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Food Preference of Rhesus Monkey (*Macaca mulatta)* in the Margalla Hills National Park, Islamabad, Pakistan

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SA developed study design, collected field data and wrote the manuscript. ARK supervised the study and reviewed the manuscript. MIA identified plants and helped in data collection. MAJ developed a study area map and performed statistical data analysis. KS conducted macro-scopic and microscopic fecal analysis in the lab.

Key words
Food preference, Rhesus monkey, Foraging, Provisioning, Scavenging

ABSTRACT

Study on food preference of Rhesus monkey (*Macaca mulatta*) was conducted from September 2019 to September 2020 in the Margalla Hills National Park (MHNP) near Islamabad ,which falls in Murree foothills between 450m--1500m elevation (N 330 44'25.5" E 0730 03'15.3"). Topography is rugged and the climate is sub-tropical semi-arid. The flora of the park is mainly subtropical evergreen scrub forest on the lower slopes and subtropical pine forest at higher elevations. The data were collected by direct field observations on five selected groups: A, B, C, D and E of rhesus monkey in various parts of the study area. Food remnants method was used in combination with fecal analysis and visual observation for food composition. Both macroscopic and microscopic fecal analysis were carried out using 150 fecal pellets, collected from study area. The microhistological fecal analysis showed the presence of 29 dietary plant species as compared to 30 plant species observed in the field. No animal derived food component was noticed in the diet. The results revealed that food composition consisted of 83% plants diet, 14% provisioned food items and 03% scavenging on garbage bins. To study food resource preference, the monkeys were classified into five age/sex classes: Adult males, adult females, sub adults, juveniles and infants. Analysis of food resources preference of five age/ sex classes of rhesus monkeys revealed that it mainly varied due to nutritional requirements and physiological conditions of monkeys. Rhesus monkeys preferred succulent foods to the non-succulents. Eight different feeding categories: arboreal, ground, provisioning, scavenging, begging, stealing, snatching and suckling were defined. A total of 540 observations were taken for all age and sex classes. The arboreal and ground feeding were widely used by the monkeys while stealing and snatching were little used. There is a need to conduct research on feeding ecology, parasitology, food preference based on nutritional requirements of Rhesus monkey in MHNP.

INTRODUCTION

In the wild, animals spend a significant proportion of their time in foraging. Wild primates may spend 25 percent to 90 percent of their waking hours in foraging having diverse diets which may include browse, seeds, leaves, flowers, fruits, insects, gum, and animal matter (Clutton-Brock and Harvey, 1977). Primates have a variety of specialized foraging adaptations and preferences. Models of the ecology of primate groups have predicted that foraging competition among adult females in female-bonded species such as rhesus monkey (*Macaca mulatta*) should occur in rich, clumped food conditions, rather than in meager dispersed conditions. Spatial and temporal conditions affect competition in rhesus monkeys (Clutton-Brock and Harvey, 1977).

A primate's food intake in the wild is linked to seasonal variation, habitat quality, availability, and distribution of food, distributional patterns (Oates, 1988; Agetsuma and Nakagawa, 1989; Nakagawa, 1989; Agetsuma, 1995; Hill, 1997; Hanya, 2004; Jaman and Huffman, 2008) and nutritional properties of food items (Oates *et al*., 1980;

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Iwamoto, 1982; Wrangham *et al*., 1991; Yeager *et al*., 1997; Takemoto, 2003; Worman and Chapman, 2006; Fashing *et al*., 2007; Hanya *et al*., 2007; Yamashita, 2008).

In non-human primates, Rhesus monkey shows the widest range of geographical and ecological distribution in the world. It is found naturally in Afghanistan, India, Pakistan, China, Laos, Bangladesh, Bhutan, Burma, Nepal, Thailand, and Vietnam. This species is found in a variety of habitats throughout its range, including urban areas (Fleagle, 1988). The Rhesus monkey is one of the two primate species found in Pakistan, the other one is Grey Langur (*Semnopithecus entellus*) distributed in district Mansehra, Pallas Kohistan, and Azad Jammu and Kashmir (AJK) (Roberts, 1997). In Pakistan, the distribution of rhesus monkey is restricted to mountainous areas having forest cover, typically associated with Himalayan moist temperate forest. It extends in the northwest from Kafir valleys of southern Chitral, southwards though Dir and eastwards through Swat/Kohistan and Hazara district (Roberts, 1997). The subspecies *Macaca mulatta villosa* occurs in lower Kaghan valley around Paras and Shogran and also in Neelam valley of AJK. The same sub species occurs throughout the Murree hills. Individuals from the outer foothill of Himalayan range such as Margalla Hills appear to be much smaller in size (Roberts, 1997). No doubt, it is much more widespread in distribution than langur but Rhesus monkey has become very rare both in Swat Kohistan and Chitral due to persecution by local villagers (Roberts, 1997). Currently, Rhesus monkey is considered Near Threatened in Pakistan (Sheikh and Molur, 2005). Globally it has got the status of 'LC' (Least Concern) (Timmins *et al*., 2015).

In all habitat types, feeding and resting are the major activities of the rhesus macaques' day and they spend the rest of their time traveling, grooming, playing, and other activities (Seth and Seth, 1986). Rhesus monkeys dominate in the tropical, subtropical, and temperate forests below 3,000 m a.s.l. all over Nepal. Assamese monkeys (*Macaca assamensis*) were patchily distributed along rivers in the tropical and subtropical areas. Both species principally utilized forests parapatrically. Discontinuous distribution of Assamese monkeys probably appeared because of the expansion of rhesus monkey distribution in the mid- and late-Pleistocene (Wada, 2005). They are synanthropic, thriving in human-altered environments, including urban of some communities. This adaptive characteristic as evolutionary strategy has made Rhesus macaques the most widely distributed and successful primates in the world (Hasan *et al*., 2013). Habitat use and positional behavior by sympatric Rhesus macaques and Aasamees macaques were interspecific in limestone habitat at Nonggang Nature Reserve, southwestern Guangxi, China. These differences in positional behavior and habitat use are linked to differences in limb length and body size in the two species, and may be explained by the spatial distribution of preferred foods and structure of the forest in different areas of the limestone hills (Huang *et al*., 2015).

Rhesus monkeys are diurnal in feeding activity and forage to a considerable extent on the ground. Studies in India indicate that they usually move regularly along a rough circuit within a particular territory, feeding as they go and sleeping in a fresh place each night (Roberts, 1997). It is observed that if they are undisturbed and food supplies are plentiful they will feed in the same area for several consecutive days, returning at night to the same group of trees. In the spring and early summer, they eat a lot of grasses and forbs and have been observed greedily pulling up handfuls (Roberts, 1997).

Rhesus monkey is largely vegetarian. Its diet includes leaves, flowers, fruits, berries and seeds of many species of plants, grass, grains and algae from ponds. It also eats insects, spiders and is known to eat small birds, lizards, or similar small animals. Macaque eats fruits, berries, leaves, flowers, seeds and bark from over 70 species of plants (Lindburg, 1977). Insects (termites, grass-hoppers, ants and beetles) and occasionally honey combs of wild bees are eaten when available. Sometimes during the sunny part of the monsoon season a group spends the whole day catching and eating grasshoppers (Lindburg, 1977). There is seasonal variability in the consumption of more important food plants while foraging, the monkeys quickly fill their cheek pouches with food, especially small fruits and berries, and then sit in a safe place and in an alert position while continuing to chew (Lindburg, 1977).

No study has been done on foraging and food composition of Rhesus monkey in the past in Margalla Hills National Park (MHNP), Islamabad. The present study was conducted on important aspect of Rhesus monkey i.e. food composition and preference in Margalla Hills National Park Islamabad. It provided basic data on food composition and preference of Rhesus monkey in various seasons, which will be helpful in habitat management and improvement of this species in the park.

MATERIALS AND METHODS

Study sites

The study was conducted in the MHNP, covering an area of 14,786 hectares which runs along the northeast border of the federal capital city of Islamabad (Fig. 1). The Margalla Hills are one of the western most extensions of Indo-Himalayan ecosystem. The hills represent a contact zone with the arid Irano-Saharan ecosystem, which extends southwesterly. The MHNP hosts 250 species of birds, 38

of mammals, at least 13 taxa of reptiles and numerous taxa of other animals (GOP, 1992). Topography is rugged and elevation ranges from 456 m to 1580 m. The general aspect is southerly and terrain is interspersed with both large and small valleys. The rocks have been observed to date back to Jurassic and Triassic ages. Soils are dark, with high mineral contents and are capable of supporting good tree growth despite being shallow (Anwar and Chapman, 2000). The climate is sub-tropical semi-arid. The region lies in the monsoon belt and experiences two rainy seasons. Winter season lasts from January to March and summer season from July to September with average rainfall 1900 mm. There have been occasional incidents of light snowfall in severe winters. Average minimum and maximum temperature is -3.9°C and 46.6°C, respectively (PMD, 2018) (https://nwfc.pmd.gov.pk/new/monthly-reports.php).

