, ciliate. Calyx tube longer, minutely 5 toothed, ribbed and hairy. Corolla tube cylindrical, 4.5-6.8 mm long, unequally 5 lobed and hairy. Stamens; 4, all fertile and anthers appendaged. Ovary; tetra lobed with short style. Fruits; four, 1 seeded, sub-cylindrical and smooth nutlets (Plate 79a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Triangular polar view and oblate-spheroidal equatorial view shape. Exine sculpturing Psilate-scabrate. Polar diameter 28.7(25.2-31.2)±1.03 µm and equatorial view distance 29.1(23.7-33.7)±1.65 µm. P/E ratio 0.98. Colpi length 6.60(5.25-8.75)±0.57 µm, colpi width 6.90(5.50-7.75)±0.44 µm and mesocolpium distance 14.8(11.2-17.7)±1.11 µm. Exine thickness 4.45(3.75-5.25)±0.26 µm. Pollen fertility 89.5% and sterility 10.4% (Plate 79b,c,d & e).

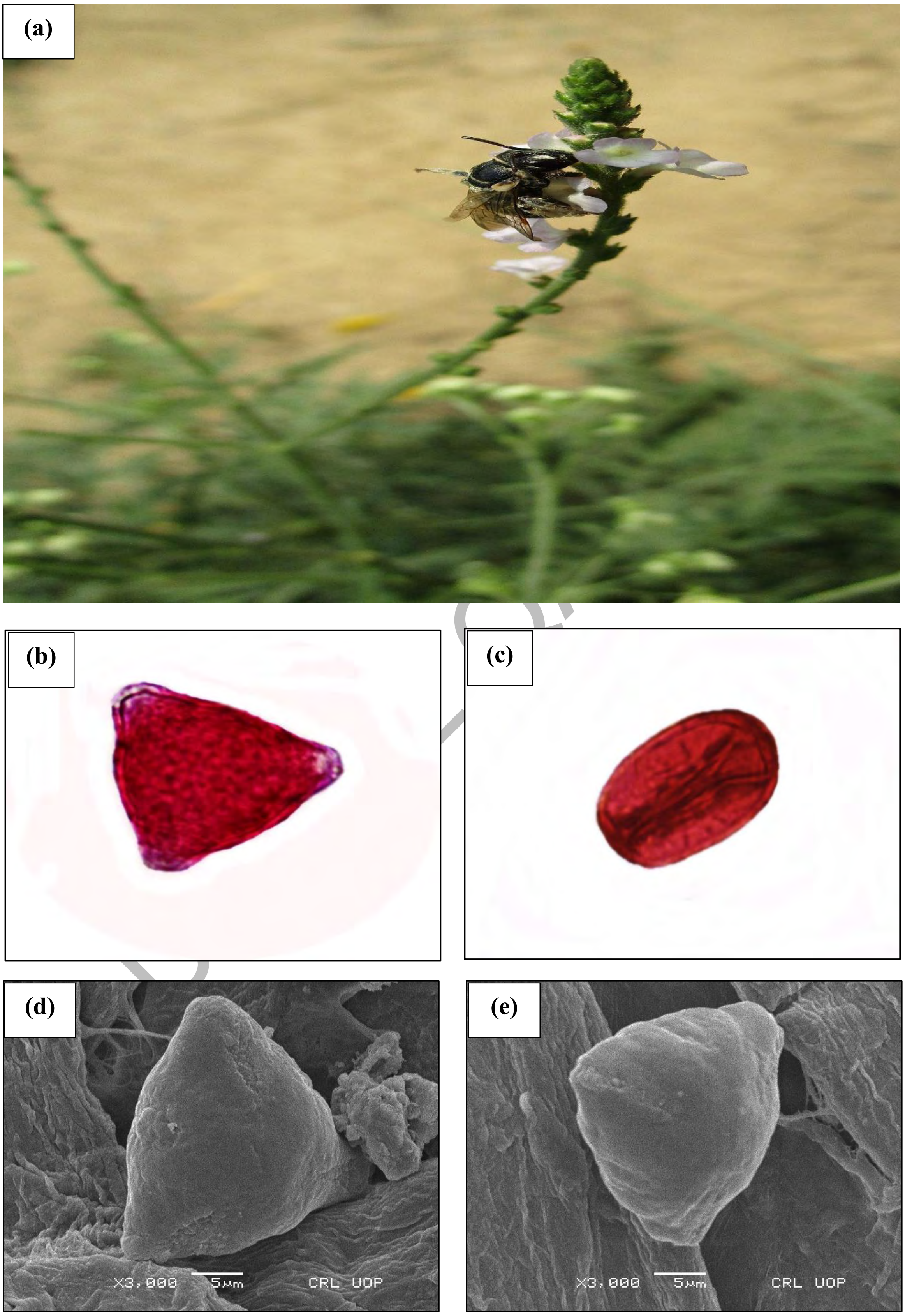

Plate 79: *Verbena officinalis L.* (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.17 Melisso-palynomorphs of Acanthaceous Honeybee flora

1. *Barleria cristata* L.

Synonym	*Barleria alba* Lodd.
Family	Acanthaceae
Common Name	Philippine Violet, Bluebell barleria
Habit	Herb
Habitat	Mostly grows in shadow of shrubs
Flowering period	October to November
Status	Wild
Distribution	California, South Arizona, Pakistan, China, Myanmar, Burma
Morphology	Much branched, erect, up to 1.4 m tall, unarmed shrub let with hairy twigs, leaves with 2-3 cm long, petiole hairy: lamina oblong-elliptic to lanceolate, 4-1.5 cm x 1-3.5 cm, both surfaces hairy, apically acute-acuminate, and entire. Flowers purple, pink 3-4 cm long, in short, 1-5 flowered, terminal spikes. Calyx 2 outer lobes much larger, ovate lanceolate, 2.2-2.6 x 7-8 cm, acuminate, margins hairy, glabrous, 2 inner linear lobes, 7 to 9 mm long, pointed. Corolla pubescent, glandular, 2.5-4 cm long tube, limb oblong, 2 cm long, lobes unequal (Plate 80a).
Melissopalynology	Pollen are monad, medium sized, and tricolporate. Rounded polar view and equatorial view prolate-Spheroidal. Exine sculpturing elements lophoreticulate. Polar diameter 34.5(27.2-40.5) ±2.1 µm and equatorial distance 33.8(31.7-36.5) ±2.04 µm. P/E ratio 1.02. Length of colpi 1.4(1.1-1.7)±0.08 µm and colpi width 1.11(0.8-1.45)±0.05 µm. Exine thickness calculated 5.55(4.75-6.25)±0.30 µm. Mesocolpium distance 13.2(9.5-17.4)±1.12 µm. Pollen fertility 81.6% and sterility 18.4% (Plate 80b,c,d & e).

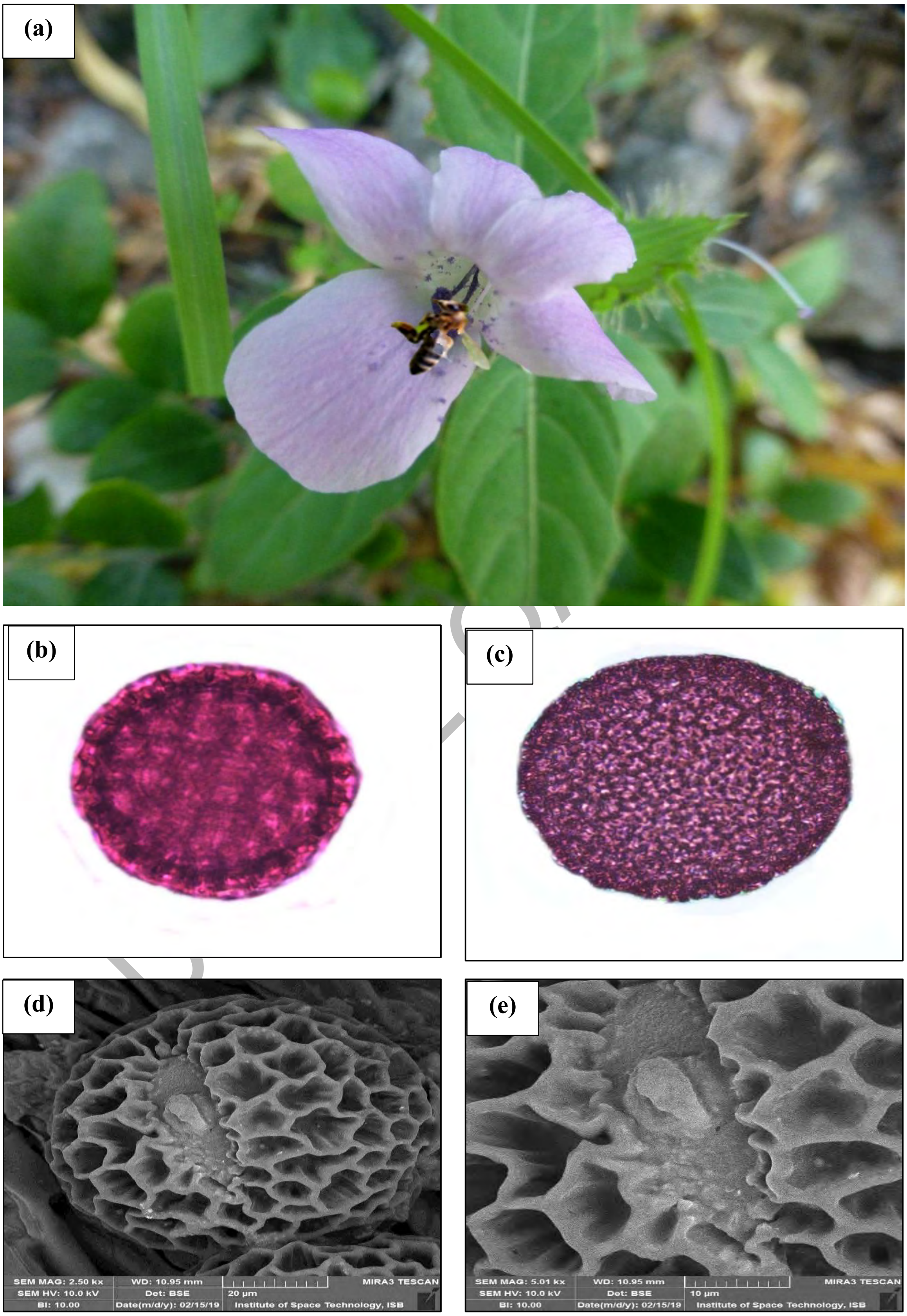

Plate 80: *Barleria cristata* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Dicliptera bupleuroides* Nees

Synonym	*Dicliptera roxburghiana* var. *bupleuroides* (Nees) C.B.Clarke
Family	Acanthaceae
Common Name	Kalu
Habit	Herb
Habitat	Along Roadsides, forests and shady places
Flowering period	March to September
Status	Wild
Distribution	Bangladesh, Pakistan, Bhutan, China, India, Nepal, Afghanistan
Morphology	Herb, much branched, erect, up to 90 cm, hairy twigs. leaf petioles 3-18 mm long; lamina lanceolate ovate, basally acuminate cuneate, entire. pink Flowers with purplish tinge, cymes; terminal and axillary, bracts 4-11 mm long, variable in shape, elliptic-obovate, pubescent, entire, acute to obtuse, mucronate, ciliate, white cilia, multicellular or absent; bracteoles linear-lanceolate, nearly if calyx lobes. Calyx lobes linear, 6-8 mm long and pubescent. Corolla 3.5 mm, outside pubescent, lip in lower position orbicular, 1.2 × 1.8 mm; lip in upper position oblong, 2.1 × 1.5 mm, tri lobed, lobes ovate, and 0.4 × 0.2 mm. Seeds verrucose (Plate 81a).
Melissopalynology	Pollen are monad, medium sized and heterocolpate. Elliptic polar view and equatorial view shape prolate. Narrow sunken aperture orientation Exine sculpturing coarsely reticulate. Polar diameter 23(22.30-24.90) ±0.22 µm and equatorial view distance 14.4(12.4-16.2) ±0.36 µm. P/E ratio 1.59. Colpi length 2.74(2.6-2.90) ±0.02 µm and colpi width 2.72(2.5-2.8) ±0.03 µm. Exine thickness calculated 2.52(2.3-2.80) ±0.04 µm. Mesocolpium distance 8.6(6.4-10.3) ±0.39 µm. 1.38. Pollen fertility 83.6% and sterility 17.4% (Plate 81b,c,d & e).

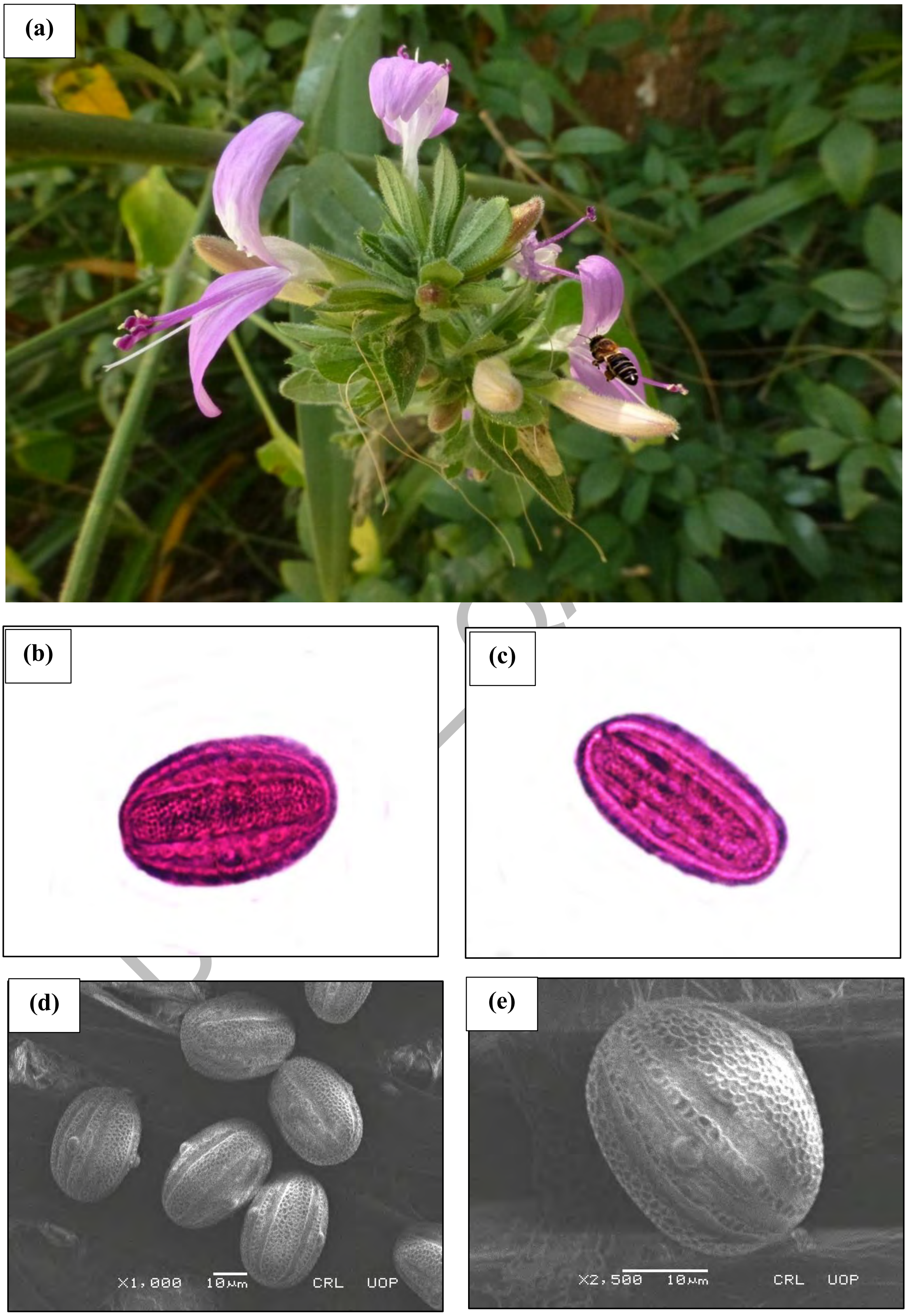

Plate 81: *Dicliptera bupleuroides* Nees (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Justitia Adhatoda* L.

Synonym	*Adhatoda vasica Nees*
Family	Acanthaceae
Common Name	Malabar Nut
Habit	Shrub
Habitat	Wetlands areas and in moist soils and with the presence of trees
Flowering period	March to September
Status	Wild
Distribution	India, Sri Lanka, Pakistan, Afghanistan, China
Morphology	Woody shrub, 43 cm, Leaves petiole 1.5-4 mm long; entire, lamina lanceolate or, both sides hairy, subacute. Inflorescence an axillary, spike 3-9 mm across. 7.9 mm long Flowers, sessile; Calyx 4-lobed at base, margins ciliated. Corolla funnel tube shaped. Filaments glabrous, 3 to 4 mm long, base hairy. Stamens: 2, filaments 1.3-1.8 cm long, anthers; oblong and basally apiculate. Ovary apex sparsely hairy; hairy in the lower half, filiform. Capsule: clavate, 4.5 mm long, 4-angled, hairy towards the apex, mucronate. Seeds: glabrous, orbicular, papillate and concentric (Plate 82a).
Melissopalynology	Pollen grain are monad, medium sized and heterocolpate. Elliptical polar view and equatorial view shape prolate. Exine sculpturing finely reticulate. Polar diameter 35.9(26.2-44.5)±2.37 µm and equatorial distance 26.0(20.7-35.5)±1.29 µm. P/E ratio 1.38. Colpi length 3.70(1.75-5.50)±0.4 µm, colpi width 4.22((2.25-6.75)±0.4 µm and mesocolpium distance 21.1(19.7-22.7)±0.5 µm. Exine thickness 5.07(3.25-7.25)±0.45 µm. Exine ornamentation is finely reticulate. Pollen fertility 80.9% and sterility 19.04% (Plate82b,c,d & e).

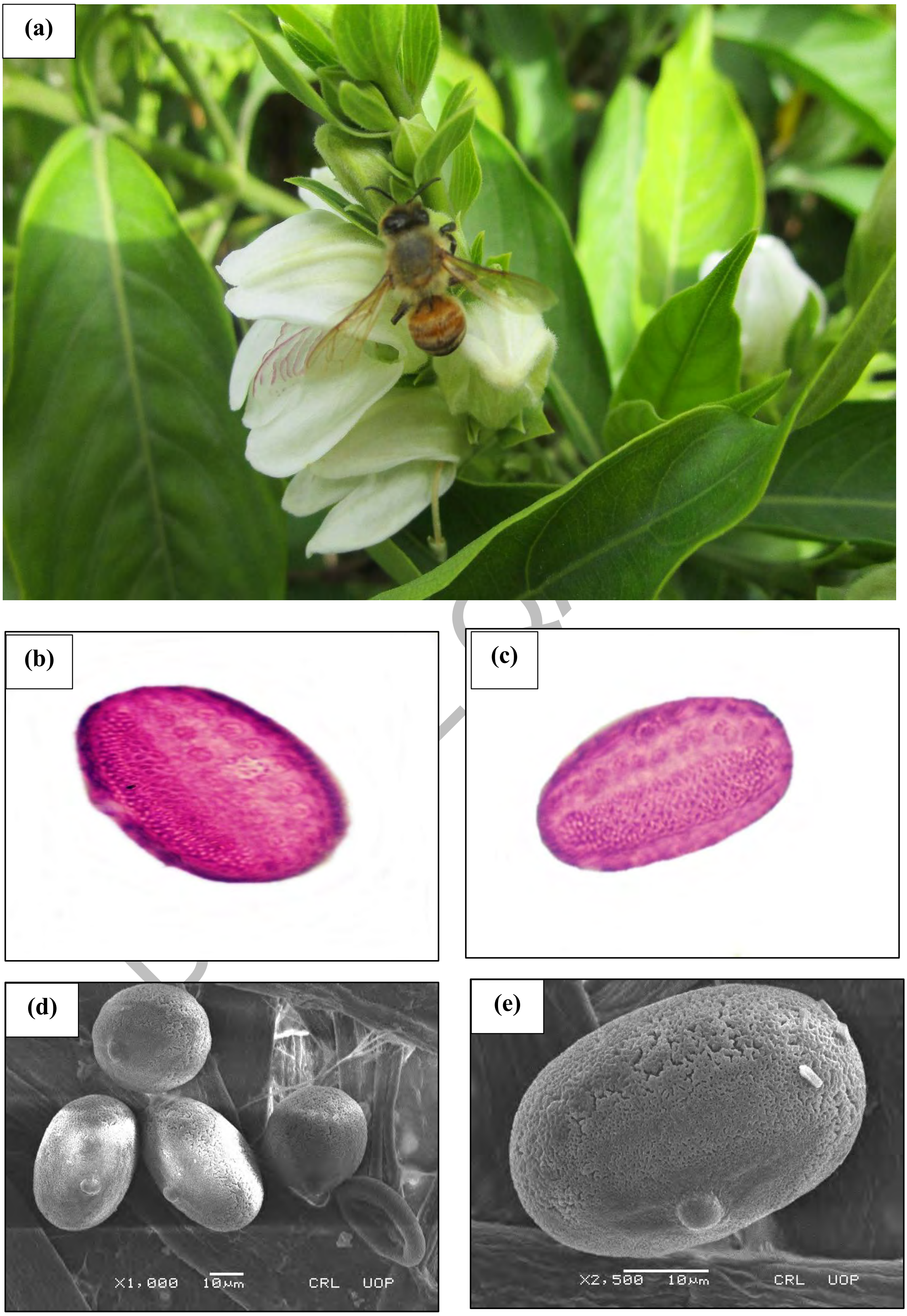

Plate 82: *Justicia Adhatoda* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.18 Melisso-palynomorphs of Apiaceous Honeybee flora

1. *Coriandrum sativum* L.

Synonym	*Bifora loureiroi* Kostel.
Family	Apiaceae
Common Name	Coriander
Habit	Annual Herb
Habitat	Grown mostly in plains, hills and garden
Flowering period	March to June
Status	Wild
Distribution	Brazil, Indian, Indonesia, Italy, Morocco, Pakistan
Morphology	Glabrous plant; 45-65 cm high. Leaves: basal and lower, 2-pinnatisect. Petiole: 10-12.6 cm, sheathing at base; blade ovate, to 13.5 × 9 cm; pinnae flabelliform, 1.2–2.5 × 0.8–1.6 cm, toothed or incised, ultimate segments broad. Cauline leaves: mid and upper position ternate, 2-pinnatisect, reduced to stem. Segments: linear to filiform, 1.6-11.5 × 0.8–1.4 mm, obtuse and entire. Peduncles: 3.2–10.5 cm, rays; 1.5–7.5, 1.6–2.3 cm, bracteoles: 5, linear and entire, umbellules, 5-8 flowered. Pedicels: 2.2-5.5 mm. Calyx: teeth ovate, deltoid and ovate-lanceolate and unequal. Fruit: 1.5–5 mm wide (Plate 83a).
Melissopalynology	Pollen are monad, iso polar; small to medium sized and tricolporate. Triangular polar view and equatorial view shape per-prolate. Exine sculpturing scabrate gemmate. Polar diameter 28.2(24.5-31.5)±1.29 µm and equatorial view distance 11.90(10.25-13.2)±0.53 µm,. P/E ratio 2.36. Colpi length 8.55(7.25-10.2) ±0.51 µm and colpi width 5.85(4.75-7.00) ±0.37 µm. Exine thickness 2.00(1.75-2.25) ±0.07 µm. Mesocolpium distance 10.0(8.25-12.2)±0.70 µm. Pollen fertility 87.7% and sterility 12.2% (Plate83b,c,d & e).

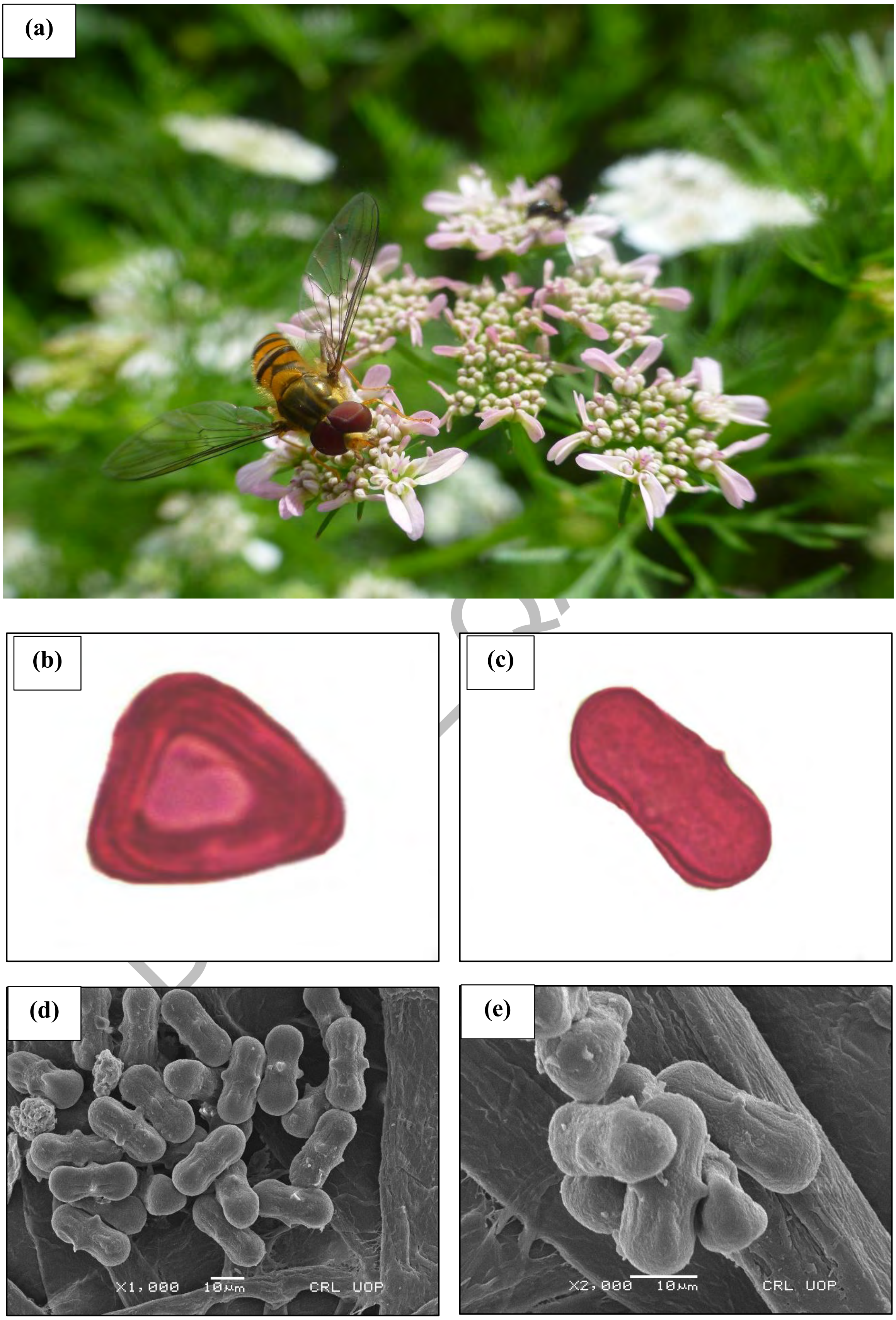

Plate 83: *Coriandrum sativum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Foeniculum vulgare* Mill.

Synonym	*Anethum dulce* DC.
Family	Apiaceae
Common Name	Fennel
Habit	Perennial Herb
Habitat	On roadsides, railway easements and rubbish dumps
Flowering period	March to August
Status	Wild
Distribution	Australia, Newzeland, Pakistan, California, China, France
Morphology	Habit; Perennial herb, tap rooted, 0.6-2.5 m, glaucous, licorice and glabrous. Stem; erect, branched and solid. Leaf; petiole, 5-13 cm, sheathing, blade; 2.5-4 diameter wide, triangular, pinnately dissected, segments 3 to 35 mm and thread like. Inflorescence; compound umbel, peduncle, bracts, rays 15 to 40, unequal, 0.8-3.5 cm, ascending, pedicels; 0.8-11 mm and equal. Flower; calyx lobes, petals wide, yellow, narrowed tips. Fruit; 3-4 mm, oblong ovate, compressed, glabrous; ribs equal, prominent and acute. Fruit axis; divided to base. Seed; face generally flat (Plate 84a).
Melissopalynology	Pollen are monad, small to medium sized, and tricolporate. Angular polar view and prolate equatorial view shape. Exine sculpturing surface Verrucate scabrate. Polar diameter 28.8(26.2-31.2)±0.88 µm and equatorial view distance 15.3(13.7-17.7)±0.65 µm. P/E ratio 1.88. Colpi length 6.65(3.25-8.75)±0.95 µm and colpi width 4.90(3.75-5.75)±0.35 µm. Exine thickness 1.2(0.75-1.75)±0.16 µm. Mesocolpium distance 15.3(13.7-16.7)±0.65 µm. Pollen fertility 96.05% and sterility 4.1% (Plate 84b,c,d & e).

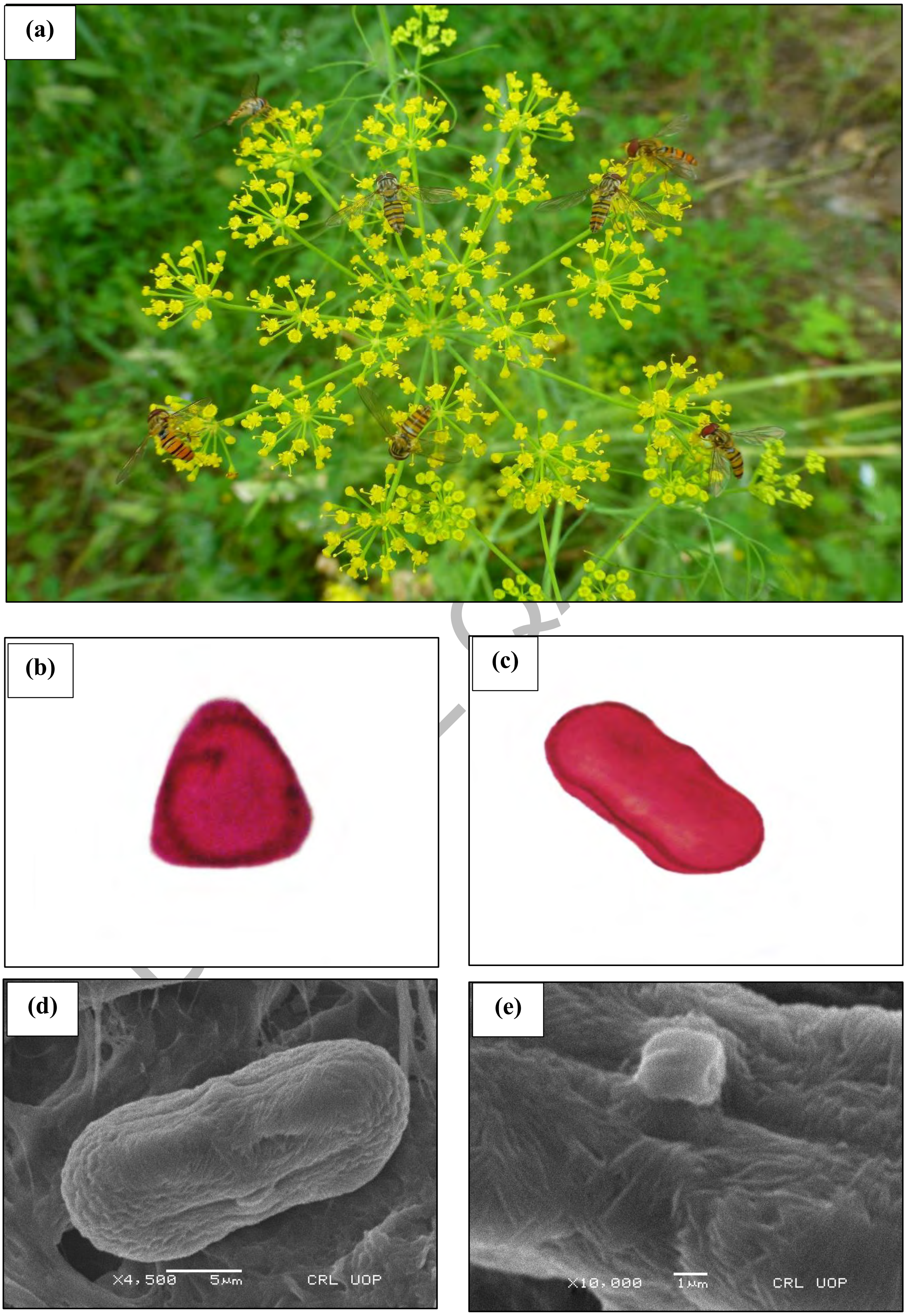

Plate 84: *Foeniculum vulgare* Mill. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Torilis leptophylla* (L.) Rchb.f.

Synonym	*Torilis xanthotricha* Stank.
Family	Apiaceae
Common Name	Hedge parsleys
Habit	Herb
Habitat	In meadows, moist places and fields,
Flowering period	March to May
Status	Wild
Distribution	France, Pakistan, England, Iran, Iraq, Israel, Jordan, Belgium
Morphology	Herbaceous, up to 45-58 cm tall and hispid. Stem: very thinly furnished, downwardly appressed, strigulose hairs, terete, striate, numerous branches. Leaves; alternate, compound, bipinnate and segments linear. Leaf blade: lobed Peduncles; 2.5-6.5 cm long and stout. Umbels; usually lateral. Involucral bracts absent. Rays; 3-7, unequal, 1.5-5 cm long. Involucel of linear bracelets. Calyx teeth; acuminate. Petals and sepals: separate. Fruit; oval to ovoid, 2.8-4.5 mm long, bristly; bristles sub-glochidiate, shining and stigma subsessile. Fruit: linear-oblong and dry (Plate 85a).
Melissopalynology	Pollen are monad, small sized and trizonocolporate. Triangular polar view and sub-prolate equatorial view shape. Colpi orientation sunken, linear and margins rounded. Exine sculpturing striate regulate. Polar diameter 19.1(14.5-23.2)±1.76 µm and equatorial view distance 16.3(12.2-18.7)±1.14 µm. P/E ratio 1.17. Colpi length 7.90(5.50-10.2)±0.75 µm, colpi width 4.30(2.75-5.25)±0.42 µm and mesocolpium distance 17.2(15.5-18.7)±0.64 µm. Exine thickness 3.85(3.00-5.75)±0.49 µm. Pollen fertility 80.8% and sterility 19.1% (Plate 85b,c,d & e).

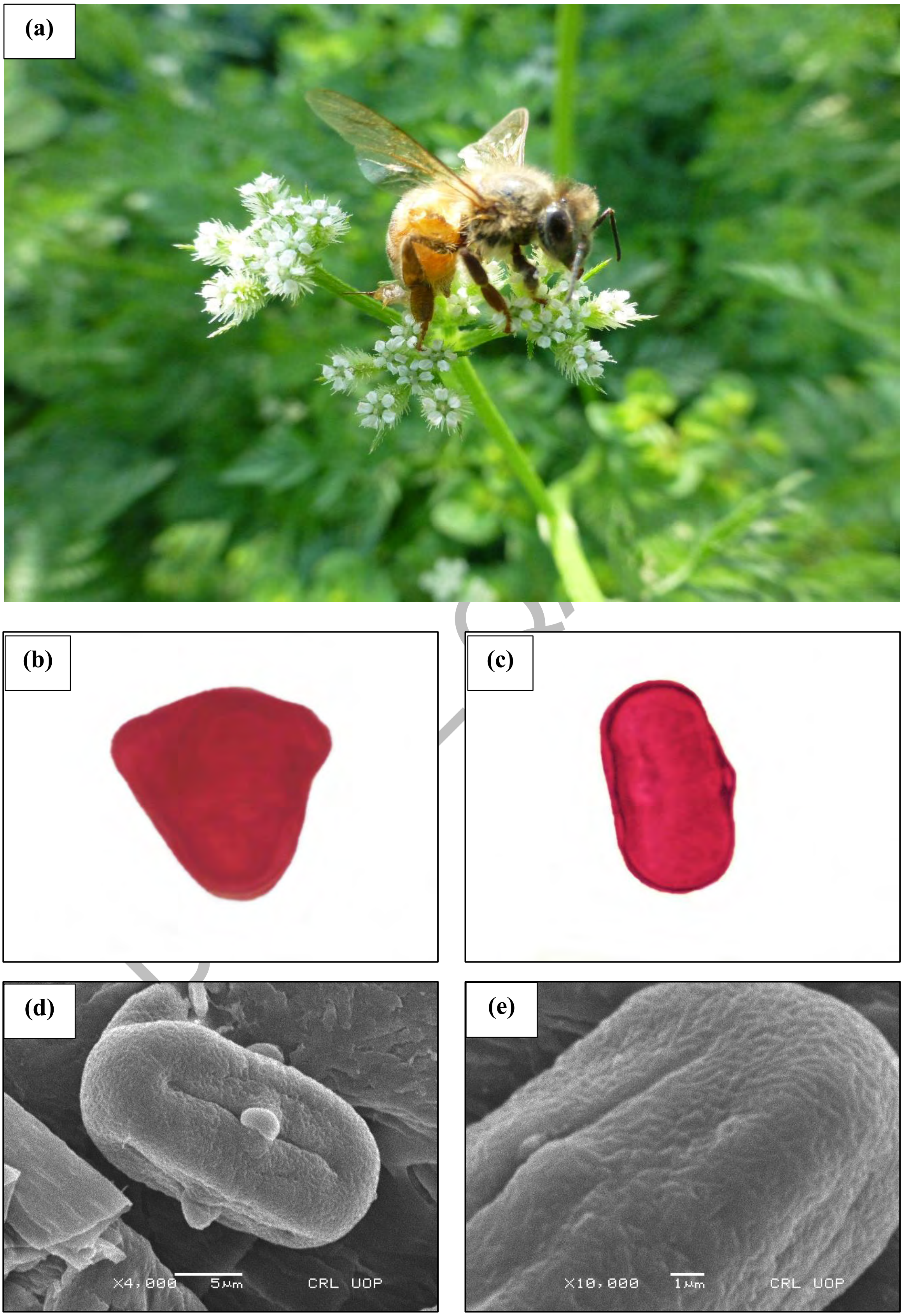

Plate 85: *Torilis leptophylla* (L.) Rchb.f. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.19 Melisso-palynomorphs of Euphorbiaceous Honeybee flora

1. *Chrozophora tinctoria* (L.) A.Juss.

Synonym	*Chrozophora cordifolia* Pazij
Family	Euphorbiaceae
Common Name	Dyers croton
Habit	Annual Herb
Habitat	Dry places
Flowering period	May to September
Status	Wild
Distribution	Middle East, India, Ukarine, Pakistan, Central Asia
Morphology	Erect herb; up to 65-75 cm, densely stellate. Petioles; 4-11 cm long. Leaf blades; broadly ovate to lanceolate, 4-5 × 3.5-6 cm, subacute, cuneate sub entire, 4 nerved from the base, densely pubescent. Stipules; filiform, 0.5-1.5 mm long. Inflorescence; 0.5-3 cm long. Male flowers; subsessile, sepals lanceolate, 2.5-3 mm long, pubescent; petals elliptic, 2-4 mm long, yellowish green disc, stamens; 3-13, filaments united into a column; 3-4.5 mm high, anthers biseriate, 2 mm long. Female flowers; pedicels 4-5 mm long, styles; 1.5-3 mm long. Fruit; trilobate, 4.5-7 × 6.5-10 mm, tuberculate, lepidote, tinged reddish purple. Seeds; triangular ovoid, 3-5.5 × 3.5-4 mm, tuberculate and grey (Plate 86a).
Melissopalynology	Pollen are monad, large sized, and 6-colporate. Slightly rounded polar view and oblate-spheroidal equatorial view shape. Aperture orientation sunken and narrow. Exine sculpturing reticulate heterobrochate. Polar diameter 74.0(70.5-80.2)±1.76 µm and equatorial diameter 76.1(72.7-78.2)±1.00 µm. P/E ratio calculated 0.97. Colpi length 8.00(7.25-9.75)±0.46 µm, colpi width 10.8(9.75-12.7)±0.51 µm. Mesocolpium length 21.2(18.7-23.0)±0.79 µm. Exine thickness 2.25(1.25-3.00)±0.3 µm. Pollen fertility 83.9% and sterility 16.07% (Plate 86b,c,d & e).

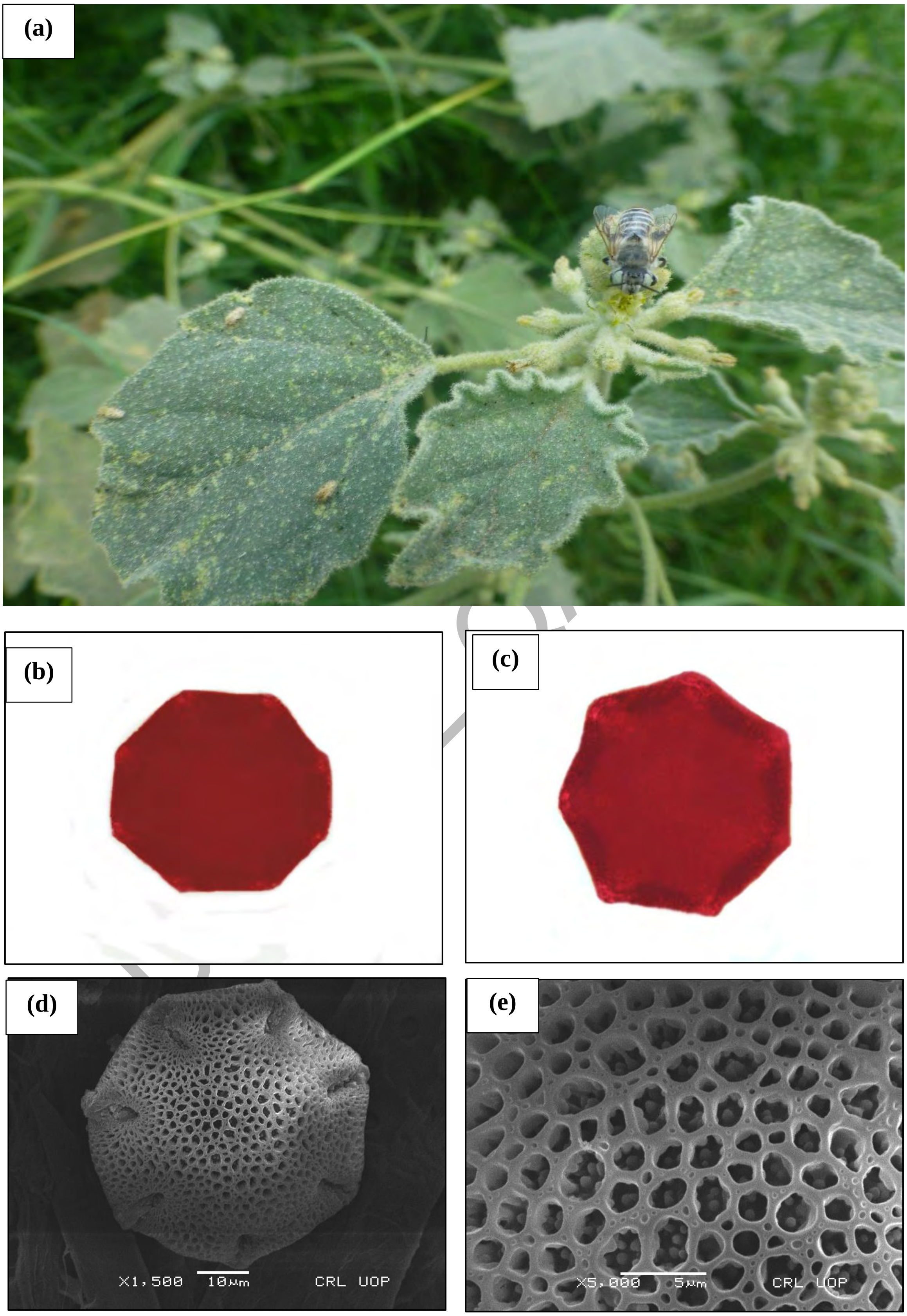

Plate 86: *Chrozophora tinctoria* (L.) A.Juss. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Euphorbia helioscopia* L.

Synonym	*Tithymalus obovate* Raf.
Family	Euphorbiaceae
Common Name	Sun spurge
Habit	Annual Herb
Habitat	In Meadows and fields, litters irrigation fields,
Flowering period	February to April
Status	Wild
Distribution	Korea, Kazakhstan, Pakistan, Japan, China, Iran
Morphology	Fleshy annual herbs, erect sparingly up to 49 cm tall but most common is 12-28 cm tall. The leaves of such a plant are alternative, short petiolate which is 1-3 mm long, rounded at the apex, obtuse, 1 to 1.4 cm, serrulate at apex, and tapered the base, deciduous and leaving scars. Inflorescence; umbel shape, leaves -5, whorled, and upper stem leaves. Such a plant is ovate transversely glands and garnishes in color. The fruit of such a plant is roundly trilobite, deep groves, and sub-globose, 2.4-3 × 2.4-3.4 mm. style of the flower is recurved, spreading and united. Stigma; bipartite and slightly swollen. Seeds strongly reticulate, obtusely, brown and apiculate (Plate 87a).
Melissopalynology	Pollen are monad, symmetrical and tricolporate. Semicircular polar view and prolate-spheroidal. Exine sculpturing reticulate. Aperture: irregular margins and acute ends. Long aperture-colpus with acute ends and irregular margins. Polar diameter 28.1(27.25-29.00)±0.29 µm, and equatorial view distance 26.3(24.0-28.0)±0.73 µm. P/E ratio 1.06. Exine thickness 2.25(1.50-3.00)±0.28 µm. Colpi length 2.25(1.50-3.00)±0.28 µm and colpi width 9.45(8.25-10.2)±0.40 µm. Mesocolpium distance 14.5(13.2-15.2)±0.38 µm. Pollen fertility 90.7% and sterility 9.23% (Plate 87b,c,d & e).