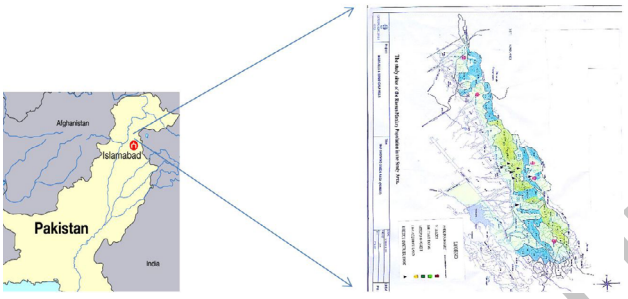

Fig. 1. Map showing study sites of rhesus monkey in the study area (MHNP) Islamabad.

The flora of the park is mainly subtropical evergreen scrub forest on the lower slopes and subtropical chir pine forest at higher elevations. The vegetation has been classified into five major phytocommunities on the basis of physiognomy, floristic composition and dominance of the vegetation. These include: Olea-Acacia, Acacia-Carissa, Olea-Carissa, Myrisine-Dodonea and Pinus-Quercus community (Anwar and Chapman, 2000).

The dominant wildlife of the park include wild boar (*Sus scrofa)*, Rhesus monkey, barking deer *(Muntiacus muntjak),* grey goral (*Naemorhedus goral)*, jungle cat (*Felis chaus)*, Indian crested porcupine (*Hystrix indica)*, Indian hare (*Lepus nigricollis)*, palm civet *(Paguma larvata),* small Indian mongoose *(Herpestes javanicus),* palm squirrel *(Funambulus pennantii),*common rat *(Rattus rattus),* long-eared hedgehog *(Hemiechinus collaris)* and common serotine bat (*Eptesicus serotinus*) (Nawaz *et al*., 2007).

There are over 30 settlements in and immediately around the periphery of the National Park. The total population in the settlements in national park is close to 70,000. The largest settlement is in Nurpur with a population of just over 15,000 persons, followed by Chauntra with 12,000, and Kot Hathial, Gokena, Talhar and Shah Allah Ditta with about 9,000 persons each. Major threats to the national park are encroachments, woodcutting and grazing, wild fires, alien invasive plant species, quarries and increasing number of visitors (IWMB, 2019).

Field observations for food preference

As a first step, a reconnaissance survey of study area was conducted to know the potential feeding sites of the monkeys and to divide the area into five study sites (Kuwait-hostel, E-7 hill side road, wildlife view point, Daman-e-koh and Lohe dunde) on the basis of distribution of monkey groups and different food resources. Five monkey groups were named as group A, group B, group C, group D and group E according to their potential feeding sites, Kuwait-hostel, E-7 hill side road, wildlife view point, Daman-e-koh and Lohe dunde, respectively. The second step involved the detailed analytical study on food composition of rhesus monkey using various techniques given as follows:

Food composition of the species based on field observation was studied by continuous-recording sampling method and instantaneous and scan sampling by employing two observation methods (Altmann, 1974). Food remnants method was used in combination with fecal analysis and visual observation. It is useful when the animal was not directly visible but the researcher was close enough to identify the species on which it was feeding. When the animal had moved on, the feeding location was investigated and collected food remnants were characterized (Ullrey *et al*., 2003).

Sample collection

A total of 150 fecal pellets were collected from MHNP in winter and summer season. None of the fecal pellets from which samples were taken was judged to be more than 24 h old. Fecal analysis technique was used by collecting the samples of fecal matter of the species from various sites of study area. Both macroscopic and microscopic techniques were used to find out the indigestible hard parts such as seeds and fibrous material of ingested food (Ullrey *et al*., 2003).

Slide preparation

In different seasons, plant species from different study area were collected. Reference slides were prepared following William (1962) and Ward (1970). The required vegetative parts of the plants were obtained and dried. These fresh specimens/dried tissues are soaked in plant soaking solutions (distilled water, ethyl alcohol, and

glycerin (1:1:1)) for a night then washed with tap water for about 10-20 min each specimen of plant tissue was ground in virtis homogenizer with distilled water. These contents were poured in microsieve. This microsieve was composed of 6cm long hollow cylinder having 0.05mm mesh of stainless steel wire that is fitted with a rubber stopper at one end of cylinder in such a way that it could be left filled with 1% sodium hypochlorite for clearing the specimen and was kept soaked in a sodium hypochlorite solution of 5% chlorax and 4 parts of distilled water (1:4) for 20-30 min. To neutralize the basic effect of sodium hypochlorite equal amount of dilute acetic acid was added to the tissues, were placed in mordant solution for 15-30 min, and then this distilled water was dripped into the sieve to remove any basic residues.

The contents were placed in hematoxylin stain for 10-15 min then washed with tap water. On a clean slide a drop of Apathy of mounting medium (100cc distilled water and 100g gum Arabic) was placed. The stained plant material was mixed with this mounting medium with a wet camel brush and the material was uniformly spread over 22x40 mm of slide. Two drops of mounting medium were added to the plant material and were covered with glass cover of 22x40 mm and pressed tightly by a peril eraser for uniform contact of glass cover and slide. Labeling of slides was done for identification and was left at room temperature overnight for fastening of material on these slides.

Slide interpretation

The segments in each fecal slide were identified on the basis of shape, size and relationship of short cells, structure of cell wall of long cells, stomatal patterns along with guard cells, nature and arrangement of epidermal hair. Two observers, trained in the procedures of Holechek and Gross (1982), analyzed both diet and fecal samples using AmScope B490 binocular compound microscope. Samples were analyzed at 100X, although 200X magnification was sometimes used for higher resolution (Holechek and Valdez, 1985).

Food composition

Dietary plant species found in the fecal sample were confirmed after a detailed examination of all cell features by making comparison with the reference plant microphotographic key. The relative frequency of a plant species in the fecal samples was determined and shown as a relative importance value (RIV) (Jnawali, 1995).

$$\text{RIVx} = \frac{\text{Absolute frequency of a species}}{\text{Total frequencies of all species}} \times 100$$

The relative importance value was the total number of segments identified for a particular dietary plant species divided by the total number of all the counts made in the sample, multiplied with 100 (Jnawali, 1995). The data on provisioning feeding and scavenging were collected directly by observations and questionnaires were used to interview the visiting tourists. The field study techniques of focal animal sampling and all animals sampling (Altmann, 1974) were used to find out feeding bout, feeding rate and feeding behavior.

Statistical analysis

The data obtained on foraging and food composition were subjected to statistical analysis using Estimate S (8.20) and one-way ANOVA test (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Food composition based on field observations

Food composition based on flora

Rhesus monkeys exploited a wide range of food varieties, but they concentrated on small number of selected plant species. They consumed 30 plant species in the study area (Table I). Their diet included leaves, fruit, flowers, buds, seeds, petioles and wood extract. Fruits were the most important energy rich components of diet but leaves, seeds and flowers were important too. Fruits generally contain relatively large quantity of simple sugars and are readily useable source of energy. Leaves were the major parts of plant consumed overall which probably satisfied certain nutritional requirements of the Rhesus monkey. They prefer young leaves of plants over mature ones which contain fairly high concentration of calcium (Biddulp, 1959) while young leaves have high percentage of raw proteins (Struhsaker and Oates, 1975).

Food composition determined on the basis of field observations showed seasonal variations linked to current vegetation structure of the locality and abundance of seasonal plants in study area. Groups A, B and C shared almost the same feeding ecology due to the same vegetative structure in those localities. Group A fed on 15 plant species around the year but *Carrisa opaca*, *Dalbergia sissoo* and *Morus alba* dominated their diet. They consumed leaves of 9 species (*Acacia nilotica, Acacia modesta, Bambusa arundinacia, Lepidium sativum, Carissa opaca, Cynodon dactylon, Dalbergia sissoo, Eleusine indica* and *Zizyphus mauritiana*), buds of 7 species (*A. nilotica, A. modesta, Albizia lebbek, Carissa opaca, D. sissoo, Lantana. camara* and *Morus alba*), fruit of 4 species (*Broussonetia papyrifera, Ficus carica, M. alba* and *Z. mauritiana*), seeds/pods of 6 species (*A. nilotica, A. modesta, Carissa opaca, Ficus carica, Lantana camara* and *Pinus roxburghii*), flowers (*L. camara*) and sap of only one (*A. lebbek*) species.

Table I. Plant species consumed by Rhesus monkey in MHNP based on field observations.

S. No	Family	Name of species (Local name)
Trees		
1	Apocynaceae	*Acacia nilotica* (Kikar)
2		*Acacia modesta* (Phulai)
3	Mimosaceae	*Albizia lebbek* (Siris)
4	Moraceae	*Broussonetia papyrifera* (Jungle tut)
5	Caesalpinaceae	*Cassia fistula* (Kinjal/ Amaltas)
6	Papilionaceae	*Dalbergia sissoo* (Sisham)
7	Moraceae	*Ficus bengalensis*(Bohr)
8		*Ficus carica* (Anjir)
9		*Ficus religiosa* (Pipal)
10		*Morus alba* (Tut)
11	Oleaceae	*Olea ferruginea* (Kahu)
12	Euphorbiaceae	*Phyllanthus emblica* (Aamla)
13	Pinaceae	*Pinus roxburghii* (Chir)
14	Rosaceae	*Pyrus pashia* (Batangi)
15		*Zizyphus mauritiana* (Beri)
16		*Zizyphus nummularia* (Malah)
17	Primulaceae	*Anagallis arvensis*
Shrubs		
18	Poaceae	*Bambusa arundinacia* (Baans)
19	Buxaceae	*Buxus papillosa* (Papri)
20	Apocynaceae	*Carissa opaca* (Granda)
21	Moraceae	*Ficus virgate* (Phagwara)
22	Verbenaceae	*Lantana camara* (Panch phuli)
23	Euphorbiaceae	*Mallotus phillippensis* (Kamila)
24	Celastraceae	*Maytenus royleana* (Pataki)
25	Punicaceae	*Punica granatum* (Anaar)
Herbs		
26	Liliaceae	*Asparagus officinalis* (Marchob)
27	Poaceae	*Brachiaria ramose* (Bajra)
28		*Cynodon dactylon* (Khabal)
29		*Lepidium sativum* (Halim)
30		*Eleusine indica* (Dubrra)

Group B foraged on 11 plant species but major ones were *Carissa opaca, D. sissoo, C. dactylon* and *Z. mauritiana*. They consumed leaves of 6 species (*A. nilotica, A. modesta, C. sativum, Carissa opaca, D. sissoo* and *Z. mauritiana*), buds of 6 species (*A. nilotica, A. modesta, A. lebbek, Carissa opaca, L. camara* and *Z. mauritiana*), flowers of only one species (*L. camara*), fruits of 2 species (*F. carica* and *Z. mauritiana*), seeds/pods of 4 species (*A. nilotica, A. modesta, Carissa opaca* and *Z. mauritiana*) and sap of only one species (*A. lebbek*).

Group C consumed 13 plant species throughout the year but major ones were *A. nilotica, Carissa opaca* and *D. sissoo*. They consumed leaves of 11 species (*A. nilotica, A. modesta, A. lebbek, Asparagus officinalis, C. sativum, Carissa opaca, D. sissoo, E. indica, Phyllanthus embellica* and *Z. mauritiana*), buds of 7 species (*A. nilotica, A. modesta, A. lebbek, Carissa opaca, D. sissoo, L. camara* and *Z. mauritiana*), flowers of only one species (*L. camara*), fruit of 3 species (*F. carica, P. embellica* and *Z. mauritiana*), seeds of pods and fruits of 4 species (*A. nilotica, A. modesta, Carissa opaca* and *L. camara*) and sap of only one species (*A. lebbek*).

Group D consumed 8 plant species throughout the year but major ones were *Carissa opaca*, *Cassia fistula* and *Ficus bengalensis*. They consumed leaves of 4 species (*A. lebbek, Asparagus officinalis, Carissa opaca, Cassia fistula* and *Ficus bengalensis*), buds of one species (*Ficus bengalensis*), flowers and wood extract were not observed to make food constituent, fruit of 4 species (*Ficus bengalensis, F. carica, Punica granatum* and *Pyrus pashia*), seeds of pods and fruits of 4 species (*Cassia fistula, Pinus roxburghii, Punica granatum* and *Pyrus pashia*).

Group E consumed 12 plant species throughout the year but major ones were *Buxus papilosa, Carissa opaca. Cassia fistula*, *Ficus bengalensis* and *Ficus religiosa*. They consumed leaves of 8 species (*Brachiaria ramosa, Buxus papillosa, Carissa opaca. Cassia fistula*, *Ficus bengalensis* and *Ficus religiosa*, *Olea ferruginea, Phyllanthus embelica*), buds of 4 species (*Brachiaria ramosa, Ficus bengalensis*, *Ficus religiosa* and *L. camara),* flowers of only one species (*L. camara*), fruit of 7 species (*Buxus papillosa, Cassia fistula, Ficus bengalensis*, *Ficus carica, F.* religiosa*, Olea ferruginea and Phyllanthus embelica*), seeds of 5 species (*Brachiaria ramosa, Buxus papillosa, Carissa opaca, Cassia fistula* and *L. camara*) and sap of only one species (*Carissa opaca*).

In feeding range of each particular group, food composition also varied seasonally. Group A, group B and group C consumed 15, 11 and 13 plant species, respectively. In general, young leaves, buds and mature fruits were more commonly consumed than flowers and mature leaves. This is due to nutritional requirements in terms of higher protein contents and lower cellulose levels found in these plant parts compared to mature leaves (Hladik, 1977). Su and Lee (2001) reported that food composition of Formosan monkeys (*Macaca cyclopis*) consisted of 56 plant species including fruits, stems, leaves, flowers and shoots. There was seasonal variation in the proportion of each food type in the diet of the macaques. Fruits comprised the highest proportion (53.8%), flowers (7.32%), leaves (14.92%), stems (11.76%), shoots (2.44%) and insects (9.76%) in the diet of Rhesus monkey. The proportion of fruits was higher mainly in summer and they mostly consumed the fruits of two plant species *Trema orientalis* and *Ficus irisana.* The leaves and stems were consumed every month but

their proportion was high during the winter. Insects were mainly consumed during summer (July and August) due to insect abundance during rainy (July-August) season and their feeding reduced in September and October due to shortage of insects and severe interspecific competition with insectivorous birds. Hence, the macaques switched on to plant matter in the fall and winter seasons.

Food composition of red howler monkey (*Allouatta seniculus*) by field observations showed that they fed on 195 plant species from 45 families and major feeding categories were mature fruits (21.5%), young leaves (54%) and flowers (12.6%). Other feeding categories were old leaves, unripe fruits, bark and moss and termitarium soil. The monkeys were less selective in feeding than other Howler monkey groups *Alouatta* spp. because 19 plant species accounted only for one percent of their food composition and showed seasonal diet variations (Julliot and Sabatier, 1993).

Provisioning

Rhesus monkeys consumed over a dozen kinds of provisioned food items in the study area. Major food items (Fig. 2A) included junk foods (slanties, lays, biscuits etc.) (20.4%) and white bread slices (13.6%) followed by Chapatties (3.4%) and fruits > (4%). Consumption rates of various food items varied and depended on size and texture of provisioned food items (Fig. 2B). Present study showed that there is no pronounced variation in food items offered by the tourists to Rhesus monkeys in the park except in seasonal fruits which tourists carried with them.

Ciani and Chiarelli (1988) studied qualitative and quantitative parameters of foraging in macaques. Assessment of ecological preferences and individual foraging strategies in food gathering was done in the forest of Simla, India. Their studies showed that monkeys had short bout duration indicating high consumption rate for provisioned and town food resources compared to free ranging monkeys. Foraging of different age and sex classes show pronounced discriminations. Adult males spent much less time for feeding than other classes and showed a preference for urban food resources. Contrary to adult males, lactating mothers in adult females were sluggish and giving extra time to foraging. Sub-adults showed the intermediate characteristics of foraging compared to adult females and males. Infants showed high dependency on lactation and low foraging to town food resources. The quality and exploitation of food patches greatly influenced the foraging in the study area. These monkeys showed competition in foraging; particularly males showed agnostic feeding for access to nutritious town food resources.