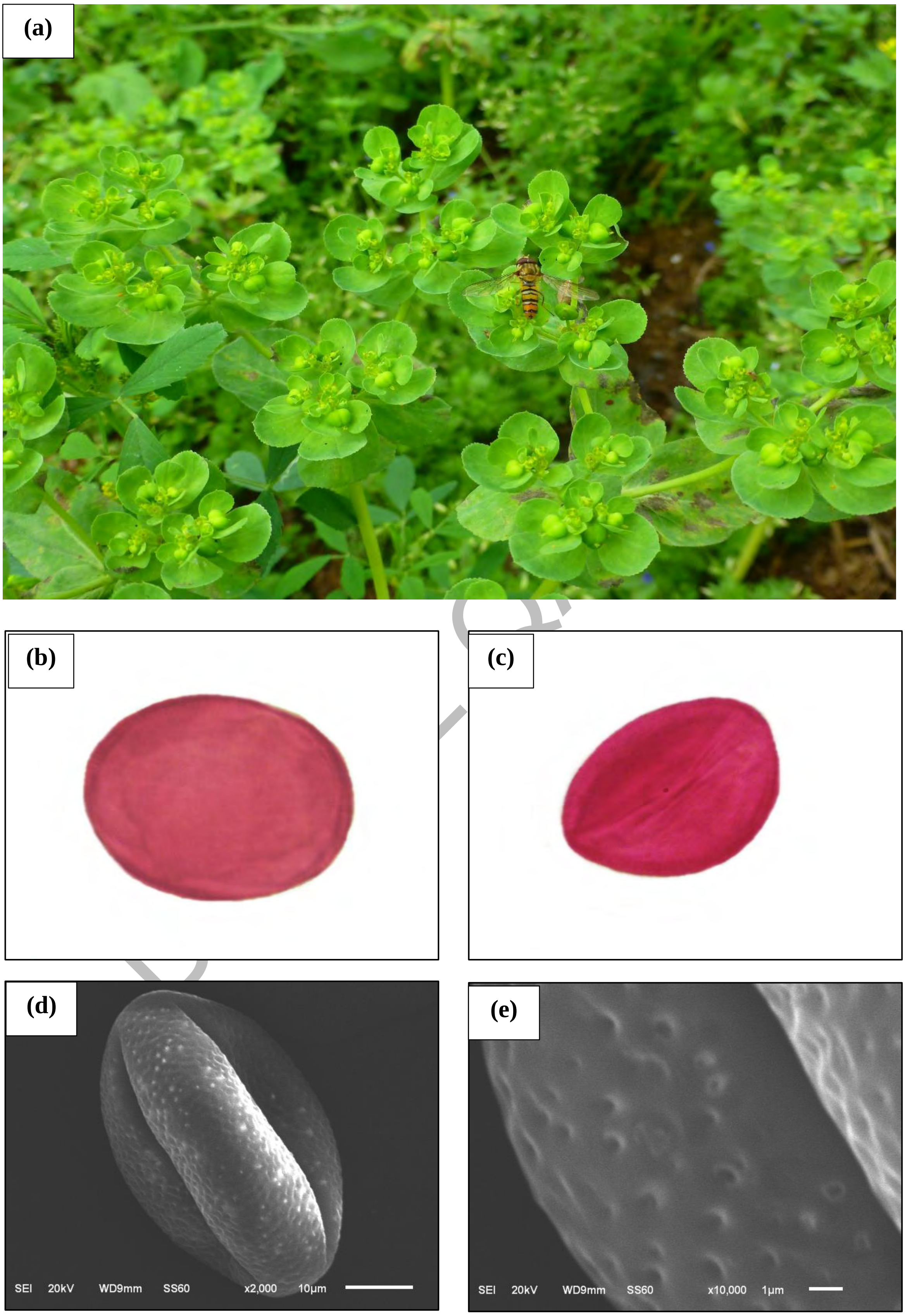

Plate 87: *Euphorbia helioscopia* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Euphorbia hirta* L.

Synonym	*Chamaesyce hirta* (L.) Millsp.
Family	Euphorbiaceae
Common Name	Garden spurge
Habit	Annual Herb
Habitat	Cultivated fields, perennial grasslands, roadsides, fallow lands
Flowering period	July to December
Status	Wild
Distribution	Ghana, Indonesia, Yemen, Colombia, Australia, Pakistan
Morphology	An erect-ascending hispid sparingly branched annual herb up to 5 cm; hairs multicellular, drying yellow. Petioles 1-3 mm long. Leaf-blades rhombic-ovate to rhombic-lanceolate, 2-6 × 1-2.2 cm, subacute or obtuse, asymmetrically cuneate or rounded-cuneate at the base, serrulate at least in the upper part, with 2 to 3 pairs lateral nerves from near the base running up the blade, bright green, often purplish-tinged, above, pale green beneath. Stipules subulate, 1 to 2.5 mm long. Cyathia aggregated together into dense axillary pedunculate clusters 0.6-1.3 cm across; peduncle 0.4-1.5 cm long. cyathial glands and their appendages minute. Fruits sharply trigonous, smooth, pubescent (Plate 88a).
Melissopalynology	Pollen are monad, symmetrical, small to medium sized and tricolpate. Semicircular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing reticulated. Aperture: irregular margins and pointed ends. Polar diameter 24.4(23.2-25.7)±0.50 µm and equatorial view distance 23.7(23.0-25.2)±0.39 µm. P/E ratio 1.02. Colpi length 1.65(0.75-2.25)±0.25 µm and colpi width 2.90(2.00-4.25)±0.40 µm. Exine thickness 2.95(2.00-4.25)±0.39 µm. Mesocolpium distance 16.0(14.7-18.0)±0.55 µm. Pollen fertility 85.7% and sterility 14.23% (Plate 88b,c,d & e).

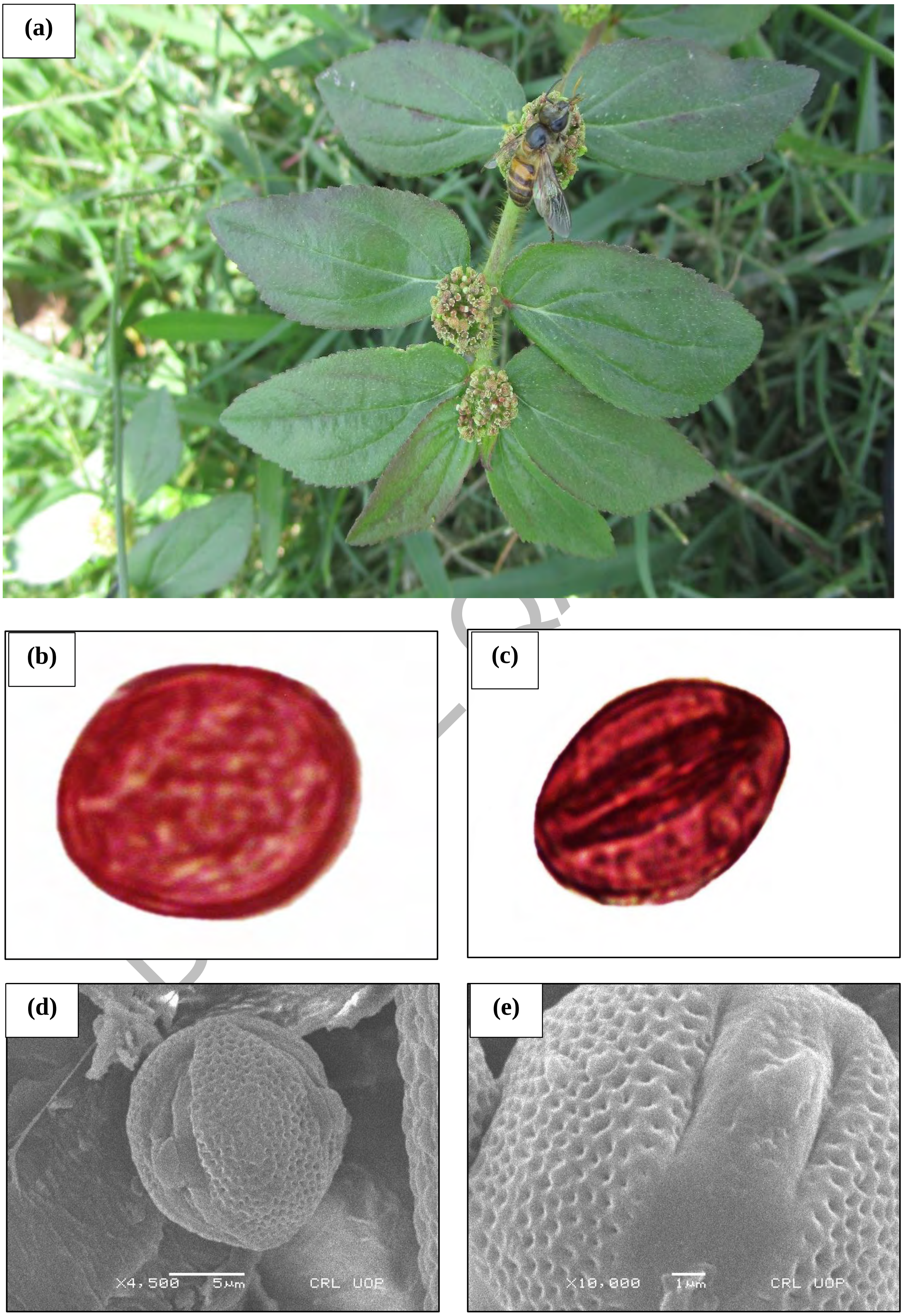

Plate 88: *Euphorbia hirta* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.20 Melisso-palynomorphs of Myrtaceae Honeybee flora

1. *Callistemon citrinus* (Curtis) Skeels

Synonym	*Melaleuca citrina* (Curtis) Dum.Cours.
Family	Myrtaceae
Common Name	Crimson bottlebrush
Habit	Evergreen Shrub
Habitat	It is commonly grown as a specimen or hedge in frost-free climates.
Flowering period	March to May
Status	Wild
Distribution	North America, Australia, Victoria, New South Wales, Pakistan
Morphology	Large evergreen, upright shrub, grow to 8-18 inches tall. It can also be trained as a tree to 25' tall. Leaves: alternate, simple, entire, lanceolate 4.5–13 mm wide, 2.5–8 cm long, with distinct rigides. Leaf venation: pinnate and cuneate at base. Spike: 4–10 cm long. Filaments: red, 18–24 mm long. Capsule: 4.8–7.5 mm diameter. Flowers feature; very showy, numerous bushy, bright red stamens, rounded to cylindrical spikes. Calyx tube hairy and glabrous. Stamens: filaments 2.5–3.2 cm long and bright crimson colored. Flowers bloom intermittently, attractive to bees. Leaves; lance-shaped, narrow-elliptic 3 inches long and lemony scent. Fruit: depressed globose, round shape, brown colored and less than 0.6 inches (Plate 89a).
Melissopalynology	Pollen are monad, small sized, and tricolporate. Angular polar view, prolate-spheroidal equatorial view. Aperture orientation slightly bulged. Exine sculpturing Psilate to scabrate. Polar view diameter 24.4(23.2-25.7)±0.47 µm and equatorial diameter 21.3(18.7-22.7)±0.73 µm. P/E ratio 1.14. Colpi length 4.15(3.25-5.25)±0.36 µm, colpi width 9.70(8.75-10.2)±0.27 µm and mesocolpium distance 18.6(17.0-20.2)±0.65 µm. Exine thickness 5.30(4.75-6.2)±0.27 µm. Pollen fertility 86.09% and sterility 13.9% (Plate 89b,c,d & e).

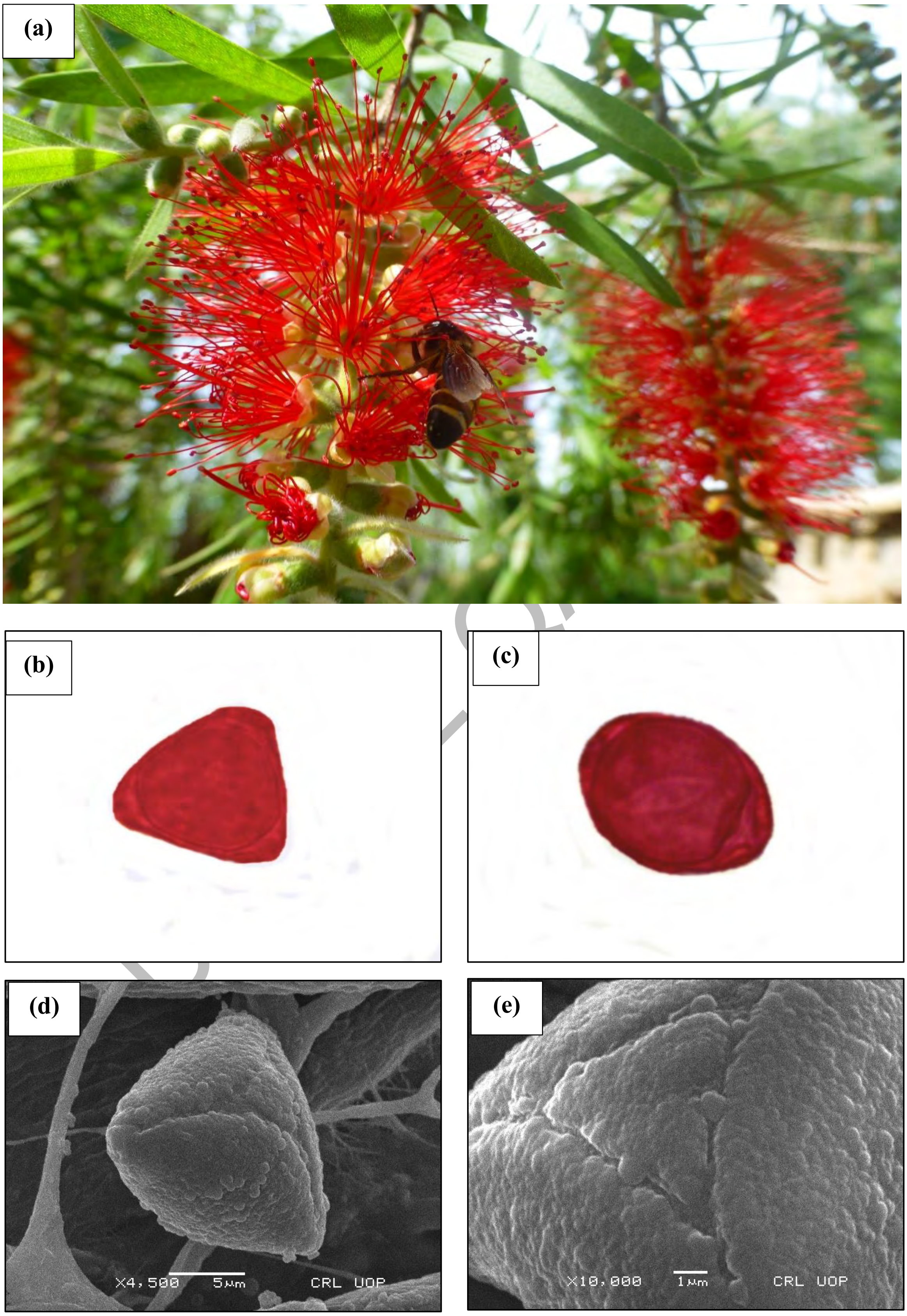

Plate 89: *Callistemon citrinus* (Curtis) Skeels. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Eucalyptus camaldulensis* Dehnh.

Synonym	*Eucalyptus camaldulensis* var. *camaldulensis*
Family	Myrtaceae
Common Name	River red gum
Habit	Perennial Tree
Habitat	Found in dry and salty areas
Flowering period	March to October
Status	Wild
Distribution	Australia, Iran, Pakistan, Japan, England, Saudi Arabia and India
Morphology	Perennial tree, growing to a height of 20 meters (65ft) but sometime to 45 meters (148ft). Branches: pendulous and terete. The bark is smooth white or cream colored with patches of pink, yellow and brown. Leaves: opposite, lance-shaped, 81 to 181 mm long and 14-26 mm wide. Leaf blade: broadly lanceolate, 4-5.5 × 3-4.6 cm. Mature leaves: lance-shaped, rounded, dull green or greyish green coloured, 51-300 mm long and 6.5-33 mm wide on a petiole 7.9- 34 mm long. Flower buds: ovoid and 3.8-7.5 mm. Stamens: 6-8 mm; anthers; elliptic, dehiscing longitudinally. Capsule: globose and 4-7.5 mm in diameter (Plate 90a).
Melissopalynology	Pollen are monad, small sized and tricolpate. Triangular polar view and equatorial view shape oblate-spheroidal. Exine ornamentation scabrate reticulate. Polar diameter 21.4(27.5-17.5)±2.30 µm and equatorial view distance 22.0(28.7-17.5)±1.13 µm. P/E ratio 0.97. Colpi length 4.66(7.50-2.25)±3.94 µm and colpi width 6.08(9.50-2.75)±1.90 µm. Mesocolpium 16.6(22.5-12.5)±3.42 µm. Exine thickness 3.5(5.25-2.25)±1.00 µm. Pollen fertility 82.2% and sterility 17.3% (Plate 90b,c,d & e).

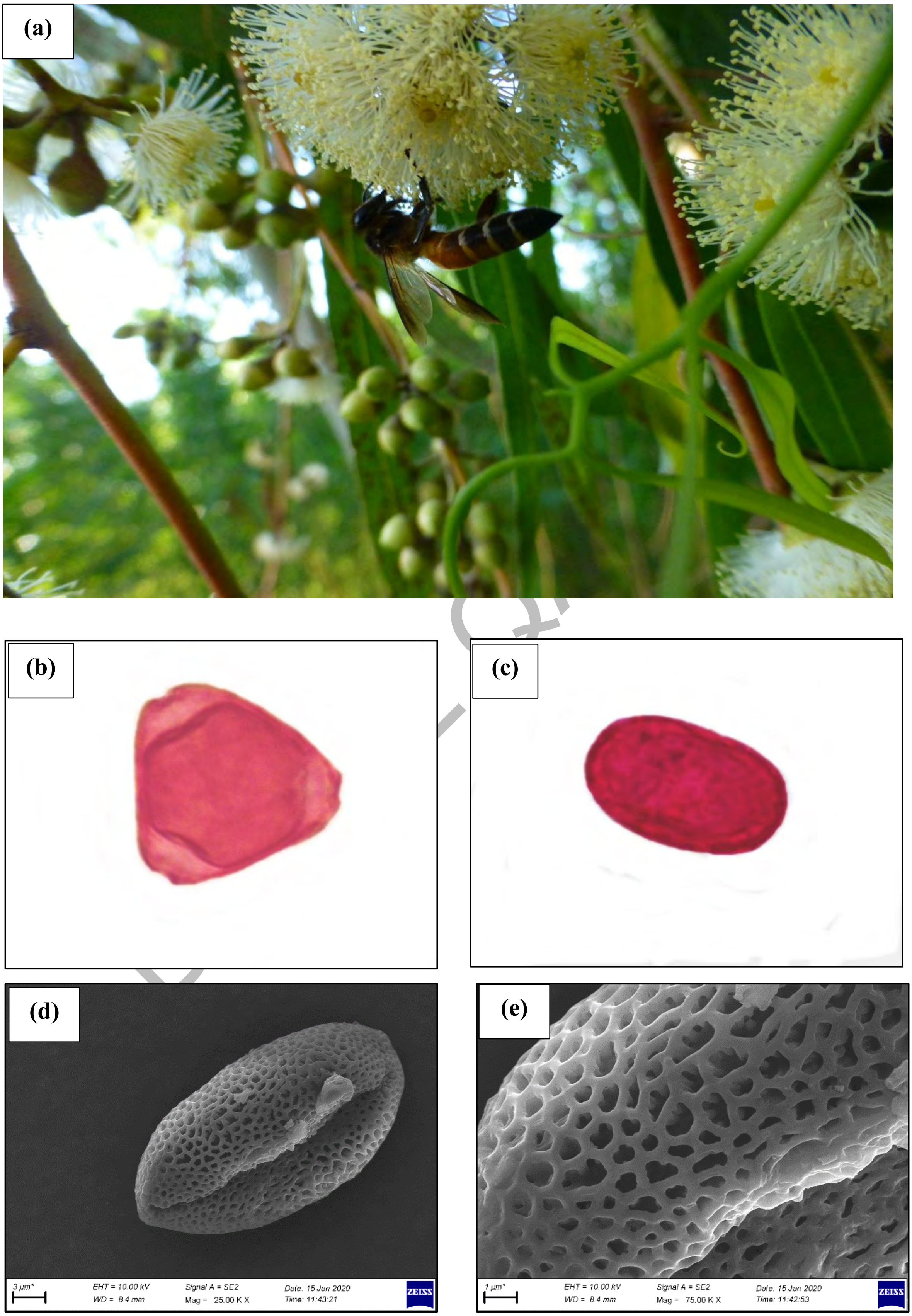

Plate 90: *Eucalyptus camaldulensis* Dehnh. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Psidium guajava* L.

Synonym	*Psidium guava* Griseb.
Family	Myrtaceae
Common Name	Common guava
Habit	Tree
Habitat	Along forest edges, pastures, grasslands and riparian habitats
Flowering period	March to May
Status	Cultivated
Distribution	Chile, Tonga, Fiji, Ghana, Pakistan, Cambodia
Morphology	Tree, 12.5 m tall. Bark; gray, smooth, in strips. Branchlets; angular, pubescent. Petiole 5 mm; leaf blade oblong, elliptic, 5-10 × 3.8-6.5 cm, leathery, abaxially pubescent, adaxially rough, secondary veins; 10-16, usually impressed, reticulate veins obvious, base rounded, apex obtuse. Flowers; solitary, 2 to 3, cymes. Hypanthium; campanulate, 4-5 mm, pubescent. Calyx cap nearly rounded, 5-8 mm and irregularly opening. Petals; white, 1.3-1.8 cm. Stamens; 5-8.5 mm. Ovary; adnate. Style; as long as stamens. Berry; globose, ovoid, pyriform, 2-9 cm, persistent calyx lobes, flesh white, yellow; placenta reddish, well developed fleshy (Plate 91a).
Melissopalynology	Pollen are monad, isopolar, small sized and tricolporate. Triangular polar view and spherical equatorial view shape. Colpi orientation sunken and tapering at end. Exine sculpturing Verrucate-gemmate. Polar diameter 22.2(23.7-20)±1.38 µm and equatorial view distance 22.0(25-18.7)±2.59 µm. P/E ratio 1.0. Colpi length 13.8(15-12.5)±0.92 µm, 7.85(8.7-7.25)±0.57 µm and mesocolpium distance 21.1(23.7-18.7)±1.97 µm. Exine thickness 5.5(7.75-4.25)±1.32 µm. Pollen fertility 88.6% and sterility 9.5% (Plate 91b,c,d & e).

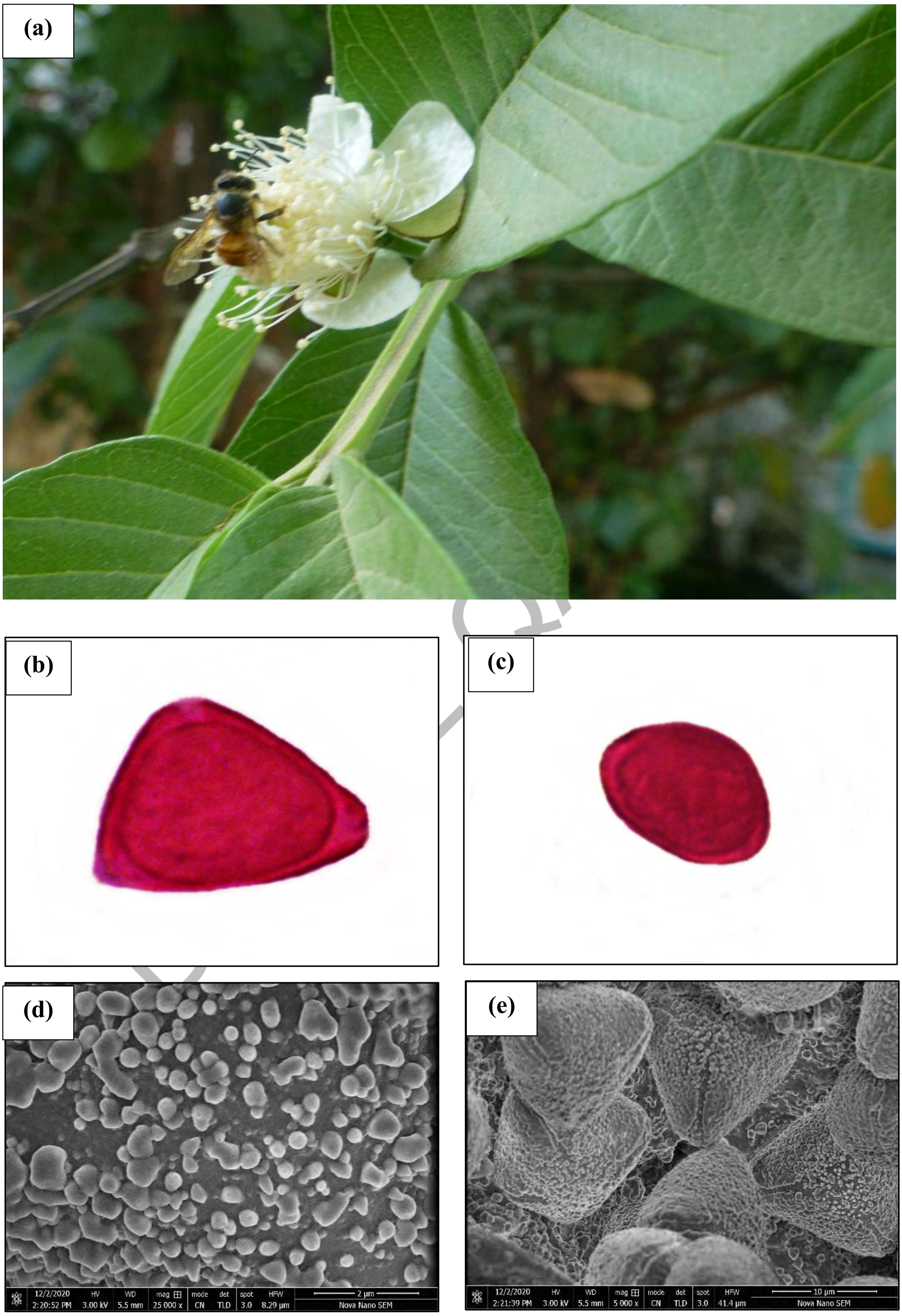

Plate 91: *Psidium guajava* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.21 Melisso-palynomorphs of Convolvulaceous Honeybee flora

1. *Convolvulus arvensis* L.

Synonym	*Convolvulus arvensis* f. *arvensis*
Family	Convolvulaceae
Common Name	Sun spurge
Habit	Annual Herb
Habitat	In Meadows and fields, orchards, vineyards, roadsides, ditch banks
Flowering period	March to June
Status	Wild
Distribution	Canada, Qatar, Turkey, Italy, Norway, Pakistan, Egypt
Morphology	Climbing and prostrate annual or perennial herbs, branching at the base. Stems 35-100 cm long, glabrous to pubescent. Leaves; glabrous to pubescent, 22-40 x 3-35 mm, ovate to broadly oblong or linear to linear-oblong, sagittate to hastate, acute to obtuse, petiole 8-20 mm long. Flowers campanulate, bracteate, axillary, pale pink to lilac with dark purple bands, pedicellate, pedicel 8-17 mm long, pubescent to glabrous, bracteoles linear, 3-5.5 mm long. Sepals scarious, 2.5-5 mm long, broadly oblong, obtuse, apiculate, sparsely pubescent to glabrous. Corolla 18 mm long. Filaments unequal, 4.5-8 mm long, anthers 2 mm long. Ovary glabrous, on a disc. Stigma; 2-4.5 mm long, filiform. Capsule globose, 4.5 mm in diameter. Seeds; 4 mm long, dark brown, tuberculate (Plate 92a).
Melissopalynology	Pollen are monad, medium sized, Psilate and tricolporate. Rounded polar view and equatorial view shape sub-prolate. Exine sculpturing sparsely perforated. Polar diameter 46.5(42.7-50.25) ±1.54 µm and equatorial view distance 39.2(36.2-43.0) ±1.15 µm. P/E ratio1.18. Colpi length 6.80(5.50-7.75)±0.40 µm and colpi width 6.95(6.25-8.00)±0.31 µm. Exine thickness 9.10(7.75-10.7)±0.52 µm. Mesocolpium distance 23.6(22.2-25.2)±0.48 µm. Pollen fertility 86.1% and sterility 13.8% (Plate 92b,c,d & e).

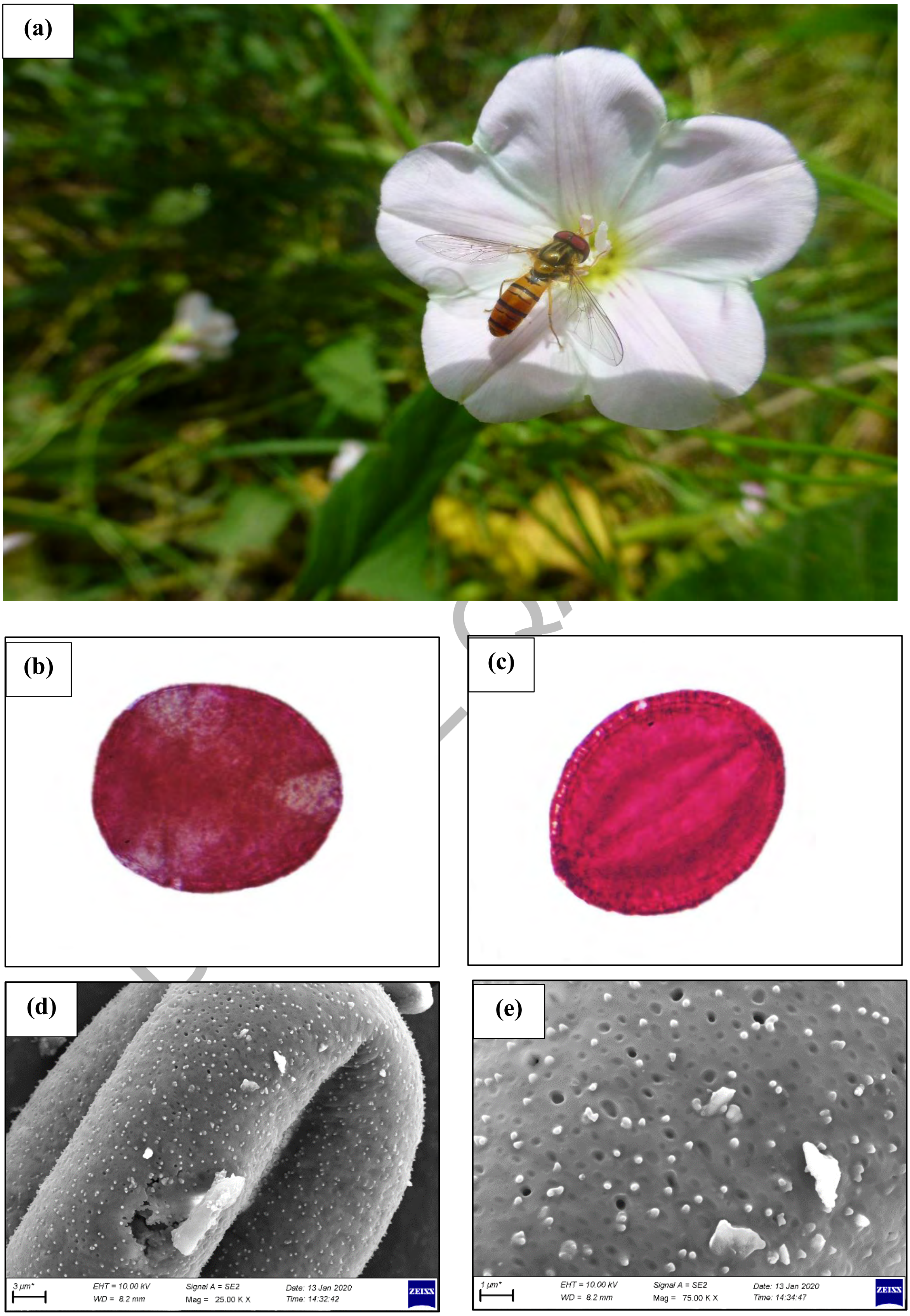

Plate 92: *Convolvulus arvensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Ipomoea purpurea* (L.) Roth

Synonym	*Convolvulus purpureus* L.
Family	Convolvulaceae
Common Name	Common morning glory
Habit	Annual Herb
Habitat	Grows along roadsides, in waste places
Flowering period	June to August
Status	Wild
Distribution	South Africa, Pakistan, Turkey, Portugal
Morphology	Herb, annual, twining, short axial part, short pubescent and long retrorse hirsute. Stems; 1.5-3.5 m. Petiole; 2.5-14 cm; leaf blade; broadly ovate, 2-15×4-18 cm, strigose, base cordate, margin entire, apex acute and acuminate. Inflorescences; 1 to 5-flowered; peduncle; 3-10 cm; bracts linear, 4-7 mm and spreading hirsute. Pedicel; recurved, 1.5-1.9 cm. Sepals; sub-equal, 1-18 cm, hirsute abaxial, basal, oblong, apex acuminate; inner lanceolate. Corolla; red, purple, blueish purple, funnelform, 3-6 cm and glabrous. Stamens; unequal; filaments pubescent and basally. Pistil; ovary glabrous, trilocular. Stigma; trilobed. Capsule: sub-globose, 6-10 mm in diameter. Seeds; black, straw colored and ovoid-trigonous, glabrous (Plate 93a).
Melissopalynology	Pollen are monad, large sized, and tricolporate. Rounded polar view and equatorial view shape prolate-spheroidal. Exine sculpturing echinate-perforate. Polar diameter 60.7(51.2-67.7)±2.89 µm and equatorial distance 57.1(47.7-70.7)±3.85 µm. P/E ratio 1.05. Colpi length 5.80(4.75-6.50)±0.30 µm and colpi width 6.00(3.00-7.75)±0.79 µm and mesocolpium distance 41.2(38.7-43.7)±0.92 µm. Spine length 5.75(3.75-6.75)±0.57 µm and spine width 1.20(0.25-2.75)±0.46 µm. Exine thickness 6.40(5.25-7.75)±0.40 µm. Pollen fertility 93.7% and sterility 6.25% (Plate 93b,c,d & e).

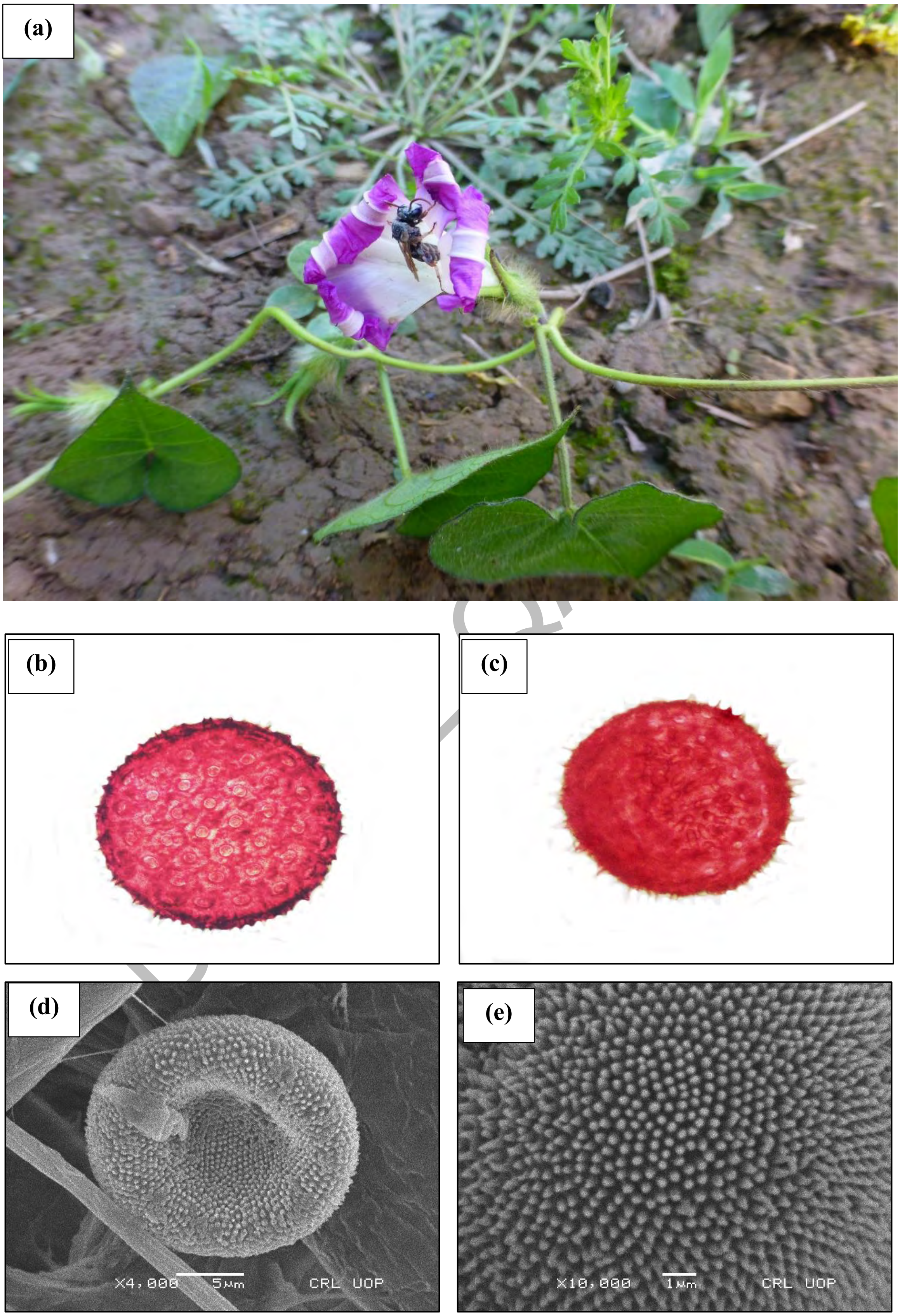

Plate 93: *Ipomoea purpurea* (L.) Roth (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.22 Melisso-palynomorphs of Cucurbitaceous Honeybee flora

1. *Cucumis melo* L.

Synonym	*Cucumis acidus* Jacq.
Family	Cucurbitaceae
Common Name	Muskmelon
Habit	Annual vine
Habitat	Cultivated fields, loamy soil, waste places
Flowering period	May to August
Status	Cultivated
Distribution	Iran, Australia, Turkey, Korea, North America, India, Pakistan
Morphology	Annual or perennial herbaceous plant. Stem has covered with scabrous hairs, leaves have ovate, triangular, 3-6 lobed Flowers have small, rarely in pairs, peduncle 6 to 10 mm long, densely hipsid. Male flowers: fasciculate. Pedicels: filiform, 0.3-3.5 cm and pubescent. Female flowers: solitary, ovary ellipsoid, fusiform, 4-11 × 2-5 mm. Calyx tube: campanulate, 2.3-5.5 mm, densely hispidulous and white villous. Calyx 1-5.2 mm long, subulate. Corolla 5.5-7 mm long, yellow, lobes ovate oblong. Fruit: variable size, shape, texture and colour, glabrous ellipsoid, oval-globose, sometimes obscurely trigonous, smooth and glabrescent, 4.1 × 2.6 cm, mostly with dark green stripes. Seeds: white, oblong and emarginated (Plate 94a).
Melissopalynology	Pollen are monad, medium sized and triporate. Semicircular polar view and equatorial view shape prolate-spheroidal. Exine sculpturing reticulate scabrate. Polar diameter 41.6(33.7-47.7)±2.47 µm and equatorial view distance 37.7(26.2-42.7)±2.97 µm. P/E ratio 1.103. Pore length 3.10(2.00-4.75)±0.50 µm and pore width 4.25(3.25-5.50)±0.39 µm. Exine thickness 3.10(2.25-3.75)±0.26 µm. Mesocolpium distance 35.0(27.7-39.0)±2.00 µm. Pollen fertility 88.09% and sterility 11.9% (Plate 94b,c,d & e).

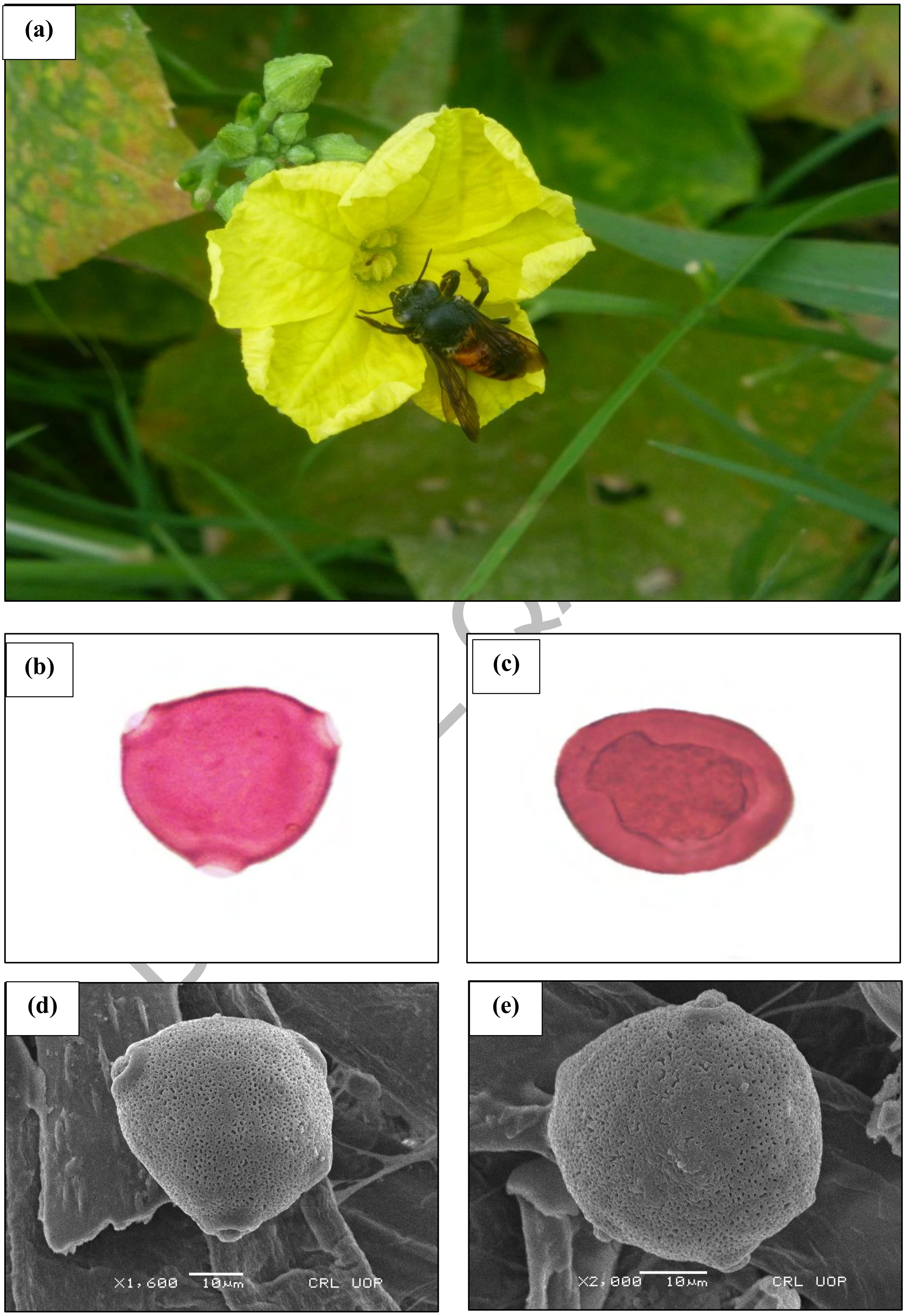

Plate 94: *Cucumis melo* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Luffa cylindrica* (L.) M.Roem.

Synonym	*Bryonia cheirophylla* Wall.
Family	Cucurbitaceae
Common Name	Sponge gourd
Habit	Annual climber
Habitat	In forest, woodland, bushland, thicket and grassland
Flowering period	July to October
Status	Cultivated
Distribution	East Himalaya, Nigeria, Somalia, Pakistan, Korea, Kenya, Senegal
Morphology	Stem and branches scabrous, sulcate-angular, puberulent. Tendrils rather robust, usually 2 to 4 fid. Petiole; 10-12 cm, scabrous, subglabrous; leaf blade triangular or suborbicular, 10-20 cm, palmately 5 to 7-lobed; 7-12 cm, base deeply cordate, margin dentate. Male flowers; 15-20 in a raceme; peduncle robust, 12-14 cm, pubescent; pedicels 1-2 cm; calyx campanulate, 4-11 mm, puberulent; segments reflexed, ovate, lanceolate, 8-13 × 4-7 mm, acuminate apex; corolla yellow, rotate, 5-9 cm in diameter. Stamens; 5, filaments 6-8 mm, base white pubescent and connate. Female flowers; solitary; pedicel 2-10 cm; narrowly cylindric, puberulent and stigmas expanded. Fruit; cylindric, straight or slightly curved, 15-45×3-6 cm, smooth, costate. Seeds; black, ovate, smooth or very sparingly tuberculate and margin slightly winged (Plate 95a).
Melissopalynology	Pollen are monad, small sized, radially symmetrical, isopolar and tricolporate. Triangular polar view and prolate equatorial view shape. Exine ornamentation psilate reticulate. Sexine thinner or thicker than nexine. Polar diameter 20.1(18.2-22.7)±0.79 µm and equatorial diameter 11.4(6.00-20.5)±3.18 µm. P/E ratio 1.76. Colpi length 6.35(5.25-7.75)±0.40 µm and width of colpi 5.70(5.25-6.25)±0.16 µm. Pore present circular in shape. Exine thickness 3.35(3.00-3.75)±0.12 µm. Mesocolpium measurement 19.2(17.2-21.0)±0.72 µm. Pollen fertility 87.7 % and sterility 12.2 % (Plate 95b,c,d & e).