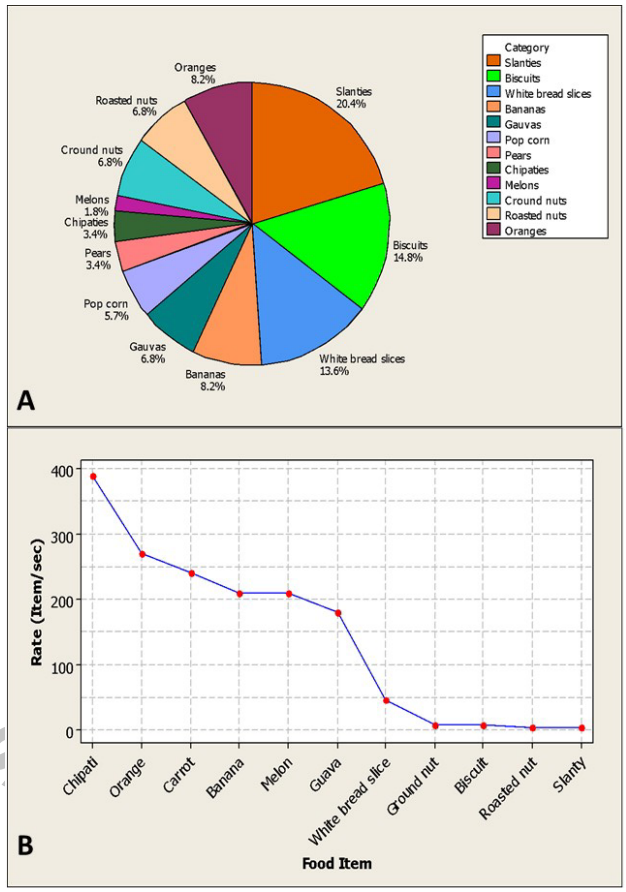

Fig. 2. (A) shows the percentage consumption of major provisioned foods. (B) consumption rate of single piece of provisioned food item by the Rhesus monkey in MHNP.

Fig. 3. Fecal pellets of rhesus monkey from the MHNP, Islamabad.

Scavenging

A total of 19 types of food items were found in scavenging food composition of the monkeys in the study

sites (Table II) which were qualitatively analyzed as major and minor food components based on the availability in the study sites. Of these food items, 15 were major while remaining 4 types were minor food items. The plant based and cooked expired food stuff were major food items while tetra packs, canned food material was minor in the scavenging food composition (Table II). The solid waste bins from CDA were the major source of the food in the human surrounding/ intervened sites (Kuwait Hostel, E-7 sector, Wildlife View point, Daman-e-Koh) in the study area.

Food composition based on fecal analysis

Mechanical fecal analysis

The mechanical fecal analysis of 150 fecal pellets (Fig. 3) of Rhesus monkey showed presence of indigestible hard parts including seeds, seed coats, blades of forbs and soil components (Table III). The seeds and seed coats of different plant species were identified as they slightly changed in color, texture and shape during digestion (Fig. 4). The seeds of 7 plant species were found including guava (*Psidium guajava*) (8.67%), oranges (*Citrus sinensis*) (5.34%), pomegranate (*Punica granatum*) (2.67%), tomatoes (*Solanum lycopersicum*) (4%), pears (*Pyrus pashia*) (2%), Kinjal (*Cassia fistula*) (12%) and *Ficus bengalensis, Ficus carica* and *Ficus religiosa* (7.34%). The seed coats found in fecal matter were pieces of ground nuts (10.67%), tomatoes (4%), Kinjal fruits (3%) and grams (9%). The results showed occurrence of high percent frequency of seed and seed coats consumed by monkeys (Table III). Fruits and seeds not observed during the field observations were also found as major components of their diet.

Blades of grasses and forbs found in the analyzed fecal matter included *Elusine indica* (32%), *Asparagus officinalis* (2.6%) and *Cynodon dactylon* (27.67%). Pebbles (18%) were the only soil components found in fecal matter but their presence in the feces did not support the geophagic (soil eating) habit of Rhesus monkeys in the study area as no field observation regarding this matter was recorded by the researchers.

Table II. Scavenging food composition of Rhesus monkey in MHNP based on field observations.

S. No.	Food items observed	Parts of food item consumed	Volume in scavenging diet
1	Peas (residuals and whole)	Pea , not pods	Major
2	Turnip (residuals)	Skin and peduncle	Major
3	Onions (residuals and whole)	As a whole	Major
4	Potatoes (residuals)	As a whole	Major
5	Carrots (residuals)	Juice extracted blended mass and stem portion	Major
6	Cabbage (residuals)	Stems	Major
7	Cauliflower (residuals)	Stems and green leaves	Major
8	Brinjal (residuals)		Major
9	Cooked rice	As a whole	Major
10	Chipatti ,Naans	As a whole	Major
11	Vegetable broth	As a whole	Major
12	Orange (residuals)	Remaining pulp only	Major
13	Banana (residuals)	Remaining pulp only	Minor
14	Lady finger (residuals)	Upper part close to stem	Major
15	Pumpkin (residuals)	As a whole	Major
16	Tomatoe (expired)	As a whole	Minor
17	Tetra packs containing traces of milk, cream, curd and fruit juices,	Remaining drops of milk, cream and curd by licking the torn or opened packs.	Minor
18	Glass and plastic bottles of jam, jelly and pickles	Jam, jelly and pickles in trace quantities	Minor
19	Wrappers of junk food (cerisps, slanties, nimko, biscuits etc.)	Remaining smaller fragments and spicy powder of chips, Slanties, popcorn, nimko and biscuits	Minor

Table III. Contents of macroscopic fecal analysis of Rhesus monkey in the study area.

S. No.	Parts	Plant species	Frequency of occurrence (n)	Percent frequency
1	Seeds	Guava (*Psidium guajava*)	13	8.67
		Orange (*Citrus sinensis*)	08	5.34
		Pomegranate (*Punica granatum*)	06	2.67
		Tomatoe (*Solanum lycopersicum*)	06	04
		Pears (*Pyrus pashia*)	03	02
		Kinjal (*Cassia fistula*)	18	12
		Ficus spp.	11	7.34
2	Seed coats	Ground nuts (*Arachis hypogaea*)	16	10.67
		Tomatoes (*Solanum lycopersicum*)	06	04
		Kinjal (*Cassia fistula*)	05	03
		Grams (*Vigna radiata*)	14	09
3	Soil components	Pebbles	27	18
4	Blades of grasses	Yard grass *(Eleusine indica)*	48	32
		Khabbal (*Cyanodon dactylon*)	37	22.67
		Marchob *(Asparagus officinalis)*	04	2.6

Fig. 4. Identified food components from mechanical analysis of fecal pellets of rhesus monkey collected from MHNP.

Micro-histological fecal analysis

The results of micro-histological fecal analysis (Supplementary Fig. 1) showed significant differences in relative importance of preferred food plant species in feces of Rhesus monkey. The percent occurrence of the plant species in fecal samples revealed diet selective pressure in habitat of the monkeys of each feeding range in the study area and showed that during the spring and summer seasons monkeys exploited diverse food resources and all feeding categories (Table IV). The presence of cells and cell fragments (Microhistolgical reference fecal slide plates) of *Carissa opaca* 136 (90.67%), *Cassia fistula* 29 (90.67%), *Cynodon dactylon* 54 (36%), *Dalbergia sissoo* 113 (75.34%) and *Ficus bengalensis* 32 (21.34%) in the slides showed their relative importance as dominant plant species in the seasonal diets.

Plant species identified from fecal samples during autumn and winter seasons

Rhesus monkey showed restricted foraging preference during autumn and winter season (Storr, 1961). Relatively small proportion of plant species in fecal samples showed that during autumn and winter seasons the monkeys exploited restricted food resources and selective feeding categories such as mainly leaves (Table IV). The presence of the cells and cell fragments of *Carissa opaca* 119 (79%), *Cassia fistula* 24 (16%), *Cynodon dactylon* 34 (22.67%), *Dalbergia sissoo* 113 (75.34%) and *Ficus bengalensis* 44 (29.34%) in the slides showed their relative importance in the seasonal diets (Table IV). Hence, main dietary plant

species based on percent frequency were *Carissa opaca, Cassia fistula, Cynodon dactylon, Dalbergia sissoo* and *Ficus bengalensis* in autumn and winter season in the study area. The leaves were the major parts of dietary plant species found in the fecal samples.

Table IV. Plant species identified in the fecal samples of Rhesus monkey in autumn-winter and spring-summer season.

S. No	Leaves of plant species	No. of fecal samples containing plant parts (Frequency)	
		Autumn-winter season	Spring-summer season
1	*Acacia modesta*	09 (6%)	04 (2.67%)
2	*Acacia nilotica*	18 (12%)	34 (22.67%)
3	*Asparagus officinalis*	11 (7.34%)	27 (18%)
4	*Anagallis druens*	04 (2.67%)	04 (2.67%)
5	*Bambusa arundinacia*	16 (10.67%)	08 (5.34%)
6	*Bauhinia variegata*	19 (12.67%)	19 (12.67%)
7	*Broussonetia papyrifera*	21 (14%)	-
8	*Brachiaria ramosa*	-	08 (5.34%)
9	*Buxus papillosa*	05 (3.34%)	52 (34.67%)
10	*Lepidium sativum*	16 (10.67%)	16 (10.67%)
11	*Carrisa opaca*	129 (79%)	136 (90.67%)
12	*Cassia fistula*	24 (16%)	46 (30%)
13	*Cynodon dactylon*	34 (22.67%)	21 (14%)
14	*Dalbergia sissoo*	113 (75.34%)	129 (86%)
15	*Eleusine indica*	18 (12%)	18 (12%)
16	*Ficus bengalensis*	63 (42%)	63 (42%)
17	*Ficus carica*	44 (29.34%)	89 (59.34%)
18	*Ficus religiosa*	24 (16%)	24 (16%)
19	*Ficus virgata*	03 (2.0%)	37(24.67%)
20	*Mallotus phillippensis*	-	08 (5.34%)
21	*Maytenus royleana*	-	04 (2.67%)
22	*Olea ferruginea*	-	04 (2.67%)
23	*Phyllanthus emblica*	-	04 (2.67%)
24	*Pyrus pashia*	-	08 (5.34%)
25	*Zizyphus nummularia*	12 (8.0%)	23 (15.34%)
26	*Zizyphus mauritiana*	-	18 (12%)

Plant species identified from fecal samples during spring and summer seasons

Rhesus monkey showed broad foraging preferences during spring and summer seasons (Storr, 1961). Relatively high proportion of plant species in fecal samples showed that the monkeys exploited diverse food resources and all feeding categories (Table IV). The total food plant species identified in the micro-histological analysis were 25 as compared to 19 of autumn and winter season. The (frequency) presence of cells and cell fragments of *Carissa opaca* 136 (90.67%), *Dalbergia sissoo* 129 (86%) and *Ficus bengalensis* 89 (59.34%), *Elusine indica* 63 (42%) *Buxus papillosa* 52 (34.67%) *Ficus religiosa* 37 (24.67%), *Acacia nilotica* 34 (22.67%), *Cynodon dactylon* 34 (22.67%), *Asparagus officinalis* 27 (18%) *and Cassia fistula* 24 (16%), in the slides showed their relative importance in the seasonal diets (Table IV). The least consumed food plant species were *Acacia modesta* 04 (2.67%), *Anagalis druens* 04 (2.67%), *Maytenus royleana* 04 (2.67%), *Olea ferruginea* 04 (2.67%), *Phylanthus embellica* 04 (2.67%).

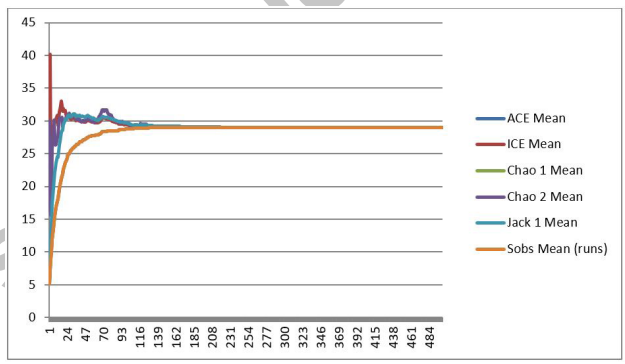

Fig. 5. The species richness in micro-histological fecal analysis of Rhesus monkey.

Estimation of species richness

A comparison of species observed mean (runs) in fecal samples with other species richness estimators such as ACE mean, ICE Mean, Chao 1 Mean, Chao 2 Mean and Jack 1 Mean using Estimate S.8.2.0 was made for data analysis (Fig. 5). Total plant species observed in the micro-histological fecal analysis were 29 as compared to 30 observed in field observations consumed by Rhesus monkey in study area. ICE Mean shows the highest possible food plant species in the study area would be 41 but Jack 1 mean confirmed the total observed species were 29 in more than 500 fecal samples. The microscope technique can only be a useful tool if observers have a 90% or more recognition level of the plant species being examined, and if they become careful not to overestimate species with stellate trichomes or hairs. Identification of such species should be based only on those trichomes attached to recognizable epidermal tissues and cell pattern and/ or stomata pattern on peridermal tissues (Alipayo *et al*., 1992). The overall food composition of Rhesus monkey in the study area consists of 83% plants material,

14% provisioned material and 03% scavenged diet (Fig. 6).

Su and Lee (2001) while studying feeding habits of Formosan rock macaque (*Macaca cyclopis)* through fecal analysis and field observations found that monkeys were mainly frugivorous and fed on 51 plants species and insects of five orders but differences were found in the results of both of these methods. They analyzed 101 fecal samples and found the frequencies of occurrence of fruits (96%), plant bodies (98%), flowers (3%), and animal matter (82.3%). They found 46 species of fruits by seeds in the feces and remains of partially digested leaves and stem of one plant species. Lindburg (1977) reported the food composition of *Macaca mulatta* in Siwalik forest in north India based on fecal analysis which showed 65-70 percent frugivorous food habit. Su and Lee (2001) reported the relative importance of fruits (46.2%), plant bodies (47.6%), and animal matter (6.2%) respectively in fecal samples of Formosan rock macaque. Flowers were found in traces and relative importance in fecal samples varied seasonally (Sanders *et al*., 1980). Fruits and animal matter increased during spring and summer while plants in autumn and winter.

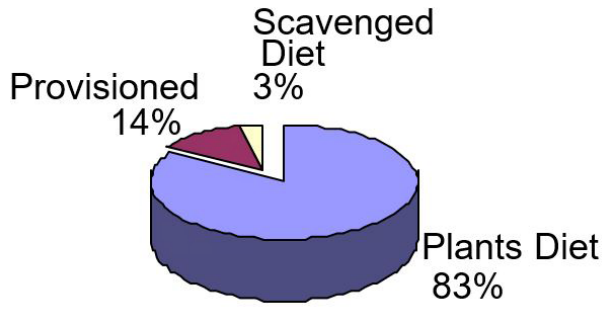

Fig. 6. Food composition of Rhesus monkey in the MHNP, Islamabad.

Food resources preferences

The food resources exploited by different age/sex classes were significantly different as the 'p' value is greater than the significance level (Table V). The food resources exploited by different age/sex classes were calculated on the basis of total number of 5 min interval scan samples for each food resource and the percentage value were estimated (Table VI). Food resource preference was mainly based on availability and relative abundance of the food resources in the study area (Hanya *et al*., 2011). Adult females (young leaves 52%, mature leaves 5%, fruits 16%, seeds 15% buds 9% and flowers 3%) and juveniles (young leaves 52%, mature leaves 4%, fruits 13%, seeds 11%, buds 14% and flowers 6%) were more selective in feeding and would climb to the highest canopies of *Carissa opaca* and other food plant species to gather young buds. It could be possible that adult females (Fig. 7A) and juveniles (Fig. 7B) preferred young leaves/ buds and were using this resource as an additional source of protein. Lactating females were found to consume seeds. Seeds are extremely high in protein and fatty acids (Heller *et al*., 2002), and thus, seeds likely represent adult females' means of obtaining adequate levels of these nutritional components.

Table V. Comparison of feeding resources of different age/sex classes of Rhesus monkey in MHNP.

S. No.	SV	df	SS	MS	F_{crit}	F value	P value
1	SVB	3	1356	452	3.10	0.33	0.804
2	SVW	20	27390	1369			
Total	TSV	23	28746	-----			

Significant at p>0.05

Table VI. Food resources preference of Rhesus monkey in MHNP.

Feeding category age/ sex class	Adult males No. (%)	Adult females No. (%)	Sub adults No. (%)	Juveniles No. (%)
Young leaves	75 (32%)	149 (52%)	89 (49%)	89 (51%)
Mature leaves	82 (35%)	14 (5%)	18 (10%)	7 (4%)
Fruits	33 (14%)	46 (16%)	29 (16%)	23 (14%)
Seeds	21 (9%)	42 (14%)	15 (8%)	19 (11%)
Flowers	07 (3%)	09 (3%)	7 (4%)	11 (6%)
Buds	17 (7%)	26 (9%)	24 (13%)	25 (14%)
Total feeding	**235(26.79)**	**286 (32.61)**	**182(20.75)**	**174(19.84)**

Agetsuma and Nakagawa (2007) studied the foraging behaviour of Japanese free ranging monkey (*Macaca fuscata*) in two different climatic habitats: a cool temperate habitat (Kinkazan Island) and a warm temperate habitat (Yakushima Island). Both habitat types differ significantly in diet composition and daily activity patterns. Time spent feeding on Kinkazan Island was 1.7 times that on Yakushima Island. They concluded that two factors were responsible for these: (1) the energy required for thermoregulation of monkeys on Kinkazan Island is greater than that on Yakushima Island; and (2) the food quality, which affects the intake speed of available energy, is lower on Kinkazan Island. However, monkeys in both habitats increased their moving time and decreased their feeding time when they fed on foods of relatively high quality.