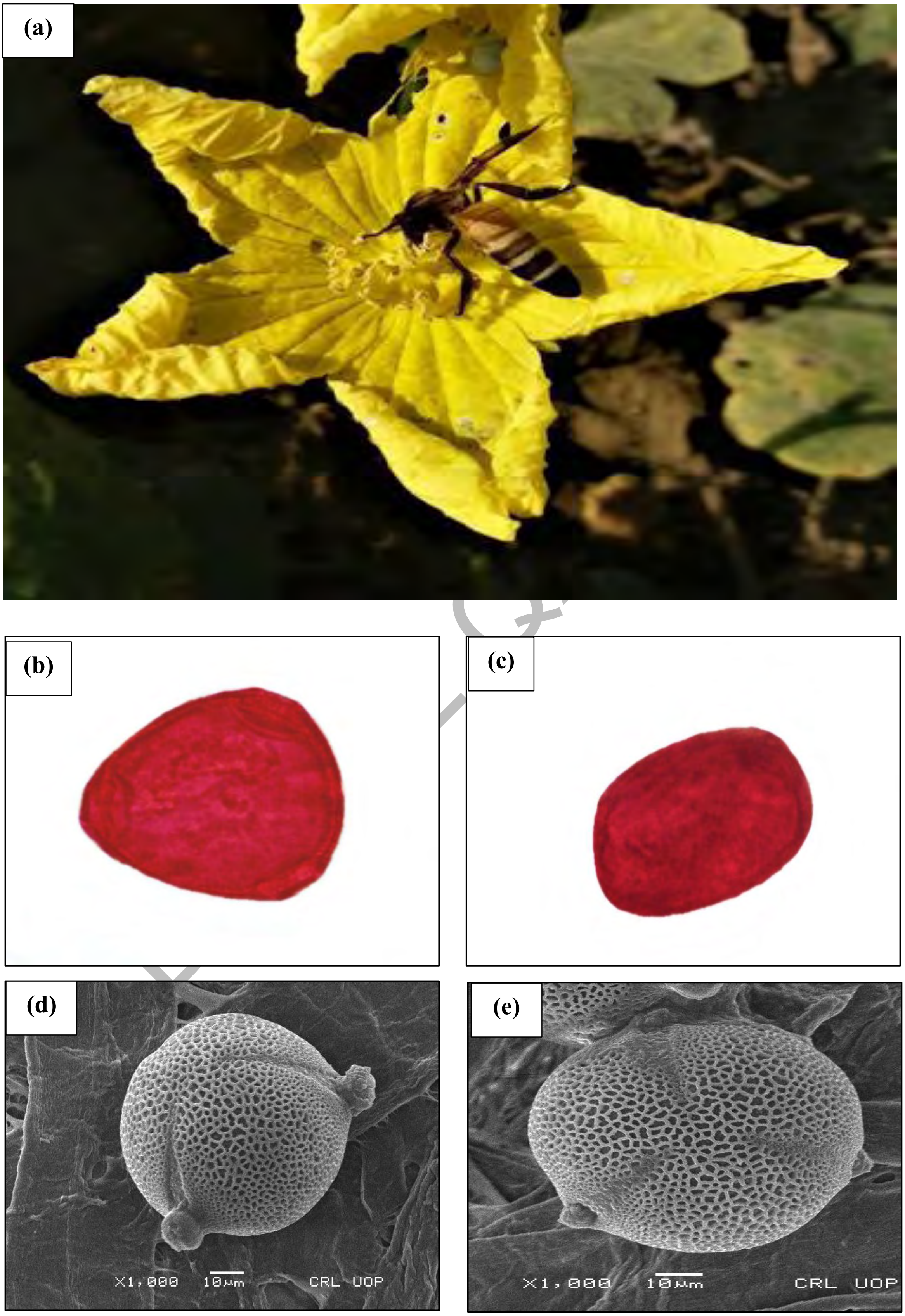

Plate 95: *Luffa cylindrica* (L.) M.Roem. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.23 Melisso-palynomorphs of Lythraceae Honeybee flora

1. *Lagerstroemia indica* L.

Synonym	*Lagerstroemia chinensis* Lam.
Family	Lythraceae
Common Name	Crape myrtle
Habit	Shrub
Habitat	In gardens, yards, public parks, parking lots and along highways
Flowering period	May to October
Status	Cultivated
Distribution	Bangladesh, Iran, Singapore, Pakistan, Puerto Rico
Morphology	Shrub and 6 to 7 m tall. Branchlets; slender, tetra angular, sub-alate, puberulous and glabrescent. Leaves; sessile, petiolate and 2.5 mm. Leaf blade; elliptic, oblong or obovate, sub-orbicular and mucronate, 2-8 × 2-5.5 cm, slightly leathery, glabrous, slight indumentum, lateral veins 3 to 7 pairs, base broadly cuneate, apex acute, obtuse with small retuse. Panicles; sub-pyramidal, 5-22 cm, puberulous and densely flowered. Floral tube; hexamerous, 5-13 mm, smooth walled and glabrous. Sepals; 3-5 mm, glabrous adaxial, annulus present and epicalyx absent. Petals; purple, fuchsia, pink, orbicular and 1.3-2.2 cm. Stamens; 30-38 and dimorphic. Ovary; glabrous (Plate 96a).
Melissopalynology	Pollen are monad, iso polar, medium sized, and tricolporate. Polygonal polar view and equatorial view shape prolate-spheroidal. Exine sculpturing scabrate Verrucate. Sunken aperture orientation. Polar diameter 28.8(22.7-33.5)±1.47 µm and equatorial view distance 25.3(21.2-28.7)±1.47 µm. P/E ratio 1.13. Colpi length 6.90(4.75-8.00)±0.57 µm, colpi width 7.60(6.75-9.25)±0.44 µm and mesocolpium distance 21.2(19.5-23.7)±0.76 µm. Exine thickness 5.90(4.75-7.75)±0.52 µm. Pollen fertility 85.7% and sterility 14.2% (Plate 96b,c,d & e).

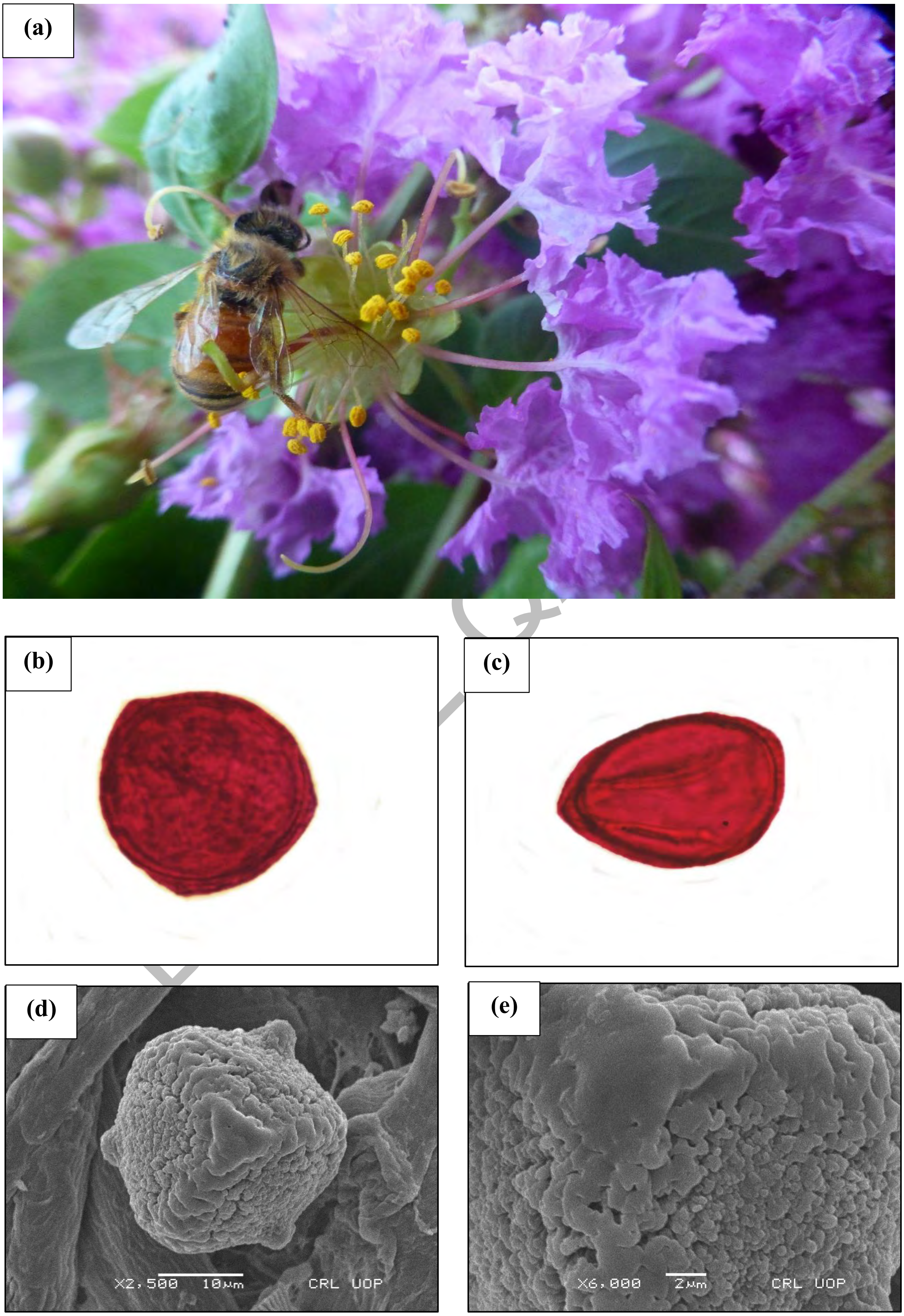

Plate 96: *Lagerstroemia indica* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Punica granatum* L.

Synonym	*Punica nana* L.
Family	Lythraceae
Common Name	Pomegranate
Habit	Deciduous Shrub
Habitat	Found in gardens, homes, nurseries, roadsides
Flowering period	April to July
Status	Cultivated
Distribution	Afghanistan, Iran, Libya, Pakistan, Indonesia, Morocco
Morphology	Deciduous shrub up to 1.7-5.5 m long, branches tetra-angular, terete, terminate as indurate spines. Petiole: 2.4-12 mm; leaf blade: adaxial shiny, lanceolate, elliptic-oblanceolate, 1.8-8.5 × 1.5-2 cm, base attenuate and apex mucronate. Leaves glabrous, lustrous 19-30 × 9-16 mm, oblong-lanceolate to obovate, sub petiolate, entire, apex sub-actue. Flowers scarlet red, conspicuous, 3.3 cm. Calyx 21 to 36 mm long, reddish, 5-7 lobes, 8.2 mm long, triangular. Petals 15-22 × 10-14 mm, obovate, wrinkly, alternating with the sepal lobes. Filaments; 7.2 mm long, multiseriate, persistent. Ovary sub-globose; style thick, 1.2 cm long, reddish; stigma simple; slightly bilobed (Plate 97a).
Melissopalynology	Pollen are monad, small to medium sized and tricolpate. Semicircular polar view and spherical equatorial view shape. Colpi orientation sunken, tapering at end. Exine sculpturing regulate-Verrucate. Polar diameter22.2 (23.7-20)±1.38 µm and equatorial view distance 22.0(25-18.7)±2.59 µm. P/E ratio 1.00. Colpi length 13.8(15-12.5)±0.92 µm, colpi width 7.85(8.7-7.25)±0.57 µm and mesocolpium distance 21.1(23.7-18.7)±1.97 µm. Exine thickness 5.5(7.75-4.25)±1.32 µm. Pollen fertility 83.8% and sterility 16.1% (Plate 97b,c,d & e).

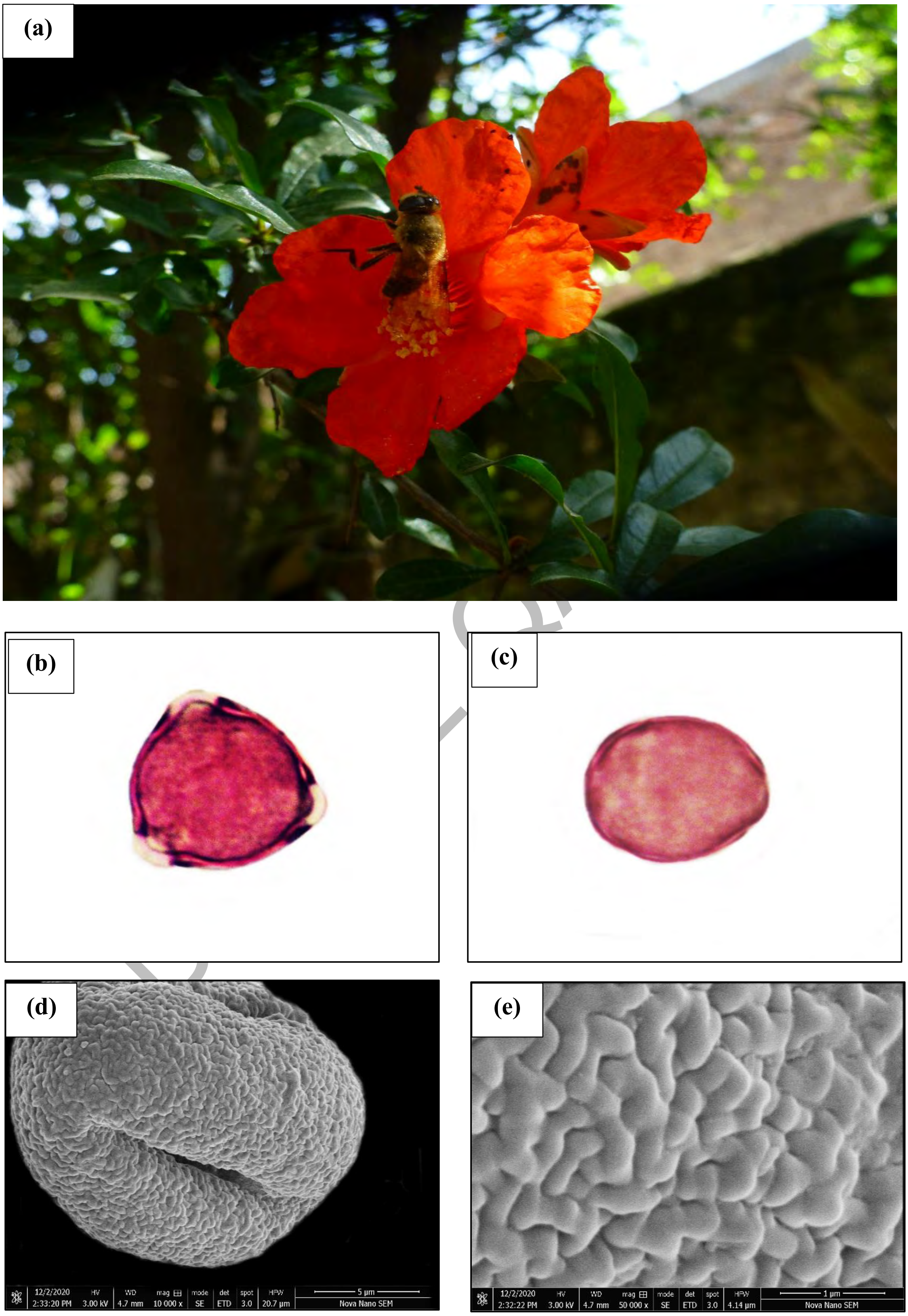

Plate 97: *Punica granatum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.24 Melisso-palynomorphs of Rhamnaceae Honeybee flora

1. *Zizyphus jujuba* Mill.

Synonym	*Ziziphus jujuba* (L.) Lam.
Family	Rhamnaceae
Common Name	Common jujube
Habit	Deciduous Tree
Habitat	Forests, plains and hilly areas.
Flowering period	June to September
Status	Wild
Distribution	Uzbekistan, Kazakhstan, Pakistan, China, India, Korea
Morphology	Deciduous shrub, 1 to 3 m high; branches flexuous, with strong paired spines, one spine straight and longer (2.5–5.8 cm). Leaves alternate, shortly petiolate, simple, ovate to lanceolate, 1–4.5 cm long and 0.5–2 cm wide, 3-nerved, glabrous, upper leaf surface lustrous and dark green, the lower surface light green. Flowers; axillary, single or in cymes, actinomorphic, hermaphrodite, pentamerous, yellowish-green, 4-6 mm across. Calyx; lobes 5, 1.3 mm long, thickened at margin, with triangular apex. Petals; 5, spathulate-obovate. Stamens as many as petals, anthers dorsifixed. Ovary; bicarpellary, bilocular. Fruit; a small drupe, globose to ellipsoid, 0.8–2.5 cm long, 0.6–2 cm in diameter, orange-red. Stone globose to ellipsoid, obtuse, superficially tuberculate, with two plumpish seeds, brown in color, each seed 2 × 4 mm (Plate 98a).
Melissopalynology	Pollen are monad, iso polar, medium sized and tricolporate. Semi Circular polar view and sub-prolate equatorial view shape. Exine sculpturing regulate. Polar diameter 25.6(23.7-28.7)±0.92 µm and equatorial view distance 21.3(18.7-23.7)±1.01 µm. P/E ratio 1.20 Colpi length 4.20(3.25-4.75)±0.30 µm, colpi width 4.80(4.25-5.25)±0.20 µm and mesocolpium distance 21.3(18.75-23.7)±0.94 µm. Exine thickness 4.70(4.25-5.25)±0.16 µm. Pollen fertility 87.9% and sterility 12.06% (Plate 98b,c,d & e).

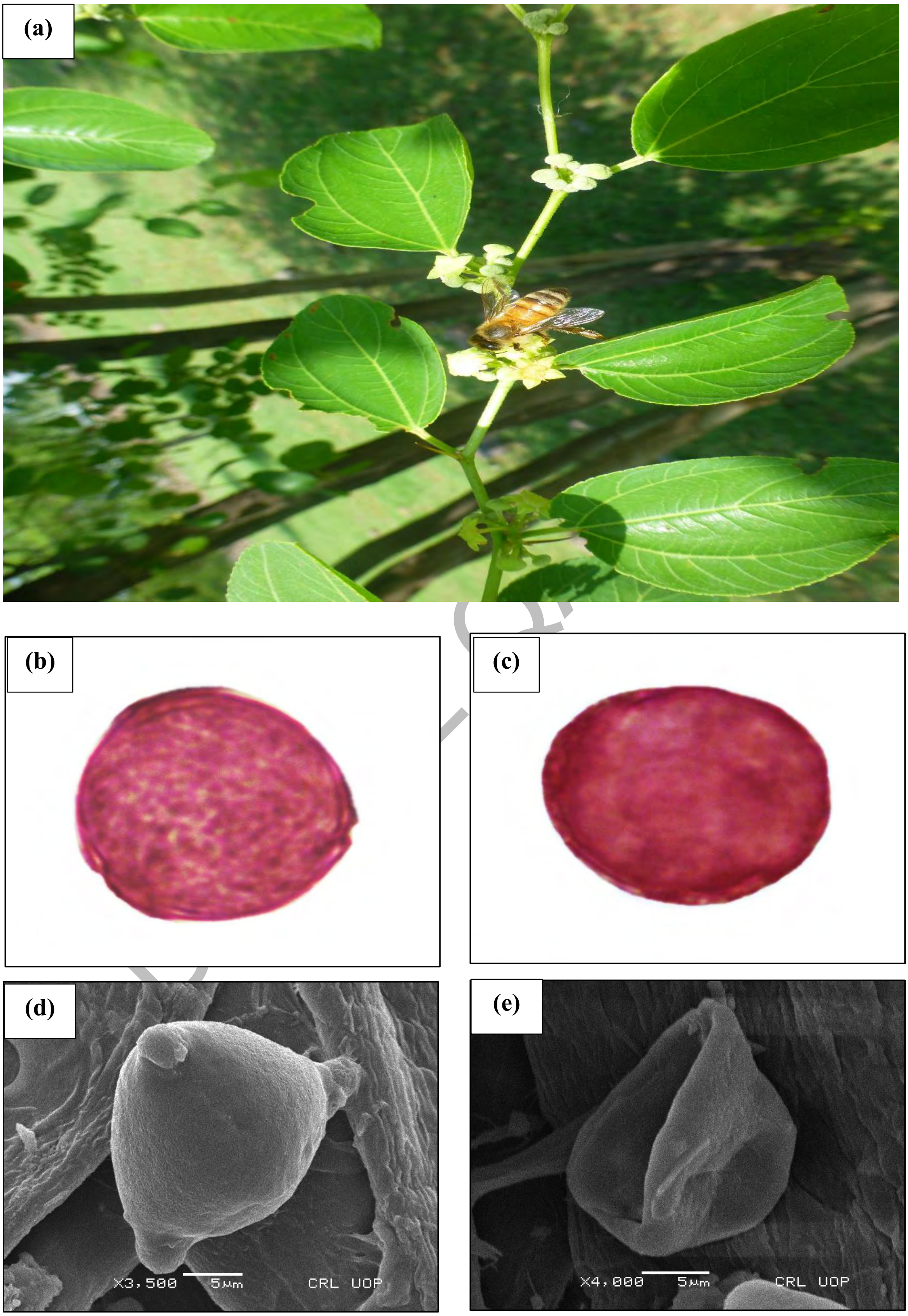

Plate 98: *Zizyphus jujuba* Mill. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Ziziphus oxyphylla* Edgew

Synonym	*Ziziphus acuminata* Royle
Family	Rhamnaceae
Common Name	Leaf Jujube
Habit	Perennial Tree
Habitat	Grow in very dry or moist pastureland
Flowering period	March to June
Status	Wild
Distribution	Tanzania, Algeria, Albania, Sudan, China, India
Morphology	Small almost glabrous, shrub or tree have stipular spines slender branches, unequal, a little recurved, larger one straight, 1.5 mm tall, the leaves 2-6.5 cm × 1.5-3 cm, egg-shaped, acuminate, base is little oblique, serrate to crenate serrate. Petiole 5-11 mm long, cymes is glabrous axillary. Flowers; 3-4.2 mm in diameter, glabrous, pedicel 1.3-3 mm long, glabrous, wiry. Calyx 5-lobed, not keeled glabrous 2-3 mm tall, ellipsoid, obtuse. Petals hooded, spathulate 1.4 mm long; Disc thin almost 5-lobed. Fruit fleshy ovoid 9 to 11 mm tall, orange-black when ripe, 1-celled (Plate 99a).
Melissopalynology	Pollen are monad, medium sized, iso-bisymmetrical, heteropolar, non-operculate and tricolporate. Triangular polar view shape and oblate-spheroidal equatorial view shape. Exine sculpturing regulate-scabrate. Polar diameter 39.72(23.70-46.05)±1.9 µm and equatorial view distance 41.9(31.80-48.15)±1.72 µm. P/E ratio 0.94. Colpi length 4.65(5.25-3.75)±0.57 µm, colpi width 8.05(8.50-7.75)±0.32 µm and mesocolpium distance 21.7(22.5-20.2) ±1.08 µm. Exine thickness 0.99(0.60-1.50) ±0.12 µm. Pollen fertility 78.57% and sterility 21.42% (Plate 99b,c,d & e).

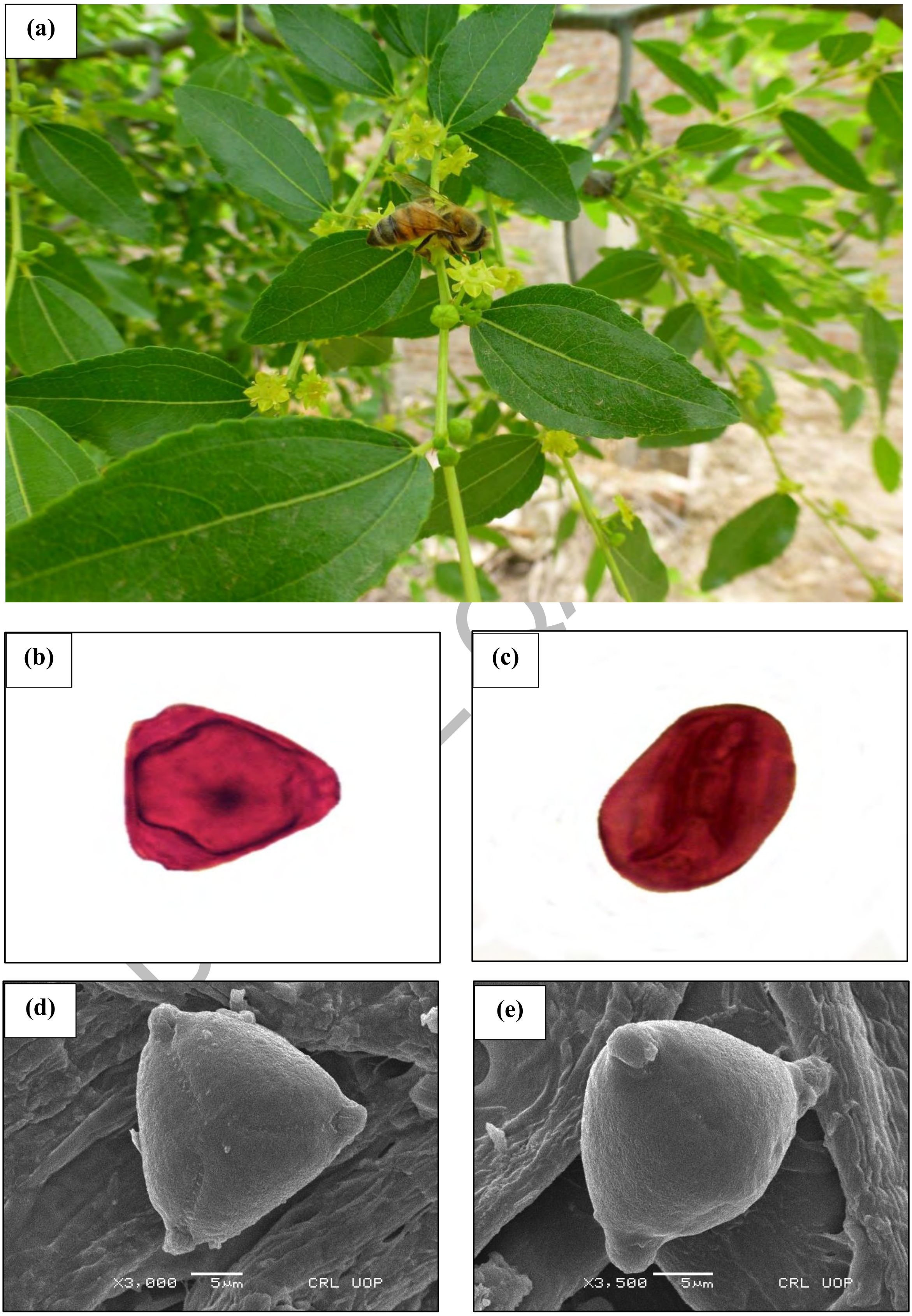

Plate 99: *Ziziphus oxyphylla* Edgew (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.25 Melisso-palynomorphs of Rosaceae Honeybee flora

1. *Malus domestica* Borkh.

Synonym	*Malus domestica* var. *rinkii* (Koidz.) Ohle
Family	Rosaceae
Common Name	Apple
Habit	Deciduous Tree
Habitat	Gardens, Cultivated and uncultivated lands
Flowering period	April to June
Status	Cultivated
Distribution	Australia, Belgium, Bosnia, India, Albania, China, Pakistan
Morphology	Deciduous and semi evergreen trees, bud's ovoid, with several imbricate scales. Leaves; alternate, simple, stipulate, petiolate, venation craspedodromous and merely toothed. Inflorescences corymbose. Flowers: pedicellate, hypanthium bowl shaped. Sepals 5, persistent or caducous. Petals 5, white, pink, or red, sub-orbicular. Stamens 15–50, with white filaments and yellow anthers. Ovary inferior, 3 to 5 loculed, with 2 ovules in each cell; styles 3-5, connate at base, glabrous. Seeds brown or black, cotyledons plano-convex (Plate 100a).
Melissopalynology	Pollen are monad, medium sized and tricolpate. Triangular polar view and prolate-spheroidal equatorial view shape. Colpi orientation sunken and pointed. Exine sculpturing striate regulate. Polar diameter 36.3(37.5-35)±1.03 µm and equatorial view distance 31.8(32.7-30.2)±1.03 µm. P/E ratio 1.14. Colpi length 7.55(7-8.25)±1.06 µm, colpi width 10.1(10.7-9.50)±1.06 µm and mesocolpium 20.6(22.5-18.7)±1.31 µm. Exine thickness 2.45(3-1.75)±0.48 µm. Pollen fertility 90.4% and sterility 11.1% (Plate 100b,c,d & e).

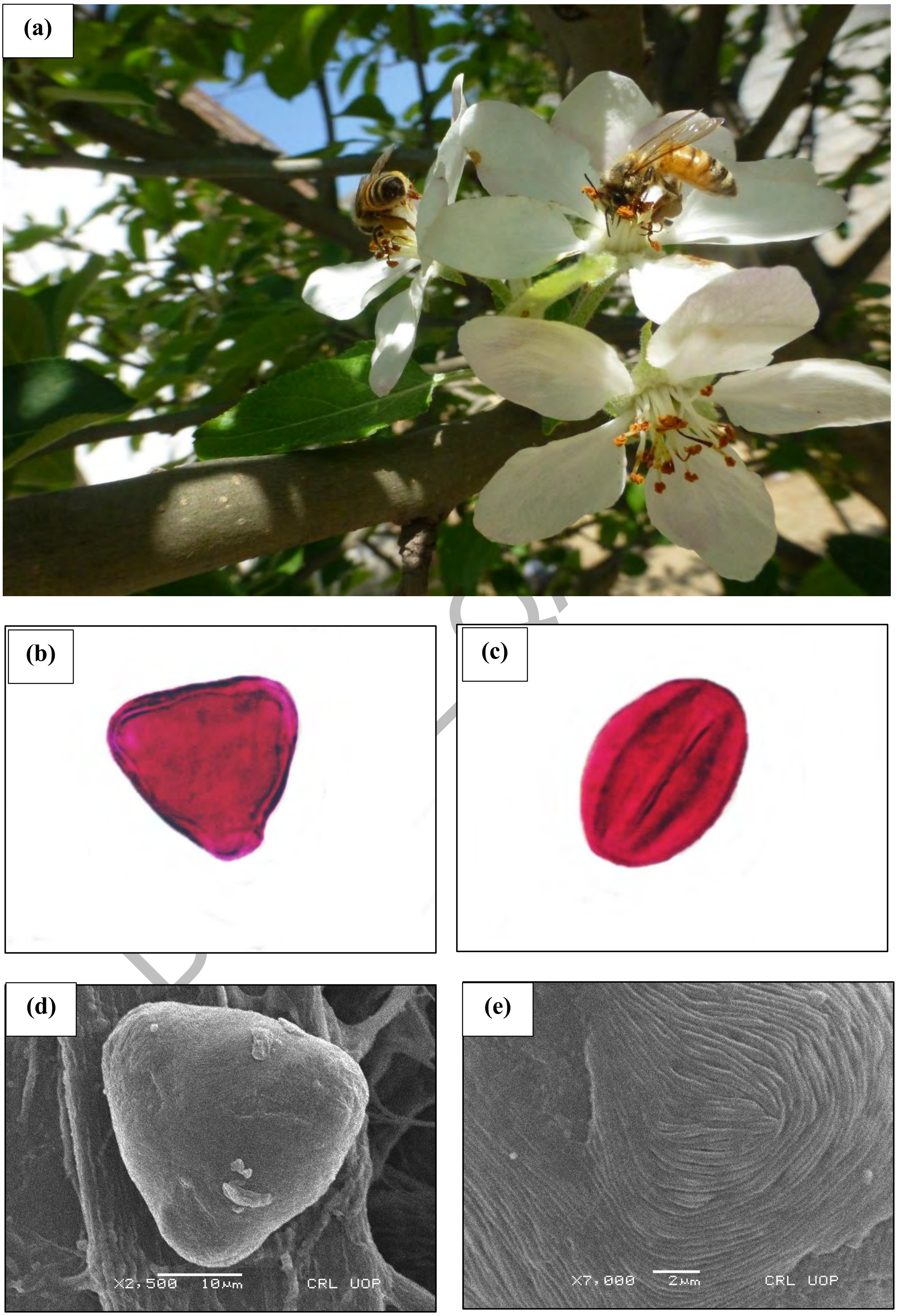

Plate 100: *Malus domestica* Borkh. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Rosa indica* L.

Synonym	*Rosa indica* Lour.
Family	Rosaceae
Common Name	Rosa cymosa
Habit	Spiny Shrub
Habitat	Grown in home gardens
Flowering period	May to September
Status	Cultivated
Distribution	Pakistan, Himalaya, Southwest China, Afghanistan
Morphology	Much branched, shrub and up to 1.5-4 m tall. Prickles; compressed, broad at base, chestnut red, numerous, contiguous and mixed with needle like prickles. Leaflets; 7-18, up to 35 mm long, oblong, elliptic, acute apex, serrate, entire in lower half, glabrous and pubescent. Stipules; narrow and with divergent auricles. Flowers; solitary, up to 42 mm in diameter, petals; 4 and white. Sepals; 4, entire, ascending in fruit and persistent. Styles; densely, pubescent and compact head. Stamens: numerous, several whorls and insert at disc. Carpels: free, numerous, insert at margin of hypanthium, and ovule pendulous. Fruit; pyriform, short, thickened pedicel and red when ripe (Plate 101a).
Melissopalynology	Pollen are monad, medium sized, radially symmetrical and tricolporate. Circular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing striate regulate. Polar diameter 33.05(26.2-42.7)±3.49 µm and equatorial view distance 32.6(24.7-41.2)±3.51 µm. P/E ratio 1.01. Colpi length 7.05(6.25-7.75)±0.25 µm, colpi width 8.40(7.25-9.75)±0.50 µm and mesocolpium distance 18.2(12.7-20)±1.38 µm. Exine thickness 4.70(4.25-5.25)±0.16 µm. Pollen fertility 77.7% and sterility 22.2% (Plate 101b,c,d & e).

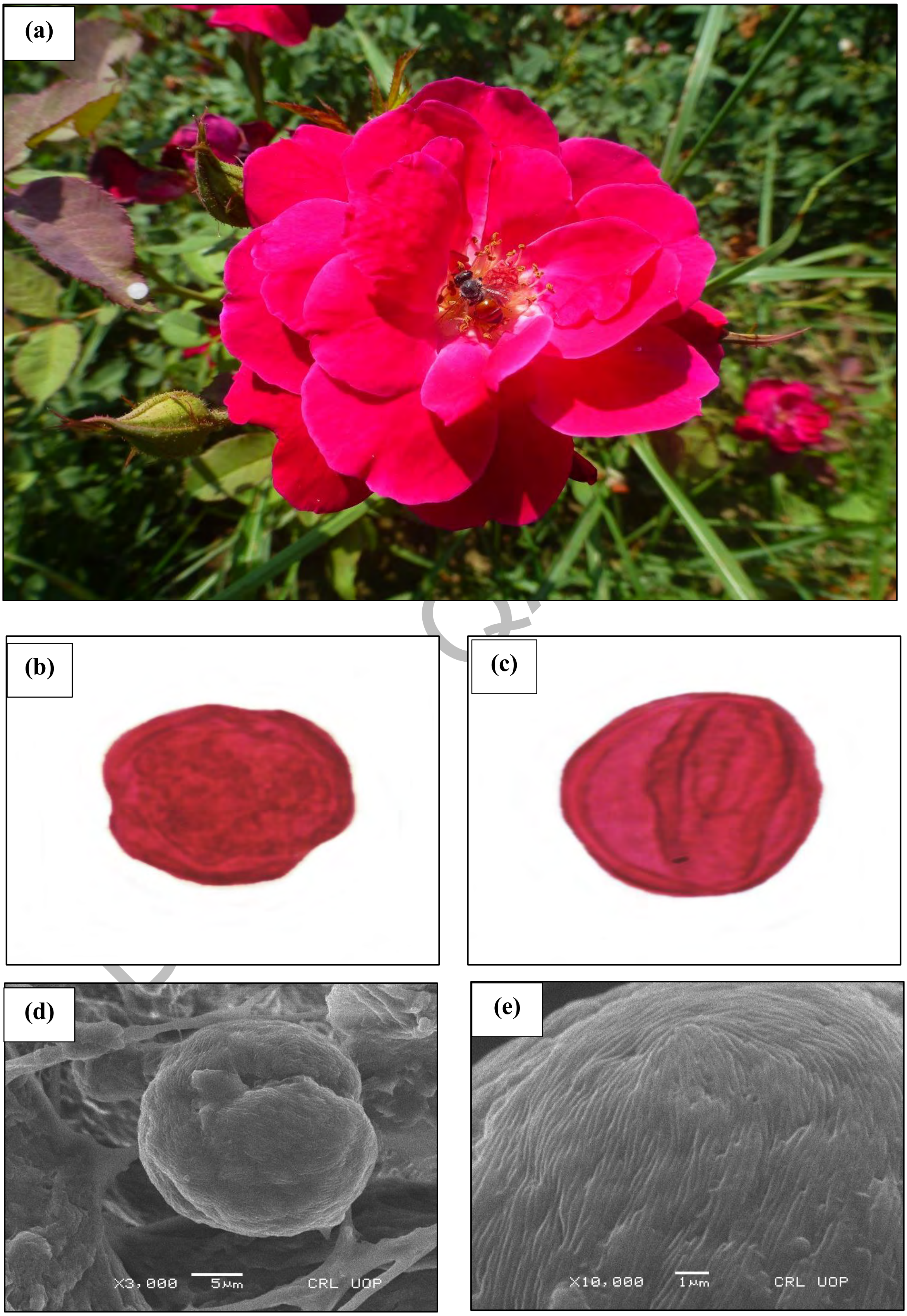

Plate 101: *Rosa indica* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.25 Melisso-palynomorphs of Rutaceae Honeybee flora

1. *Citrus limon* (L.) Osbeck

Synonym	*Citrus limonia* Osbeck
Family	Rutaceae
Common Name	Lemon
Habit	Tree
Habitat	Grow in very infertile, very poor soil
Flowering period	July to September
Status	Cultivated
Distribution	Colombia, Amazonia, Brazil, India, Gambia, Pakistan, Peru
Morphology	Reaches 10 to 20 ft in height and sharp thorns on twigs. Alternate leaves, reddish when young, become dark-green above, oblong, elliptic or long-ovate, 6.25-11.25 cm long, finely toothed, slender wings on petioles. Mildly fragrant flowers, solitary clustered in leaf axils. Buds; reddish, opened flowers have 4 or 5 petals, 2 cm long, white on upper surface, purplish outside, 17-40 more or less united stamens, with yellow anthers. Fruit; oval, nipple like protuberance, 6 -13 cm long; peel light-yellow dotted oil glands; 4-11 mm thick; pulp pale-yellow, in 8 to 10 segments, juicy and acid. Some fruits, seedless, elliptic, ovate, pointed, smooth, 9.3 mm long and white inside (Plate 102a).
Melissopalynology	Pollen are monad, medium sized, isopolar, radially symmetrical, and tetracolporate. Circular polar view and spheroidal equatorial view shape. Colpi long, sunken; apertures long narrow circular shape. Exine sculpturing micro-reticulate psilate. Polar diameter 25.4(22.2-27.7)±0.95 µm and equatorial distance 25.3(21.7-31.0)±1.74 µm. P/E ratio 1.00. Colpi length 3.95(2.75-5.25)±0.41 µm, colpi width 4.40(3.75-5.25)±0.26 µm and exine thickness 4.65(3.50-5.50)±0.35 µm. Mesocolpium distance 17.80(15.2-20.2)±0.91 µm. Pollen fertility 91.9% and sterility 8.01% (Plate 102b,c,d & e).

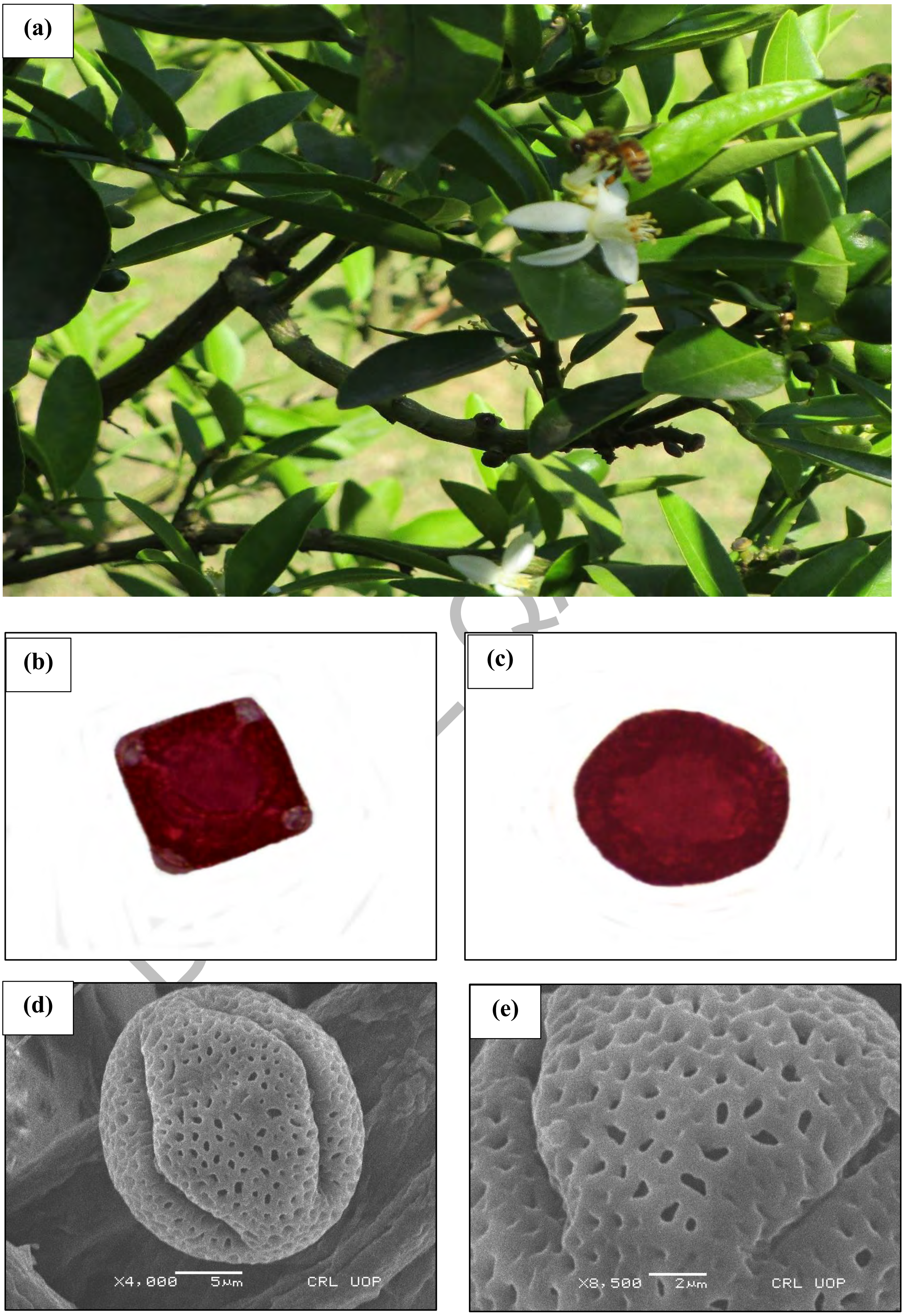

Plate 102: *Citrus limon* (L.) Osbeck (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Citrus sinensis* (L.) Osbeck

Synonym	*Citrus sinensis* var. *brassiliensis Tanaka*
Family	Rutaceae
Common Name	Navel Orange
Habit	Evergreen Tree
Habitat	In loamy, heavy clay and prefers well-drained soil
Flowering period	March to May
Status	Cultivated
Distribution	United Kingdom, Vietnam, China, Australia, Pakistan
Morphology	Spinous; tree, up to 10-12 m tall, spines few, slender and flexible. Twigs: angled in young conditions, with thick spines. Leaves; alternate, aromatic, 7-11.5 cm, ovate-oblong, ovate, entire, serrulate, acute to obtuse. Petiole; narrowly winged and wings oblanceolate. Flowers: born in whorls of 6 (3.5-5.5 cm wide), five white petals and 16–24 yellow stamens. Flowers; hermaphrodite, waxy greenish-white, axillary, 1-6 cymes flowered. Petals; reflexed. Calyx: broad saucer shaped. Stamens 20. Fruit; globose, slightly oval, 5-11 cm in diameter. Rind; deep yellow, orange-red, thick; pulp orange-yellow, reddish, sweet and slightly acidic (Plate 103a).
Melissopalynology	Pollen are monad, medium sized and tetracolporate. Circular polar view equatorial view shape prolate spheroidal. Exine sculpturing macro-reticulate. Polar diameter 30.7(28.0-32.7) ±0.79 µm and equatorial view distance 26.9(26.2-28.0)±0.40 µm. P/E ratio 1.14. Colpi length 4.25(3.75-4.75)±0.17 µm, width of colpi 6.25(4.75-7.75)±0.57 µm and exine thickness 2.25(1.25-3.00)±0.30 µm. Mesocolpium distance 6.25(13.5-18.0)±0.70 µm. Pollen fertility 96.6% and sterility 3.31% (Plate 103b,c,d & e).