Analysis of food resources preference of five age/ sex classes of Rhesus monkeys revealed that it mainly

varied due to nutritional requirement and physiological condition of monkeys (Kumar and Solanki, 2003). Adult females and juveniles were more selective in feeding and would climb to the highest canopies of food plant species to gather young buds, males were rarely engaged in this behaviour. The food resources preference, social dominance and spatial distribution of particular food plant species were factors which gave rise to feeding agnostics in the monkeys.

The analysis of food resources preference revealed that it also mainly varied showing higher food resource preference particularly during the mating season as did the other age/ sex classes of Rhesus monkey (Hanya and Chapman, 2013). Adult males showed low preference for young leaves over mature leaves but showed almost equal preference for the fruits as other groups (Fig. 7C). Ciani (1986) reported that males showed high inter-troop feeding aggressions in the town where they were competing for highly valuable food resources. The sub-adults showed almost similar food resources preference as the juveniles. They showed higher preference for young leaves over mature leaves but fruit and seeds were given nearly the same preference as did the adult males (Fig. 7D).

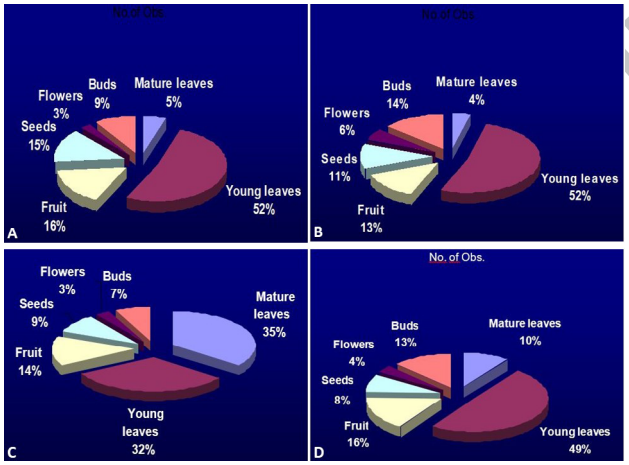

Fig. 7. Food resources preference by adult females (A), juveniles females (B), adult males (C), and sub-adults (D) in the study area.

Rhesus monkeys preferred succulent foods over the non-succulents. Most of the plants consumed by Rhesus monkeys were succulents as these plants store excess water in their roots, leaves and shoots (Sajeva and Costanzo, 1997), providing the macaques an excellent source of water and additional nutrients. Adult males, juvenile males and, to some extent, juvenile females engaged vigorously in feeding activity than adult females, making it necessary to fulfill water needs through vegetation during foraging bouts and thus likely that they would more frequently exploit this resource.

CONCLUSIONS

Rhesus monkey is an omnivore species in the Margalla Hills National Park. It actively selected feeding sites having a human influence in the form of a tourist resort, residential areas or garbage dumps which helped them in acquiring food easily. The major natural plant source dietary items in their diet were *Carissa opaca, Cynodon dactylon, Cassia fistula, Dalbergia sissoo, Elusine indica* and *Ficus bengalensis*. Rhesus monkey showed preference for fruits on leaves in their diet. Rhesus monkey showed competition in the provisioned feeding. Provision of food (14%) by tourists accounted an important source in the food composition of Rhesus monkey in the study area. Rhesus monkey regularly visited garbage dumps daily and scavenged on selected food remnants, as a part of their food. Presence of water bodies in their foraging ranges was an important factor but scarcity of water in their feeding ranges was also noted.

RECOMMENDATIONS

i. Extraction/ cutting of natural vegetation in some areas of Rhesus monkey habitat in the national park must be controlled; this is the leading cause of habitat as well as natural foods destruction in the study area.
ii. Protection and management of plant species consumed by Rhesus monkey should be done on priority basis by concerned authorities. This will give increased food availability and reduce competition for them.
iii. There is immediate need to build up water sources such as ponds for drinking and bathing purposes for Rhesus monkey by concerned authorities.
iv. Provisioning feeding by tourists should be minimized or stopped as this poses serious risks for transmission of contagious diseases from humans to monkeys and thus threatens their survival.
v. Serious and immediate steps should be taken for the regular collection of garbage in the study areas which attract Rhesus monkey for scavenging that may lead to outbreak of diseases in monkeys and thus put their survival at risk.
vi. There is need to conduct research on feeding ecology, food preference based on nutritional requirements of Rhesus monkey in MHNP.

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Ethical statement

No animals and plants were harmed in the data collection from the field.

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20210724200757

Statement of conflict of interest

The authors have declared no conflict of interest.

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Supplementary Material

Food Preference of Rhesus Monkey (*Macaca mulatta)* in the Margalla Hills National Park, Islamabad, Pakistan

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0030-9923/2022/0001-0001 $ 9.00/0

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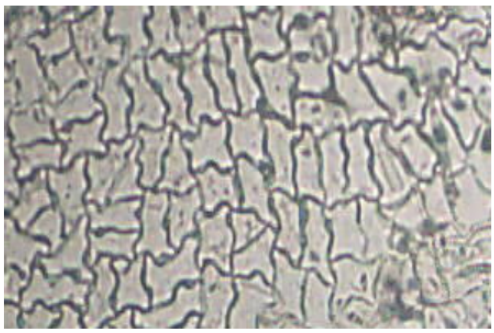
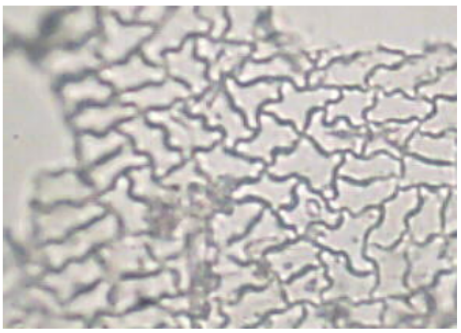

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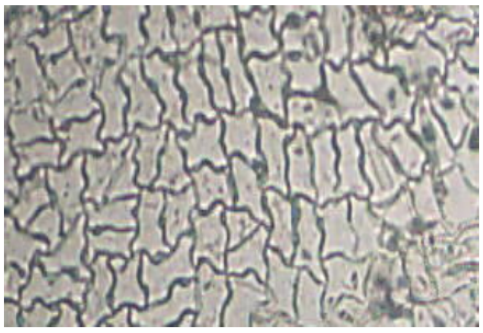
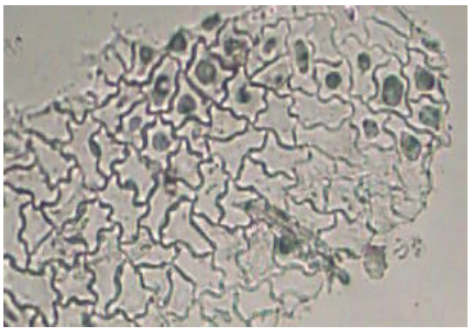

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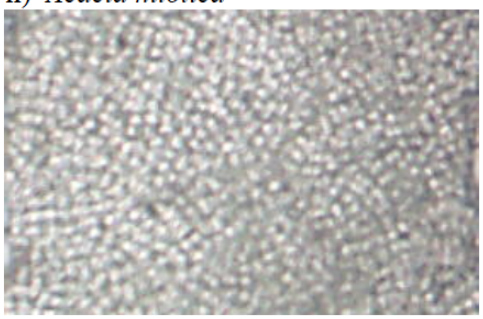
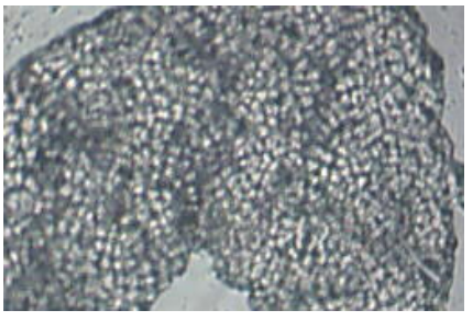