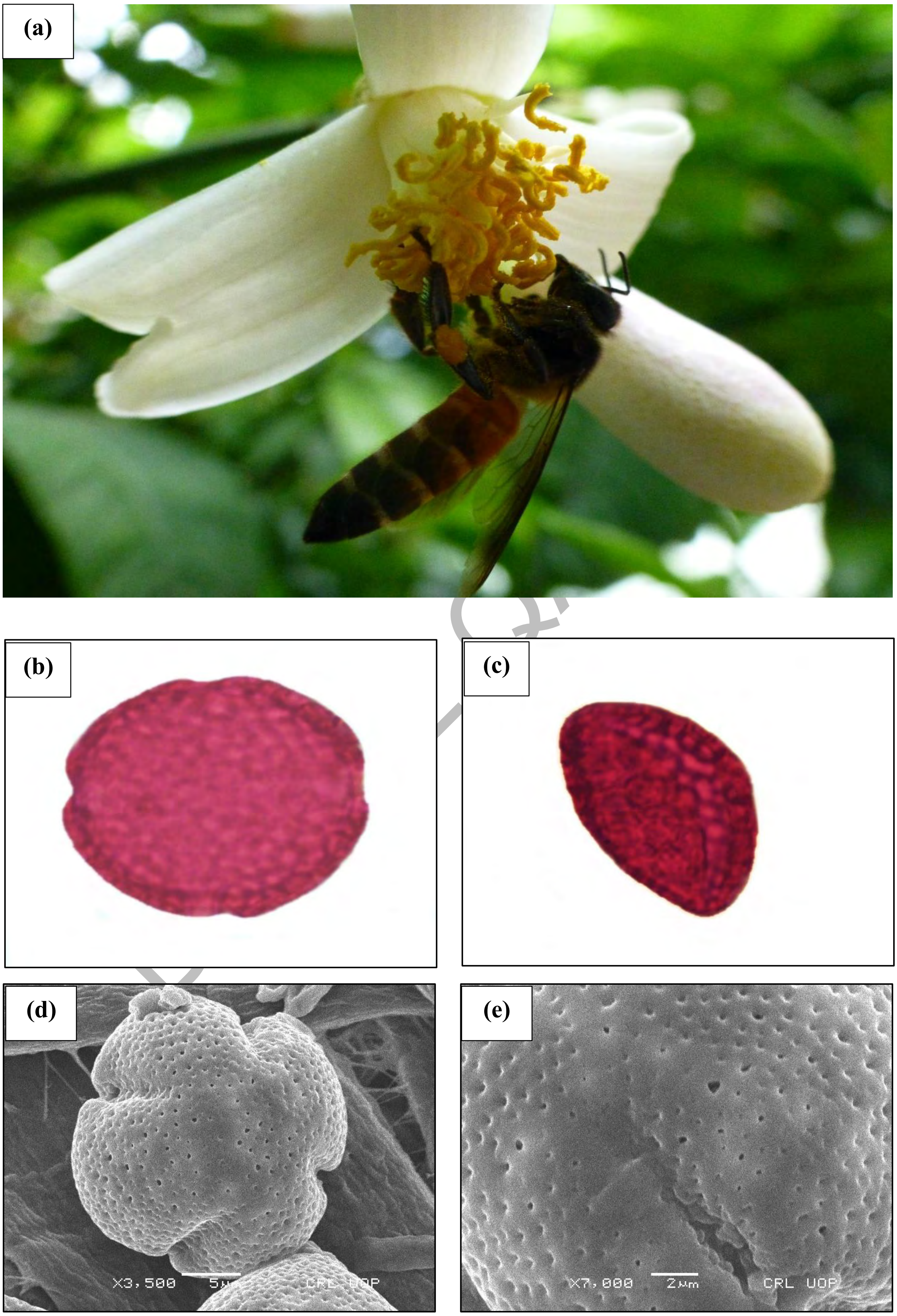

Plate 103: *Citrus sinensis* (L.) Osbeck (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.27 Melisso-palynomorphs of Zygophyllaceae Honeybee flora

1. *Fagonia indica* Burm. F

Synonym	*Fagonia indica* var. *aucheri* (Boiss.) Boiss.
Family	Zygophyllaceae
Common Name	Fagonia
Habit	Herb
Habitat	Slopes on Clays, sandy clays, deserts and dry regions
Flowering period	March to August
Status	Wild
Distribution	Pakistan, India, North and East Africa, Turkey
Morphology	Annual to perennial, usually covered with whitish pruinose or sessile glands or glabrous shrub let. Stem basally somewhat woody, branches procumbent or erect, cylindrical, striate, internodes 3-6 cm long. Leaves usually unifoliolate or basal ones trifoliate and upper unifoliolate, leaflets linear-oblong or lanceolate, 7-38 mm long, 4-5 mm broad, mucronate, short to long petiole or sessile;, patent to ascending, equal to shorter than leaves, occasionally deficient or minute. Flowers mediocre, 1.4 cm across, pinkish-purple; pedicel 5-6.5 mm long. Sepals ovate, 4-7 mm long, glandular outside, acute, persistent. Petals spathulate, 7 mm long, 4 mm broad, obtuse. Stamens with 8 mm long filaments (Plate 104a).
Melissopalynology	Pollen are monad, medium sized and tricolpate. Circular polar view and spheroidal equatorial view shape. Aperture: irregular margins and acute ends. Exine sculpturing reticulate. Polar diameter 36.7(19.7-80.2)±4.83 µm, and equatorial view distance 34.5(18.0-75.2)±4.65 µm. P/E ratio 1.06. Colpi length 4.30(2.75-5.50)±0.18 µm and colpi width 4.58(1.75.7.75)±0.40 µm. Exine thickness 5.95(2.75-10.2)±0.49 µm. Mesocolpium distance 23.8(14.7-45)±2.39 µm. Pollen fertility 89.02% and sterility 10.9% (Plate 104b,c,d & e).

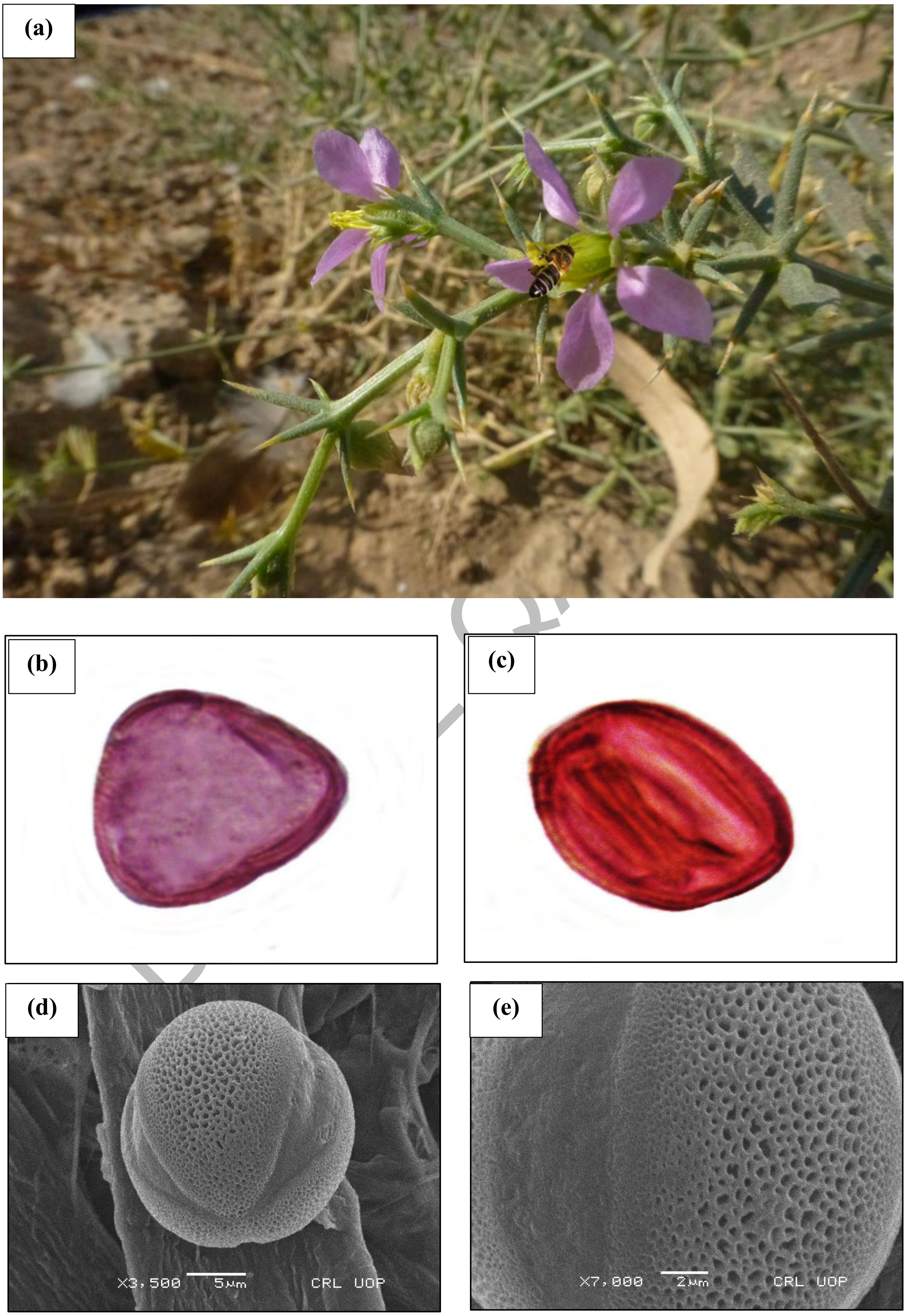

Plate 104: *Fagonia indica* Burm. F (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Tribulus terrestris* L.

Synonym	*Tribulus lanuginosus* L.
Family	Zygophyllaceae
Common Name	Puncture vine
Habit	Herb
Habitat	Occurs in any soil type but grows best in dry, loose and sandy soils
Flowering period	September to November
Status	Wild
Distribution	Pakistan, Malyasia, India, Africa, Australia, Taiwan
Morphology	Annual, prostrate, appressed, whitish silky pubescent. Stem; hirsute to sericeous and branches spreading. Leaves; paripinnate, 2-6 cm long, stipules; lanceolate to falcate, 2.5-5 mm in length; leaflets 4-7 pairs, elliptic-oblong, 4-11 mm long, 2.5-9 mm broad, and acute. Flowers; yellow, 1.2-1.8 cm across; pedical up to 2 cm long. Sepals; ovate to lanceolate, 4 to 8 mm long, 2.5 mm broad and acute. Petals; obovate, 3-6 mm long, 2-5 mm broad and obtuse. Stamens 10, filaments 2.3-5 mm long and anthers versatile. Ovary ovoid, hirsute; style 1.3 mm long and stigmas decurrent. Fruit 3-8 mm long, mericarps densely crested, tuberculate, densely hairy, 2 long patent and 2 short downwardly spines (Plate 105a).
Melissopalynology	Pollen are monad, medium sized and pantoporate. Rounded polar view and oblate-spheroidal equatorial view shape. Colpi orientation sunken and tapering. Exine sculpturing reticulate. Polar diameter 39.3(32.7-43.4)±1.85 μm and equatorial view distance 40.55(35.2-44.7)±1.56 μm. P/E ratio 0.98. Pore length 1.35(0.75-2.25)±0.29 μm and pore width 1.40(0.25-2.25)±0.35 μm. Exine thickness 4.85(4.25-5.50)±0.23 μm. Pollen fertility 95.3% and sterility 6.54% (Plate 105b,c,d & e).

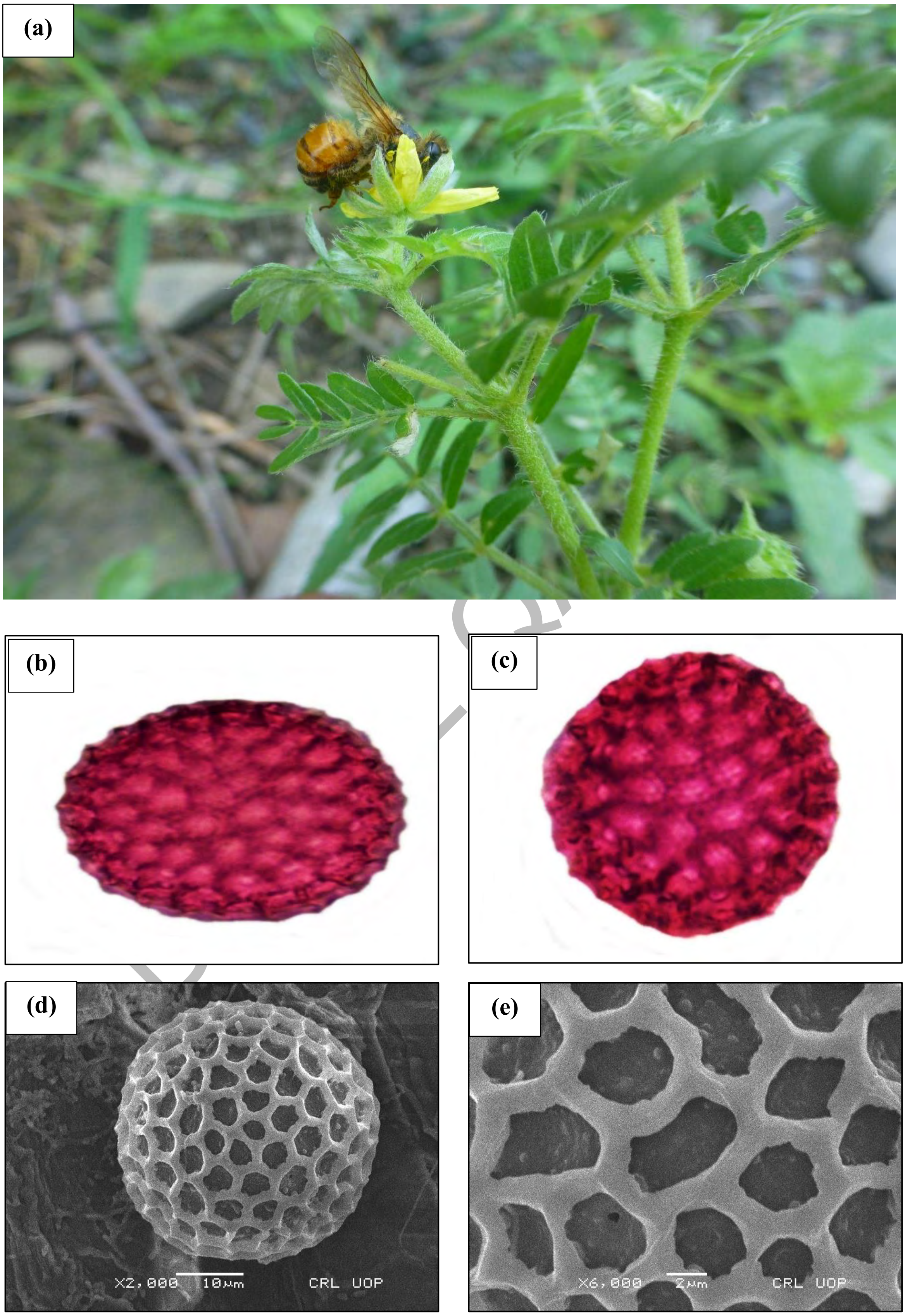

Plate 105: *Tribulus terrestris* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3.2.28 Other Honeybee flora

1. *Anagallis arvensis* L.

Synonym	*Anagallis arvensis* f. *caerulea* (L.) Lüdi
Family	Primulaceae
Common Name	Red scarlet
Habit	Annual Herb
Habitat	Loamy soil
Flowering period	February to April
Status	Wild
Distribution	Srilanka, Iran, Bangladesh, Pakistan, Nepal, Afghanistan.
Morphology	Decumbent to the erect stem. Leaves opposite-decussate, sessile, pale green, 10-15 × 7-11 mm, ovate-oblong, gland-dotted, and minutely papillose. The flower is red or blue color, solitary axillary, 1.3-2.4 cm long, glandulose, and nodding in bud condition. Calyx of the flower is campanulate, and lobes 3.4-4 mm long. Corolla of the flower is obovate, rotate, glandular stipulate, and lobes 4-6 mm long. The stamen filaments are 2-2.4 mm long, glandular, reddish-pink color, anther is 2 mm long and basifixed. Ovary 2 mm broad, globose; style 1-2.3 mm is long, persistent, and pinkish color. Stigma is capitate. Petals, stamen, carpels, ovary is clear and can be easily differentiated into each other. Flower is colorful which attract honeybees for pollination and honey make up. All insect visited toward flower due to petals and unique inflorescence (Plate 106a).
Melissopalynology	Pollen are monad, small sized and tricolporate. Circular polar view and oblate-spheroidal equatorial view shape. Exine sculpturing scabrate Verrucate. Polar diameter 22.3(20.2-24.7)0.73 µm and Equatorial view distance 23.6(22.2-26.2)0.70 µm. P/E 0.94 ratio. Exine thickness noted 2.45(2.00-3.0)±0.18 µm. Colpi length 4.95(3.75-6.25)±0.47 µm and colpi width 7.10(5.25-8.25)±0.57 µm. Mesocolpium distance 18.6(15.2-21.2)±1.04 µm. Pollen fertility 94.2% and sterility 5.7% (Plate 106b,c,d & e).

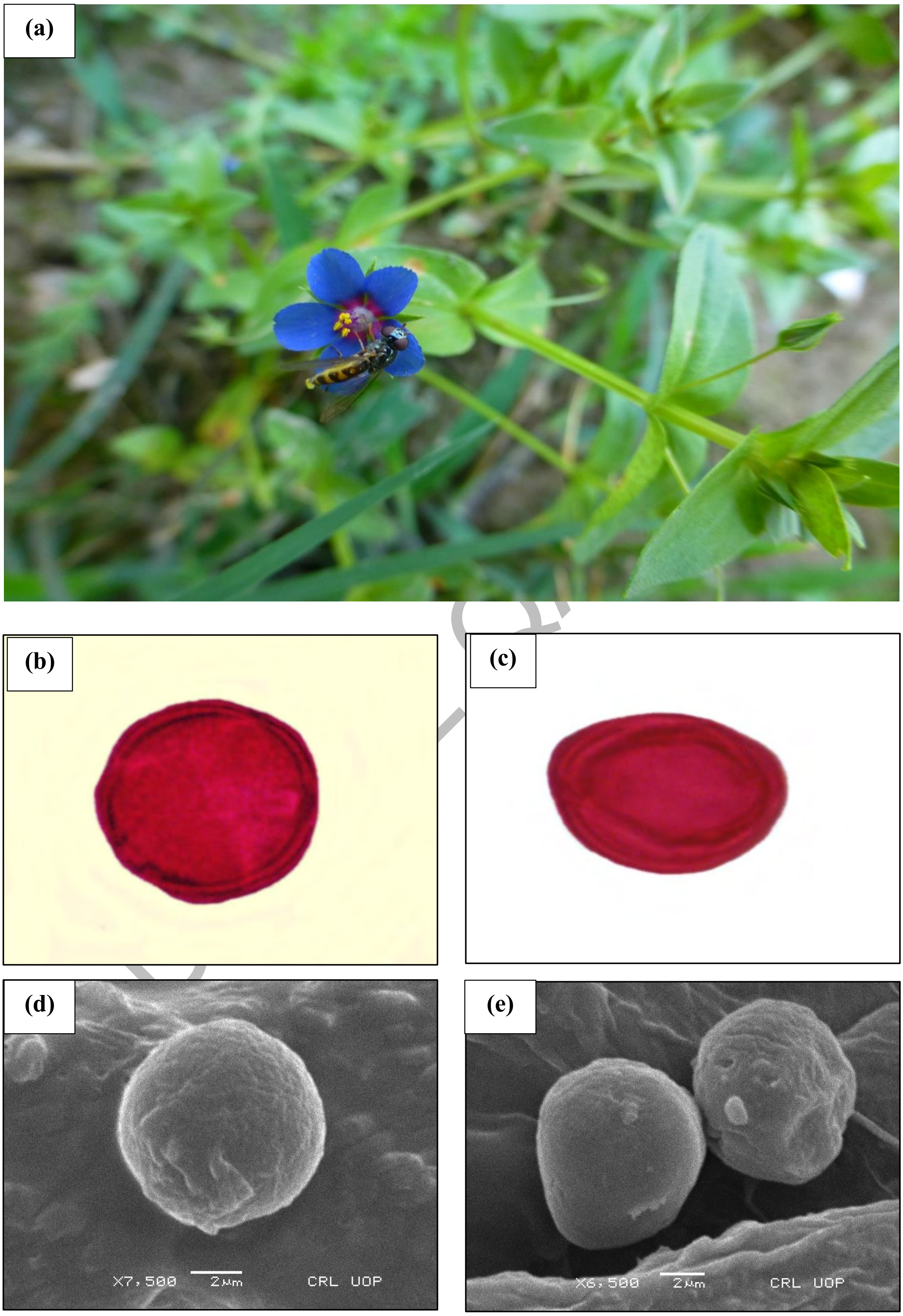

Plate 106: *Anagallis arvensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

2. *Boerhavia procumbens* Banks ex Roxb

Synonym	*Boerhavia coccinea* Mill.
Family	Nyctaginaceae
Common Name	Red spiderling
Habit	Herb
Habitat	Common in rural areas, agricultural land, and pastures
Flowering period	August to October
Status	Wild
Distribution	Argentina, Paraguay, Chile, Trinidad, Hawaii, Japan, Pakistan
Morphology	Perennial, diffuse, straggling and puberulous herb. Stem; woody below, branches often reddish. Leaves; opposite and unequal, ovate, oblong to sub-cordate, 2.5-6 × 0.9-4.2 cm, sinuate to repand, cuspidate or obtuse, puberulous, often whitish. Bract and bracteoles 1.2-2.5 mm long, ovate, acuminate, puberulous, margin membranous. Flowers 3 mm long, in diffuse axillary panicles. Perianth; campanulate, pinkish, as long as or longer than the lower half and deciduous. Stamens; 2-4, exerted. Filaments; slender, rosy, arising in the axil of a scale. Ovary less than 1 mm long, ovoid; style 1.2 mm long, stigma capitate. Anthocarp; turbinate to broadly clavate, 2.1-3 mm long, 5 ribbed, glandular and papillose (Plate 107a).
Melissopalynology	Pollen are monad, radially symmetrical, medium to large sized, apolar and pantoporate. Polar view shape spheroidal and prolate-spheroidal equatorial view shape, sexine thicker or thinner than nexine. Exine tectum sculpture tubuliferous and spinulose. Polar diameter 50.2(25.2-80.2)±7.59 µm and equatorial view distance 46.5(20.2-75.2)±7.59 µm, P/E ratio 1.07. Pore length 4.32(2.75-5.50)±0.27 µm and pore width 3.52(1.75-5.50)±0.46 µm. Exine thickness is 7.45(5.25-10.2)±0.67 µm. Pollen fertility 92.2% and sterility 7.29% (Plate 107b,c,d & e).

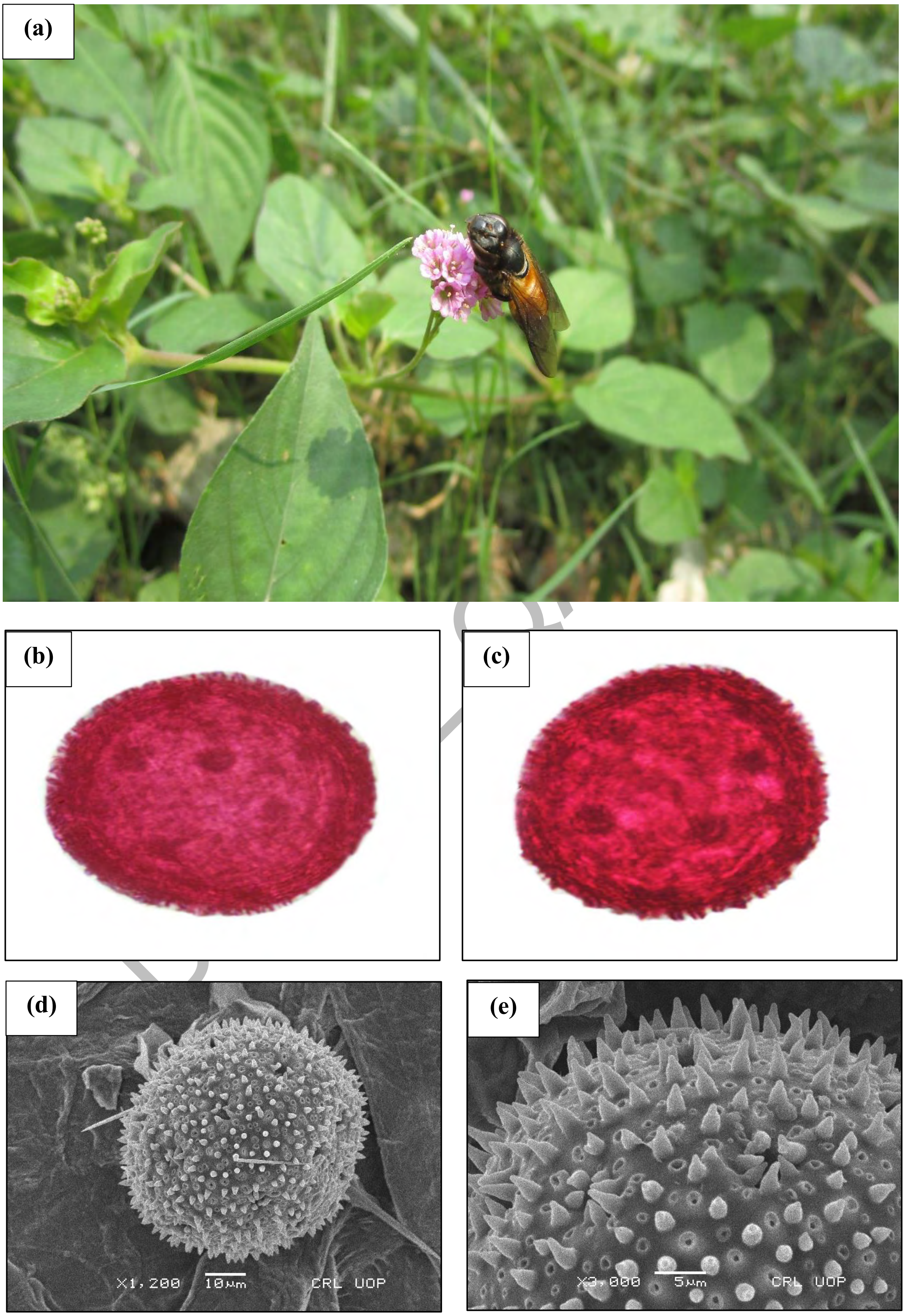

Plate 107: *Boerhavia procumbens* Banks ex Roxb (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

3. *Campsis radicans* (L.) Seem.

Synonym	*Bignonia coccinea* Steud.
Family	Bignoniaceae
Common Name	Trumpet vine
Habit	Perennial vine
Habitat	In soils with regular moisture in full sun to part shade
Flowering period	April to July
Status	Cultivated
Distribution	North America, Ohio, China, Pakistan, Taiwan, Michigan
Morphology	Climbing, sprawling woody vine. Stem: pale bark and yellowish wood with long internodes. Stems; stiff, peeling bark, smooth or flexible. Opposite leaves; pinnately compound; 4-12 leaflets. Leaflet blades; rounded oblique, lanceolate, pubescence along with midrib. Inflorescence; terminal, compound cyme, 8-24 bisexual flowers. Calyx; campanulate, orange, leathery and five lobed. Corolla; cylindrical, red orange. 2 pairs of didynamous stamens; pollen sacs and one staminode. Located; top of tube, but not extend beyond the calyx. Single, 2-carpellate pistil, Ovary: slim, superior with 2-lobed stigma. Fruit: dehiscent capsule, 12-18 cm long, with two locules (Plate 108a).
Melissopalynology	Pollen are monad, medium sized, iso polar and tricolpate. Circular polar view, oblate-spheroidal equatorial view. Exine sculpturing reticulate. Polar diameter 26.4(23.7-28.7)±0.86 µm and equatorial diameter 27.05(23.731.25)±1.32 µm. P/E ratio 0.97. Colpi length 4.80(3.75-5.75)±0.43 µm, colpi width 7.55(6.25-8.75)±0.56 µm. Mesocolpium distance 19.6(15.7-23.2)±1.26 µm. Exine thickness 0.80(0.50-1.00)±0.93 µm. Pollen fertility 86.7% and sterility 13.3% (Plate 108b,c,d & e).

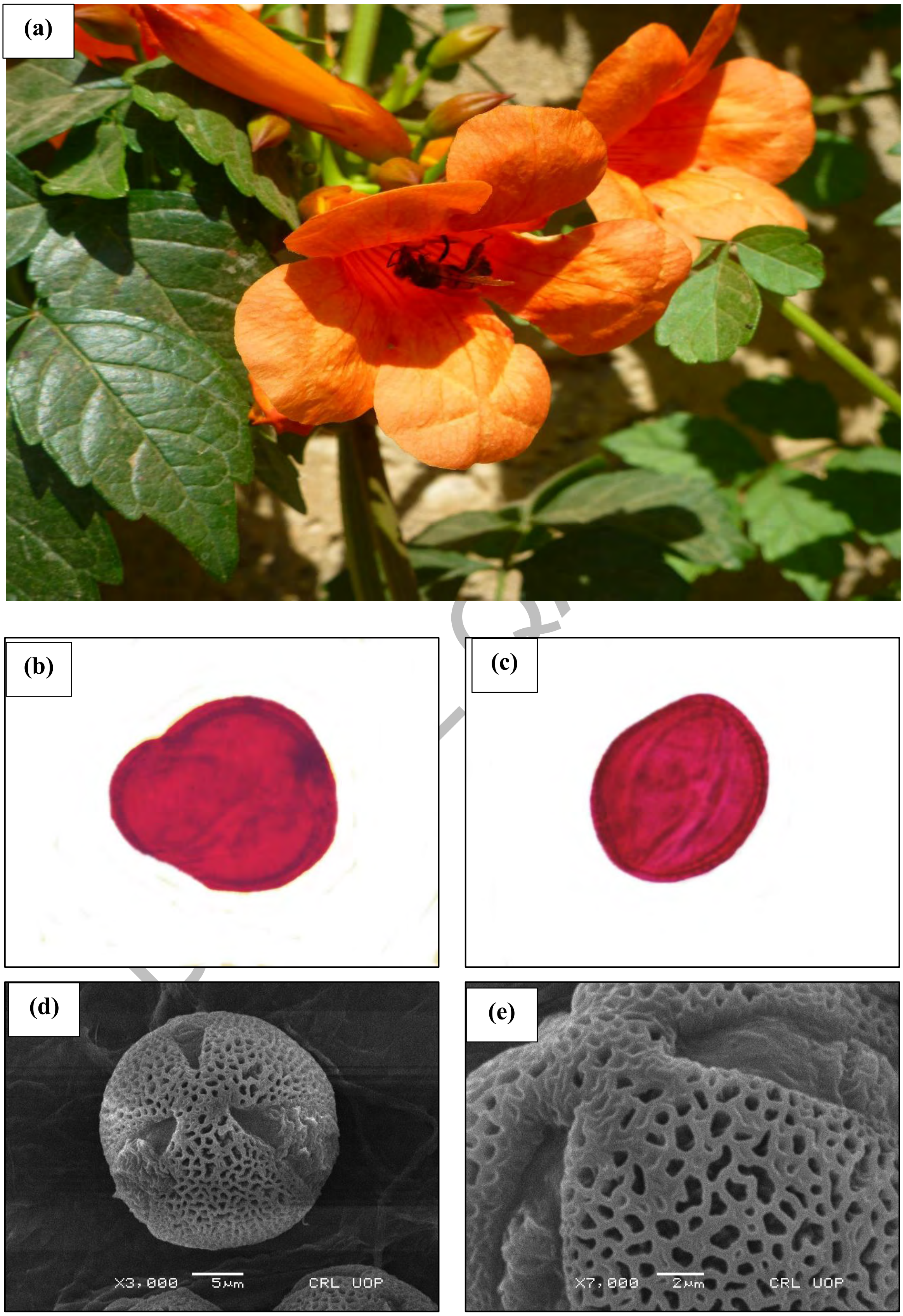

Plate 108: *Campsis radicans* (L.) Seem. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

4. *Cannabis sativa* L.

Synonym	*Cannabis chinensis* Delile
Family	Cannabaceae
Common Name	Hemp
Habit	Annual Herb
Habitat	Floodplain woodlands, low-lying fields, weedy meadows along rivers
Flowering period	April to September
Status	Wild
Distribution	China, Iran, Belgium, Sweden, Florida, Pakistan
Morphology	Annual, 50-65 cm tall, slender; stem; branched, slightly angular, appressed hairs. Leaves; palmately 3-10, foliolate, petiole 1.5-8 cm, pubescent, hairs white, lobes sessile, lanceolate, palmti nerved, serrate, acuminate, 3-10 cm long, 4-17 mm broad; scabrid stiff hairs; lower surface densely pubescent, sessile glands, stipules; 3.5-7 mm long. Male flowers; 3-7 mm across, greenish, pedicel; 2-3.5 mm long and filiform. Tepals; elliptic, pubescent, 2-4.5 mm long, 1.3-2.5 mm broad and acute. Stamen; 3-5 mm long, bracts foliaceous, 3-14 mm long, covered glandular hairs, linear and 1.7-2.8 mm long. Ovary; sessile, sub-globose, 0.8 mm long, styles; 2.5-4 mm long, brown and caducous. Achene; 2.5-4 mm in diameter, shining, brown and minutely pilose (Plate 109a).
Melissopalynology	Pollen are monad, iso-polar, small sized, and tricolporate. Circular polar view, prolate equatorial view. Exine sculpturing granulate. Polar diameter 22.3(20.2-24.0)±0.60 μm and equatorial diameter 14.0(20.2-22.7)±0.44 μm. P/E ratio 1.59. Colpi length 0.90(0.25-1.75)0.26 μm, colpi width 2.40(1.75-3.25)±0.26 μm, and mesocolpium distance 18.6(13.7-23.7)±1.73 μm. Exine thickness 2.4(1.75-3.25)±0.26 μm. Pollen fertility 92.1% and sterility 7.82% (Plate 109b,c,d & e).

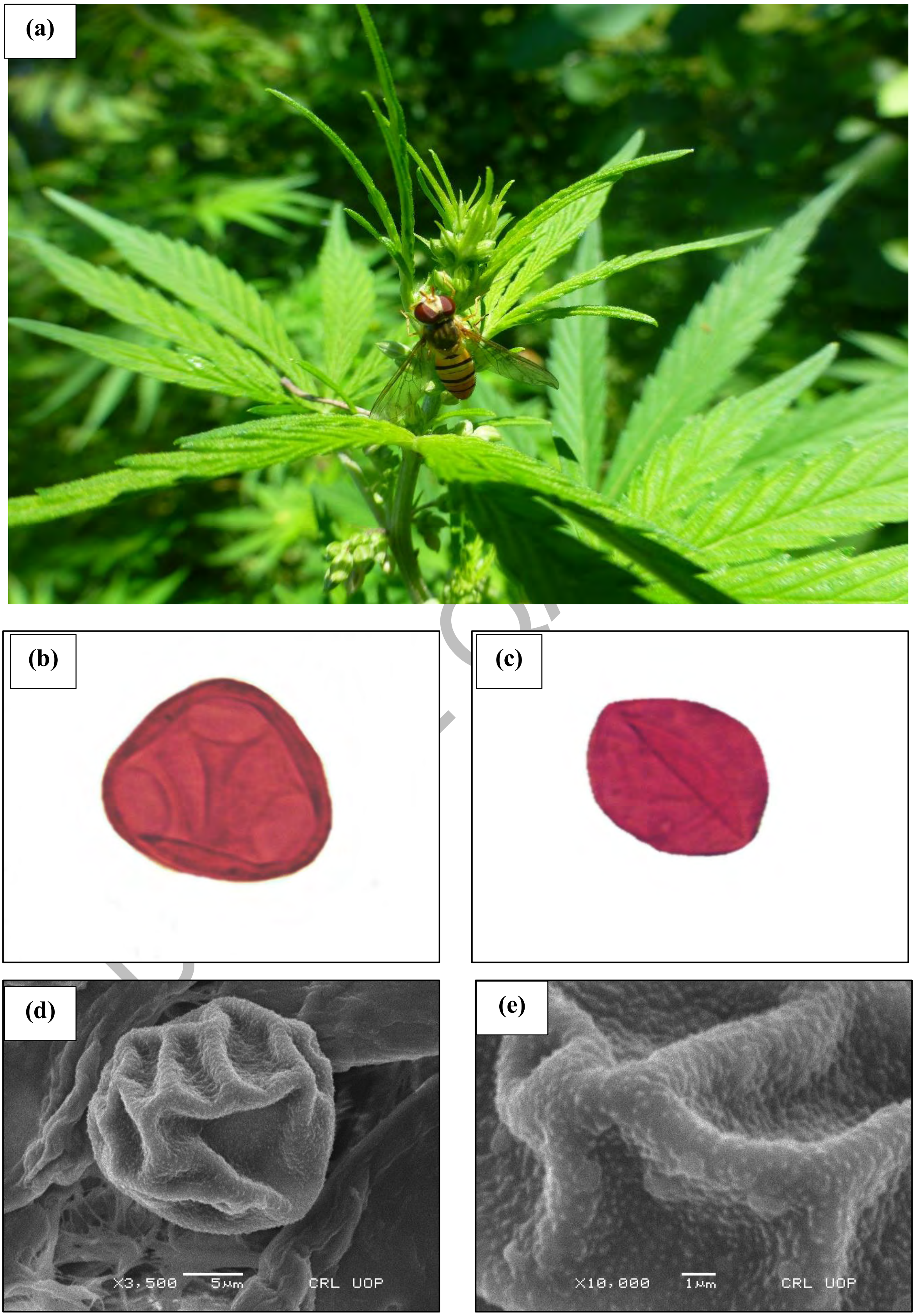

Plate 109: *Cannabis sativa* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

5. *Centaurium pulchellum* (Sw.) Druce

Synonym	*Centaurium pulchellum* var. *caspica* (Griseb.)
Family	Gentianaceae
Common Name	Pink centaury
Habit	Annual Herb
Habitat	Found in cultivated and wild habitats, banks of river and canals
Flowering period	March to May
Status	Ornamental
Distribution	Europe, England, Pakistan, North America, China, India.
Morphology	Annual, 6-42 cm long, branched, spreading, erect and herbaceous. Leaves: basal and cauline type. Basal leaves: 0.8-2.4 × 0.45-1.3 cm, lanceolate, acuminate and entire. Cauline leaves: 0.6-2.8 × 0.3-1.1 cm, elliptic, acute-acuminate and entire. Inflorescence: dichasial cyme and numerous flowered. Flowers: 0.5-12 cm long, pedicellate; pedicel 0.3-045 cm long. Calyx: tubular, almost equal to length of corolla tube; 2.2-4.5 mm long, lobes 4.6-7.5 × 0.6-2.4 mm, linear and acuminate. Corolla: tubular, pink-purple; 0.7-15 cm long; corolla tube longer, 0.5-1.4 cm long; lobes 0.3-0.9 × 0.4-0.6 cm, obtuse and entire. Stamens: 5, filaments inserted middle of corolla tube. Anthers: basifixed. Ovary: 4.2-8.5 × 1.3-2.7 mm, oblong lanceolate. Stigma: bi-lobed. Capsules: oblong and sessile. Seeds: numerous, minute and globose (Plate 110a).
Melissopalynology	Pollen grains are monad, medium sized and tricolpate. Semicircular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing striated type. Polar diameter 31.7(37.5-24.5)±5.21 µm and equatorial view distance 29.1(32.7-22.0)±3.71 µm. P/E ratio 1.08. Colpi length 5.2(8-2=5.2)±2.51 µm and colpi width 17.82(0.7-4.50)±2.51 µm. Mesocolpium 17.7(22.5-12.7)±3.40 µm. Exine thickness 3.72(5.75-1.75)±1.44 µm. Pollen fertility 83.3% and sterility 16.6% (Plate 110b,c,d & e).

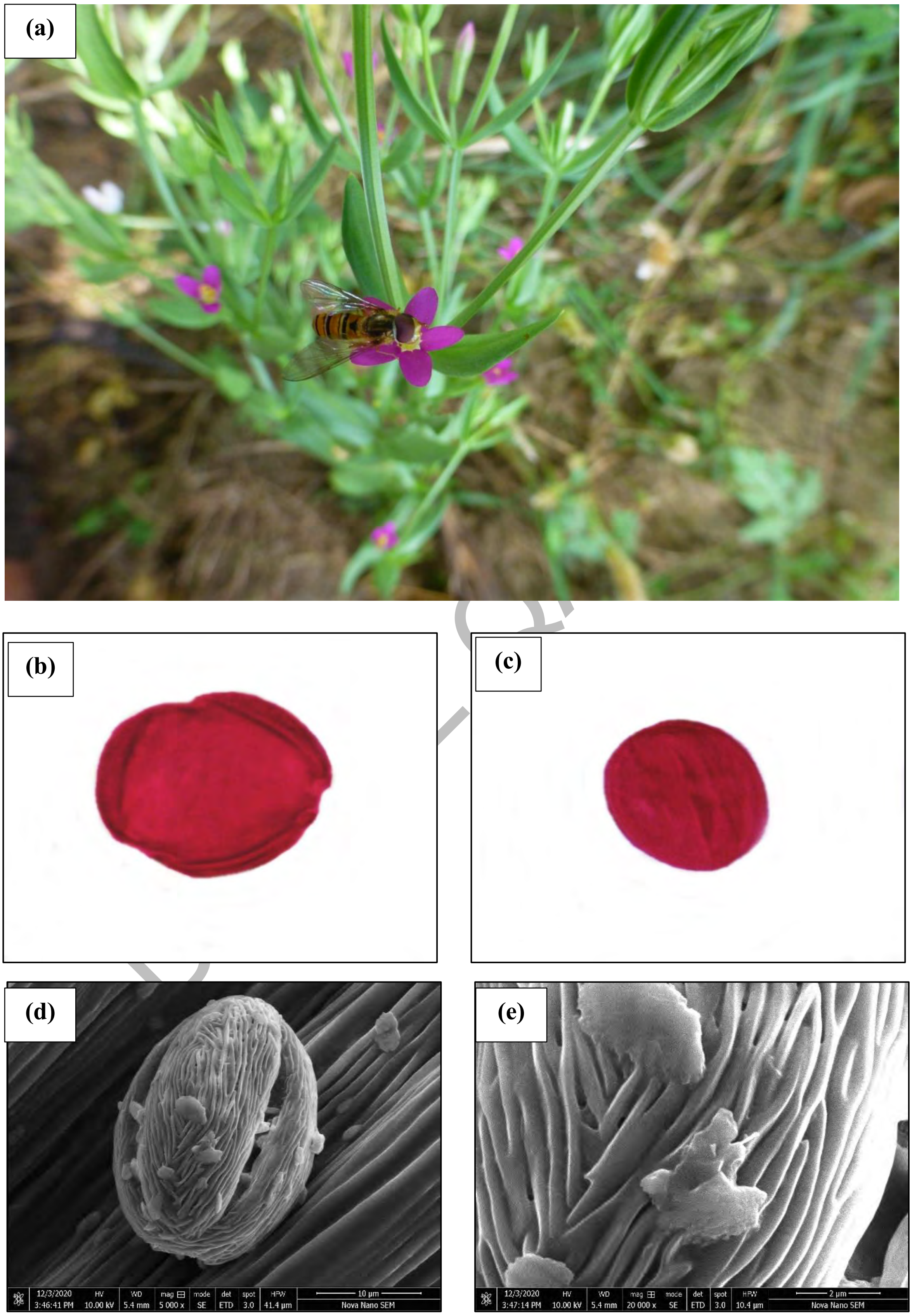

Plate 110: *Centaurium pulchellum* (Sw.) Druce (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

6. *Cleome viscosa* L.

Synonym	*Arivela viscosa* (L.) Raf.
Family	Cleomaceae
Common Name	Tick weed
Habit	Annual Herb
Habitat	Open woodland scrub and sandy soils, calcareous and rocky soils
Flowering period	April to August
Status	Wild
Distribution	Panama, Egypt, China, Cuba, Florida, Pakistan
Morphology	Tall herb, up to 1.5 m high, hairy glandular. Leaves; 2.5-5 cm, foliolate, petiolate; leaflets; obovate, oblong, 3-4 cm long, 1.3-3 cm broad, petiole; 4-5 cm long. Racemes; elongated, up to 25-30 cm long, corymbose flowers and bracteate. Flowers; 8-14 mm across, whitish, pedicels, 5-22 mm long; foliaceous bracts. Sepals; lanceolate, 3-4.5 mm long, 1.2-2.5 mm wide, pubescent. Petals; 5-16 mm long, 2-5 mm broad and oblong obovate. Stamens; 8-14 and gynophore absent. Fruit; 20-55 mm long, 3.5-6 mm broad, linear oblong, tapering, glandular pubescent, slender; style; 1.5-4 mm long; seeds; many, 1-1.2 mm in diameter, glabrous transverse ridges and dark brown (Plate 111a).
Melissopalynology	Pollen are monad, medium sized and tricolporate. Triangular polar view and prolate spheroidal equatorial view. Colpus membrane verrucate. Exine sculpturing reticulate. Polar diameter 27.2(22.2-32.7)±2.08 µm and equatorial view distance 25.9(20.7-31.2)±2.10 µm. P/E ratio 1.05. Colpi length 4.40(3.50-5.25)±0.33 µm, colpi width 7.60)7.00-8.00)±0.20 µm. Exine thickness 3.85(2.25-6.25)±.65 µm. Mesocolpium distance 28.2(25.5-30.5)±0.86 µm. Pollen fertility 92.6% and sterility 7.36% (Plate 111b,c,d & e).

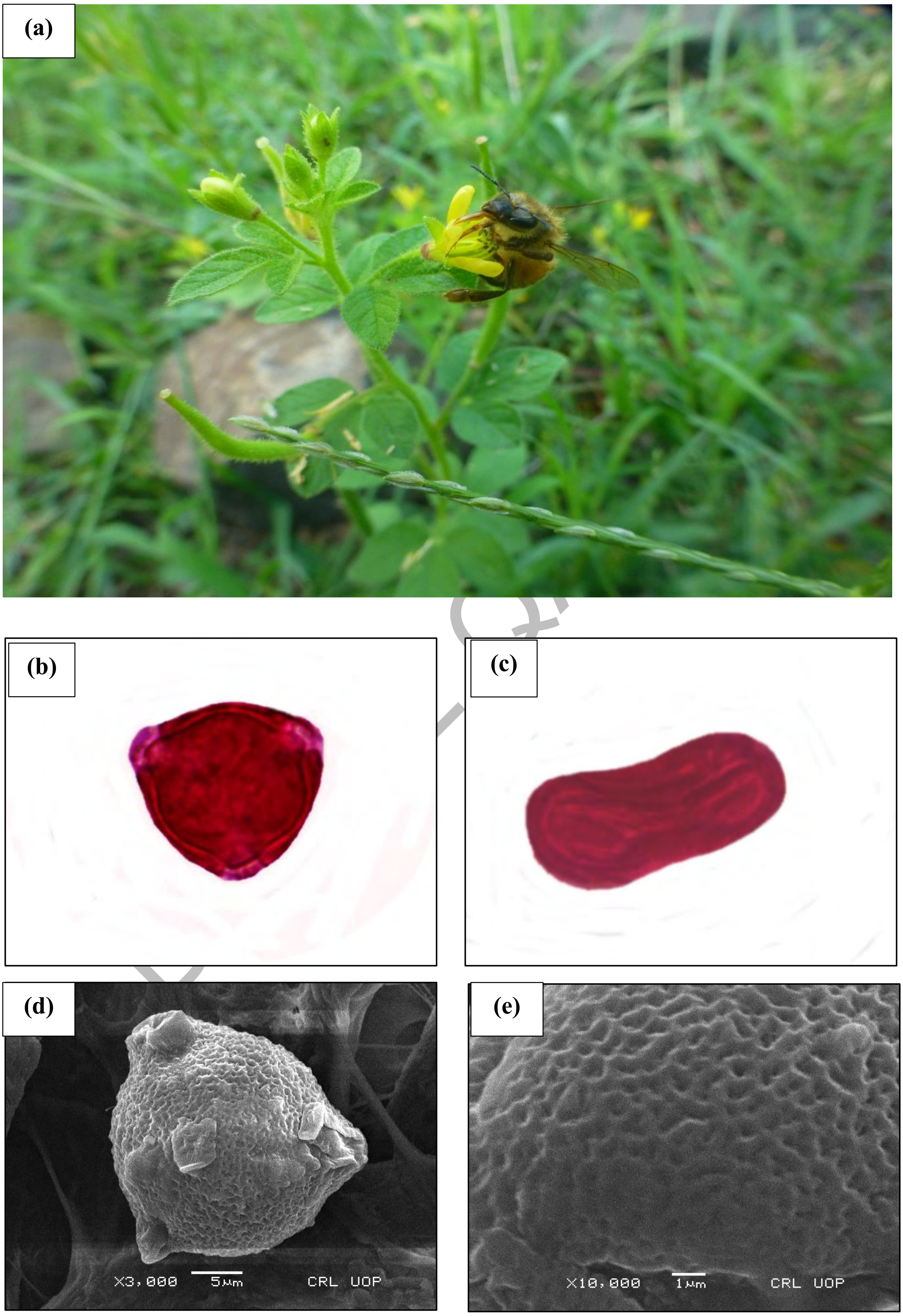

Plate 111: *Cleome viscosa* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

7. *Commelina benghalensis* L.

Synonym	*Commelina canescens* Vahl
Family	Commelinaceae
Common Name	Tropical spiderwort
Habit	Herb
Habitat	Wide range of habitats varying from water saturated to dry soils
Flowering period	July to September
Status	Wild
Distribution	Ethiopia, Somalia, Georgia, Pakistan, Brazil, Spain
Morphology	Erect, prostrate perennial herb, 22-55 cm long, dichotomously branched from base, glabrous, pubescent, rooting below, often developing subterranean or concealed, whitish flowers on underground scapes developed from lower nodes. Leaves; ovate to ovate oblong, sub-sessile to shortly petioled, sheathing base, 2-7.3 cm long, 1-3.2 cm broad, entire, acute to sub-rounded apically; petiole 3.5-12.2 mm long; sheaths 0.4-1.8 cm long, ciliate on margins. Upper cymes; 2-4 flowered, lower 1 to 2 flowered, and suppressed. Aerial flowers blue, short cymes subtended by spathes, maturing earlier than sub-terranean flowers. Seeds; rugose or closely pitted, sometimes wanting in aerial flowers (Plate 112a).
Melissopalynology	Pollen are monad, small sized, bilaterally symmetrical, Psilate and monosulcate. Elliptical polar view and oblate-spheroidal equatorial view shape. Exine ornamentation spinulose baculoid. Polar diameter 18.5(16.2-20.5)0.80 μm and equatorial view distance 18.8(17.2-20.2)0.64 μm. P/E ratio 0.98. Colpi length 2.35(1.75-3.00)0.23 μm, colpi width 3.55(2.75-4.75)0.40 μm. Exine thickness 3.30(1.75- 4.75)0.59 μm. Mesocolpium distance 16.1(13.5-18.7)0.85 μm. Pollen fertility 91.4% and sterility 8.59% (Plate 112b,c,d & e).

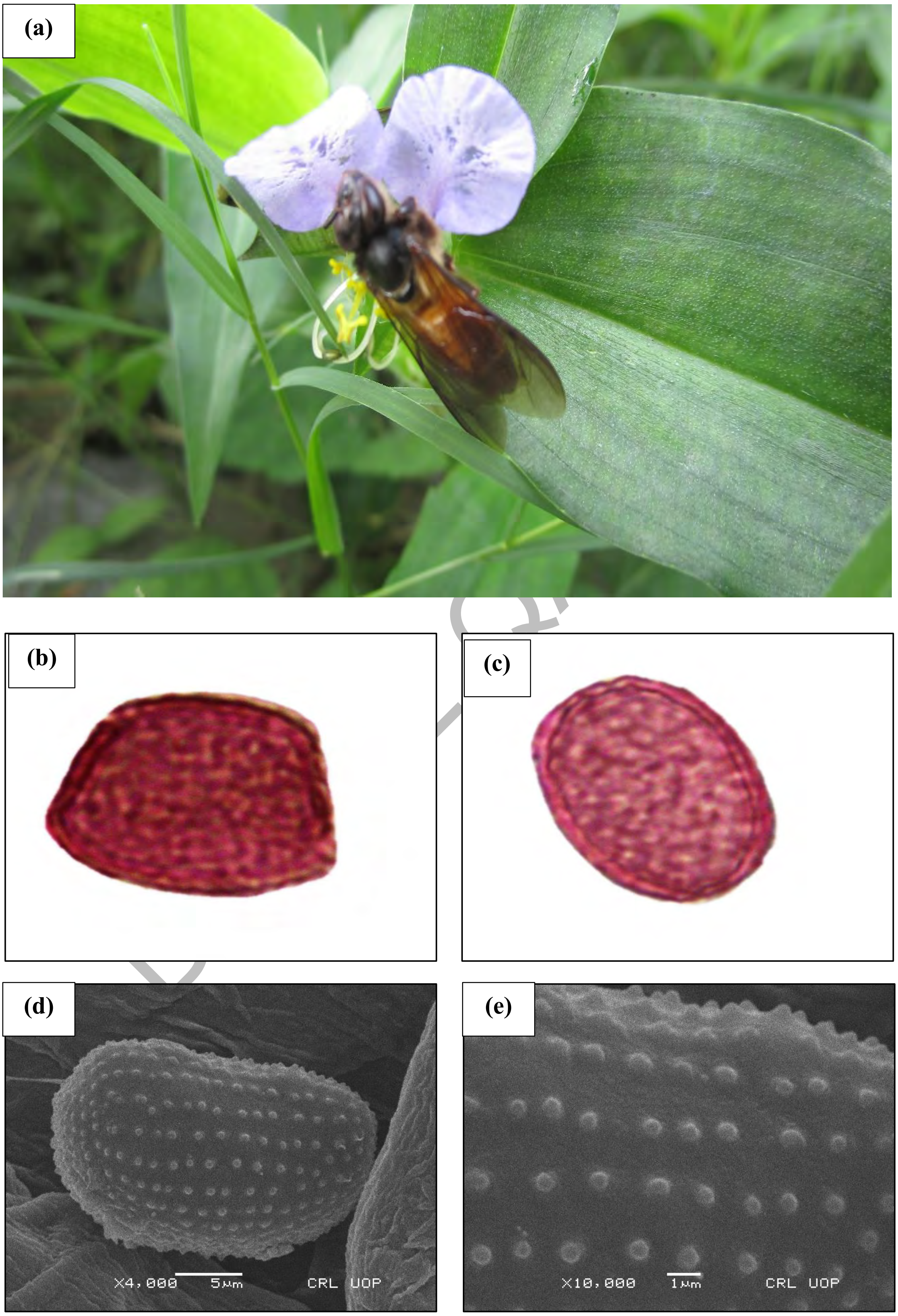

Plate 112: *Commelina benghalensis* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

8. *Hamelia patens* Jacq.

Synonym	*Hamelia coccinea* Sw.
Family	Rubiaceae
Common Name	Firebush
Habit	Shrub
Habitat	In open areas and thickets in the moist lower foothills
Flowering period	July to December
Status	Wild
Distribution	Brazil South, Panama, Pakistan, Cuba, Costa Rica, Colombia
Morphology	Evergreen shrub or small tree, up to 2-3 m, young branches angular, pubescent-puberulous or villous. Stipules; 3 to 4 mm long. Leaves in whorls of 4, 2-10 × 3-5 cm, elliptic, oblong or oblong-ovate, glabrous-tomentose beneath, glabrate-glabrous above, rarely sparsely hairy, acute or acuminate, entire. Inflorescence terminal, scorpoid cymes. Flowers 2.5-4 cm long, scarlet, pedicel 0.8-1.5 mm long. Hypanthium bell shaped, 4.5 mm long, pubescent, lobes minute, deltoid. Corolla tubular, 1.2 cm long, 4-ridged, shortly 5 lobed. Stamens 5, filaments adnate near the middle of the corolla-tube, 2-3 mm long. Ovary surrounded by thick conical disc. Style 1.5 mm long. Fruit ellipsoid-oblong or globose, berry, 7 mm long, red in color. Seeds brown or yellowish brown (Plate 113a).
Melissopalynology	Pollen are monad, medium sized, iso polar, radially symmetrical. And tricolporate. Semi angular polar view and equatorial view shape prolate-spheroidal. Exine sculpturing scabrate granulate. Polar diameter 31.7(21.7-43.2)±2.89 µm and Equatorial view distance 29.1(19.7-39.7)±2.51 µm. P/E ratio 1.08. Colpi length 3.60(1.75-5.25)±0.35 µm, colpi width 6.32(4.75-8.00)±0.36 µm and mesocolpium distance 22.3(16.0-30.7)±1.67 µm. Exine thickness 4.52(2.75-6.25)±0.36 µm. Pollen fertility 96.07% and sterility 3.93% (Plate 113b,c,d & e).

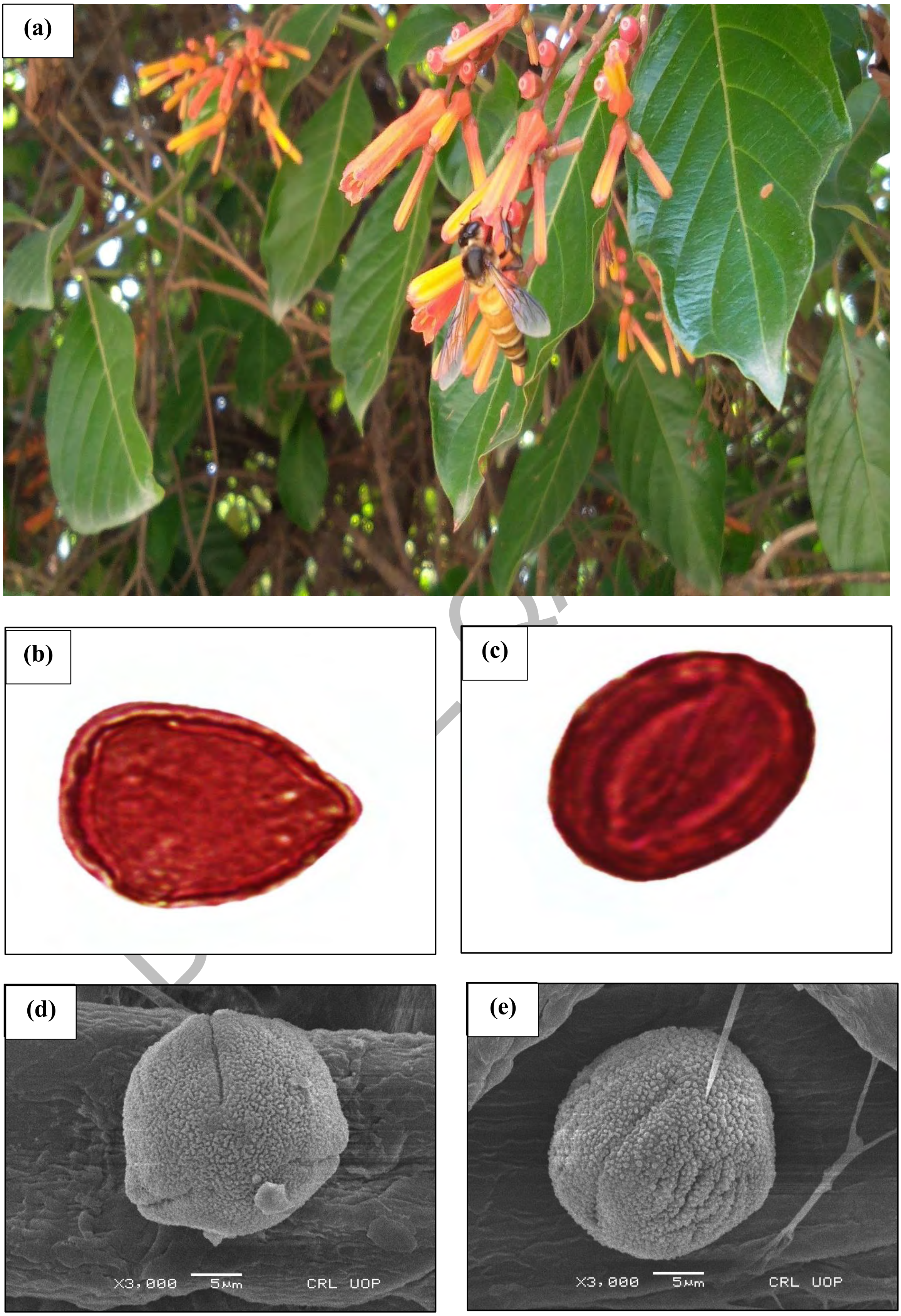

Plate 113: *Hamelia patens* Jacq. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

9. *Ligustrum lucidum* W.T.Aiton

Synonym	*Ligustrum lucidum* var. *esquirolii* H.Lév.
Family	Oleaceae
Common Name	White wax tree
Habit	Annual Tree
Habitat	Found in gardens, roadsides, nurseries
Flowering period	April to June
Status	Cultivated
Distribution	Argentina, Australia, New Zealand, USA, Pakistan, China, India
Morphology	Small tree 2.5-11 cm tall. Leaves are hairless and vary from ovate like egg shape, 6.6-17 cm long while 3.1-8.8 cm wide and have leathery or papery with the base rounded and the acute to acuminate, the leaves have between 4 to 12 primary veins on each side of the mid vein, slightly obscure or raised. Petiole: 0.8-2.5 cm, leaf blade; ovate elliptic, lanceolate, 5.5-15 × 3.2-8.5 cm, leathery, base rounded, attenuate, apex acute, acuminate, obtuse, primary veins, 3-12 each side midrib. Flowers: ceramic white, strongly scented, sessile or nearly so with four white or cream petals have calyx 2-2.5 mm and corolla 4-5.5 mm. Fruit; obovoid, sub-globose, 5-8 mm in diameter and purplish blue (Plate 114a).
Melissopalynology	Pollen grains are monad, medium sized, iso-bisymmetrical, heteropolar and non-operculate. Slightly rounded polar view and oblate-spheroidal equatorial view shape. Exine ornamentation micro-reticulate. Polar diameter 39.72(23.70-46.05)±2.4 µm and equatorial view distance 41.9(31.80-48.15)±2.13 µm. P/E ratio 0.94. Colpi length 5.71(9.25-3.75)±1.79 µm, colpi width 7(10.0-4.50)±1.41 µm and mesocolpium distance 18.9(22.5-15.0)±2.16 µm. Exine thickness 0.99(0.60-1.50)±0.08 µm. Pollen fertility 82.5% and sterility 17.4% (Plate 114b,c,d & e).

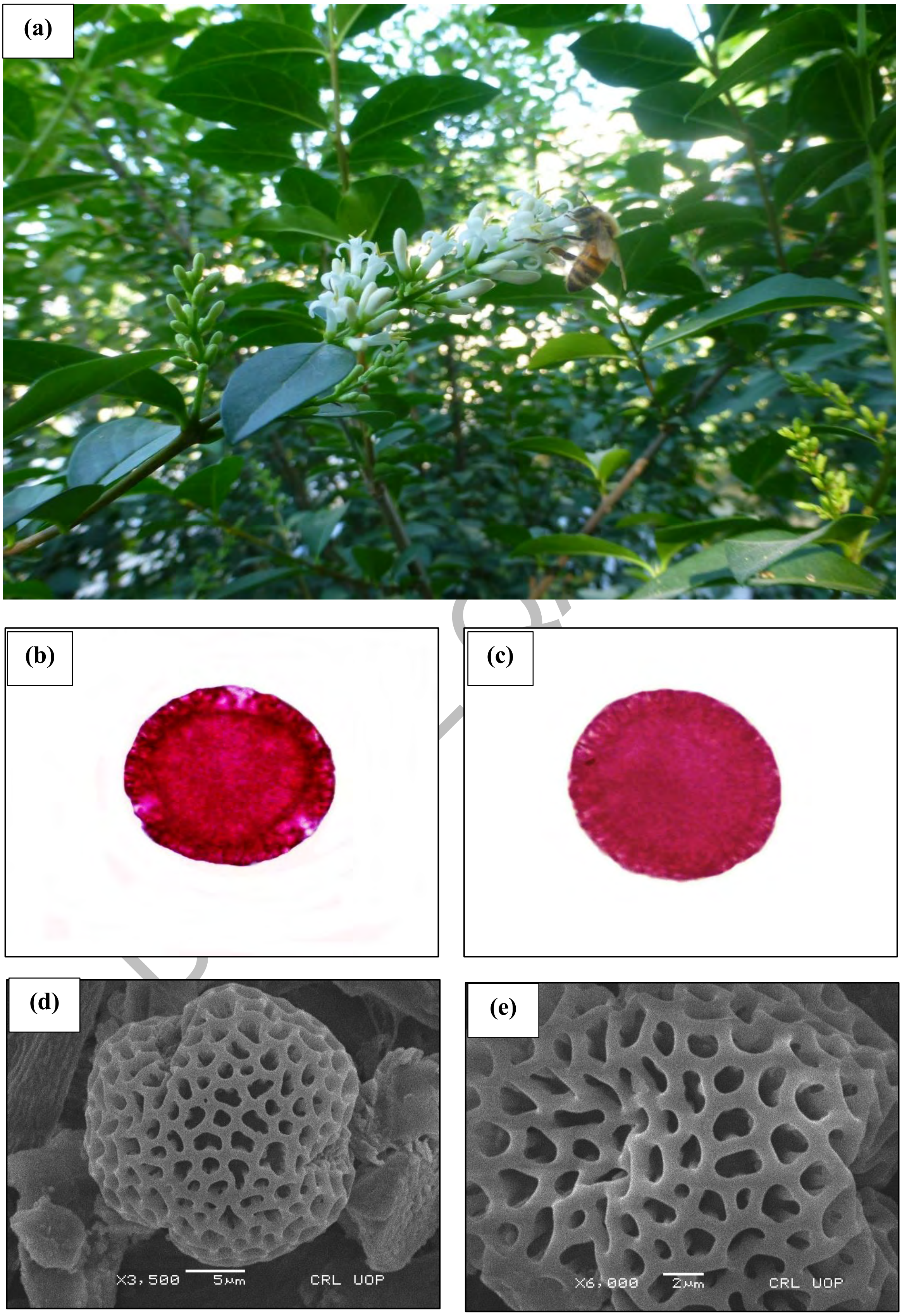

Plate 114: *Ligustrum lucidum* W.T.Aiton (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

10. *Mangifera indica* L.

Synonym	*Mangifera austroyunnanensis* Hu
Family	Anacardiaceae
Common Name	Mango
Habit	Tree
Habitat	Along riversides, forests, natural grasslands and pastures
Flowering period	March to May
Status	Wild
Distribution	Ecuador, Tonga, Pakistan, California, Singapore
Morphology	Glabrous tree; up to 13-15 m tall, branches brown and glabrous. Petiole: 1.5-4.5 cm, grooved, leaf blade: oblong-lanceolate, 10-23 × 2.6-6 cm, leathery, glabrous on both surfaces, base cuneate, margin entire, undulate, apex acute, lateral veins; 15-22 pairs, midrib prominent and reticulate venation. Leaves; 10-22 × 3-10 cm, oblong, lanceolate, acuminate, coriaceous and dark green. Petiole; 3-6 cm, grooved apically, inflated, leaf blade; oblong lanceolate, 11-35 × 4.5-7 cm. Flowering; panicles erect, conspicuous and pubescent. Calyx; lobes ovate, pubescent outside. Petals; imbricate, oblong, inner surface 3 nerved. Drupe, ovoid outline, compressed, 3.2-25 cm long. Mesocarp; fleshy. Endocarp; hard and fibrous. Ovary; oblique, ovate, 1.8 mm in diameter. Style; 2.4 mm and eccentric. Drupe; oblong, sub-reniform and greenish (Plate 115a).
Melissopalynology	Pollen are monad, small sized, iso polar, and tricolporate. Semicircular polar view and prolate-spheroidal equatorial view shape. Exine sculpturing verrucate scabrate. Polar diameter 21.6(20.2-22.7)±0.43 µm and equatorial view distance 20.7(19.7-21.7)±0.35 µm. P/E ratio 1.04. Colpi length 2.65(2.00-3.25)±0.23 µm, colpi width 2.80(2.25-3.25)±0.16 µm and mesocolpium 18.1(16.7-19.7)±0.53 µm. Exine thickness 3.25(2.75-3.75)±0.17 µm. Pollen fertility 94.6% and sterility 5.31% (Plate 115b,c,d & e).

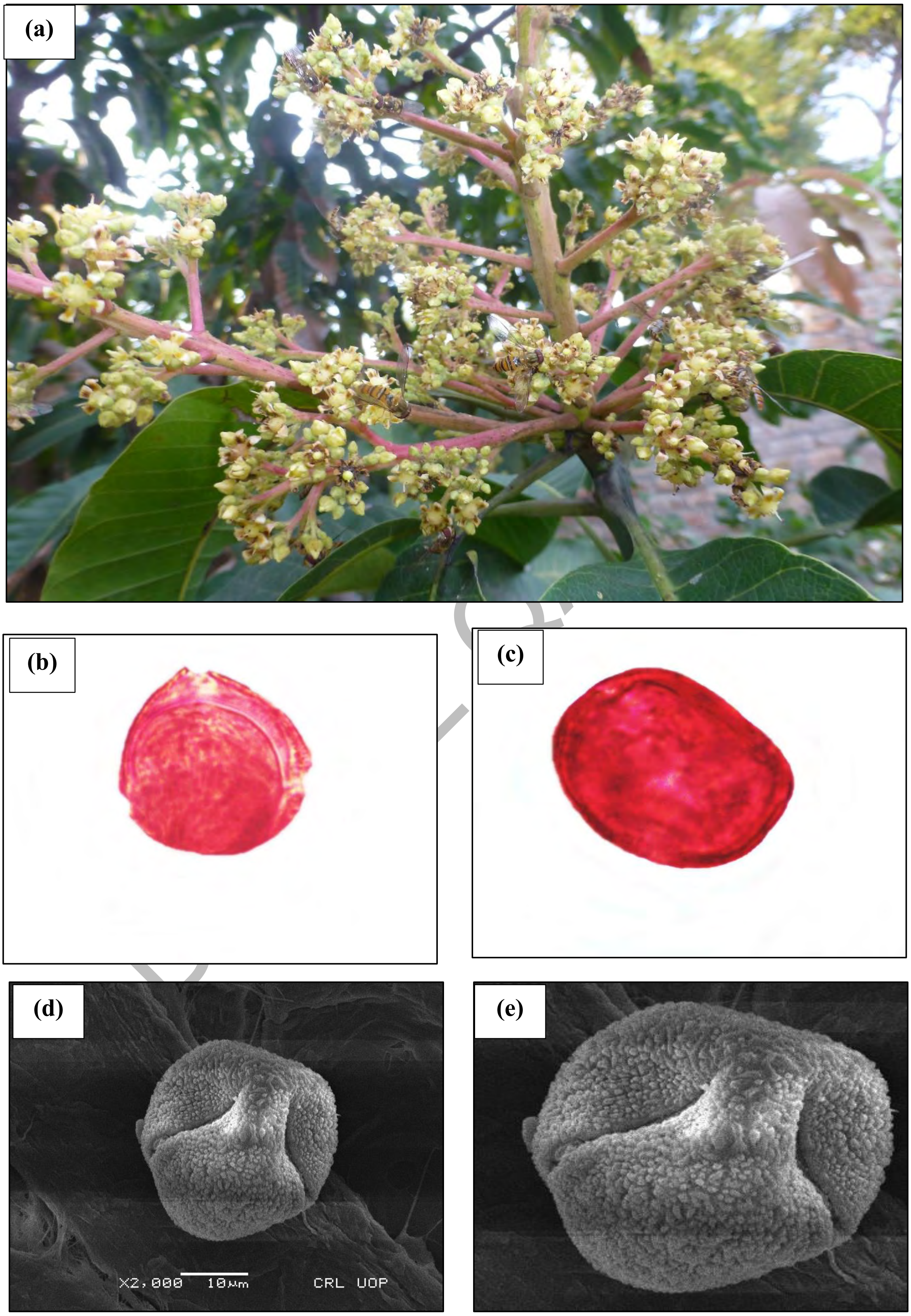

Plate 115: *Mangifera indica* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

11. *Martynia annua* L.

Synonym	*Carpoceras angulata* A. Rich.
Family	Martyniaceae
Common Name	Tiger claw
Habit	Herb
Habitat	Along disturbed sites, moist thickets, riverbanks and pastures
Flowering period	August to November
Status	Wild
Distribution	China, Vietnam, Mexico, Pakistan, Australia, Madagascar
Morphology	Herbs, erect, 23-90 cm tall. Stems; terete, woody at base, 1.5-3.2 cm in diameter. Petiole; 4-15 cm; leaf blade, broadly ovate to triangular ovate, 7-20 × 8-25 cm, base cordate, margin sinuolate dentate and apex acute. Inflorescence; 12-23-flowered; bracts pale red, broadly ovate, 1-2.6 × 0.9-1.2 cm, membranous; bractlets ovate to oblong; 0.4-1.8 cm × 2.5-13 mm. Calyx lobes pale yellow to green. Corolla; dark red, white to pale red adaxially, with pale purple red spots, 2.5 to 4 cm; lobes with yellow and purple spots adaxially, purple striate abaxial. Filaments; white, glabrous, 0.8-1.4 cm. Capsules; ovoid, 3-4.2 × 2.5-3 cm, 0.3-1.2 cm thick, densely glandular pubescent, spiny along suture (Plat 116a).
Melissopalynology	Pollen are monad, medium to large sized and monocolpate. Semicircular polar view and sub-prolate equatorial view shape. Exine sculpturing clavate, tectum netted. Polar diameter 56.3(51.2-68.7)±3.21 µm, and equatorial view distance 46.2(42.2-49.7)±1.49 µm. P/E ratio 1.21. Colpi length 3.40(2.75-4.75)±0.35 µm, colpi width 5.00(4.25-5.50)±0.22 µm and mesocolpium 28.4(32.4-32.7)±1.77 µm. Exine thickness 6.20(4.25-7.75)±0.70 µm. Pollen fertility 90.7% and sterility 9.27% (Plate 116b,c,d & e).

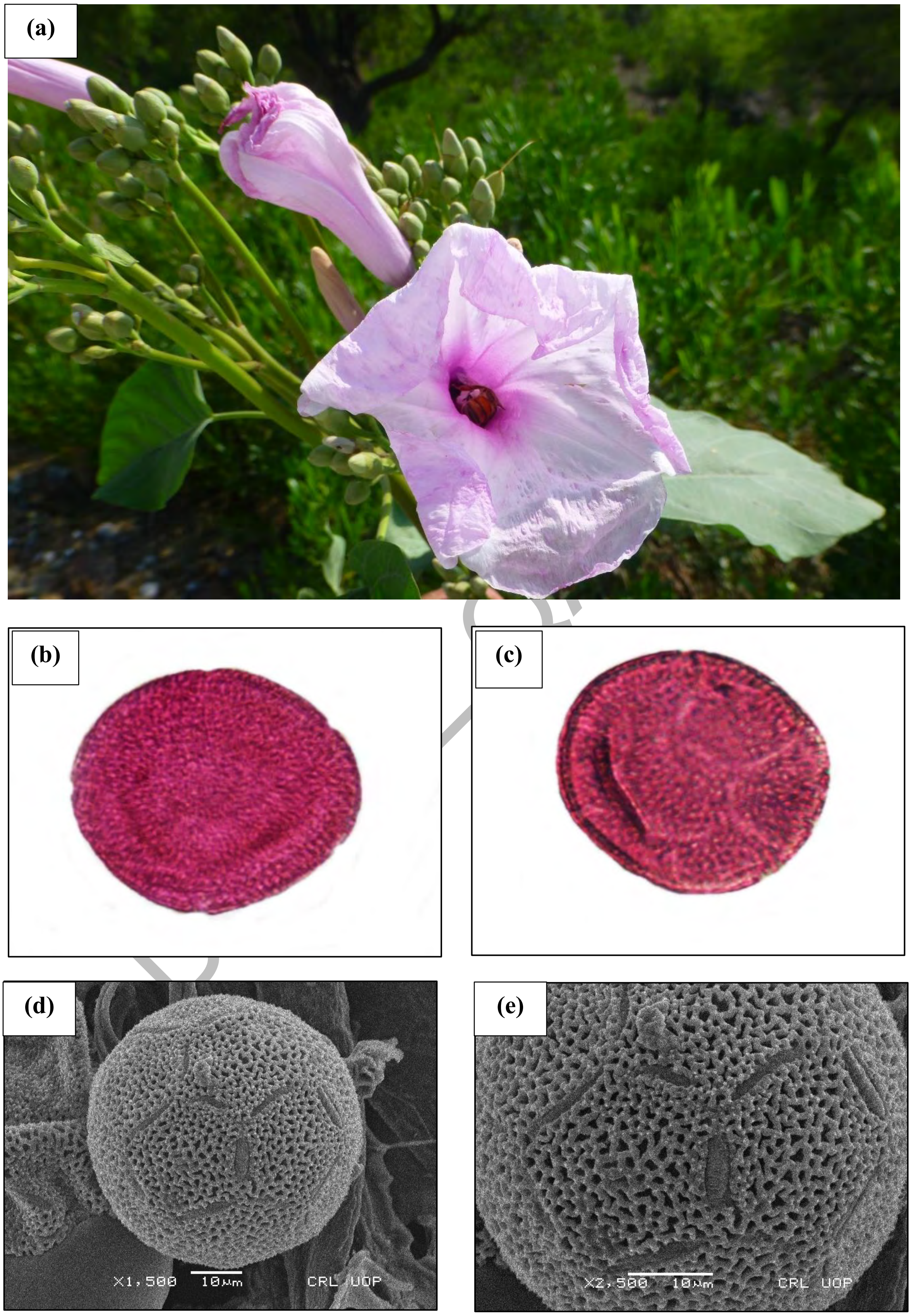

Plate 116: *Martynia annua* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

12. *Melia azadirachta* L.

Synonym	*Antelaea canescens* Cels ex Heynh.
Family	Meliaceae
Common Name	Indian lilac
Habit	Deciduous Tree
Habitat	Found along roadsides, fencerows and disturbed areas
Flowering period	March to June
Status	Wild
Distribution	Iran, Iraq, Somalia, Kashmir, China, Middle East, Pakistan
Morphology	Deciduous tree up to 12 m tall; young shoots tomentose. Bark: brownish gray and longitudinally exfoliate. Branches spreading; branchlets with leaf scars Leaves: pinnate, up to 61 cm tall: leaflets opposite, elliptic, 3-5 cm long, 5.5-20 mm broad, serrate, acuminate. Flowers; sweet-scented, in axillary panicles; pedicel 2-3 mm long, puberulous. Calyx 5 to 6, lobed; 2.2 mm long, pubescent. Petals 7.1-9.4 mm long, spathulate to lanceolate, ciliate. Staminal tube 6.1-7.2 mm long, cylindrical, expanded at the base and apex. Anthers sessile. Ovary usually 5 locular; style 4.1-5.2 mm long; stigma capitate. Fruit: drupe 1.6-2.2 cm long, globose, 3-6-seeded, ellipsoidal, and yellow when ripe (Plate 117a).
Melissopalynology	Pollen are monad, medium sized, and tricolpate. Circular polar view and oblate-spheroidal equatorial view shape. Exine sculpturing perforate-psilate. Polar diameter 37.9(92.5-17.5)±6.19 µm, and equatorial view distance 40.9(112.5-17.5)±9.8 µm. P/E ratio 0.92. Colpi length 7.06(20.2-2.25)±5.58 µm, colpi width 7.7(15.2-2.75)±3.63 µm and mesocolpium 30(47-12.5)±25 µm. Exine thickness 3.37(5.25-2.25)±0.91 µm. Pollen fertility 88.3% and sterility 11.6% (Plate 117b,c,d & e).

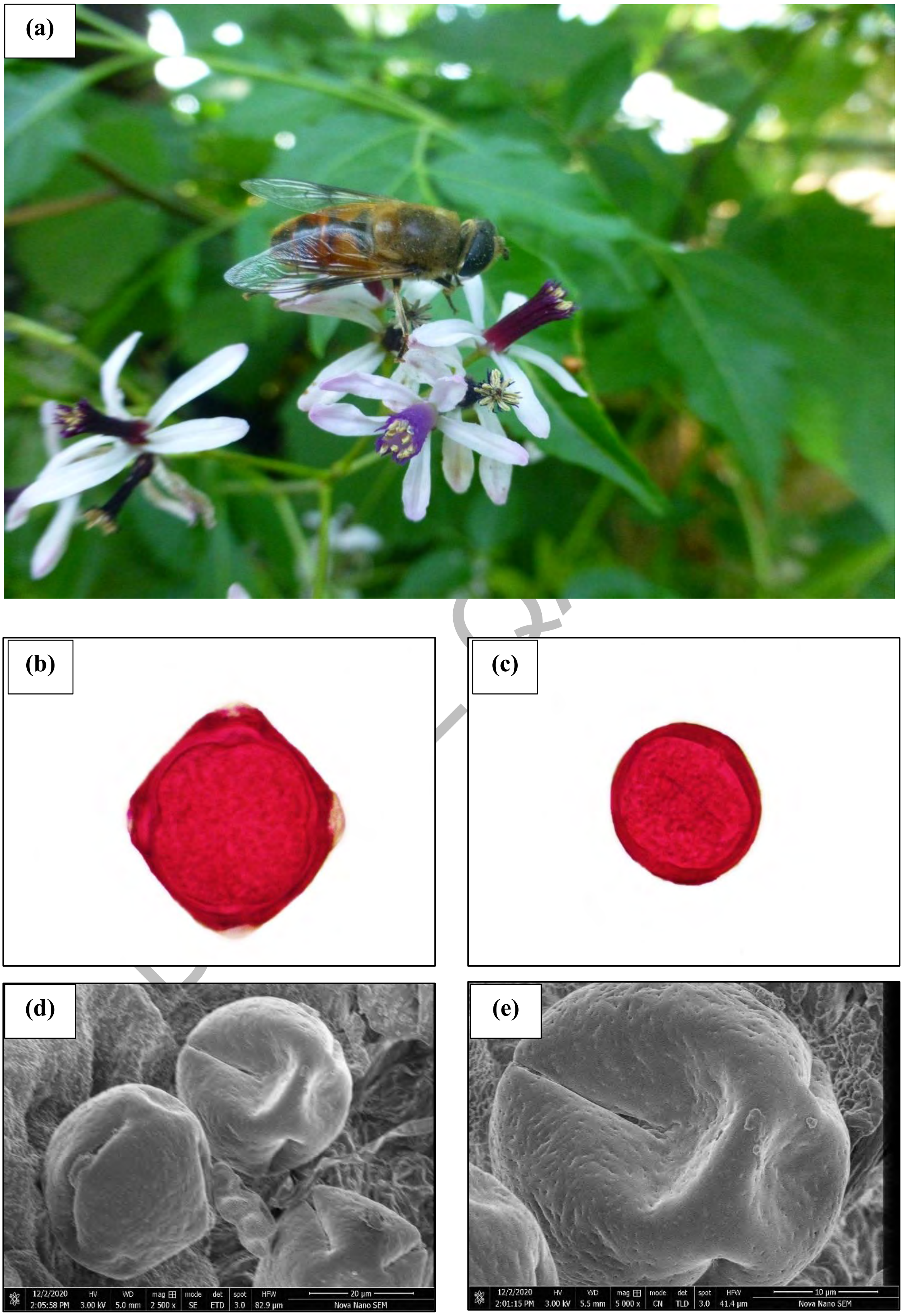

Plate 117: *Melia azadirachta* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

13. *Nerium oleander* L.

Synonym	Nerium oleander subsp. kurdicum Rech.f.
Family	Apocynaceae
Common Name	Oleander
Habit	Shrub
Habitat	Common in rocky stream beds, also cultivated and naturalized
Flowering period	October to January
Status	Cultivated
Distribution	Nepal, Italy, Pakistan, Syria, Oman, Lebanon, Bermuda, Algeria
Morphology	Erect, evergreen shrub, branches glabrous with milky juice, young branches green. Leaves 10-15 x 1-2 cm, linear-lanceolate, tapering at both ends, acuminate, thick coriaceous, midrib prominent, nerves numerous, petiole 5-7.5 mm long. Flowers white, pink or dark red, single or double in cultivated, form, fragrant 3-4 cm across, peduncle and pedicel hairy, bracts small, 5-7.5 mm long. Calyx 6.25 mm long, divided into 5 linear, acute lobes. Corolla tube 1.8 cm long, hairy within, throat narrow, tips rounded, corona of 5 scales near the throat of the corolla, cleft into 4-7 linear segments. Stamen included, filament short, Anthers connectives hairy, produced upward into long thread-like hairy appendages. Ovary with two distinct carpels, style filiform; stigma two lobed. Fruit 12-20 cm x 7:5 mm long (Plate 118a).
Melissopalynology	Pollen are monad, medium sized, and tetracolporate. Semicircular polar view and prolate-spheroidal equatorial view shape. Apertures: globular shape. Exine sculpturing eutectate psilate. Polar diameter 36.5(28.0-40.50)±2.25 µm and equatorial view distance 32.3(25.2-36.7)±1.98 µm. P/E ratio 1.13. Colpi length 3.00(2.25-3.75)±0.25 µm, colpi width 2.55(2.00-3.00)±0.18 µm and mesocolpium distance 20.4(18.7-21.7)±0.53 µm. Exine thickness 5.05(4.50-5.50)±0.18 µm. Pollen fertility 91.1% and sterility 8.86% (Plate 118b,c,d & e).

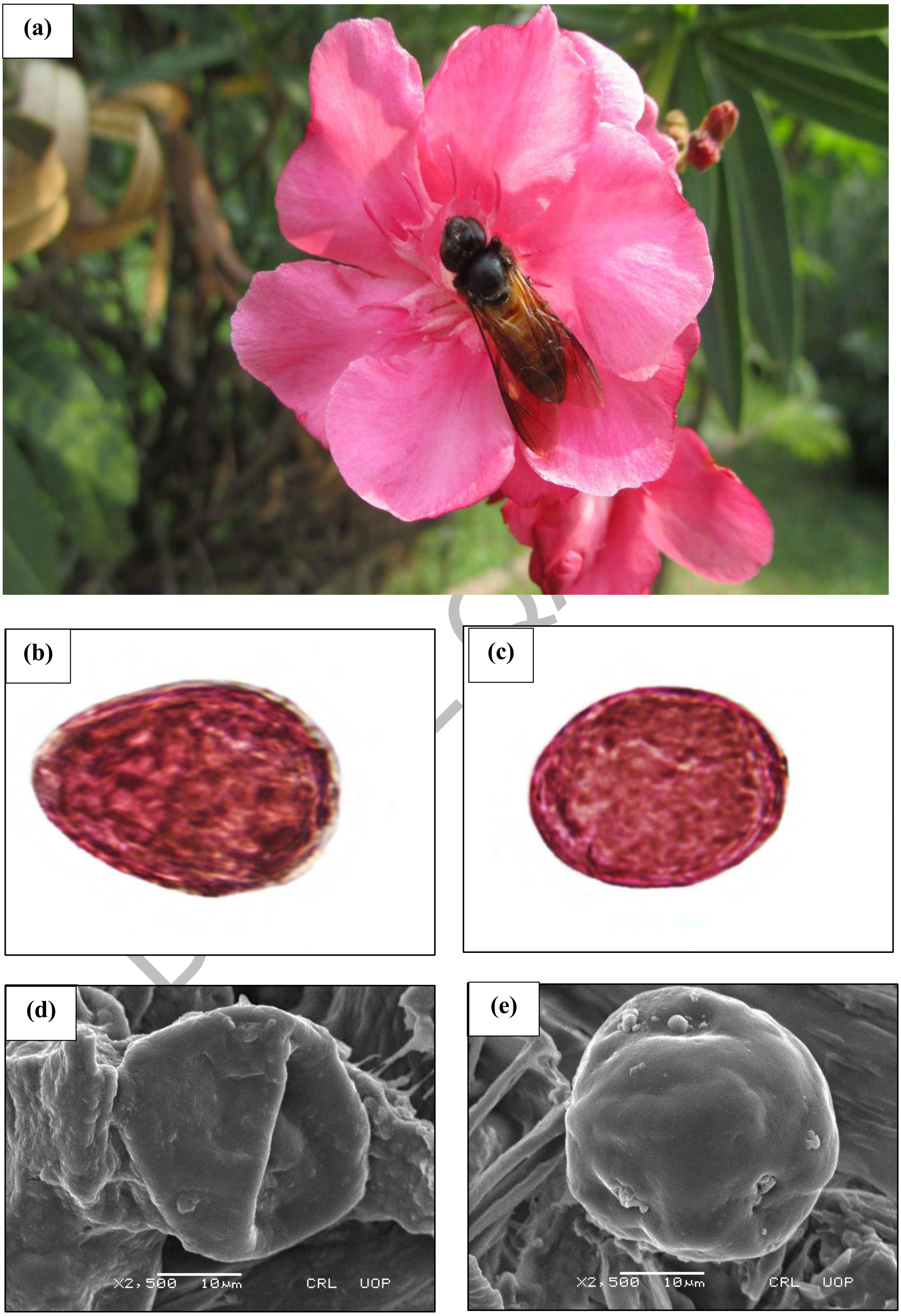

Plate 118: *Nerium oleander* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

14. *Oenothera rosea* L'Hér. ex Aiton

Synonym	*Oenothera rosea* var. *parvifolia* J.M. Coult.
Family	Onagraceae
Common Name	Sun cups
Habit	Perennial Herb
Habitat	Found in wild habitats, gardens and nurseries
Flowering period	April to July
Status	Wild
Distribution	Africa, Asia, Pakistan, North America, South America, India
Morphology	Perennial herb, decumbent, rhizomatous, 1 to 4.5 cm tall, rarely mixed to sparse villous hairs. Stem: 5.5-50 cm, branched, strigillose and long spreading hairs. Leaves; sinuate- pinnatifid elliptic (kidney like shape), inconspicuous veins, sparsely strigillose, 2-5 × 1-2.5 cm, the petiole 2.2-18 mm tall. Flowers opening near sunrise; mature buds erect. Floral tube 4.1-8.2 mm long. Sepals 7-12 mm long; sepal tips 0.1-0.5 mm long. Petals rose to rose-purple, obovate, 4.1 to 13 mm long. Style 0.9-1.5 cm long. Capsule clavate, 1.3-3 cm long, the ridge on each valve prominent. Seeds in several indistinct rows in each locule, oblong-obovoid to obovoid, 0.8-0.9 mm long, the surface finely granular (Plate 119a).
Melissopalynology	Pollen are monad, medium sized, and tricolpate. Triangular polar view and oblate-spheroidal equatorial view shape. Exine sculpturing Verrucate-scabrate. Polar diameter 36.3(92.5-17.5)±27.2 µm and equatorial distance 39.7(112.5-17.5)±32.6 µm. P/E ratio 0.91. Colpi length 7.52(20.2-2.25)±6.03 µm, colpi width 8.23(15.2-2.75)±3.76 µm and mesocolpium distance 31.1(90.0-12.5)±27.3 µm. Exine thickness 3.89(5.25-2.25)±0.95 µm. Pollen fertility 64.2% and sterility 35.7% (Plate 119b,c,d & e).

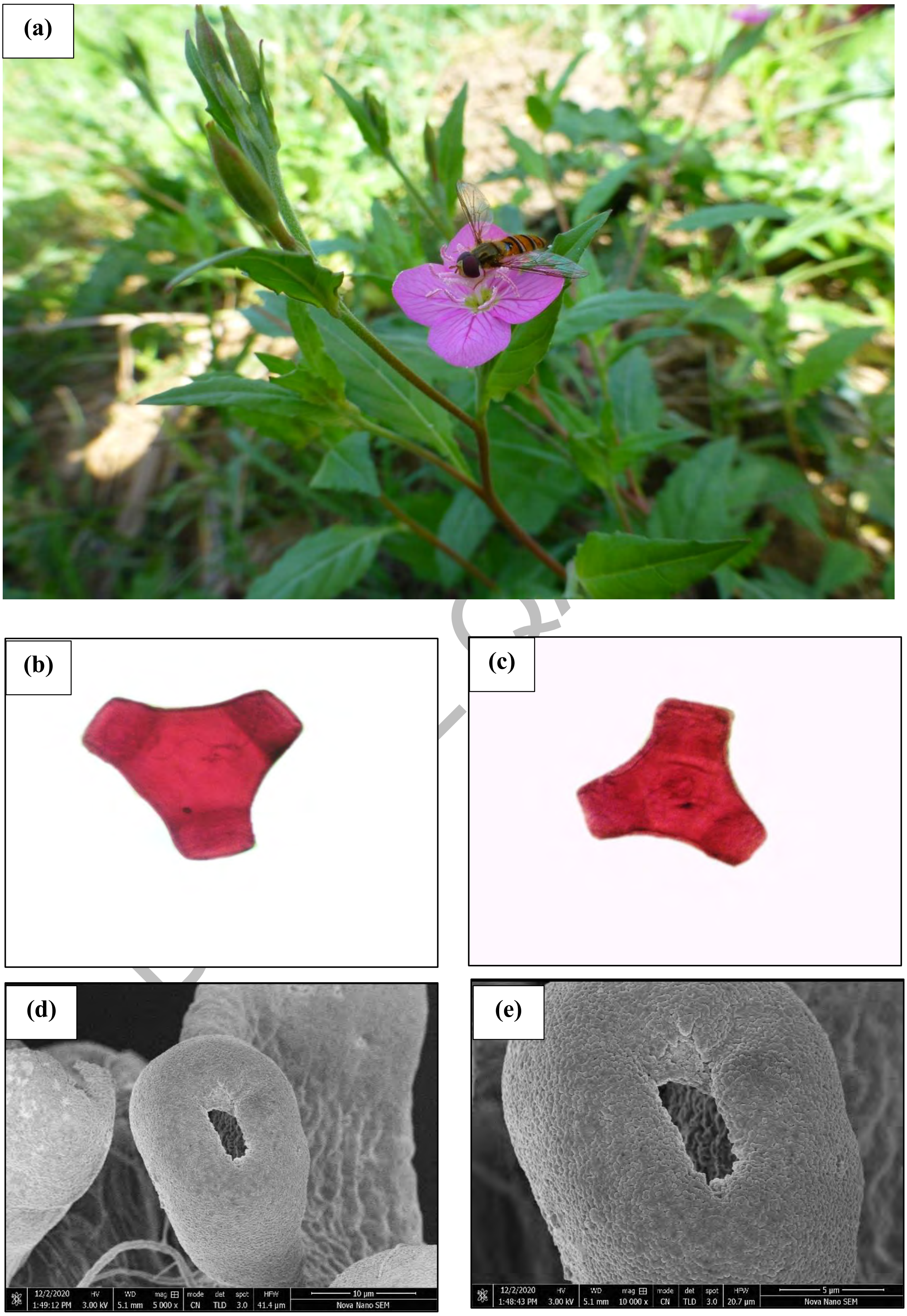

Plate 119: *Oenothera rosea* L'Hér. ex Aiton (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

15. *Opuntia dillenii* (Ker Gawl.) Haw.