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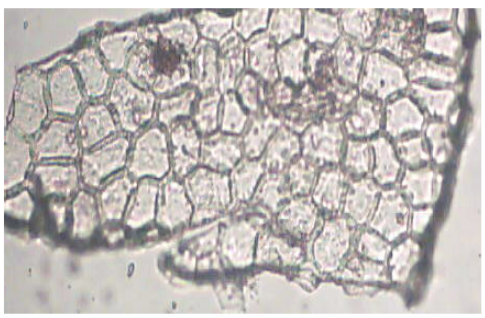


iv) *Anagalis druens*

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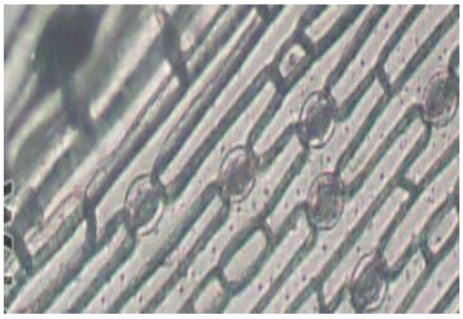
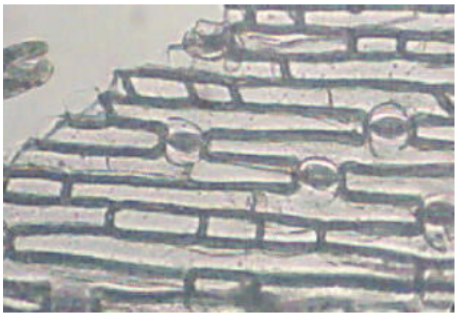

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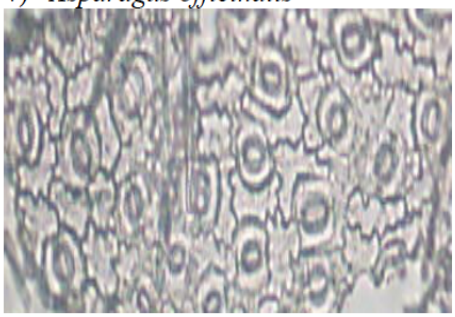
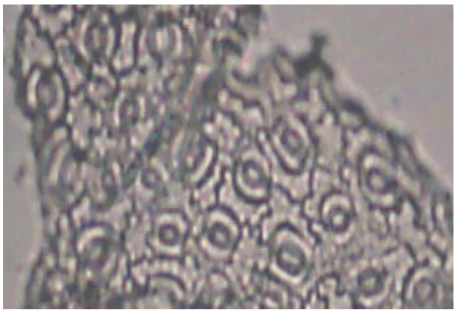

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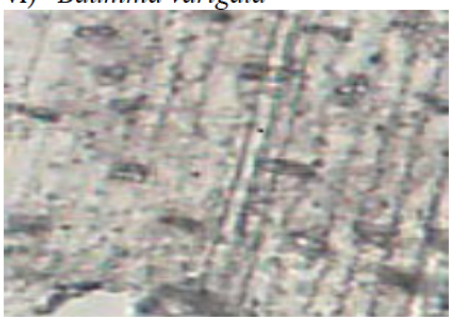
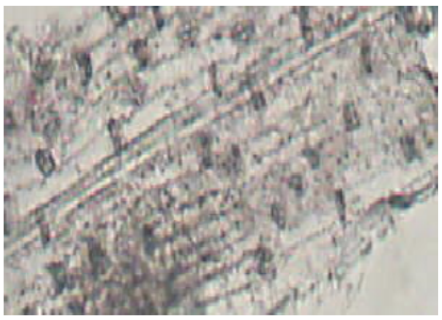

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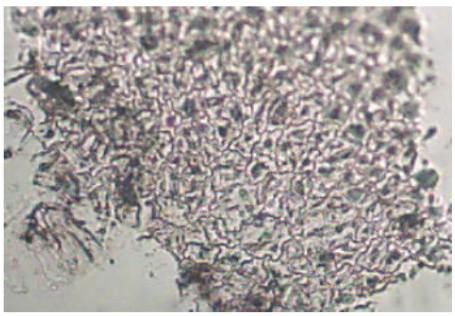
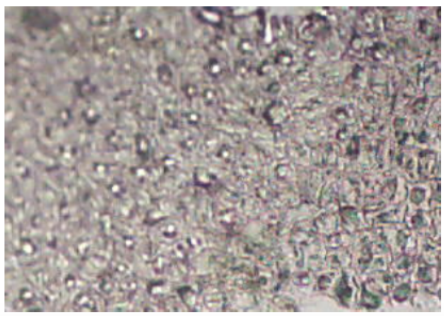

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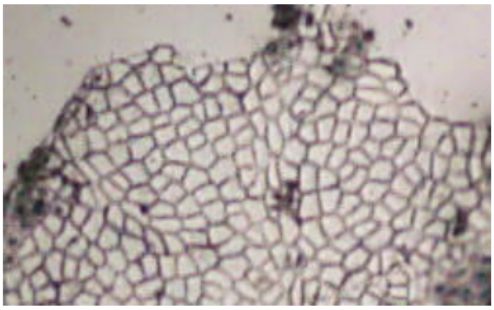
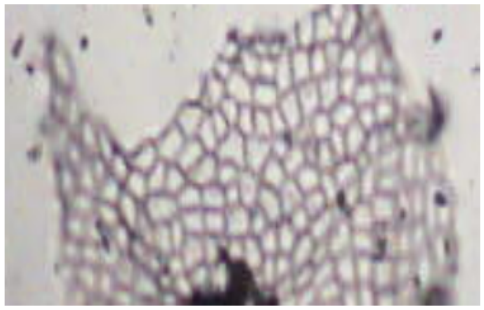

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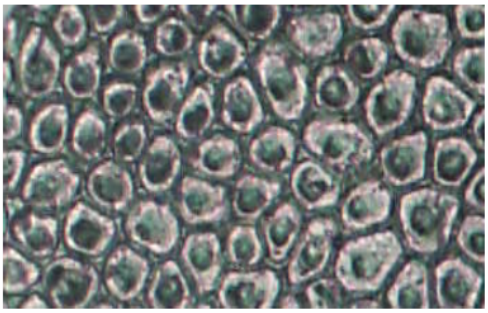
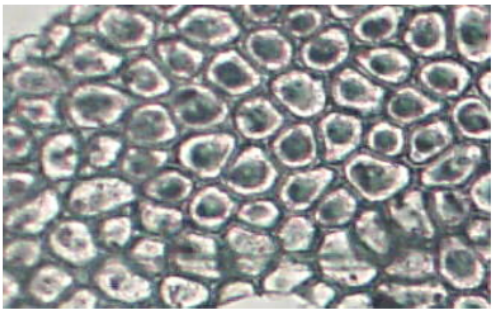

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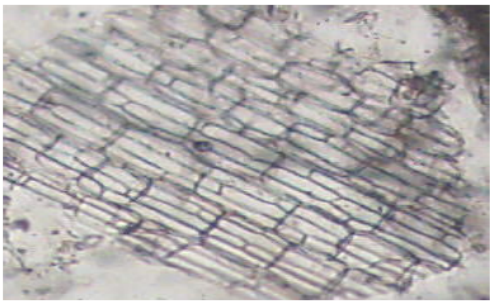
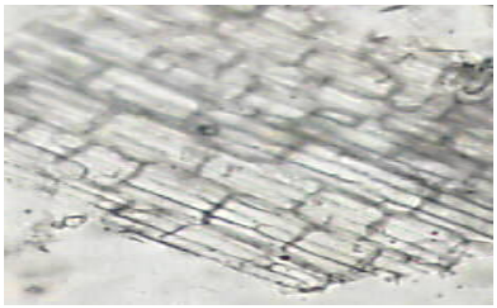