Synonym	*Cactus chinensis* Roxb.
Family	Cactaceae
Common Name	Erect prickly pear
Habit	Shrub
Habitat	Inhabit open woodlands, rangelands, grasslands and pastures
Flowering period	May to July
Status	Wild
Distribution	Pakistan, Ecuador, Mexico, South Carolina, Texas, Florida
Morphology	Xerophytic shrub, sprawling, 1-3.5 m tall, trunk absent, stem and branches flattened, usually growing 45-90 cm tall. Fleshy stem segment: cladodes elliptical shape, 11-24 cm long and 5-18 cm broad. Areoles: present on the cladode, 2.1-3.6 cm long, short barbed bristles, glochidia in the base. Spines: 1-13 per areole, spreading and yellow. Flower: yellowish orange to lemon yellowish, 4.5-8.3 cm long and 5.2- 8 cm across. Perianth rotate, numerous petals and stamens. Sepaloids: greenish yellow margin, broadly deltoid-obovate, 8-22 × 4-10 mm and margin entire. Seeds: light tan, orbicular and 3.5-5.2 × 3.8-4.2 mm (Plate 120a).
Melissopalynology	Pollen are monad, medium sized and pantoporate. Circular polar view and sub-prolate equatorial view shape. Exine sculpturing perforate reticulate. Polar diameter 42.7(39.2-44.5)±0.90 µm and equatorial view distance 34.8(30.7-39.7)±1.45 µm. P/E ratio 1.22. Pore length 2.55(1.75-3.25)±0.25 µm, pore width 2.50(2.00-3.25)±0.22 µm. Exine thickness 3.90(3.25-4.75)±0.31 µm. Pollen fertility 80.9% and sterility 19.04% (Plate 120b,c,d & e).

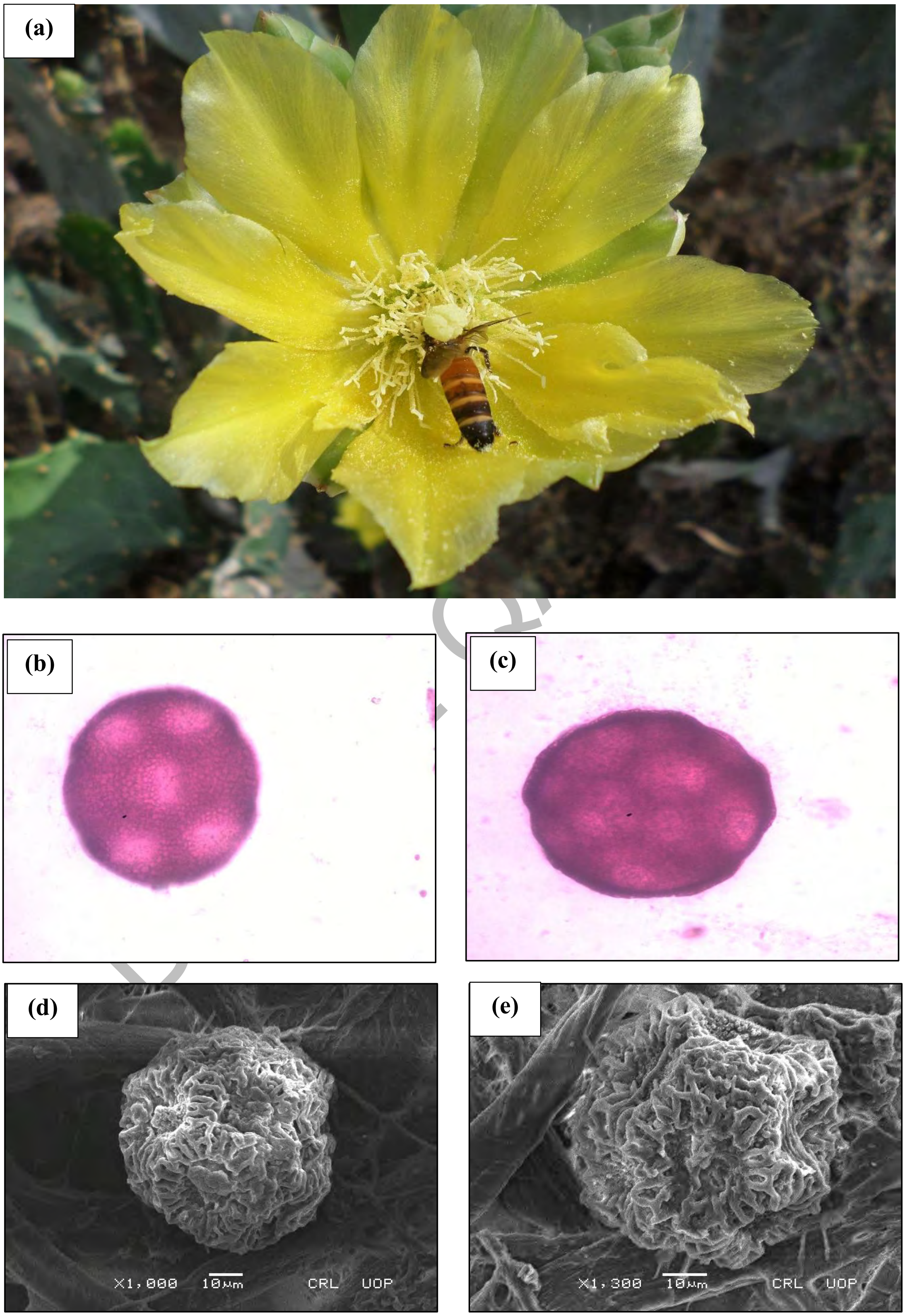

Plate 120: *Opuntia dillenii* (Ker Gawl.) Haw. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

16. *Oxalis corniculata* L.

Synonym	*Acetosella corniculata* (L.) Kuntze
Family	Oxalidaceae
Common Name	Creeping wood sorrel
Habit	Perennial Herb
Habitat	In gardens, lawns, arable land, disturbed sites and pastures
Flowering period	June to October
Status	Wild
Distribution	West Indies, Pakistan, Texas, Morocco, Afghanistan, Bhutan
Morphology	Herbaceous plant, creeping, caulescent, pubescent and rooting at nodes. Aerial stem: commonly 2–6 basally, decumbent, stolon like, 3.2-14 cm, herbaceous, sparsely, strigose-villous. Leaflets; 3.5-18 mm long, 6-30 mm broad, obcordate and pilose tomentose. Petiole: 2.2-5.2 cm; leaflets 3, bronze-purple, obcordate. Flowers; solitary, 3-6 flowered and axillary umbels. Pedicel; 4-17 mm long and deflexed in fruit. Bracts; 2-5 and linear. Sepals; 5 linear, lanceolate and pilose. Petals; 5 and yellowed color. Filaments; glabrous. Carpels; 5, pubescent, styles longer and shorter stamens. Capsule; 1.5-3 cm long, sub-cylindrical and pubescent. Seeds; 1.8 mm long, brown and transversely ribbed (Plate 121a).
Melissopalynology	Pollen are monad, iso polar, medium sized, and tricolpate. Oblique polar view and prolate-spheroidal equatorial view shape. Exine sculpturing reticulate. Polar diameter 41.8(36.5-48.7)±2.09 µm and equatorial view distance 40.7(33.0-46.5)±2.29 µm. P/E ratio 1.02. Colpi length 3.35(2.75-4.00)±0.23 µm, colpi width 4.15(2.75-4.75)±0.36 µm and mesocolpium is 12.1(11.2-13.7)±0.43 µm. Exine thickness 4.85(3.00-6.25)±0.63 µm. Pollen fertility 92.1% and sterility 7.84% (Plate 121b,c,d & e).

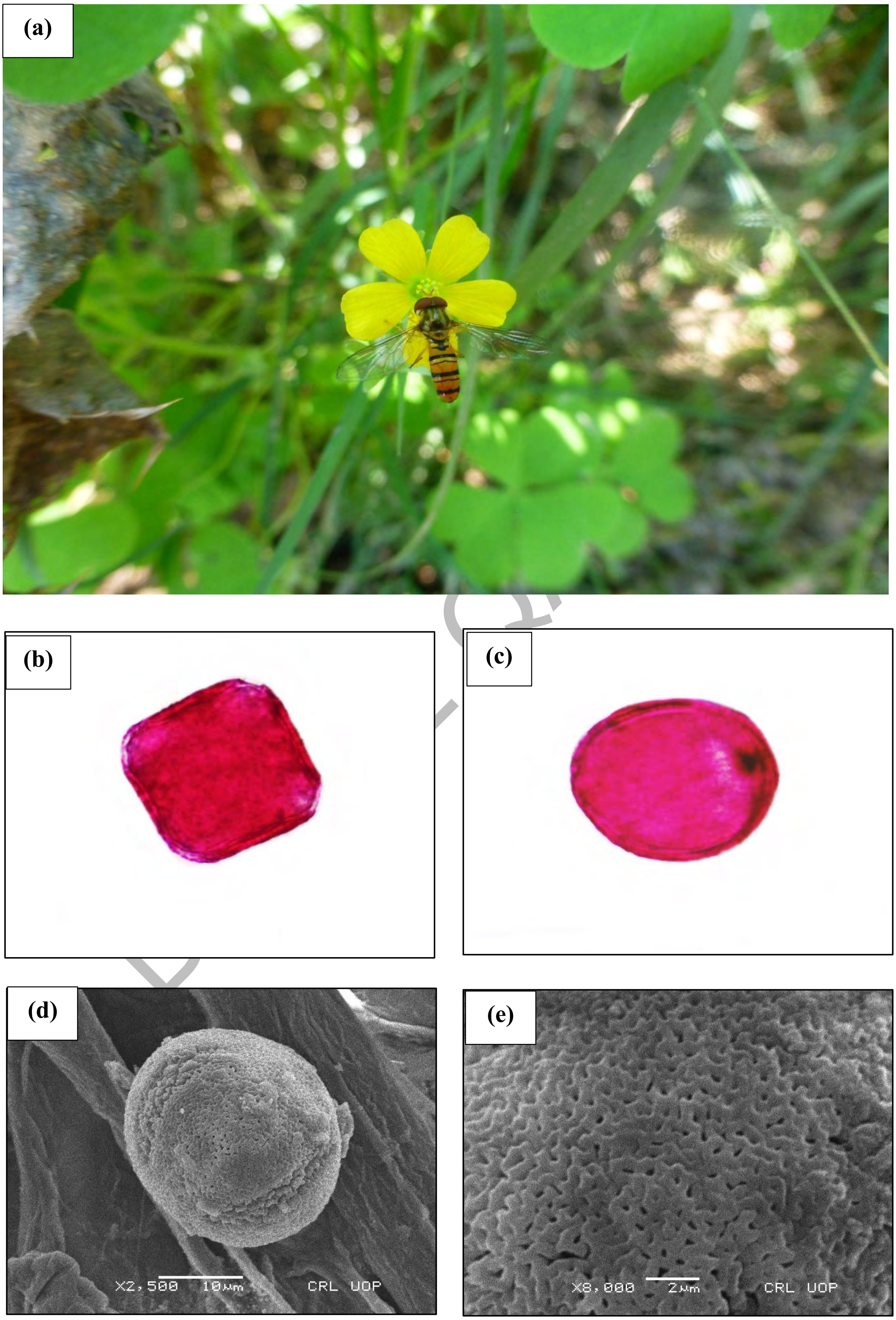

Plate 121: *Oxalis corniculata* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

17. *Papaver somniferum* L.

Synonym	*Papaver somniferum* var. *setigerum auct*. non (DC.) Corb.
Family	Papaveraceae
Common Name	Opium poppy
Habit	Annual Herb
Habitat	Constructed, industrial, artificial and freshwater habitats
Flowering period	May to September
Status	Wild
Distribution	Hungary, Germany, China, Turkey, Austria, Pakistan
Morphology	Robust, annual herb, 30-110 cm tall, glabrous, glaucous and branched. Leaves; oblong, cordate, undulate, serrate, dentate, pinnatipartite, 4-18 cm long. Peduncle; 12-21 cm long, sparsely bristly. Flower bud; oblong, 15-28 mm long. Flowers; large, showy, usually 5-10 cm in diameter, white, pinkish, pale violet. Sepals; glabrous and caducous. Petals; obovate, orbicular, margin wavy, caducous. Stamens; yellowish filaments; anthers; 1.8-4.2 mm long, oblong. Capsule; sub-glabrous, smooth, rounded base, abruptly ending, very short stipe 0.5-2.5 mm long, stigmatic disk; usually 6-12 stigma rays, Seeds; small, white, dark-grey to black (Plate 122a).
Melissopalynology	Pollen are monad, iso-polar, medium sized, and tricolpate. Rounded polar view and oblate-spheroidal equatorial view shape. Exine sculpturing scabrate-verrucate. Polar diameter 28.9(24.7-32.7)±1.64 µm and equatorial view distance 29.5(26.0-34.2)±1.36 µm. P/E ratio 0.97. Colpi length 10.3(8.25-11.7)±0.66 µm, colpi width 5.35(3.50-6.50)±0.52 µm and mesocolpium distance 14.5(12.0-17.7)±0.95µm. Exine thickness 1.55(1.00-2.25)±0.21 µm. Pollen fertility 93.1% and sterility 6.86% (Plate 122b,c,d & e).

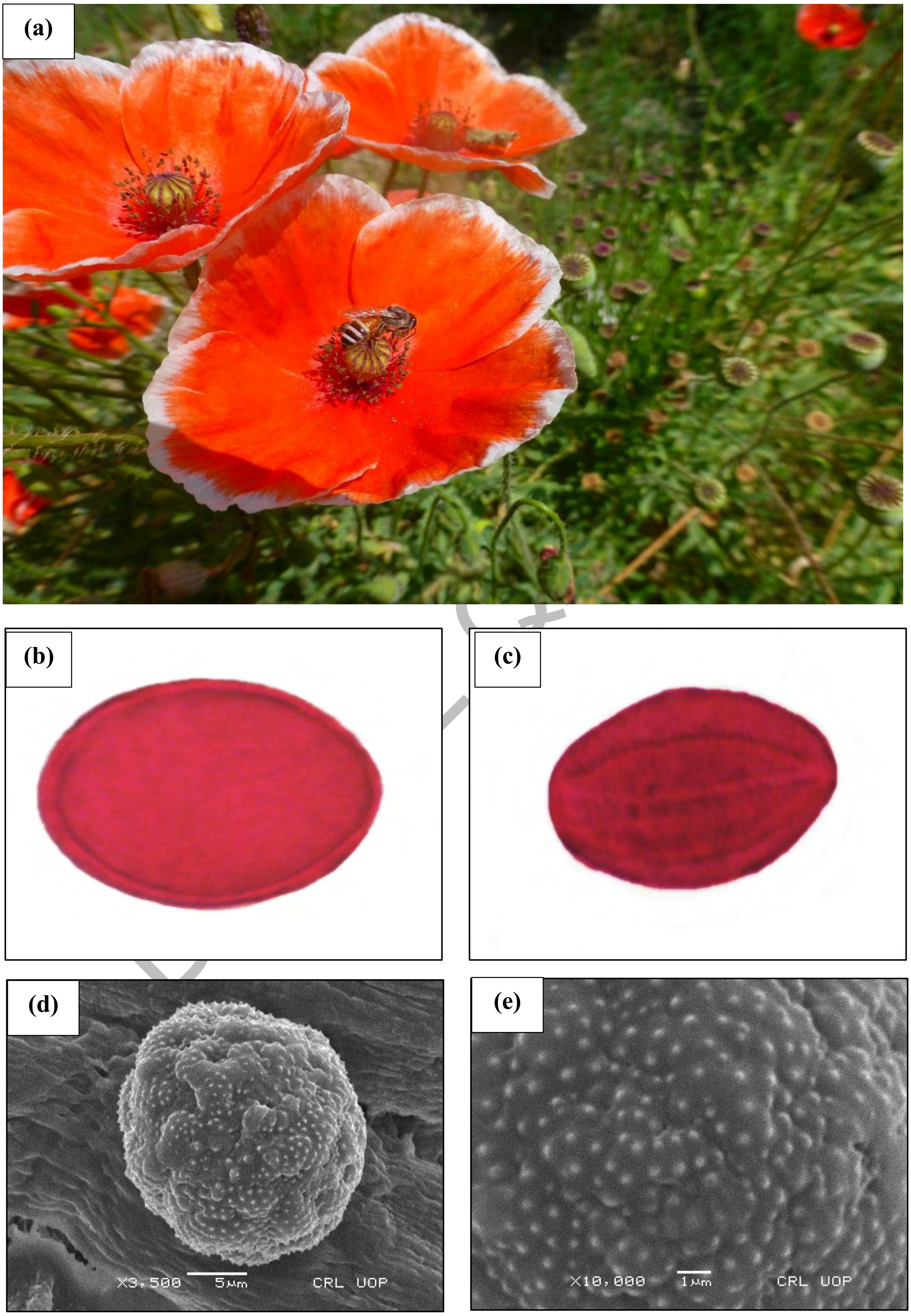

Plate 122: *Papaver somniferum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

18. *Peganum harmala* L.

Synonym	*Harmala multifida* All.
Family	Nitrariaceae
Common Name	Wild rue
Habit	Herb
Habitat	Found in dry steppes, dry waste places and in saline soils
Flowering period	May to October
Status	Wild
Distribution	Southeast Morocco, Pakistan, Iraq, Uzbekistan, Tajikstan,
Morphology	Perennial, 21-55 cm tall and corymbosely branched and glabrous herb. Leaves; sessile, 3.5-7 cm long, irregularly, pinnatisectly dissected into 2.5-7 cm long, 3-6 mm broad, linear to lanceolate or sub-elliptic, acute ;stipules setaceous, 1.2-2.9 mm long. Flowers; yellowish white, 1.2-2.8 cm across; pedicel 1.6 cm long and filiform. Sepals; 5 linear, 8-13 mm long, glabrous, acute, entire pinnatifid. Petals; 5 oblong, sub-equal, 11-16 mm long, 3-7 mm broad and obtuse. Stamens; 15, filaments 3.4 to 7 mm long, anthers longer than filaments, 4.5-6 mm long and dorsifixed. Ovary; 4.5-10 mm long style, upper 6.5 mm triangular. Capsule; 5-12 mm across, trigonous, depressed at the apex, with persistent style. Seeds; blackish to brown, triangular, 1.4-2.5 mm long (Plate 123a).
Melissopalynology	Pollen are monad, small sized and tricolpate. Circular polar view and prolate-spheroidal equatorial view shape. Aperture sunken orientated. Exine sculpturing reticulate-scabrate. Polar diameter 24.0(19.7-18.0)±0.73 µm equatorial view distance 23.3(20.5-25.2)±0.45 µm. P/E ratio 1.03. Colpi length 2.55(0.75-4.25)±0.34 µm, colpi width 3.70(2.00-5.25)±0.37 µm and mesocolpium distance 16.0(13.7-18.7)±0.49 µm. Exine thickness 3.10(2.00-4.25)±0.21 µm. Pollen fertility 87.7% and sterility 12.2% (Plate 123b,c,d & e).

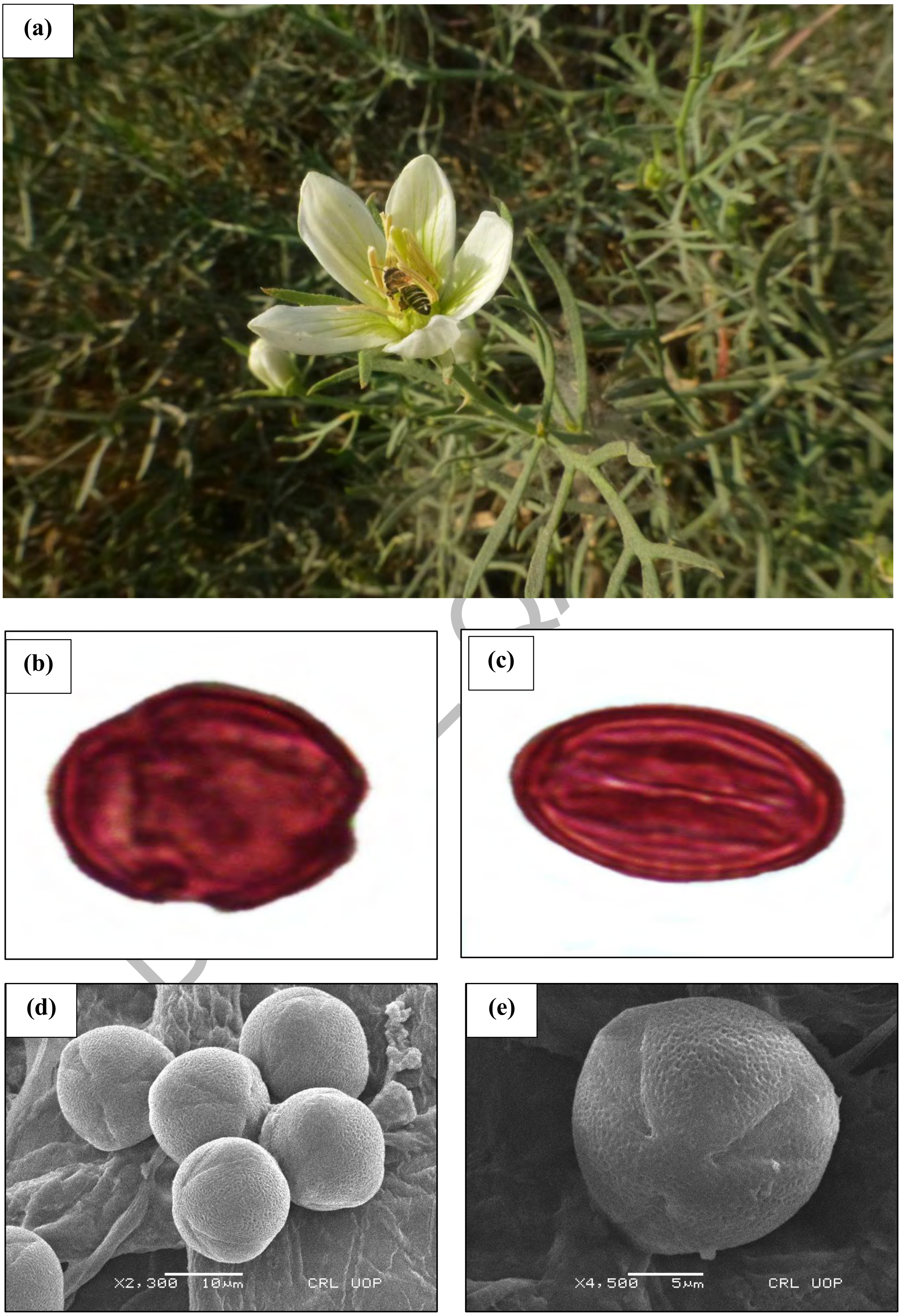

Plate 123: *Peganum harmala* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

19. *Trianthema portulacastrum* L.

Synonym	*Trianthema littoralis* Cordem.
Family	Aizoaceae
Common Name	Black pigweed
Habit	Annual Herb
Habitat	Wastelands, roadsides, lawns, gardens and paddy fields
Flowering period	July to October
Status	Wild
Distribution	India, Mexico, Peru, Australia, Thailand, Pakistan
Morphology	Annual, up to 25-30 cm long. Stem; glabrous, sparsely pubescent. Leaves; sub-orbiculate to obovate, 1.4-2.8 cm long, 0.8-3 cm broad, obtuse to acute; petiole 3-14 mm long, papillose-glabrous, base dilated, clasping, with bilateral stipular appendages. Flowers; axillary solitary and sessile. Calyx tube; closely sheathed, by the leaf base; sepals 5, oblong, 2-3.5 mm long and shortly aristate. Stamens; 7 to 12, unequal, filaments 2-3.2 mm long. Ovary 2.5 mm long, more or less conical; style 1, linear, 1.3-2.2 mm long, persistent. Pyxidium; 4.5 mm long; amphora 4 to 5-seeded, lid 2.6-3.3 mm broad. Seeds 1.2-92 mm broad, black and rugose (Plate 124a).
Melissopalynology	Pollen grains are monad, medium sized and polycolporate. Circular polar view and prolate-spheroidal equatorial view shape. Colpi orientation sunken, linear, and margins rounded. Exine sculpturing reticulate-foveolate. Polar diameter 40.0(35.5-43.2)±1.39 µm and equatorial view distance 36.4(34.5-39.7)±0.94 µm. P/E ratio 1.09. Pore length 4.30(2.75-5.25)±0.42 µm and pore width 7.35(6.75-8)±0.23 µm. Exine thickness 5.40(4.75-6.25)±0.24 µm. Pollen fertility 92.7% and sterility 7.29% (Plate 124b,c,d & e).

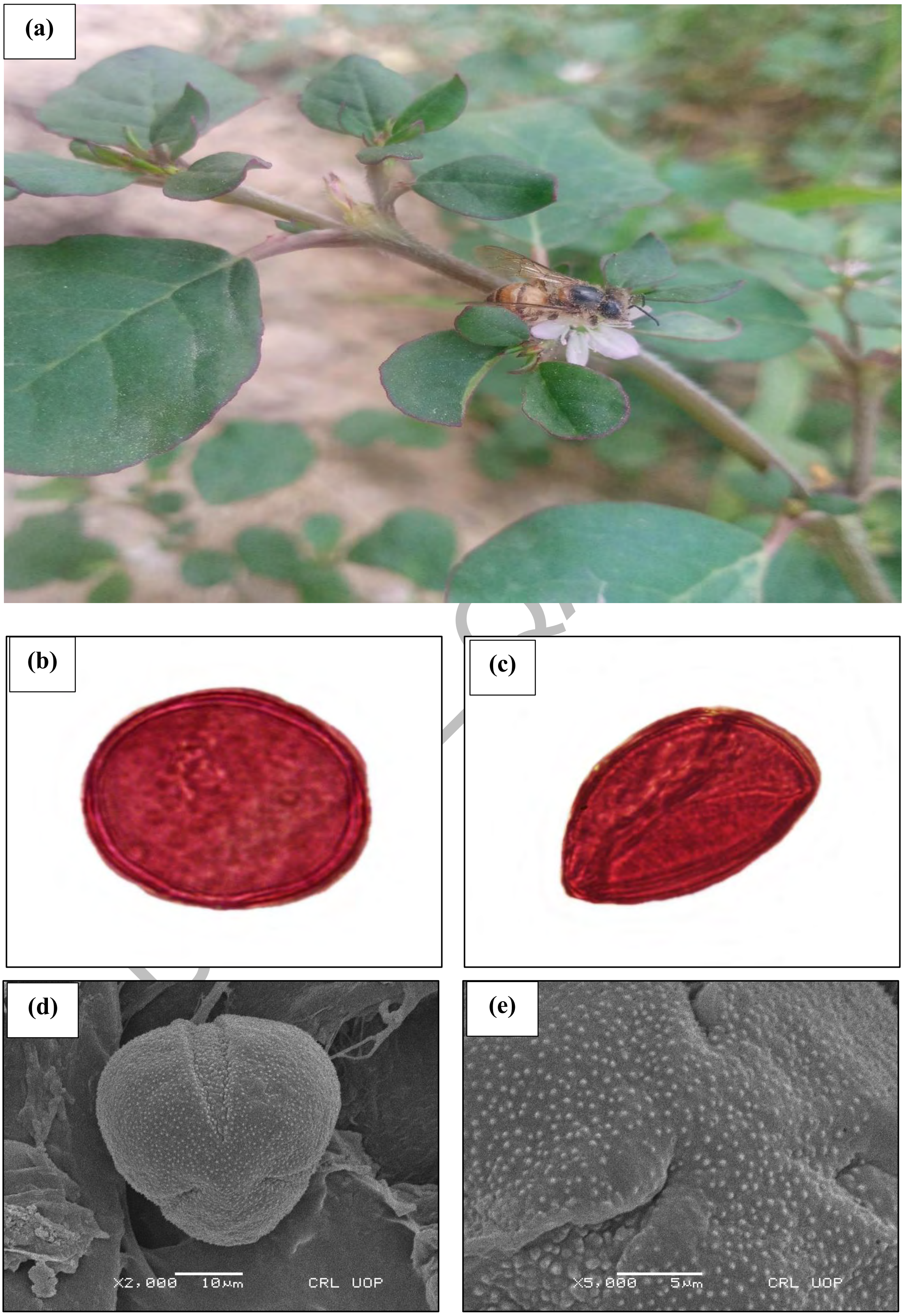

Plate 124: *Trianthema portulacastrum* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

20. *Trichodesma indicum* (L.) Lehm.

Synonym	*Boraginella indica* (L.) Kuntze
Family	Boraginaceae
Common Name	Indian Borage
Habit	Herb
Habitat	On roadsides and stony dry wastelands
Flowering period	March to August
Status	Wild
Distribution	Afghanistan, Pakistan, India, Philippines, Mauritius
Morphology	Annual herb, spreading and densely hairy branches; hairs; dimorphic, shorter ones thin, appressed, up to 0.7 mm long; longer ones stiff, up to 0.8 mm long with smaller bases. Leaves; oblanceolate to lanceolate, 2.4-7.5 x 0.5-24 cm, amplexicaul; middle cauline ones largest, hairy on both surfaces, the upper surface with hairs up to 1.5 mm long. Inflorescence; terminal, lax, few flowered. Bracts leafy. Pedicel; 12-22 mm long. Flowers; mauve to pinkish blue or lilac. Calyx; 5 partite, hairy, 8-12 mm long, lobes oblong. Corolla; exceeding calyx length, infundibuliform, sparsely hairy on outside; lobes sub-orbicular, sub-acuminate. Anthers; hairy, aristate, connectives later twisting together. Nutlets; 3-6 mm long, ovoid, smooth, white to bluish (Plate 125a).
Melissopalynology	Pollen are monad, medium sized and tricolpate. Semicircular polar view and prolate-spheroidal equatorial view shape. Colpi orientation sunken and pent. Exine sculpturing spinose. Polar diameter 41.9(21.7-80.2)±5.90 µm and equatorial view distance 38.9(18.0-75.2)±5.81 µm. P/E ratio 1.07. Colpi length 15-4.35(2.75-5.50)±0.20 µm, colpi width 3.98(1.75-7.25)±0.40 µm and mesocolpium 26.2(14.2-45.2)±2.95 µm. Exine thickness 6.31(2.75-10.2)±0.62 µm. Pollen fertility 98.03% and sterility 1.96% (Plate 125b,c,d & e).

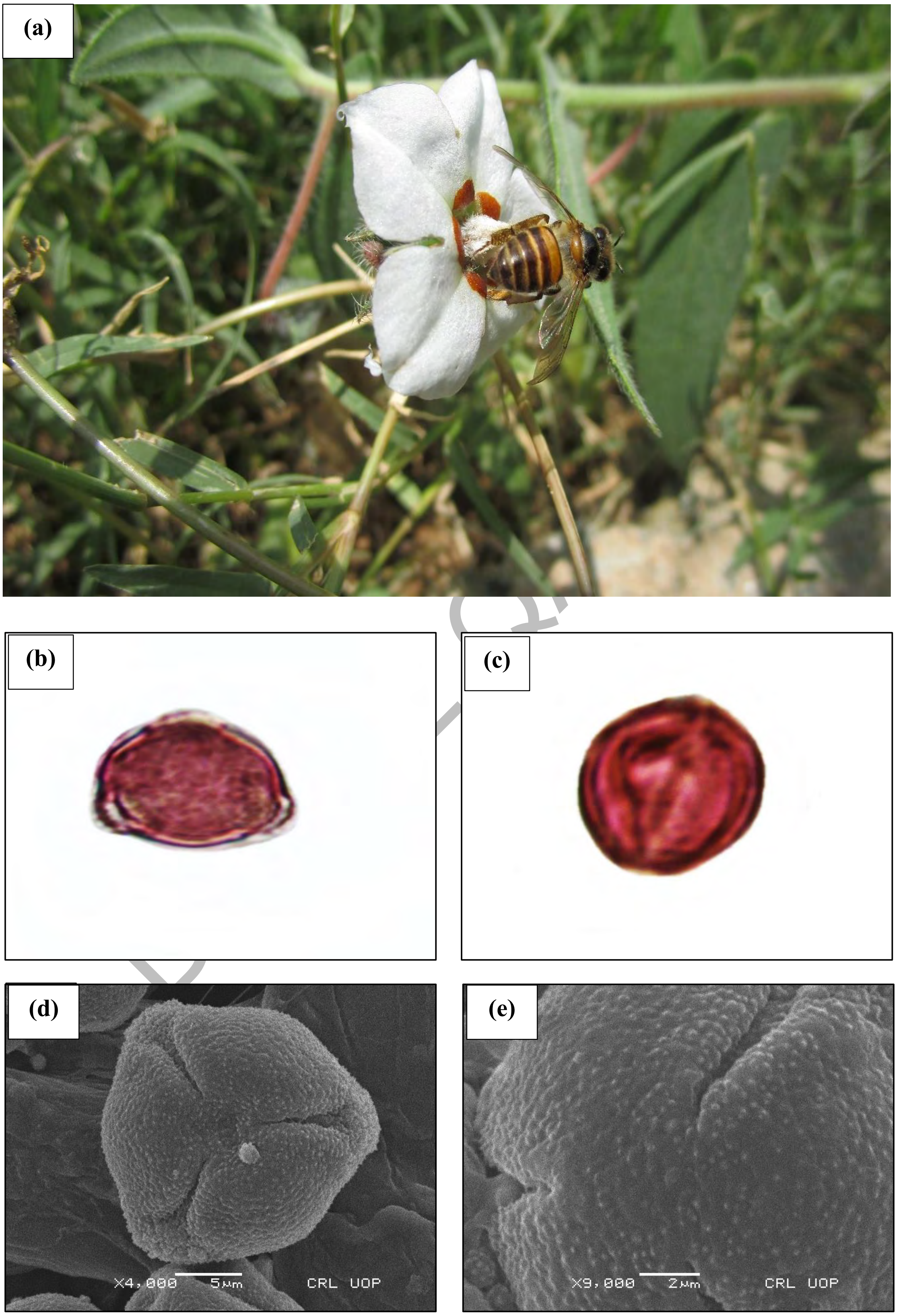

Plate 125: *Trichodesma indicum (L.) Lehm.*a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

21. *Tropaeolum majus* L.

Synonym	*Cardamindum majus* Moench
Family	Tropaeolaceae
Common Name	Garden Nasturtium
Habit	Annual Herb
Habitat	Disturbed sites, gardens, dumps, shrubland and herb field
Flowering period	May to July
Status	Wild
Distribution	Japan, Hawaii, India, Argentina, China, Pakistan
Morphology	Trailing annual herb and glabrous. Leaf blade; orbicular, reniform, 3.5-12 cm in diameter, peltate, nerves radiating from petiole, margin angled or sinuate, entire and abaxial surface papillose. Flowers; axillary, solitary, yellow, orange, varicolored, 3-7 cm in diameter. Pedicel; 5-14 cm. Torus; cup shaped. Sepals; 5, lanceolate, 1.4-2.5 × 0.7-1 cm; spur 2-3.6 cm and curved. Petals; 5, apex rounded, even toothed; apical petals 2-5.5 × 1.2-2 cm and margins entire. Stamens; 8, distinct and unequal. Ovary; 3-loculed; style 1; stigma linear and 3 lobed. Fruit; oblate, separating into 1-seeded mericarps (Plate 126a).
Melissopalynology	Pollen are monad, medium sized and tricolpate. Triangular polar view and oblate-spheroidal equatorial view shape. Exine sculpturing reticulate heterobrochate. Polar diameter 24.9(21.2-28.7)±1.57µm and equatorial view distance 25.5(21.2-27.7)±1.11 µm. P/E ratio 0.97. Colpi length 8.65(6.25-11.2)±0.80 µm, colpi width 3.75(2.00-5.25)±0.51 µm and mesocolpium distance 17.0(15.7-18.7)±0.54 µm. Exine thickness 4.30(3.75-5.25)±0.27 µm. Pollen fertility 98.08% and sterility 1.91% (Plate 126b,c,d & e).

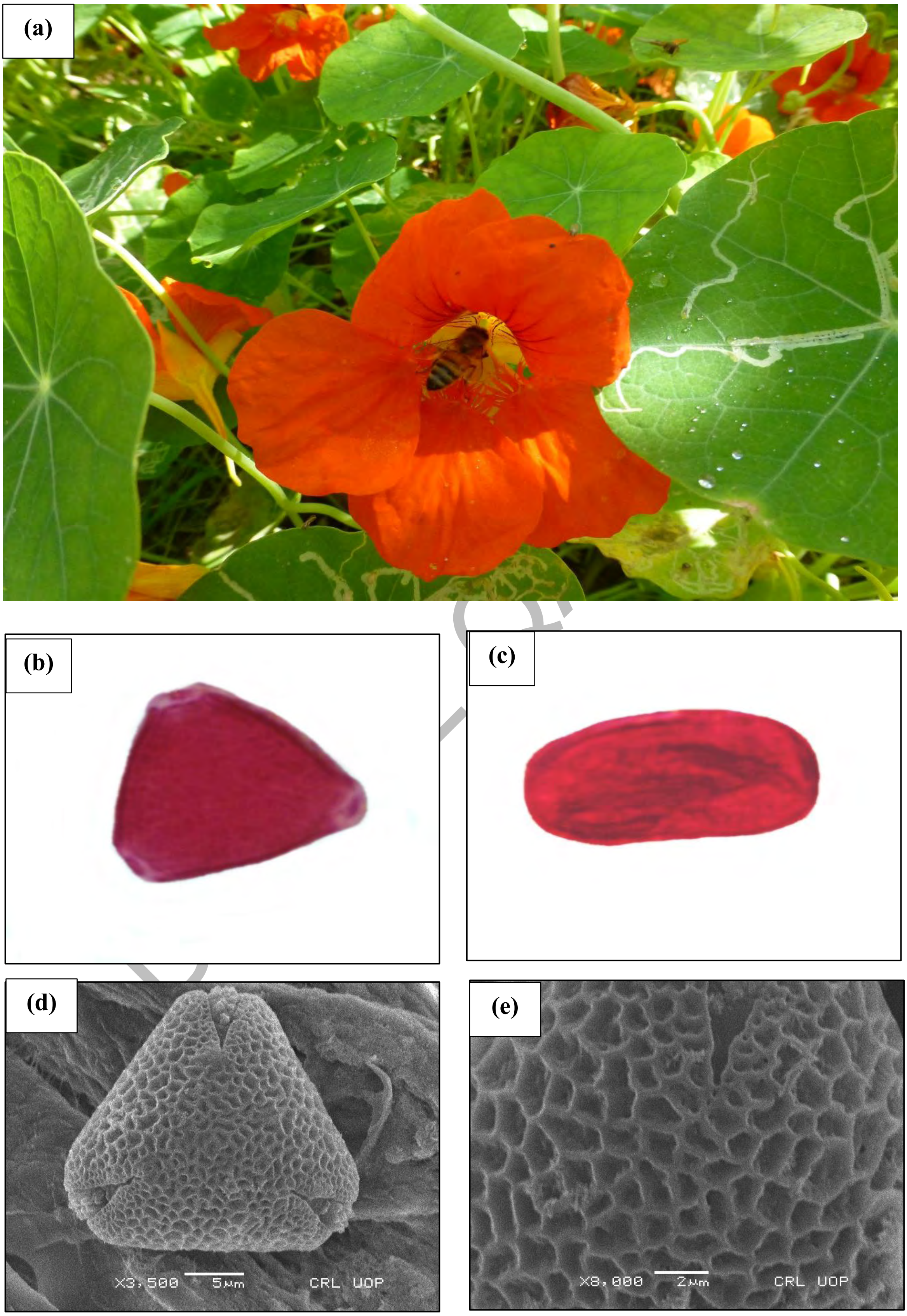

Plate 126: *Tropaeolum majus* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

22. *Verbascum Thapsus* L.

Synonym	*Verbascum thapsus* subsp. *Crassifolium* (DC.) Murb.
Family	Scrophulariacae
Common Name	Mullein
Habit	Biennial Herb
Habitat	Roadsides, railroads, old fields, pastures
Flowering period	April to August
Status	Wild
Distribution	Europe, North Africa, Siberia, Pakistan, China, India
Morphology	Annual or biennial herb, 1.3 m tall and densely with stellate hairs. Lower stem leaves: petiolate; leaf blade oblanceolate, 11 × 5 cm and margin crenate. Leaves usually simple, alternate, basally rosulate. Inflorescences terminal, spicate, racemose, or paniculate. Calyx 5 lobed. Corolla usually yellow, rarely purple or white; tube short; limb rotate; lobes 5, subequal, radiate. Stamens 4 or 5; filaments usually woolly; anthers 1-loculed, confluent, anterior anthers linear-oblong or reniform, posterior anthers reniform or transverse. Ovary 2-loculed. Capsule septicidal. Seeds numerous, conically cylindrical 6-8-ribbed (Plate 127a).
Melissopalynology	Pollen are monad, small to medium sized and tricolpate. Rounded polar view and sub-oblate equatorial view shape. Exine sculpturing micro reticulate. Polar diameter 21.9(22.7-20.0)±1.10 µm and equatorial view distance 26.3(27.5-25.0)±1.14 µm. P/E ratio 0.83. Colpi length 2.7(3.25-2.25)±0.37 µm, colpi width 4.4(5.00-2.75)±0.92 µm and mesocolpium distance 15.3(17.5-12.7)±1.85 µm. Exine thickness 3.65(4.75-2.25)±1.18 µm. Pollen fertility 80.4% and sterility 19.5% (Plate 127b,c,d & e).

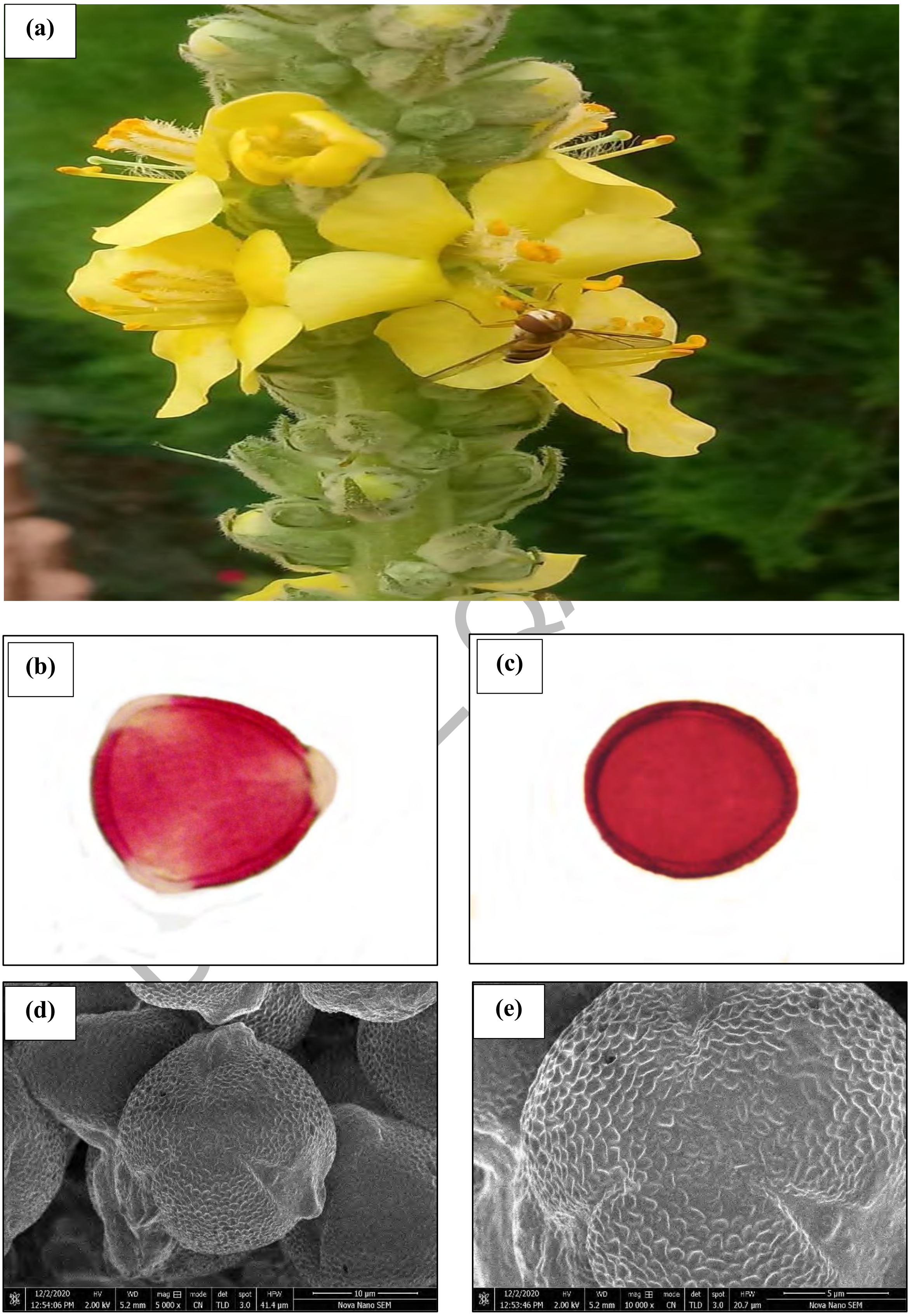

Plate 127: *Verbascum thapsus* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

23. *Viola tricolor* L.

Synonym	*Viola tricolor* var. *arvensis* (Murray) DC.
Family	Violaceae
Common Name	Wild pansy
Habit	Annual/Perennial Herb
Habitat	Found in gardens and nurseries
Flowering period	April to August
Status	Ornamental
Distribution	Iran, Pakistan, India, North America, Turkey
Morphology	Annual or perennial, ornamental herb, 8-35 cm tall, glabrous, short retrorse hairy. Stem: erect, slightly oblique, robust, angled, much branched. Leave ovate spathulate, obtuse, cordate, crenate; stipules pinnatipartite, lanceolate, crenate, foliaceous. Flowers: solitary, mixture of yellow, blue, purple and violet or multi-colored, Large, 3-6.5 cm in diameter, 2-11 flowers per stem Petals distinctly exceeding the sepals; spur 5.1-8.2 mm long, considerably straight, obtuse. Sepals lanceolate. Ovary: glabrous, styles; short and base geniculate (Plate 128a).
Melissopalynology	Pollen are monad, small sized and tricolpate. Rounded polar view and oblate-spheroidal equatorial view shape. Exine sculpturing gemmate-psilate. Polar diameter 23.2(27.5-18.7) ±2.76 µm and equatorial view distance 23.3(25.0-17.5)±2.02 µm. P/E ratio 0.99. Colpi length 6.45(9.25-4.75)±1.76 µm, colpi width 7.52(10.0-6.25)±1.26 µm and mesocolpium distance 18.5(20.2-15.0)±2.01 µm. Exine thickness 5.02(7.05-2.75)±1.48 µm. Pollen fertility 92.5% and sterility 7.5% (Plate 128b,c,d & e).

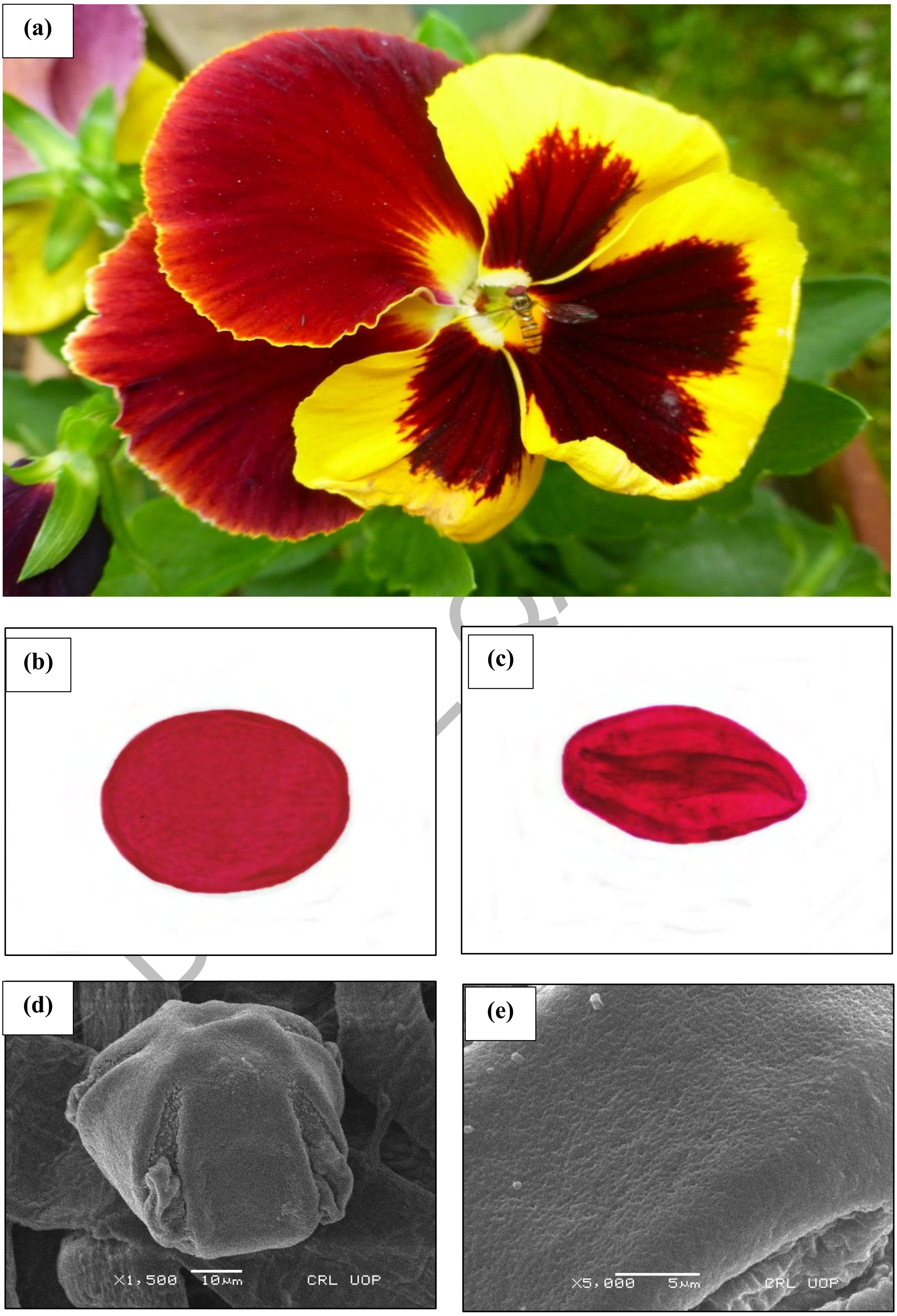

Plate 128: *Viola tricolor* L. (a) Floral part; (b & c) LM polar view and equatorial view of pollen, (d & e) SEM polar view and Exine sculpturing

Section III:

Melissopalynology of Collected Honey samples

3.3Melissopalynology of Bee flora

The results of honey pollen analysis are presented in Table 3, 4 and 5. Honey pollen research revealed the presence of monofloral and multifloral honeys. Only 14 monofloral honey types originating from three melliferous plants were produced in different areas of the zone when the data was pooled at the district level. The assessment of plant species based on pollen count revealed that the honey samples taken from the Swabi District site (ZHS), Gadoon site District Nowshera (AHG), and Ziarat Kaka Sahib (AHZ) had the highest species diversity. The 24 pollen types found in honey samples were divided into 14 plant groups (Plate 129 & 130). From 24 plant species, 31.4%, 42.5%, and 26.1% were trees, shrubs and herbs respectively.

3.3.1 Qualitative Melissopalynological Analysis

From the 24 types of honey analyzed, qualitative melissopalynology identified pollen of 24 species of plant in diverse honeys, with percentages ranging from 1 % to 62 % and categorized into 14 families (Plate 129 & 130, Table 3 & 4). The smallest (n = 12) and maximum (n = 24) number of plant taxa were found in the *Ziziphus* honey (ZHZ) and *Eucalyptus* honey (EUK), respectively. Six types of honey (*Acacia* and *Ziziphus*) included unknown PGs at relative frequencies of 2%, 1%, 2%, 1%, and 2%, respectively (Table 2). About 50% of the natural honey analyzed contained two different forms of PGs. *Acacia* spp. (family: Mimosaceae), which was discovered in six (56%) of the types of honey (*Acacia* honey samples), and *Ziziphus* spp. (family: Rhamnaceae), which was detected in four (54%) of the honeys studied, were among these types of pollen (*Ziziphus* honey samples) (Table 2). 14 honey samples were classed as unifloral, with six major pollen types: *Acacia spp.* (60% in AHN), (51% in AHS), (55% in AHG) and (62%in AHGa) in different *Acacia* honey, *Eucalyptus spp.* (50% in both EHK and EHG) in different *Eucalyptus* honey and *Ziziphus spp.* (51% = ZHT, 50% = ZHM, 49% = ZHS, 51% = ZHU, 62% = ZHP and 54% = ZHZ) in samples of *Ziziphus* honey.

Based on the total number of pollen types and the percentage of each species in the total pollen count, 10 honey samples were categorized as multifloral and 14 as monofloral honeys. Multifloral honey contains a wider variety of pollen sources than monofloral honey. This is identical to the research that has been done by Bareke and Addi (2019) in the Borana Zone in Southern Ethiopia, which found that multifloral honey contained a wide variety of honeybee plants. However, the monofloral honey sample taken from the Gulmaira site AHN (H=3.85) in district Mardan contained the highest diversity of honeybee plants. Following the monsoon season, *Acacia* species coexisted with many other honeybee plant species that were less common in the region. *Acacia* species were the most abundant (62%) honeybee plant species in this area. Eight samples of honey were tested, and the Shannon-Weaver diversity index revealed a high diversity of plant species, with values ranging from 1.28 at the Jalala site to 3.85 at the Gulmaira site. The study site location in one of the highest biodiversity zones known for its high plant diversity accounts for the richness of these bee forages. The diversity index values for 16 honey samples were lower, ranging from 0.05 in the Swabi site to 0.56 in the Umarzai site district of Charsadda. This suggests that the sparse distribution of bee forages for various purposes held responsible for low diversity of honeybee plants. The Pielou index (F) and Shannon Weaver pollen diversity index (H) results showed that the resources of PG in honey were used both heterogeneously and uniformly from the sources of pollen types that were abundant (Table 2 & 3).

3.3.2 Quantitative Melissopalynological Analysis

The absolute count of PGs in the honeys revealed that 58.33% (n = 14); ; *Acacia* honey (AHN = 18×10^3, AHS = 15×10^3, AHT = 11×10^3,AHGu = 12×10^3, AHH = 7×10^3), *Eucalyptus* honey (EHJ = 18×10^3, EHG = 18×10^3, EHU = 15×10^3, EHS = 12×10^3) and *Ziziphus* honey (ZHN = 11×10^3, ZHK = 11×10^3, ZHT = 16×10^3, ZHG = 15×10^3, ZHU = 19×10^3) were categorizedMaurizio class I (Table 4). Whereas 25% ($n = 6$) of honeysinvestigated: *Acacia* honey (AHM = 21×10^3), *Eucalyptus* honey (EHK = 22×10^3), and *Ziziphus* honey (ZHM = 23×10^3, ZHSw = 22×10^3, ZHP = 22×10^3, ZHZ = 21×10^3) were belong to Maurizio class II. Whereas16.66% ($n = 4$) *Acacia* (AHL = 235×10^3, AHG = 235×10^3, AHZ = 238×10^3) and *Ziziphus* (ZHS = 265×10^3) were Maurizio class III as shown in Table 5.

Table 3. Qualitative Melissopalynological analysis of honey collected from different botanical, seasonal, and geographical origins in KPK.

Plant species	Family	EHS-16 (%)	AHH-19 (%)	ZHM-24 (%)	ZHK-8 (%)	ZHSw-22 (%)	ZHS-11 (%)	ZHG-1 (%)	ZHU-4 (%)	ZHP-15 (%)	ZHZ-17 (%)	AHZ-20 (%)	AHM-18 (%)
Acacia spp.	Fabaceae	11	13	4	24	18	4	21	8	12	21	51	54
Anagallis arvensis	Primulaceae	1	2	1	_	_	1	_	1	2	_	_	1
Bidens spp.	Asteraceae	_	1		1	2	1	1	_	_	2	1	3
Callistemon citrinus	Myrtaceae	9	11	2	_	2	9	7	_-	1		1	2
Centaurium pulchellum	Gentianaceae	2	1	_	_	_	_	1	_	_	_	_	1
Cleome spp.	Cleomaceae		_	_	_	_	_	_	_	1	1	2	_
Coriandrum sativum	Apiaceae	2	1	2	1	2	2	_	4	_	1	_	2
Brassica campestris	Brassicaceae	_	1	1	6	_	2	1	3	_	_	1	_
Dalbergia spp.	Fabaceae	1	_	_	1	1	_	5	_	2	_	2	1
Datura spp.	Solanaceae	1	1	1	1	1	1	_	2	_	2	_	2
Eucalyptus spp.	Myrtaceae	13	5	8	5	4	15	5	8	3	6	6	2
Tripleurospermum caucasicum	Asteraceae	2	_	_	_	1	_	2	1	2	_	_	_
Eruca sativa	Brassicaceae	2	1	12	10	1	2	6	1	1	1	1	2
Foeniculum vulgare	Apiaceae	_	14	3	2	1	-	-	8	2	-	_	1
Helianthus annuus	Asteraceae	_	_	1	3	10	4	16	3	1	-	4	7
Lantana camara	Verbenaceae	-	-	_	_	_	_	-	1	_	_	_	_
Lepidium didymum	Brassicaceae	1	_	1	2	1	_	-	_	2	_	1	_
Malus domestica	Rosaceae	7	3	3	_	1	_	-	1	_	1	_	_
Nicotiana tabacum	Asteraceae	_	2	_	1	2	1	5	_	_	6	_	2
Ligustrum lucidium	Oleaceae	1	2	3	_	1		_	1	2	_	1	1
Parthenium hysterophorus	Asteraceae	2	_	1	1	_	_	2	_	_	_	1	_
Pennisetum glaucum	Poaceae	1	1	_	_	1	-	_	1	_	_	_	_

Psidium guava	Myrtaceae	_	2	_	1	_	2	1	1	_	1	_	1
Silybum marianum	Asteraceae	7	4	2	2	6	2	_	_	6	2	1	6
Solanum spp.	Solanaceae	1	_	_	_	-	1	_	4	_	_	3	_
Trifolium spp.	Fabaceae	4	13	4	2	_	2	2	2	_	2		2
Zea mays	Poaceae	3	3	1	1	4	1	2	1	_	_	1	_
Ziziphus spp.	Rhamnaceae	29	22	50	32	40	49	23	51	62	54	22	8
Unknown	Unknown	_	_	_	2	_	_	_	_	_	_	1	2
Total number of pollen grain found		333	213	654	345	643	765	432	564	645	631	686	630
Total number of pollen types		20	19	18	19	19	17	16	19	14	12	17	19
Number of unknown pollen types		-	-	-	-	-	-	-	-	-	-	1	1
Unknown pollen frequency (%)			_	_	2	_	_	_	_	_	_	1	2
No. of plant families in each sample		11	12	11	9	11	9	7	13	8	9	10	9
H		0.42	0.26	0.33	0.29	0.05	0.33	0.35	0.5	0.1	0.3	3.29	2.93
F		0.14	0.08	0.11	0.09	0.01	0.11	0.12	0.1	0.0	0.1	1.16	0.99

Keywords: EHS = *Eucalyptus* Honey Serdhari, AHH = *Acacia* Honey Hathian, ZHM = *Ziziphus* Honey Mardan, ZHK = *Ziziphus* Honey Karnal Sher Kili, ZHSw = *Ziziphus* Honey Swabi, ZHS = *Ziziphus* Honey Shahmansoor, ZHG = *Ziziphus* Honey Gulabad, ZHU = *Ziziphus* Honey Umarzai, ZHP = *Ziziphus* Honey Pabbi, ZHZ = *Ziziphus* Honey Ziarat Kaka Shahib, AHZ = *Acacia* Honey Ziarat Kaka Shahib, AHM = *Acacia* Honey Muqam , H = Shannon–Weaver diversity index, F = Evenness

Table 4. Qualitative Melissopalynological analyses of honey collected from different botanical, seasonal, and geographical origins in KPK.

Plant species	Family	AHL-13 (%)	EHJ-5 (%)	ZHN-2 (%)	AHN-7 (%)	AHS-10 (%)	AHG-19 (%)	AHT-21 (%)	AHGu-12 (%)	EHK-6 (%)	ZHT-3 (%)	EHG-9 (%)	EHU-14 (%)
Acacia spp.	Fabaceae	24	35	41	60	51	55	33	62	7	12	17	23
Anagallis arvensis	Primulaceae	1	_	_	2	1	_	1	_	_	_	1	_
Bidens spp.	Asteraceae	3	1	3	_	_	1	_	1	1	1	_	1
Callistemon citrinus	Myrtaceae	2	6	_	2	-_	_-	5	-_	6	_	1	_
Centaurium pulchellum	Gentianaceae	1	_	1	_	2	_	1	1	1	_	_	_
Cleome spp.	Cleomaceae	_	_	-	1	_	1	1	_	_	_	_	1
Coriandrum sativum	Apiaceae	2	2	3	5	2	5	_	2	1	1	1	1
Brassica campestris	Brassicaceae	_	2	_	_	1	_	2	1	1	_	6	12
Dalbergia spp.	Fabaceae	1	_	1	_	1	4	_	_	1	1	_	1
Datura spp.	Solanaceae	2	_	3	1	2	_	3	1	1	1	1	_
Eucalyptus spp.	Myrtaceae	2	7	3	3	8	3	7	2	50	51	50	20
Tripleurospermum caucasicum	Asteraceae	_	1	_	2	_	1	_	2	1	1	1	-
Eruca sativa	Brassicaceae	2	6	1	4	_	1	2	3	_	2	2	7
Foeniculum vulgare	Apiaceae	2	2	6	_	1	2	1	_	1	1	1	3
Helianthus annuus	Asteraceae	6	5	1	4	7	3	2	1	3	2	2	2
Lantana camara	Verbenaceae	_	_	1	_	_	1	_	_	1	1	_	_
Lepidium didymum	Brassicaceae	_	_	1	2	1	2	1	2	2	2	1	_
Malus domestica	Rosaceae	_	_	3	1	_	_	1	_	3	6	_	_
Nicotiana tabacum	Asteraceae	2	_	2	_	1	1	1	2	3	1	_	1
Ligustrum lucidium	Oleaceae	1	1	_	1	1	1	5	_	2	3	1	_
Parthenium hysterophorus	Asteraceae	_	1	1	_	2	1	_	2	_	_	1	1
Pennisetum glaucum	Poaceae	_	1	_	1	1	_	1	_	1	1	1	_
Psidium guava	Myrtaceae	1	_	_	1	1	_	1	1	1	1	_	1
Silybum marianum	Asteraceae	4	13	1	2	_	5	11	2	2	1	1	2
Solanum spp.	Solanaceae	_	_	2	2	5	1	2	1	1	_	1	1
Trifolium spp.	Fabaceae	2	2	_	1	1	1	1	6	2	1	7	1
Zea mays	Poaceae	_	2	_	_	1	1	3	5	2	3	_	6

Ziziphus spp.	Rhamnaceae	10	13	6	5	10	13	23	4	6	8	6%	20
Unknown	Unknown	2	_	_	_	_	_	2	_	_	1	_	_
Total number of pollen grain found		677	543	321	546	432	734	330	332	632	448	234	453
Total number of pollen types		19	18	18	19	20	20	23	19	24	22	19	18
Number of unknown pollen types		1	-	-	-	-	-	1	-	-	1	-	-
Unknown pollen frequency (%)		2	_	_	_	_	_	2	_	_	1	_	_
No. of plant families		14	9	11	12	12	13	13	9	13	10	11	10
H		0.29	1.28	1.86	3.61	2.38	2.78	0.51	3.85	0.35	0.33	0.1	0.3
F		0.09	0.44	0.64	2.84	1.83	2.13	0.37	1.3	0.25	0.1	0.03	0.1

Keywords: AHL = *Acacia* Honey Lundkhawar, EHJ = *Eucalyptus* Honey Jalala, ZHN= *Ziziphus* Honey Nowshera, AHN = *Acacia* Honey Nowshera,, AHS = *Acacia* Honey Shahmansoor, AHG = *Acacia* Honey Gadoon, AHT = *Acacia* Honey Topi, AHGu = *Acacia* Honey Gulmaira, EHK = *Eucalyptus* Honey Katlang, ZHT = *Ziziphus* Honey Takkar, EHG = *Eucalyptus* Honey Gulabad, EHU = *Eucalyptus* Honey Umarzai, Shannon–Weaver diversity index, F = Evenness

Table 5. Quantitative Melissopalynological analyses of different investigated honeys collected from different seasonal, botanical, and geographical origins in KPK.

Honey sample	APC/10 g honey	Maurizio's classes	Botanical source (Pollen species)
AHL-13	235×10^3	III	*Acacia spp. (24%), Ziziphus spp. (20%) Helianthus annuus (20%), Silybum marianum (10%)*
EHJ-5	18×10^3	I	*Acacia spp. (35%) Ziziphus spp. (13%) Silybum marianum (13%) Eucalyptus spp (7%) Callistemon citrinus (6%)*
ZHN-2	11×10^3	I	*Acacia spp. (41%) Foeniculum vulgare (11%) Ziziphus spp. (21%)*
AHN-7	18×10^3	I	*Acacia spp. (60%) Coriandrum sativum (5%) Ziziphus spp. (5%) Helianthus annuus (4%) Eruca sativa (4%)*
AHS-10	15×10^3	I	*Acacia spp. (51%) Eucalyptus spp. (8%) Ziziphus spp. (10%) Eucalyptus spp. (8%) Helianthus annuus (7%)*
AHG-19	255×10^3	III	*Acacia spp. (55%) Ziziphus spp. (13%), Silybum marianum (5%) Coriandrum sativum (5%)*
AHT-21	11×10^3	I	*Ziziphus spp. (17%) Acacia spp. (33%) Silybum marianum (10%) Eucalyptus spp. (6%) Ligustrum lucidium (3%)*
AHGu-12	12×10^3	I	*Acacia spp. (62%) Trifolium spp. (6%) Zea mays (5%) Ziziphus spp. (4%)*
EHK-6	22×10^3	II	*Eucalyptus spp. (50%) Acacia spp. (7%) Callistemon citrinus (6%) Ziziphus spp. (6%)*
ZHT-13	16×10^3	I	*Eucalyptus spp. (52%) Acacia spp. (12%) Ziziphus spp. (8%) Malus domestica (6%)*
EHG-9	8×10^3	I	*Eucalyptus spp. (50%) Acacia spp. (17%) Trifolium spp. (7%) Ziziphus spp. (6%) Brassica campestris. (6%)*
EHU-14	15×10^3	I	*Ziziphus spp. (20%) Eucalyptus spp. (20%) Acacia spp. (19%) Brassica campestris (12%) Eruca sativa (7%)*
EHS-16	12×10^3	I	*Ziziphus spp. (29%) Eucalyptus spp. (13%) Acacia spp. (11%) Silybum marianum (7%) Malus domestica (7%)*

AHH-19	7×10^3	I	*Ziziphus spp.* (22%) *Foeniculum vulgare* (14%) *Acacia spp.* (13%) *Callistemon citrinus* (11%)
ZHM-24	23×10^3	II	*Ziziphus spp.* (50%) *Eruca sativa* (12%) *Eucalyptus spp.* (8%)
ZHK-8	11×10^3	I	*Ziziphus spp.* (32%) *Acacia spp.* (24%) *Eruca sativa* (10%) *Brassica campestris* (6%)
ZHSw-22	22×10^3	II	*Ziziphus spp.* (40%) *Acacia spp.* (18%) *Helianthus annuus* (10%) *Silybum marianum* (6%)
ZHS-11	265×10^3	III	*Ziziphus spp* (49%) *Eucalyptus spp.* (15%) *Callistemon citrinus* (9%)
ZHG-1	15×10^3	I	*Ziziphus spp.* (23%) *Acacia spp.* (21%) *Helianthus annuus* (16%) *Callistemon citrinus* (7%) *Eruca sativa* (6%)
ZHU-4	19×10^3	I	*Ziziphus spp.* (51%) *Eucalyptus spp.* (8%) *Foeniculum vulgare* (8%)
ZHP-15	22×10^3	II	*Ziziphus spp.* (62%) *Acacia spp.* (12%) *Silybum marianum* (6%)
ZHZ-17	21×10^3	II	*Ziziphus spp.* (54%) *Acacia spp.* (21%) *Eucalyptus spp.* (6%) *Nicotiana tabacum* (6%)
AHZ-20	238×10^3	III	*Acacia spp.* (51%) *Ziziphus spp.* (22%) *Eucalyptus spp.* (6%)
AHM-18	21×10^3	II	*Acacia spp.* (54%) *Ziziphus spp.* (8%) *Silybum marianum* (6%)

Keywords: EHS = *Eucalyptus* Honey Serdhari, AHH = *Acacia* Honey Hathian, ZHM = *Ziziphus* Honey Mardan, ZHK = *Ziziphus* Honey Karnal Sher Kili, ZHSw = *Ziziphus* Honey Swabi, ZHS = *Ziziphus* Honey Shahmansoor, ZHG = *Ziziphus* Honey Gulabad, ZHU = *Ziziphus* Honey Umarzai, ZHP = *Ziziphus* Honey Pabbi, ZHZ = *Ziziphus* Honey Ziarat Kaka Shahib, AHZ = *Acacia* Honey Ziarat Kaka Shahib, AHM = *Acacia* Honey Muqam, AHL = *Acacia* Honey Lundkhawar, EHJ = *Eucalyptus* Honey Jalala, ZHN= *Ziziphus* Honey Nowshera, AHN = *Acacia* Honey Nowshera,, AHS = *Acacia* Honey Shahmansoor, AHG = *Acacia* Honey Gadoon, AHT = *Acacia* Honey Topi, AHGu = *Acacia* Honey Gulmaira, EHK = *Eucalyptus* Honey Katlang, ZHT = *Ziziphus* Honey Takkar, EHG = *Eucalyptus* Honey Gulabad, EHU = *Eucalyptus* Honey Umarzai, APC = Average Pollen Count

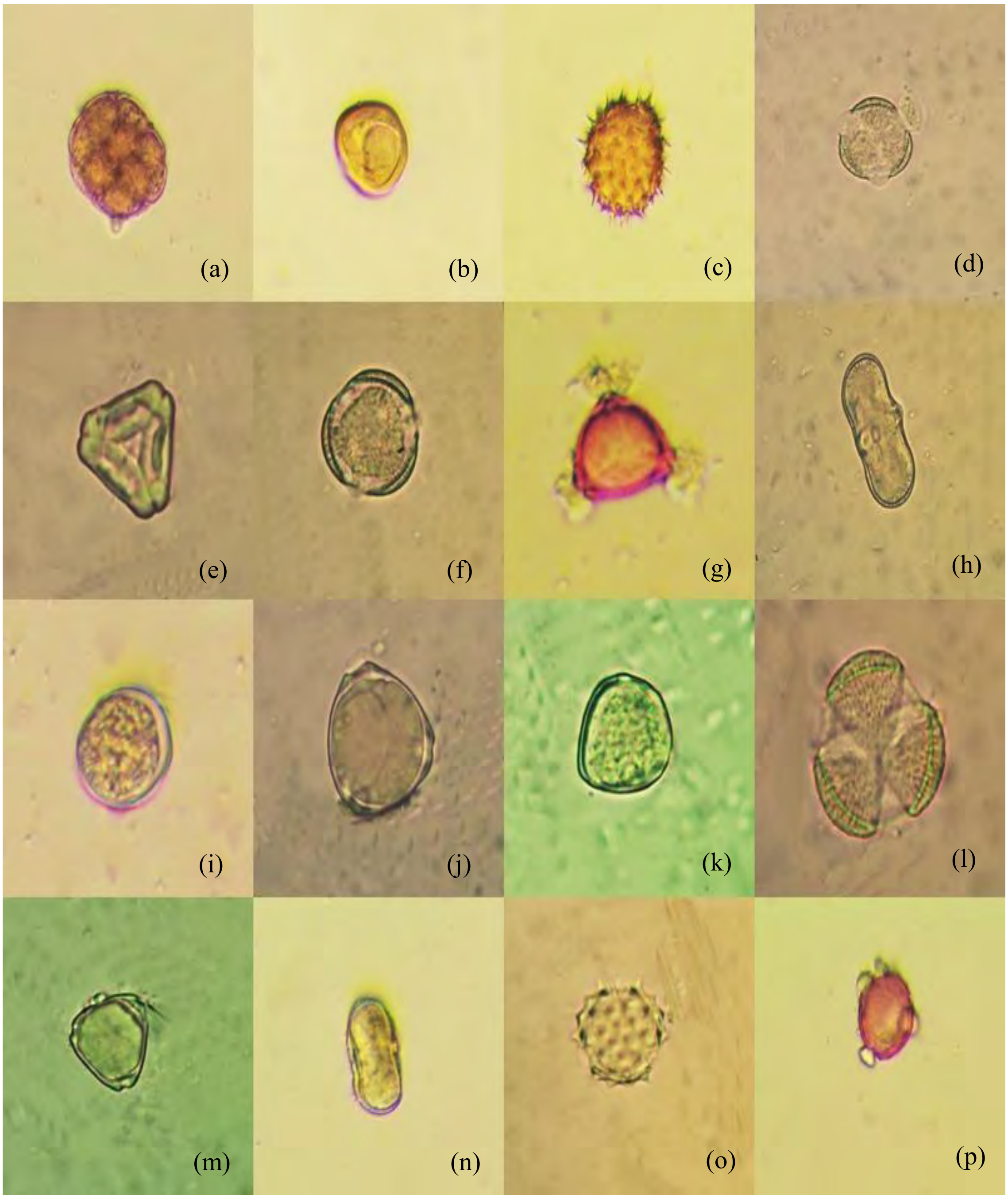

Plate 129. Photomicrographs of selected types of pollen grains from natural honey collected from different botanical and geographical origins in KPK during 2020. (a) *Acacia nilotica*, (b) *Anagalis arvensis* (c) *Biden pilosa* (d) *Brassica spp.,* (e) *Callistemon citrinus* (f) *Centaurium pulchellum* (g) *Cleome viscosa* (h) *Coriandrum sativum* (i) *Cymbopogon jwarancusa* (j) *Dalbergia sissoo* (k) *Datura spp.* (l) *Eruca sativa* (m) *Eucalyptus spp.* (n) *Foencilum vulgare* (o) *Helianthus annuus* (p) *Lantana camara*

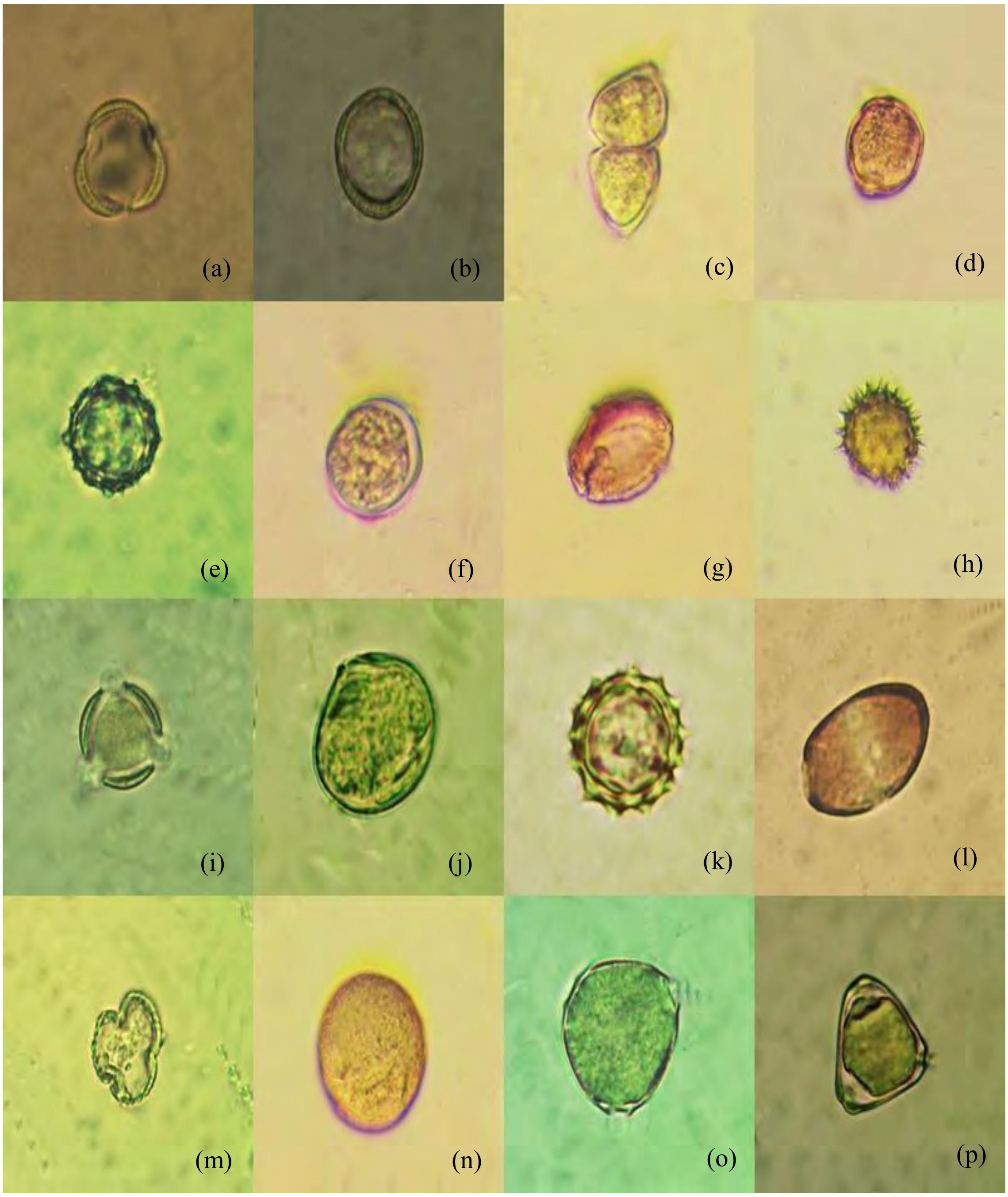

Plate 130. Photomicrographs of selected types of pollen grains from natural honey collected from different botanical and geographical origins in KPK during 2020. (a) *Lepidium spp.* (b) *Ligustium lucidium* (c) *Malus spp.* (d) *Nicotinia tabacum* (e) *Parthenium hysterophorus* (f) *Pennistum spp.* (g) *Psidium guava* (h) *Silybum marianum* (i) *Solanum spp.* (j) *Trifolium spp.* (k) *Tripleurospermum caucasicum* (l) Unknown *spp.* (m) Unknown *spp.* (n) *Zea mays* (o) *Ziziphus jujuba* (p) *Ziziphus oxyphylla*

Chapter 4
Discussion

4. Discussion

4.1 Honeybee Pollen flora

The results described in the present study demonstrate observations of bee foraging activity on various flora and the subsequent analysis of the pollen from these flowers in Khyber Pakhtunkhwa has provided a new resource for beekeepers and honey analysts. Bee pollen flora analysis by microscopy has provided in-depth descriptions of the pollen grains as well as average measurements of significant morphological characters. Thus, the contribution of this work, including the description of melliferous species highly visited by honeybees, is of great use with respect to honey production in the studied region. Nevertheless, the studied polliniferous species could be identified based on visual observation of honeybee foraging behavior.

Knowledge of the diversity of honeybee flora is essential for the identification of areas favorable for beekeeping. We were able to identify high-value bee species over a period of three months by direct and periodic monitoring of apiaries in various locations around KPK. The melliferous flora constituted by studied taxons identified as dominant shows that the pollen from these species' spectra implies their availability in the nearby vegetation around apiaries. The selected plants, being the most available and visible, attract honeybees and can be characterized quite well by the botanical and geographical origin of this honey. This work also provides useful information for a better understanding of KPK bee flora and the types of honey production.

During fieldwork, honeybees were frequently observed visiting plant species. Melissopalynology mainly contributes to the understanding of the relationships that exist between honeybees and plant pollen (Louveaux et al., 1970). Knowing about a region's honeybee flora might help beekeepers find authentic botanical sources for the production of honey food products. Honeybee floral diversity provides information that might aid in the successful management of beekeeping, allowing this profitable enterprise to expand and maximize honey exports to industrialized countries (Bhalchandra et al., 2014). One of the characteristics that honeybees use to select plants for foraging is pollen morphological ultrastructure. The shape, size, and aperture types, fastigium, mesocolpium, exine peculiarities, and pollen diameter, are correlated with the pollination mechanism (Fluri et al., 2001). Bee floral diversity has an advantage over other plant species in a region because of their high annual production rate and greater chances of their survival (Ahmad et al., 2019). Honey production is also very efficient when cutting-edge technology is used to determine the purity and adulteration of honey (Ahmad et al., 2020).

Direct field observation, as well as monitoring and counting bees in flowers, can be used to identify plants visited by forager bees. Beehive pollen is also collected to validate the botanical origin of pollen deposits (Braga et al., 2012). The key to understanding the relationship between diet and forage in pollinators is quantitative pollen identification. Pollen traps, are designed to extract pollen grains from the legs of forager bees entering the hive. The direct observation of bees feeding on plants in the wild, have traditionally been used to monitor bee foraging behavior (Donkersley et al., 2017).

Kaul (2012) also studied pollen fertility and sterility for breeding value evaluation in higher plant species. Pollen fertility is a beneficial tool to determine the percentage of the fertility of a plants growing in an unfavorable condition. The high percentage of pollen fertility indicates that honeybee flora is very stable in that area. Research work identifies the flora based on pollen morphology and fertility for further distribution. Herbaceous honeybee flora was recently evaluated for pollen fertility and sterility in Southern Khyber Pakhtunkhwa (Ullah et al., 2021). Sterility and fertility percentages of pollen in the families Asteraceae, Cactaceae, Poaceae, and Cucurbitaceae have also been reported previously (Chaubal et al., 2000; Asmat et al., 2011; Ahmad et al., 2013; Nazish et al., 2019; Majeed et al., 2020). The bees could presumably at least partly compensate for the lack of fertile pollen by buzzing around the flowers. The sparse pollen was presumably more effectively transferred to the stigma, enhancing fertilization and seed set (Siede et al., 2021).

The overall results of the honeybee pollen floral species are quite similar to the previously conducted palynological studies, with some differences. Both quantitative and qualitative characters observed through light and scanning electron microscopy revealed important information that helps in identifying the bee pollen flora using melissopalynological techniques. The botanical plant pollen that comprise the honey can be determined through pollen analysis. The honey purity, floral regions, and flowering season of bee plants, as well as their value as pollen and nectar supplies, can be estimated by comparing the pollen morphological characteristics of botanical sources and honey constitution (Ahmad et al., 2019). The dominance of Asteraceous, Fabaceous, and Poaceous honeybee flora is consistent with the findings of Zoratti et al., (1995), who discovered that the above-mentioned families contain a large number of bee foraging species. According to González-Suárez et al., (2020), the Asteraceae and Fabaceae provide the most floral resources and are the most often used by bees. Ahmad et al., (2019) have listed Poaceae being the largest number of melliferous plants. Fabaceae and Asteraceae were identified as the major floral sources by Modro et al., (2007). Martinez et al., (2019) research also identified trees as the most abundant habit of melliferous plants.

4.1.1 Asteraceous Bee flora

According to earlier records honeybee pollen collection around apiaries sites from various parts of the world, explored Asteraceous family is among the most frequently visited. This is not surprising given that Asteraceae, the family of sunflowers and thistles, with over 23,000 species, is the largest plant family worldwide (Telleria et al., 2019). The palyno-morphological characters analyzed here can be potentially used to correctly identify the Asteraceous honeybee flora most commonly visited by honeybees in the study area. The dominance of the Asteraceae family and a few pollen types in most samples of honey led us to consider that this trend could be due to the foraging behavior of *Apis mellifera* (Ahmad et al., 2022).

Azzazi (2017) examined trizonocolporate, spheroidal, echinate with long colpus pollen in *A. squamatus*. SEM images showed the exine with echino-lophate perforate sculpture in *A. squamatus* is not in accordance with previous work (Plate 15d,e). Salamah et al., (2019) defined *B. pilosa* pollen as having a spheroidal shape with an echinate surface sculpture, which contradicts our findings. In another study by Mabel et al., (2014), the pollen of *B. pilosa* appears somewhat dissimilar, having oblate-spheroidal, polypantoporate, exine spinate, and spines with blunt ends. According to earlier findings by Mohamed and Mathew (2020), the pollen of *B. pilosa* shows dissimilarity to having a tetracolporate aperture type.

Akbar and Mir (2006) reported that grains of *C. arvensis* has semi-angular, tetrazonocolporate, and non-lacunate features. However, Khan et al., (2020) considered pollen of *C. arvensis* to have some difference in the exine sculpturing was verrucate-gemmate. Besides, the present findings are consistent with Zafar et al., (2007), who reported tetracolporate, rectangular, circular, and per-prolate pollen. Whereas Nouroozi et al., (2012) described sub-oblate, micro perforate/rounded spine pollen characters in *C. arvensis*. Qureshi et al., (2019) showed similar findings with respect to prolate-spheroidal shape and echinate sculpturing (Plate 17d,e). *Carthamus oxycantha* pollen differed slightly from the observations of Bulbul et al., (2013), in that there are similarities between taxa but differences in size, shape, and spine length. Osman (2009) noticed a minor difference in *Carthamus* species, including oblate to prolate-spheroidal and trizonocolporate, sexine tectate, imperforate, reticulate to psilate sculpture. While the previous research by Qureshi et al. (2019) found a slight dissimilarity to the current study, which found that *C. oxyacantha* shape is sub-prolate (Plate 18b,c).

The current study findings coincide with previous work by Joujeh et al. (2019), examined the medium-sized, scabrate ornamented, prolate-spheroidal *C. iberica* grains, which can be explained by the fact that these features are genetic. While this study also detailed that grains of *C. iberica* with the highest diameter, pore width, and spine length was measured. Multiple ecological conditions may be the cause of the variation in pollen size (Hesse et al., 2009). Blackmore (1984) explained 15 lacunae patterns in *Cichorium intybus* with the polar area having some central spines. These results were slightly different from the observations of Qureshi et al., (2019), who found sub-prolate and echinate grains in *C. intybus.*

Maryam (2012) compared this study and discovered that the pollen grains of *C. arvense* are sub-oblate, micro-perforate, and rounded spine shaped. Nouroozi et al., (2012) also analyzed the pollen of *C. arvense*, describing them as isopolar, trizonocolporate, radially symmetrical, oblate-spheroidal to spheroidal, micro-reticulated/micro-perforated echinate ornamentation and with pointed spine tips. Hesse et al., (2009), Jafari and Ghanbarian (2007), and Yilidiz et al., (2011) demonstrate spheroidal, spherical, and sub-prolate or prolate-spheroidal shapes in the equatorial view, respectively. Meo (2005) elaborates on the circular to semi-angular shape in the polar view. Our data on *C. arvense* describes shape variation, with aperture orientation classified as bulged and reticulated echino-perforated sculpture (Plate 21d,e). Mesfin et al., (1995) earlier described the SEM morphology of *Coreopsis tinctoria* grains as radially symmetrical, spheroidal, isopolar, tricolporate, and echinate, which is consistent with our findings. Whereas Singh and Mall (2017) described the pantoporate shape, we found it different from our outcomes.

Recently, findings by Sadeq and Aliwy (2019) showed a major difference in pollen features of *E. canadensis* with a narrowly oblong shape, smooth sculpture, and straight thick wall. However, Qureshi et al., (2019) elaborate on dissimilarity in pollen shape, which appears to have an oblate spheroidal. Singh and Mall, (2017) presented the slight differences in *Gazania reigns* having pollen spherical in shape and showing different hexagonal structures. Ali et al., (2020) recently identified distinct features in *G. rigens*, including echino-lophate, spheroidal, sub-prolate, and monoporate grains.

Qureshi et al., (2019) analyzed the *H. annuus* pollen as prolate-spheroidal and echinate. Ali et al., (2020) studied the pollen of *H. annuus*, classifying them as tricolpate, isopolar, echinate, and prolate-spheroidal, which also in accordance with the present findings (Plate 25d,e). Monad, 3-colpate, prolate-spheroidal, conical pointed spines, and echinate exine were reported previously by Ullah et al., (2021). We observed the same pollen characters for this species regarding the type and number of apertures; however, exine stratification was defined here as echino-perforate. Mabel et al., (2014) earlier observation on the member of the same genus; *Launaea taraxacifolia* pollen as acolpate, prolate-spheroidal, and medium sized; spines small, short with sharp ends; pores sparsely situated, and 3 in number; dissimilar to our current findings in *L. procumbens* (Plate 26b,c,d & e).

In *P. hysterophorus* pollen findings were compared to Rajurkar's (2020), found some differences in shape (oblate-spheroidal, triangular spine outline, and acute ends spines. Previous studies have shown that *P. hysterophorus* pollen are isopolar, trizonocolporate, radially symmetrical, sub-spheroidal, non lacunate, and echinate spinulose (Basarkar, 2017; Meo and Khan, 2005). *P. hysterophorus* pollen morphology shows tectate with echinate sexine, echini with conical bases, and spine bases gradually tapering toward tips (Noor and Ahmad, 2021). According to Zafar et al., (2007), *P. hysterophorus* pollen were tricolporate, echinate and circular to semi-angular. Al-Saadi et al., (2012) reported prolate-spheroidal pollen in *S. marianum*. While previously, Osman (2009) described pointed colpi, echinate and perforate sculpture grains. Sadeq and Aliwy (2019) evaluated prolate, trizonocolporate, long narrow colpi and spinuose pollen in *S. marianum*.

The same observations were made by Ahmad et al., (2019) with regard to pollen shape and sculpturing, but they examined broad and conical echini features in *S. asper*. However Karna (2017) described hexagonal, hexaporate, and echinate hexahedral pollen of *S. asper*, which was not in line with our findings (Plate 29b,c,d & e). Mazari et al., (2012) outlined the morpho-palynology of *S. asper* and showed spheroidal, prolate, and rectangular and tri-to tetracoloporate pollen. Previously, Karna (2017) elaborated on *T. campylodes* grains with pentagonal, polyporate, echinate, and pentahedral features, which were dissimilar to our findings. Zafar et al., (2007) have reported hexacolporate, circular to semi-angular pollen. In a study by Janyerkye et al., (2014), they mentioned pollen wall echinate and exine coated circular in studied taxa. A previous study showed sub-prolate and echinate grains in *T. officinale* (Qureshi et al., 2019).

The pollen morphology of *V. encelioides* corresponds to the investigation of Ullah et al., (2021), who also described prolate-spheroidal pollen with conical pointed spines. Previous studies on *Verbesina* have shown that pollen grain shape can vary from oblate-spheroidal to prolate-spheroidal, medium-sized, isopolar, monads, and sub-triangular amb, as was reported by Moreira et al., (2019), who analyzed eight Brazilian species of *Verbesina*. Considering the new species, *Verbesina barrancae* by Harker and Reyes (2002) from Mexico described echinate, tricolporate grains with a small polar area. Yu-Lan et al., (2013) discovered that pollen in *Youngia* has highly divergent micromorphological features and that *Y. japonica* pollen has large and pentagonal oblate-spheroidal, echino-lophate, and paraporal lacunae. Whereas the earliest observations of Wang et al., (2009) outlined *Youngia spp.* explained pollen characters; oblate spheroidal, tricolporate, echino-lophate, and paraporal large and pentagonal lacunae, each ectocolpus is divided into three lacunae, connected by narrow inter-lacunar gaps (Plate 33d,e).

4.1.2 Fabaceous Bee flora

Fabaceae is also a large family and is represented by a number of species in the study area. They were used as a pollen source by the honey bee foragers (Bilisik et al., 2008). Fabaceae also contributed the maximum number of species to floral diversity for the foraging of the Asiatic Honeybee (Hemalatha et al., 2018). Honeybees, visiting species of Fabaceae, may act both as pollinators and potential competitors with native pollinators, suggesting varying levels of ecological specialization (Konarska 2020; Scaccabarozzi et al., 2020). The location of the apiaries and the mode of nectar production in the flowers follow the same location and structural pattern. The characteristics of the nectaries in Fabaceous species can be a significant taxonomic trait for accurate identification of honeybee floral plants.

From a taxonomic viewpoint, palyno-morphological features play a critical role in the classification and identification of Fabaceous species in the current study. In this study, *A. modesta* was noted to have been regulated to fossulate exine ornamentation (Plate 34d,e) in accordance with the findings of Khan et al., (2021). Attique et al., (2022) interpreted pollen of *A. modesta* as having a polar diameter of 38.6 µm, possessing no pores and colpi. We analyzed the pollen of *A. modesta* as polyads of medium size, having a polar diameter of 41 µm and an exine 10.6 µm thick and a P/E ratio of 1.07.

The present research shows the polyad pollen of sub-spheroidal shapes and rugulate exine sculpture were found in *A. nilotica* (Plate 35d,e). However, the investigation of the same species by Khan et al., (2019) shows dissimilarities to our observations in pollen shape and ornamentation. The previous research findings of Begum and Mandal (2016) noticed 16-celled polyads, oblate-spheroidal, and psilate grains in *A. nilotica* that show dissimilarity to the current study. In *D. sisso*, triangular, small grains, tricolpate, triporate, isopolar, radially symmetric, and psilate tectum were recorded (Plate 36b,c,d & e) that were slightly dissimilar to Jamwal (2021). Raj and Reddy (2019) also analyzed the *D. sisso* grains as euprolate, trizonoporate, and psilate, which was in accordance with our findings.

Zhao et al., (2016) noticed the perforated tectum architecture of apocolpium and mesocolpium in *I. heterantha* that shows dissimilarity to our findings. The earlier study examined monoporate, tricolpate, and polyporate with psilate, foveolate, and echinate exine surface grains in *Indigofera* species (Nwachukwu and Edeoga, 2006). However, this study described micro-reticulate type sculptured elements (Plate 37d,e). The previous research findings of Khan et al., (2019) noticed triangular, sub-prolate to prolate, radially symmetrical, and reticulate to faintly regulate sculpture patterns in *Medicago* species that were not in accordance with current findings. In another study by Bano et al., (2018) examined reticulate type exine in *Medicago falcata* whereas our research explained the regulate-striate type sculptured patterns analyzed in *Medicago minima* (Plate 38d,e).

Khan et al., (2019) examined *Melilotus indicus* pollen were structurally prolate, radially symmetrical, triangular in polar view, sub-prolate, isopolar, trizonocolporate with micro-reticulate ornamentation that contradicts our present findings. Previous work by Gazar (2003) described the semi-circular polar view, elongated elliptical equatorial shape, and foveolate-fossulate ornamented grains in *Medicago indicus.* In our case, micro-reticulate-foveolate type peculiarities were observed (Plate 39d,e). Ahmad et al., (2019) give a general idea of the LM pollen morphological parameters in *P. juliflora* (monad sub-oblate and tricolporate) similar to our findings, whereas Khan et al., (2020) described SEM high-resolution structural details of granular colpus and foveolate grains in *P. juliflora*.

Chanda et al., (2019) analyzed the phenology of *Sesbania* species grains as tricolporate, prolate, and exine sculpture reticulate. While this research demonstrates psilate ornamented and bulged aperture grains (Plate 41d,e). Morphological studies of legumes, including *Sesbania* species, revealed the presence of euprolate, trizonocolporate, and psilate to micro-reticulate grains (Raj and Reddy 2019) was accordance with our description. Our observations indicate that pollen morphology of *T. montana* revealed tricolporate, bulged aperture orientation, and scabrate reticulate grains (Plate 42b,c,d & e) while earlier descriptions by Sinjhusin et al., (2018) of another species, *T. turcica* reported spheroidal, circular, 3-colporate with psilate margo, and exine of the micro-reticulate pattern.

Honey contained pollen grains of *Trifolium alexandrinum*, which indicated the wide geographical distribution of appropriate plants for use by bees (El-Sofany et al., 2020). Lashin (2006) previously examined pollen of *T. alexandrinum* described colpus with tapering ends, exine micro-reticulate, and semi-tectate while this study analyzed perforate-reticulate sculpture and showed dissimilarity (Plate 43d,e). Khan et al., (2019) SEM observation on *T. alexandrinum* pollen was revealed per-prolate, reticulate, triangular polar view and elliptic equatorial view grains. *Trifolium* species were explored with tricolporate type, and showed two pollen shapes, prolate and sub-prolate, according to the equatorial dimensional view (Uslu and Babaç, 2019) while our findings analyzed oblate-spheroidal and perforate-reticulate grains in *Trifolium tomentosum* (Plate 44b,c,d & e).

4.1.3 Amaranthaceous Bee flora

This study was undertaken to document Amaranthaceous honeybee floral species using melissopalynology of honey samples and field observation. This research aimed to identify Amaranthaceous honey bee flora, their blooming seasons, frequency, and beekeeping potential.

The pollen of the Amaranthaceae family was mostly uniform in morphological features, which confirms its stenopalynous condition. According to Hussain et al., (2018) the pollen of *Achyranthes aspera* is small with a large number of pores, which is corroborated by our results. Recently, Saensouk and Saensouk (2022) explained that exine sculpturing is smooth with sparsely distributed granulates in *A. aspera*. While our visualization shows micro-echinate perforate sculptured elements (Plate 45d,e). The morphological studies by Sopaladawan et al., (2019) provide strong support for the pollen for *Amaranthus viridis*, which describes the grains as prolate to spheroidal in shape with radial symmetry and periporate type similar to our observation. While Gasma et al., (2020) briefly visualized scabrate type ornamentation, it shows dissimilarity with current findings that reveal micro-echinate perforate ornamentation (Plate 47d,e).

Zhigila et al., (2014) reported that pollen types and ornamentation of *A. spinosus* grains differed, ranging from dicolpate to monolete and micro-rugulate psilate. According to Nazish et al., (2019), examined grains of *C. album* had mostly similar spheroidal, sunken, pantoporate, and scabrate micro-echinate. Sahin and Pinar (2020) discovered operculum type aperture and scabrate semi-tectate sculpture in *C. album*. The findings of this study contradict those of Bayoumy et al., (2020), who discovered a layer of granulate-punctate exine surface in *Celosia cristata*. However, the scabrate-verrucate sculpture pattern was examined in our study (Plate 49d,e). Hussain et al., (2018) also apprehended the same type of ornamentation for *D. muricata.*

4.1.4 Solanaceous Bee flora

This study was conducted to determine the honeybee pollen preferences among the available floral diversity in Solanaceous species. In the laboratory, different pollen sources of Solanaceae were identified which were collected by *A. mellifera* during the flowering season. In our study, reticulate-regulate pattern elements of surface exine were examined in *D. innoxia* (Plate 50d,e), whereas El-Ghmaery et al., (2018) explained irregular striate type sculpture pattern, while Hassan and Amer (2019) elaborated on regulate-reticulate exine in *Datura stramonium*. Perveen and Qaiser (2007) provided detailed features such as tectum striate at mesocolpium with perforations, ornamentation coarsely reticulate-rugulate showing dissimilarity with our findings. Adedeji and Akinniyi (2015) investigate that *Nicotiana tabacum* is the only species with tetracolpate pollen grains, which marks a recent evolutionary development. However, tricolpate grains with regulated perforate sculpture were visualized in the current findings (Plate 52b,c,d & e). *N. tabacum* has 3-colporate pollen, consistent with the observation of Song et al., (2018) that the aperture of Solanaceous species is mainly tricolporate.

According to Ashfaq et al., (2020) and Prabhakar and Ramakrishna (2014) *P. minima* grains were prolate-spheroidal, triangular, trizonocolporate, colpi narrowly elliptic, and exine sculptured psilate and micro-echinate. While in our case, exine with micro-echinate scabrate (Plate 53d,e) is somewhat similar to previous work. Ashfaq et al., (2020) recently provided detailed descriptions of *S. melongena* pollen; triangular, tricolporate and scabrate perforate exine ornamentation *S. melongena* exhibits bulged aperture orientation and exine, scabrate gemmate in the current study (Plate 54d,e). Another study by Kumar et al., (2015) found that *S. melongena* pollen is trizonocolporate, ridges are absent, and exine ornamentation is mammilate micro-echinate, which is consistent with our findings

A palynological study in *Solanum* species by Lashin (2012) found significant differences in pollen shape and sculpture pattern in *S. nigrum* described as prolate spheroidal and micro-reticulate echinate. While another study by Chaurasia (2018) examined trizono-colporate to tetra-zonocolporate, angulaperturate, and granulose exine in *S. nigrum* shows dissimilarity to our study. Similarly, Ashfaq et al., (2020) also characterized scabrate to psilate stratification wall in *S. surattense* in accordance with our study. According to Perveen and Qaiser (2007), they observed scabrate type tectum and sub-psilate end actue ectoaperture in *S. surattense*.

4.1.5 Brassicaceous Bee flora

The aim of this study was to identify and document the Brassicaceous honeybee flora, as well as their phenology and pollen potential. The relevance of *Brassica* honey plants as nectar and pollen sources, as well as their life form, possible methods of propagation, and potential for honey production, could be emphasized (Wubie et al., 2014).

In a study by Basarker (2017), the pollen of *B. campestris* were small, tricolporate, and reticulate sculpture, which was similar to our findings. Another study by Yang et al., (2018) studied sub-spheroidal, trilobate, circular, tricolpate, slender, and long colpi with reticulate sculpture in *B. campestris* and found it slightly dissimilar to current findings. Amina et al., (2020) recently described *Capsella bursa-pastoris* polllen characters as having a spheroidal to prolate shape, which has micro-reticulate sculpturing, which was similar to the outcome of our research. In a study by Sagun and Auer (2017), they examined micro-reticulate, heterobrochate type surfaced pollen in *C. bursa-pastoris.*

This study was conducted to evaluate the difference in pollinator diversity around *Eruca sativa* and their relative abundance (Shakeel et al., 2021). Arora and Modi (2011) previously explained sub-oblate to prolate, tricolpate, and reticulated pollen in *E. sativa* whereas the present study showed the prolate-spheroidal shape and scabrate ornamentation under optical microscope. Pollen grains from *E. sativa* previously showed prolate, reticulate ornamentation, and irregular lumina (Gabr, 2018). Recent work by Umber et al., (2022) mentioned 3-zonocolpate, sub-oblate, and reticulated grains. However, this research study described lobate, oblate-spheroidal, and psilate-reticulate sculptured elements (Plate 59b,c,d & e).

In *Lepidium didymum* monad, circular, tricolpate, polygonal lumina, and reticulated sculpture were observed by Gabr (2018) and Zafar et al., (2019), which are consistent with our results. The palynology of *L. didymum* described by Umber et al., (2022) illustrates prolate, reticulate while pollen was identified with minute reticulate type sculpture features, although current study attributes of *L. didymum* show pollen outline with an oblate-spheroidal shape and a reticulate nature exine surface (Plate 60b,c,d & e). Amina et al. (2020) explained that *Sisymbrium irio* pollen were spheroidal and reticulate in sculpture. Syncolpate acute end with thicker sexine surface was observed in *S. irio*, according to Khan et al., (2005). Azzazy (2011) also detailed the palyno-morphs character with semi-tectate exine and micro-reticulate sculpture type pattern results according to current findings (Plate 61b,c,d & e). .

4.1.6 Lamiaceous Bee flora

We also assessed the importance of the pollen micromorphology among Lamiaceous honeybee pollen for bees and other insects by an investigation of the spectrum of insect visitors (Jachuła et al., 2018). The diversity of Lamiaceous nectariferous bee flora was observed for the presence and foraging activities of honeybees around Lamiaceous flowers (Bhalchandra et al., 2014).

Perveen and Qaiser (2004) elaborate pollen morphology of the family Labiate from Pakistan; they placed the Lammiaceous taxa based on aperture type, exine sculpturing, and shape of grains. Pollen are oblate-spheroidal to sub-oblate in shape, 6 colpate or 6 zonocolpate, exine sculpturing is finely to coarsely reticulate, and colpus is not sunken, according to their findings.

The micro-reticulate exine wall pattern interpreted in *M. longifolia* (Plate 64d,e). was compared to a few previously published data. Celenk et al., (2008) described only reticulate-type grains in *M. longifolia*. Our analysis signifies the micro-reticulate sculptured elements in *M. arvensis* (Plate 63d,e). Azzazy (2016) examined bi-reticulate sculpture grains in *M. spicata*, whereas current findings revealed semi-tectate reticulate ornamented pollen sculpture elements (Plate 65d,e). Zafar et al., (2007) examined smooth surfaced lobate pollen in *V. negundo*, whereas previous work by Qureshi et al., (2019) also show the importance of SEM as explaining reticulate ornamentation was not according to our regulate-perforate stratification exine wall (Plate 66d,e).

4.1.7 Malvaceous Bee flora

Malvaceous honeybee pollen resources determination and their collection from hives around apiary sites provide a piece of information on bee pollen foraging plants of primary importance (Abhivivek, 2021). The Malvaceae family provides the majority of bee plants, and their identification and registration as honeybee flora in various agro-ecological zones for honey production potential allows beekeepers to determine management practices (Onyango et al., 2019).

The spinule, large, pantoporate, and sub psilate pollen were found in *Abelmoschus esculentus* recently by Saensouk and Saensouk (2021). However, Bibi et al. (2010) described micro-reticulate punctate ornamentation found dissimilar to our observation, revealing echinate ornamented grains (Plate 67d,e). Shaheen et al., (2010) explained in *Alcea rosea* globose and pantoporate type pollen, that the surface pattern of the tectum varies from micro-reticulate to punctate (El Naggar et al., 2008), which was not according to our findings that described echinate pattern grains (Plate 68d,e). Earlier research by Mandal et al., (2013) found wide and asymmetrical colpus and a polygonal lumen shape in *Corchorus olitorius*. While this pollen analysis revealed fastigiate and reticulate pollen (Plate 69d,e). El-Husseini (2006) found a dissimilar surface of exine, i.e., reticulate perforate. According to Maity et al., (2009), incurved colpi margins were detected in *C. olitorius*.

The study of Bibi et al., (2008) on pollen morphological description of *H. rosa-sinensis* described spherical to globose finely reticulated tectum pollen with a 4.6 µm thickness of exine. We examined variations from present findings, which elucidate an exine thickness value of 1.75 µm and prolate-spheroidal shape and echinate sculpture features (Plate 70d,e). Previously, Cheema (2018) investigated the pollen morphology of *M. coromandelianum*, which was described as reticulate, inaperturate, and oblate-spheroidal with large spines. Shaheen et al., (2018) elucidated prolate-spheroidal, echinate, and estimated 65% pollen fertility. Although our study explained prolate-spheroidal, very large, echinate, and pantoporate pollen (Plate 71b,c,d & e).

4.1.8 Poaceous Bee flora

Exine ornamentation was observed psilate (Plate 72d,e), but this result deviates from Ullah et al. (2021a) who recently described scabrate-rugulate type sculpture in *C. jwarancusa*. Ullah et al. (2021b) also examined the reticulate type of exine sculpturing in *C. jwarancusa* shows dissimilarity with our study. Perveen (2006) findings explained the areolate cum scabrate, annulate, and operculate grains in

Pennisetum spp. The study by Neha and Kalkar (2010) described areolate to scabrate type ornamentation in wild and cultivated varieties of *P. glaucum* while our findings examined granulate sculpture elements (Plate 73d,e). Shaheen et al., (2011) showed prolate-spheroidal and angular types of pollen in *S. viridis*, whereas some differences were noted in this study such as oval-shaped scabrate grains (Plate 74b,c,d & e). Morgado et al., (2015), previously explained *Setaria* species are different in the definition of ornamentation as regulated micro-echinate to areolate micro-echinate, whereas, in the species analyzed here, ornamentation ranged from psilate to scabrate. An earlier study by Yang et al., (2018) attempted to elaborate ovoid, large and with psilate wrinkled exine thickness in *Z. mays* showed a discrepancy which can be easily explained by the small size and reticulated type surface (Plate 75b,c,d & e).

4.1.9 Verbenaceae Bee flora

Morphology of *L. camara* pollen revealed angulaperture exine sculpture type, prolate to oblate-spheroidal, and psilate to perforate pollen are in accordance with this study (Shaheen et al., 2018). Sharma and Bhat (2015) examined in *Citharexylum* quadrangular granular pitted surface with a medium exine pattern while this study revealed macro-reticulate psilate ornamented grains in *Citharexylum spinosum* (Plate 76d,e). Perveen and Qaiser (2007) analyzed *V. officinalis* pollen type as tectum striate-rugulate, which was not accordance with the present findings as psilate-perforate sculptured pattern (Plate 79d,e).

4.1.10 Apiaceae Bee flora

Avila et al., (2016) looked at *C. sativum* pollen corroborates with a similar per-prolate shape but a very different micro-reticulate ornamentation. However, according to Alam et al., (2020), a minute difference in shape was observed as sub-prolate. While Mallick (2019) reported a multiporate aperture pattern and an interacted exine wall, which was not according to the present study. Shubharani (2019) studied a similar report to our study. Seema et al., (2019) identified bi-colporate, per-prolate, and striate types of grains in *F. vulgare*, which opposed our findings. Puleku et al., (2018) examined granulate to rugulate exine with smooth furrows. However, this study focuses on the verructae scabrate type of exine in *F. vulgare* (Plate 84d,e). Our findings on the pollen morphotypes in *T. leptophylla* were similar to those of Perveen and Qaiser

(2006) described the per-prolate, striate-regulated tectum sculpture type and not the sunken ecto-colpus with irregular small margin pollen in *T. leptophylla*.

4.1.11 Acanthaceous Bee flora

Our results showed that the pollen of *B. cristata* was oblate-spheroidal with lopho-reticulate sculpturing(Plate 80b,c,d & e), while the earlier research of Shendage and Yadav (2010) showed reticulate pollen peculiarities. Acantharean distinctly eurypalynous is recognized for its pollen diversity and variation in pollen morphology is so striking that studies of pollen grains have been mandatory for descriptions of new species (Silva et al., 2017). In the previous study of Al-Hakimi et al., (2017), they also observed the prolate pollen shape in almost all species of the *Justicieae* and *Dicliptera,* whereas in polar views, trigonal and oblong shapes in *Dicliptera* and *Justicieae* genus were observed, respectively. The exine sculpturing results from SEM show that almost all species have a more or less reticulate surface. Abhivivek et al., (2021) describe bilateral symmetrical pollen in *D. bupleuroides*, and Zahoor et al., (2019) define a reticulate type sculptured pattern. Unlike *J. adhatoda* trizonicolporate micro-pitted surfaced grains found dissimilar to this study demonstrates finely reticulate stratification (Plate 82d,e).

4.1.12 Euphorbiaceous Bee flora

In the case of *C. tinctoria,* the previous findings of Perveen and Qaiser, (2005) showed that oblate-spheroidal pollen of large size was observed with coarsely reticulate ornamentation having a value of exine thickness of 1.44 µm. Our research results are in agreement with the earlier work in the case of *C. tinctoria* pollen size, shape, and type, while sculpturing is reticulate heterobrochate (Plate 86d,e) and exine thickness is 2.25 µm slightly deviated from prior work. *Euphorbia hirta* grains with a finely reticulated surface (Plate 88d,e) were illustrated and compared to sculpture fine reticulation examined by Paul et al., (2014). Basarkar (2017) examined tricolpate, reticulate usually with long exine finely reticulation grains. In *E. helioscopia*, the findings of Najmaddin (2020) show the prolate-spheroidal pollen has reticulate tectum sculpture and the noted exine thickness was 2.75 µm. The current study looked at reticulated grains with sunken apertures were the same as earlier work (Plate 87b,c,d & e).

4.1.13 Myrtaceae Bee flora

Our results of pollen morphology in *C. citrinus* were not in accordance with earlier findings of Thornhill et al., (2012), who indicated that *C. citrinus* shows grains were tricolporate to teracolporate with a rugulate exine. Pollen sides were concave, convex, and colpal morphology was parasyncolpate. While another study by Chahuhan et al., (2017) described pollen in *C. citrinus* as triangular, para-syncolpate, tricolpate, and with psilate and scabrate surfaces, our findings were somehow similar to them. In a study by Sekina and Moore (1995), *Eucalyptus camaldulensis* pollen was synocolpate, triangular with granulate sculpturing, whereas our results show dissimilarity with respect to psilate exine sculpturing and scabrate-reticulate mesocolpium (Plate 90d,e). Whereas tricorporate, oblate, and spinulose-granulose tectum ornamented pollen clearly distinguishes itself from current findings in which verructae gemmate sculpturing was investigated. *P. guajava* also with same characteristics of grains were examined which present great similarity in pollen morphology with our findings.

4.1.14 Convolvulaceous Bee flora

The current study focused on *Convolvulus arvensis* pollen, which has a sub-prolate slightly circular shape with sparsely perforated sculpture (Plate 92b,c,d & e). Whereas Oztürk et al., (2018) previously stated that *C. arvensis* tricolpate pollen has a sub-oblate spheroidal shape with a perforate tectum and micro-echinate perforate sculpture. While our results were in conflict with those of Ashfaq et al., (2018) and Sufyan et al., (2018), pollen of *C. arvensis* was found to be scabrate, psilate, and prolate with 6.25 µm exine thickness. In contrast to previous studies by Ashfaq et al., (2018), which identified sub-spheroidal grains shape and dissimilar echinate scabrate psilate and perforate ornamentation, our evidence showed that the pollen of *I. purpurea* is prolate-spheroidal with echinate perforate sculpture (Plate 93b,c,d & e).

4.1.15 Cucurbitaceae Bee flora

Cucumis melo was evaluated for reticulate scabrate exine features and prolate spheroidal grains (Plate 94b,c,d & e), which differed from earlier studies by Akhtar et al., (2019) and Perveen and Qaiser (2008). According to Levi et al., (2010), *C. melo* pollen grains have a triangular tricolpate shape and a smooth surface. Previous studies suggested that the pollen morphology of *Luffa* was spheroidal, trilobate, circular tricolporate, colpi slim sexine around pores slightly thickened, sculpture finely reticulate to striate-reticulate hetero-brochate (Tin et al., 2020; Yang et al., 2018), so while our study showed that the pollen of *L. acutangula* examined psilate to perforate pollen wall (Plate 95d,e).

4.1.16 Lythraceae Bee flora

Punica granatum pollen ornamentation were linked with the observed verrucate type (Yang et al., 2015), while in our case regulated-verrucate type exine was examined (Plate 97d,e). In contrast to the observations made by Liu et al., (2008), who recognized rugulate to verrucate and verrucae psilate ornamentation, sub-prolate, and attenuate apices of colpi in *Lagerstroemia cathayensis* pollen. However, our results revealed differences with scabrate verrucate type sculpture character in grains of the *L. indica* (Plate 96d,e).

4.1.17 Rhamnaceae Bee flora

Perveen and Qaiser (2005) found sharp endpoints with tectum striate ornamentations in *Ziziphus oxyphylla* pollen morphotypes, which contradicts our work here revealed papillate-regulate sculpture using SEM tool (Plate 99d,e). In relation to taxonomic relevance, Dinesh et al., (219) revealed pollen biology of jujube (*Z. jujuba*) with prolate-spheroidal striate and regulate pattern exine. However, the current study shows that the palyno-morphs of *Z. jujuba* differ from exine sculpturing in having a reticulate stratification (Plate 98d,e).

4.1.18 Rosaceous Bee flora

According to Mallick (2019), the exine wall of *R. indica* is round, spheroidal, polyporate, medium large, and rough. While the nectar sources of *R. indica* visited by *Apis mellifera* were oval, pointed, glandular, bilaterally symmetrical, and prolate (Khan et al., 2021). In the present study, attributes of *R. indica* show pollen with a slightly circular outline with striate ornamentation (Plate 101d,e). Nazeri (2008) showed that *Malus domestica* grains were long, unbranched, tricolpate, and striate exine sculptured. Our analysis showed *M. domestica* grains are small, tricolpate, and prolate-spheroidal (Plate 100b,c,d & e).

4.1.19 Rutaceae Bee flora

The research findings of Al-Anbari et al., (2015) illustrate that *C. limon* grains were macro-reticulate, perforate, and prolate, which disagreed with our description showing tetracolporate grains in *C. limon* (Plate 102b). The results of our study demonstrate the prolate-spheroidal pollen having macro-reticulate peculiarities of exine in *C. sinensis* (Plate 103d,e), while the findings of Inyama et al., (2015) explain why elliptic pollen has striate ornamentation. The tectate perforate exine sculptural traits that Taia et al., (2020) noticed were distinct from those in our study.

4.1.20 Zygophyllaceous Bee flora

Fagonia indica long narrow ectocolpi with a reticulate-foveolate surface was examined (Perveen and Qaiser, 2006), although our research analyzed reticulate exine with acute end aperture grains in *F. indica* (Plate 104d,e). Linn (2020) looked at medium-sized circular, periporate, thick sexine, sculpture-patterned retipilate, and heterobrochate lumina in *Tribulus terrestris*. Praglowski (1987) explained that *Tribulus* sexine was thicker than nexine and fibrillar with small globular elements and reticulate type ornamentation (Semerdjieva et al., 2011). Our examination of pollen sculpture appearance was also reticulated, similar to previous work (Plate 105d,e).

4.1.21 Melliferous Bee flora

In this section, we characterize the morpho-palynology of 23 melliferous species, each of which belongs to a different botanical family. This information will allow researchers to recognize unifloral and multifloral honey as well as to determine the honey's geographic origin. Pollen features were analyzed using light and scanning electron microscopy to describe their pollen ultrastructure.

Khan et al., (2021) reported on *Anagallis arvensis* but only described tricolporate pollen type via optical microscopy. Recently Shiha (2020) illustrated micro-reticulate features of exine that show dissimilarity with our findings. Perveen and Qaiser (2001) elaborate oblate-spheroidal, pantoporate, circular sunken, granulate pores, and spinulose tectum in *Boerhavia procumbens* was somewhat similar to our observation, which is echinate-reticulate (Plate 107d,e). While Singh and Dixit (2018) observed echinate rough surface tectum. The earlier findings of Tütüncü et al., (2007) stated that in *C. radicans* pollen of spheroidal shape with semi-tectate baculate ornamentation having average exine thickness of 0.8 µm. Our outcome elaborate reticulate lobate grains (Plate 108d,e) explains Bignoniaceae as a eurypalynous family, and it allows the accurate identification of micromorphology shared by Bignoniaceous species (de Souza et al., 201).

Sufyan et al., (2018) earlier examined scabrate to psilate surface sculpture in *C. sativa* are not in agreement with our findings. Whereas Quamar et al., (2017) analyzed 3-porate, sub-spheroidal, thicker sexine, and obscure surface patterns. *Centaurium pulchellum* grains were described as trizonocolporate, radially symmetric, oblate-spheroidal to sub-prolate, and iso-polar by Rao and Chinnapa (1983). Colpi was narrow or broad, relatively long, and tapered at the ends. The sexine was thicker than the nexine, tectate, striate-reticulate or striate, while our findings show a striate-regulated sculpture feature (Plate 110d,e). The *C. viscosa* grains were tricolporate, with a prolate-spheroidal shape and reticulated surface (Plate 111d,e). In contrast to previous studies by Mir et al., (2019), which revealed that *C. viscosa* pollen had a prolate shape and reticulate ornamentation.

Our demonstration stated that the pollen of *Commelina benghalensis* was elliptic, monosulcate with spinulose-baculoid sculpturing (Plate 112d,e), which was found to be dissimilar from Salamma et al., (2019), in which micro-echinate ornamentation was visualized. Maw et al., (2020) explained inaperturate grains with baculite sculptured pollen in *Commelina benghalensis.* Ahmad et al., (2019) described psilate ornamented pollen in *Hamelia patens*, and our study found a dissimilarity with a foveolate perforate exine peculiarities (Plate 113d,e). Subharani et al., (2013) also observed exine psilate and radial symmetry pollen in *Hamelia patens*. Wen and Wang (2012) classified *Ligustrum lucidum* grains as tricolporate, spheroidal, with exine consisting of two layers, sexine and nexine. Whereas our current study classified them as prolate-spheroidal, sunken colpus, and reticulate ornamented (Plate 114d,e).

Pollen of *M. indica* was elliptic, mostly reticulated, and iso-polar, with an oval to elliptical shape (Muniraja et al., 2020). Micromorphological characterization of *M. indica* revealed colporate, prolate, striate-reticulate, and bilaterally symmetrical grains (Shubharani et al., 2013). Exine sculpture reported scabrate verrucate in this research (Plate 115d,e), which contradicted previous studies. *Martyina annua* monocolpate grains were reported as having clavate sculptured and netted tectum grains (Singh and

Dixit, 2018). In another study by Singh et al., (2017) to determine the pollen resources of *Martyina* species, larger rounded radial symmetric grains were revealed in *M. annua*. While this study elaborates on perforate reticulated ornamentation (Plate 116d,e). Maw et al., (2020) used light microscopy to describe pollen grains in *Melia azedarach* as monad, tetracolporate, prolate, round, longicolpate, sexine thicker than nexine, and with micro-reticulate sculptured surface. Our data coincides with the authors' description of the pollen unit, but they differ in terms of the kind and number of apertures and exine ornamentation, which we classify as verrucate-scabrate under SEM (Plate 117d,e).

In a study by Maw et al., (2020), psilate sculpture grains were observed in *N. oleander* while Mallick (2020) described smooth pollen while our results described scabrate-psilate exine stratification (Plate 118d,e). Bose et al., (2012) also explained grains in *N. oleander* as trizonoporate and scabrate sculpturing. Mallick (2020) examined *Oenothera rosea* pollen and described it as concave, triangular, medium-sized, and with spiniferous exine; our findings, however, identified a verrucate-scabrate feature in the SEM (Plate 119d,e). The *Opuntia dillenii* has prolate spheroidal, large-sized, and pantoporate grains, as this study also demonstrated (Plate 120b,c). In contrast, earlier studies by Silvina Garralla and Cuadrado, (2007) claimed that the pollen grains in the genus *Opuntia* had a spherical shape. In line with earlier studies by Khan et al., (2020), we investigated the reticulate sculpting pattern in *Oxalis corniculata*. In accordance with past literature by Khan et al., (2020) the reticulate sculpting pattern in *Oxalis corniculata*. Rosenfeldt and Galati (2007) analyzed the morpho-palynological features of *Oxalis* species that are 3-colpate, triangular, and micro-reticulate.

P. somniferum grains were recently described by Ozkök and Sorkun (2016) as oblate-spheroidal, tricolpate, with traits of micro-echinate sculpture, and exine thickness (1.00 µm). *P. somniferum* pollen was described by Singh and Mall (2017) as prolate spherical with tiny spiky sculpturing. In comparison, the current findings revealed round, oblate-spheroidal, and scabrate verrucate pollen (Plate 122b,c,d & e) with a measured exine thickness of 1.55 µm. The pollen morphological description of *Peganum hermala* by Lu et al., (2018) characterized spheroidal, reticulate decorated pollen, which contrasts with the current study, which elucidates sub-oblate and regulates perforate grains (Plate 123b,c,d & e). Semerdjieva and Yankova-Tsvetkova (2017) found pollen features in *Peganum harmala*; apocolpium area multilayered, cuticular deposition, reticulate and heterobrochate. While in our study, dissimilarities were observed in reticulate scabrate exine peculiarities.

El-Naga et al., (2014) defined sparsely punctate ornamented grains in *T. portulacastrum* while this study described dissimilar foveolate punctate pollen (Plate 124d,e). Previously, Perveen and Qaiser (2000) examined in *T. triquetra* sparsely punctate tectate grains. Linn et al., (2020) stated that tricolporate, longicolpate aperture, and exine obscurely reticulate in *Trichodesma indicum* contradicted this study elaborate spinose surface peculiarities (Plate 125d,e). Pollen morphotypes in two species of *Tropaeolum* were iso-polar, 3-colporate, and aspects of the pollen surface were micro-reticulate (Al-Mashhadani et al., 2018). Whereas nectariferous bee pollen of *Tropaeloum majus* reveals reticulate heterobrochate sculpture (Plate 126d,e).

Asmat et al., (2011) previously explained the semi-angular, prolate, and psilate ornamentations on *Verbascum thapsus* pollen, while the micro-reticulate sculpture was identified in this study (Plate 127d,e). Pollen of *Viola tricolor* was oblate-spheroidal, large, stephano colporate, and micro-verrucate with inconspicuous perforations (Shrestha et al., 2005). Pollen features such as size, shape, sculpturing, diameters, apertures, and exine thickness vary, each of which contribute to the identification of melliferous species (Paudayal and Gautam, 2011). Thus, this study contributes to the conservation of honeybee flora by providing a better understanding of pollen morphological variation using multiple microscopic techniques, which aids in species delimitation up to lower taxonomic rank.

Knowledge of a regional pollen flora is a useful factor for apiculture development as well as quality control of bee pollen as a nutritional feed. Microscopic study of pollen morphometric traits and measures can be used to determine botanical identity (Layek et al., 2019). Honeybees may need to feed on a variety of plant species in order to obtain all of their vital nutrients from pollen (Colwell et al., 2017). This study demonstrated the value of both quantitative and qualitative morphometric characteristics of bee pollen in describing micro-morphological variation around apiaries. Additional details are included in regarding honeybee foraging behavior throughout the year and their function as pollinators in the study area.

4.2 Honey Analysis (Melissopalynology)

Photomicrographs and correct identification of honey's botanical and geographical identity were demonstrated in our study. The results indicated that pollen from trees largely dominated (73%). The abundance of different pollen types suggested that the studied sites contained a diversity of flora. Honey pollen content is influenced by a number of variables, including the amount of pollen produced by the plant that was visited, the climate, the pollen's diameter, how the pollen is filtered in the honey sac by the bee, and the method used to collect the sample (Battesti and Goeury, 1992).

Honeybees regularly collect a wide range of PGs, but they tend to focus on a few species (Ferreira et al., 2009). This is the first study of its kind to describe the results of melissopalynology of various kinds of honey produced in KPK. Furthermore, pollen retrieved from the honey tested offered crucial information on the flora required for bees to produce honey in KPK. Moreover, it has the ability to serve as a justification for a substantial action (proper labeling; authenticity requirements) in beekeeping sector.

Melissopalynological investigations indicate that the PGs discovered in multiple kinds of honey come from a variety of botanical sources, including farmed crops, garden plants, and wild plants. Observations made during this study were consistent with results of (Khan et al., 2022) employed pollen count during recent study in Southern Khyber Pakhtunkhwa, which revealed pollen grains analysis identified 39 melliferous plant species. The variety of grains found in honey samples indicated that the bee flora in this region is made up of plants with varying flowering periods, and this information is crucial for the production of honey in this region. In another research, (Mangi et al., 2021) pollen analysis of 16 honey samples from Sindh regions revealed 65 botanical sources belonging to 24 plant families from which bees collected pollen. The melissopalynological data represented by (Mangi et al., 2018) of natural honey analysis from Dadu district Sindh identified 25 plant species belonging to 18 different families indicate the richness of bee flora as a suitable source of pollen or nectar for honeybees.

In total of 24 honey samples studied includes the dominant families that is Fabaceae, Myrtaceae and Rhamnaceae, Asteraceae, Brassicaceae and Poaceae with considerable number of PGs in samples indicating that honeybees frequently visited plants for honey production. The production of honey depends on plants from these families, particularly *Acacia* species. 85.5% of the samples examined contained *Acacia* pollen, with Mardan *Ziziphus* (ZHM) honey having the lowest relative frequency (only 4%) and *Acacia* honey from Gulmaira (AHGu) having the highest relative frequency (62%). These data are in agreement with the results of (Cencetti et al., 2019) who found that Fabaceae was one of the most represented taxa in randomly collected 12 honey samples from Burkina Faso found PGs of *Acacia* type pollen was present in five of the 12 samples. In this regards, (El-Nebir et al., 2013) previously showed that the majority of PGs discovered in honey (43.3%) were gathered from plants of the Fabaceae family, with *Aacia nilotica* predominating the pollen spectrum (Layek and Karmakar, 2018) revealed that major nectariferous pollen types belonging to Fabaceae (81.3%) mainly of *Acacia auriculiformis* and *Acacia nilotica*.

A useful melissopalynological metric for the Myrtaceae is morphotype diversity, which can be used even in the absence of complete knowledge of the pollen morphology of the many component genera (Sniderman et al., 2018). Even if the major collected honey samples are mostly from *Eucalyptus*, palynological criteria devised for identifying *Eucalyptus* honey may not give an adequate basis for assessing the origin or authenticity of honeys. The diversity of Myrtaceae morphotypes may also separate *Eucalyptus* spp. dominated honeys from Manuka (*Leptospermum*) honeys produced (Butz Huryn, 1995).

One of the unifloral honeys derived from the Myrtaceae family, which includes the species of *Eucalyptus* that were purposely introduced into that region. The following species are the most prevalent: *Eucalyptus globulus* and *Eucalyptus camaldulensis.* In many regions where various species are widely planted, the importance of *Eucalyptus* as a source of honey is well recognized (Simeão et al., 2015). According to the current findings, *Eucalyptus* spp. was registered as the main pollen in three samples; nonetheless, its bee forages significance compares to the honey from the KPK region, where it frequently predominant. *Eucalyptus* honeys are regarded as some of the best honeys and are highly desirable from the perspective of the consumer. Therefore, the honeys collected in KPK zones were *Eucalyptus* monofloral honey.

Based on the pollen morphology of the six most significant *Ziziphus* species representing five genera of the Rhamnaceae, five different pollen types, including *Ziziphus mauritiana* and *Ziziphus oxyphylla* types were identified (Perveen and Qaiser, 2005). *Ziziphus* trees are primarily grown in the mountainous Pakistani province of Khyber Pakhtunkhwa (KPK), which also has a favorable environment for the growth of floral biodiversity. The physiochemical properties of honey are determined by the natural variability of pollen contents, which in turn depends on the native floral habitat (Ali et al., 2020). Considering the 24 individual samples, *Ziziphus spp.* appears as the dominant pollen type as an average 53.2% in five samples, which were classified as monofloral. Whereas *Hovenia dulcis* (Rhamnaceae) was found in 40% of the Santa Helena honey samples, according to Moraes et al., (2019), and this pollen type was present in 95% of the samples from Southern Brazil.

Honey analysis of the *Ziziphus* honey samples from *Apis mellifera* demonstrated that the pollen grains of *Ziziphus* spp. (33.10 %) were the major pollen in honey samples (Taha and Al-Kahtani, 2020). In a different research, PGs with the same botanical sources were discovered in honey from *Ziziphus* (Taha et al., 2018). The pollen spectrum of Algerian honey revealed mean value of *Ziziphus* lotus pollen was 70.9% was the principal plant species for honey production (Zerrouk et al., 2014). According to our findings, *Ziziphus* honey produced were are found naturally and planted in different vegetation belts in the KPK, is preferred by the majority of citizens in the KPK and Asian countries.

Conclusion & Recommendations

5. Conclusion

The present project was carried out the melissopalynological investigation of the bee flora from diverse phytogeographic regions of Khyber Pakhtunkhwa. The honey analysis technique devised is a significant tool for the investigation of the botanical and geographical source and adulteration detection. In this study, 114 bee floral species belonging to 43 plant families and their pollen types occurring most prevalently near the apiaries have been observed via microscopic techniques. Asteraceae was the most dominating family having a maximum no. of species (19) followed by Fabaceae (11), Amaranthaceae, and Solanaceae (six species each). Melisso-palynomorphs features of 19 honeybee Asteraceous species belonging to 8 different tribes were provided. Bee pollinators mostly attract flowers with shallower nectar reserves of Asteraceous species. The occurrence of echinate pollen having lacunas features sculpturing of fenestrated perforate nature. This study also authenticate 24 honey samples using ultrafiltration protocol to describe the pollen spectrum of dominant vegetation. Honey analysis revealed pollen extraction of 24 bee foraging species verified the identities nectar sources. Pollen identified using honey ultrafiltration process revealed dominant resources of *Acacia spp.* (69%) and *Eucalyptus spp.* (52%). Scanning ultrasculpturing showed diverse exine patterns: reticulate, psilate, scabrate-verrucate, scabrate-gemmate, granulate, perforate, microechinate, microreticulate, and regulate to fossulate for correct identification of honey pollen types. This study helps the beekeepers to recognize the knowledge and importance of the wild, cultivated, and ornamental honeybee floral species which may help to provide good opportunities for the beekeepers that successfully manage the beekeeping business and produce the best quality of honey. It is recommended that future studies continue to explore organic honey to establish a better understanding of the role of melissopalynology to authenticate using modern analytical techniques.

6. Future Recommendations

The proposed project will become the stepping stone for goal-oriented research in the field of Melissopalynology, honey production, and quality. It will be based on the following recommendations.

- New avenues will open for the application of modern analyzing techniques to check honey quality to attain international trade standards.
- Provide a database for beekeepers to identify the best floristic region for beekeeping to increase honey production.
- Advance molecular, chromatographic, and spectroscopic methodologies will be used for the identification of the botanical and geographical origin of honey.
- This study will serve as a reference to prepare a bee pollen atlas of bee flora.
- Country economy will boost by earning through honey export generating valuable foreign exchange

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Thesis Outcomes

Publications

List of Publications

S. No.	Paper title	Year	Impact Factor
1.	Nabila., Ahmad, M., Ali, M., Zafar, M., Sultana, S., Majeed, S., Yaseen, G. and Ahmad, S., 2021. Palynological diversity of Melliferous flora around apiaries from district Mardan Khyber Pakhtunkhwa-Pakistan. The Botanical Review, 1-34.	2021	4.56
2.	Nabila., Ahmad, M., Zafar, M., Bahadur, S., Sultana, S., Taj, S., Celep, F. and Majeed, S., 2021. Palyno-morphological diversity among the Asteraceous honeybee flora: An aid to the correct taxonomic identification using multiple microscopic techniques. Microscopy Research and Technique, 85(2), 570-590.	2022	2.89

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REVIEW

Palynological Diversity of Melliferous flora around Apiaries from District Mardan Khyber Pakhtunkhwa-Pakistan

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Abstract

The guiding principles for raising beekeeping products in developing countries provide support for commercializing honey production in order to generate income for beekeepers through the exploration of melliferous flora. The main objective of this study was to conduct a preliminary investigation into the pollen morphology of selected melliferous species that are frequently visited by honeybees in the vicinity of apiaries in the district of Mardan, Khyber Pakhtunkhwa. In this study, an updated overview was provided by reviewing the literature regarding palynological investigation of melliferous flora. The morpho-palynological features, dominant plant families visited by honeybees, and life forms of melliferous species were also discussed. The Acetolysis method was used to prepare the microscopic slides of pollen, measure and describe the qualitative and quantitative features using LM and SEM. Results showed maximum pollen polar and equatorial diameter in *M. azadirachta* (37.9 μm) and (40.9 μm) respectively. The polar to equatorial diameter ratio (P/E) was observed to be the highest in *M. domestica* (1.14). Colpi length was calculated to be the highest in the *P. granatum* (13.8 μm). The highest percentage of pollen fertility was calculated in *V. tricolor* (92.5%), whereas the lowest was in *O. rosea* (64.28%). Studied characters under LM and SEM have appeared as a useful tool for the delimitation of melliferous flora, which may lead to the correct identification of the potential and valuable bee floral resources for beekeepers. The outcomes of this study aid in the assessment of melliferous flora and help in providing conservation measures for the sustainable development of beekeeping and the honeybee flora of the region.

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RESEARCH ARTICLE

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Palynomorphological diversity among the Asteraceous honeybee flora: An aid to the correct taxonomic identification using multiple microscopic techniques

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Abstract

This study aimed to characterize the palynological morphology of melliferous species of family Asteraceae belonged to seven tribes which were categorized into 15 genera and were studied under light and scanning electron microscopy. The pollen grains were acetolyzed, measured, and described qualitatively. Quantitative data were analyzed by descriptive and multivariate statistical analysis. The species were analyzed considering 11 quantitative pollen characteristics. The study revealed that the pollen grains are circular, triangular, angular, semi-angular, quadrangular, pentagonal and hexagonal amb, and 3-colporate or 3-colpate. The size of the pollen is variable among the species, ranged from 56.1 to 23.2 μm. Three pollen types: oblate spheroidal (eight species), prolate spheroidal (six species), and suboblate (two species) were observed. The surface pattern of the exine varies from echinoperforate, echinate, echinate microperforate, fenestrate, echinoperforate reticulate, microreticulate, echinate perforate, tectate, and scabrate. Exine thickness was calculated minimum in *Cichorium intybus* (2.47 μm) and maximum in *Taraxacum campylodes* (5.15 μm). A key to studied bee floral species, based on the morphological features of pollen grains, is also provided. The palynomorphological characters here analyzed can be potentially used to correctly identify the Asteraceous honeybee floral species most commonly plants visited by honeybees in the study area.

KEYWORDS
Asteraceae, honeybee flora, light microscopy, palynology, scanning electron microscopy

1 | INTRODUCTION

The Asteraceae is a cosmopolitan family including around 24,000–30,000 species in 1,600–2,000 genera (Gavrilović, Jacas, Susanna, Marin, & Janaćković, 2019), which have been highlighted by great therapeutic potential (Camilotti et al., 2014). Asteraceae is widely distributed within diverse regions ranging from southwest of United States, Mexico, Southern Brazil, South Africa, Middle and Southwest Asia (Selvi, Paksoy, Polat, & Cakilcioglu, 2014). Members of the family are mostly annual or perennial herbs (Anderberg et al., 2007). The family consists of 12 subfamilies and 43 tribes (Funk, Susanne, Stuessy, & Bayer, 2009). It is a diverse family in terms of size, the largest in Pakistan, comprising 650 species in 15 tribes including some in cultivation (Bano, Ahmad, Zafar, Sultana, & Khan, 2015). Most Asteraceous species are herbaceous although an important component of the family consists of shrubs or even trees, and many plants in the family Asteraceae are economically important as weeds, ornamentals, medicinal, and green vegetables (Mabel, Johnson, & Temitope, 2013; Özbek, Duman, Özbek, & Aytaç, 2021). The families that contributed the most to honey production were Asteraceae, Fabaceae, and Brassicaceae (Grimau et al., 2014; Kopytina, Nenasheva, & Ivanova, 2019). The Asteraceae and Fabaceae