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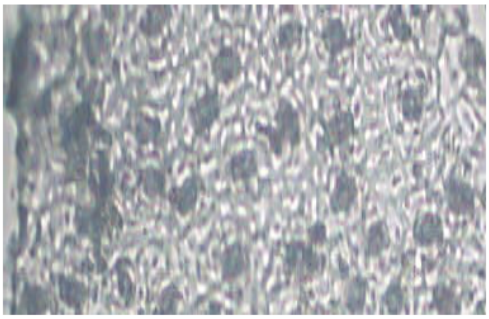
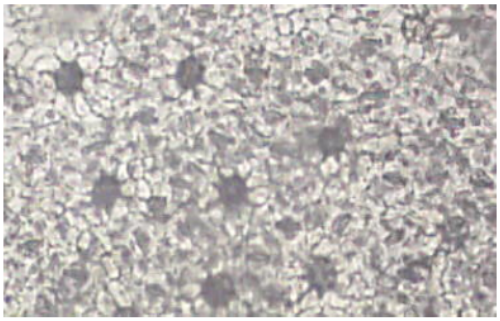

xii) *Carissa opaca*

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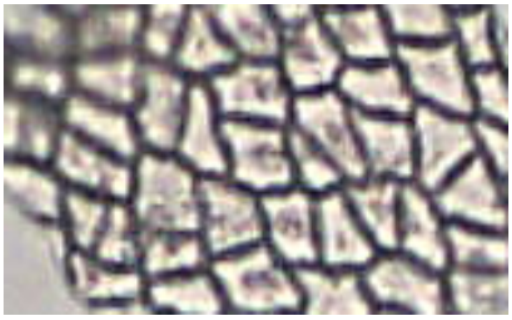

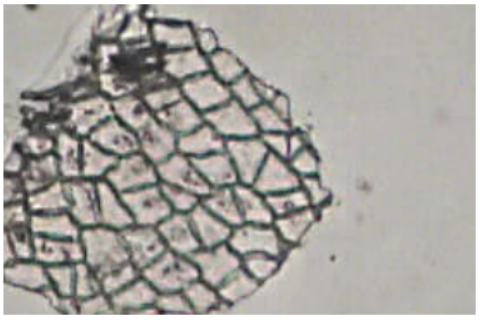

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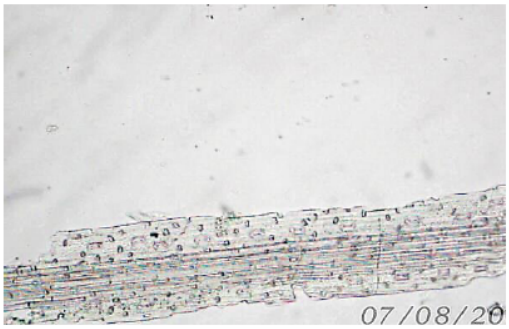

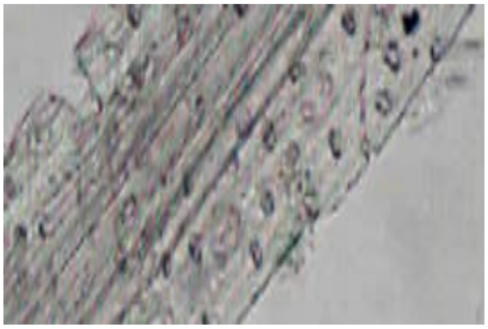

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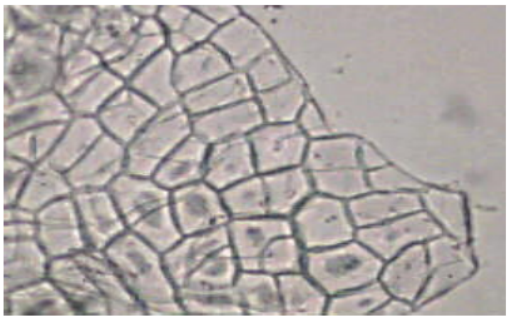

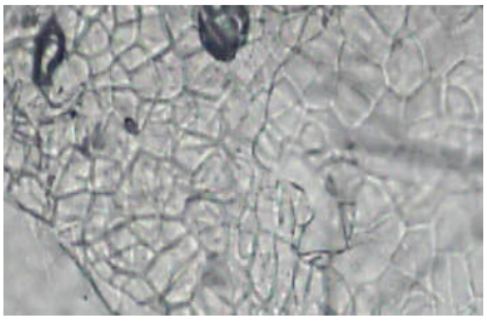

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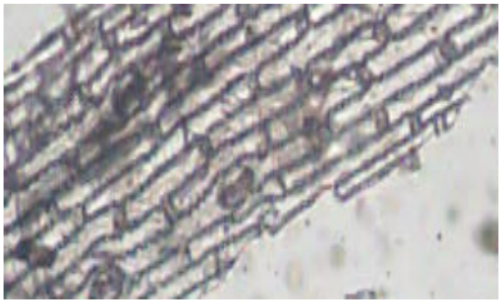

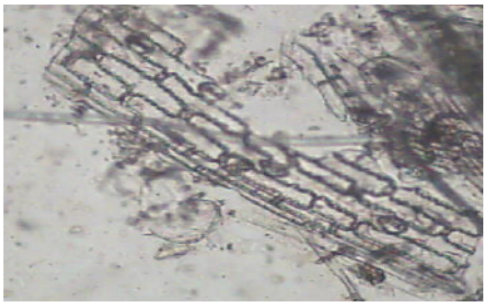

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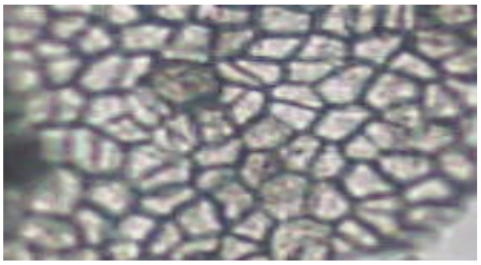
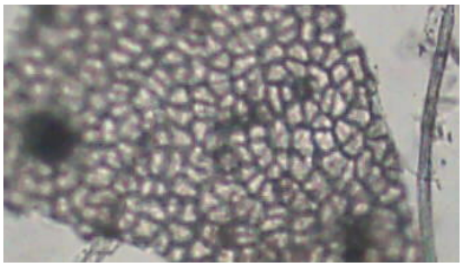

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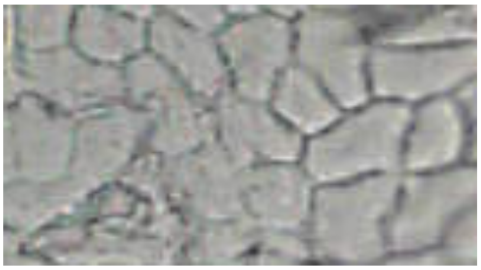
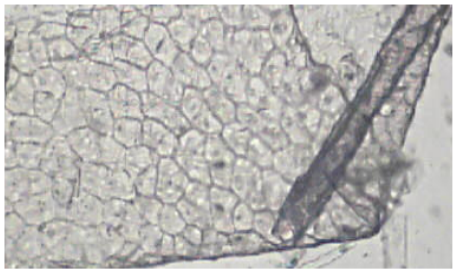

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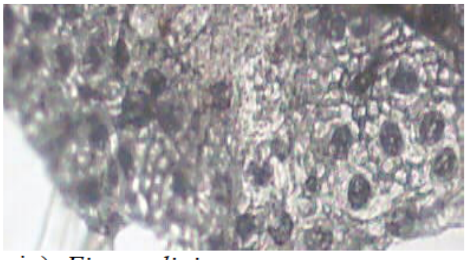
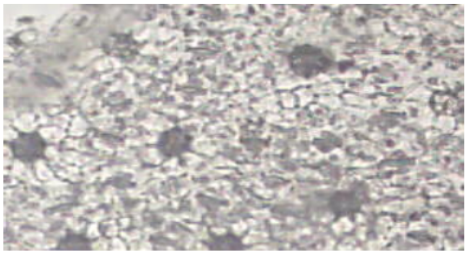

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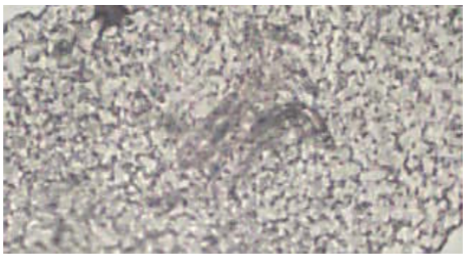
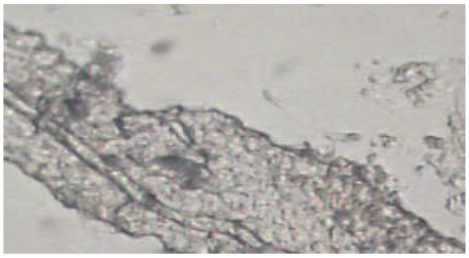

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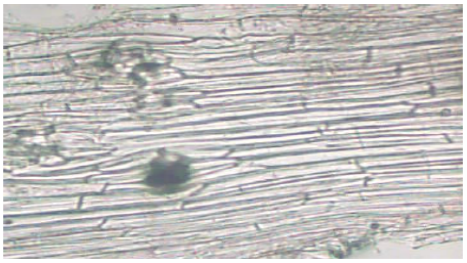
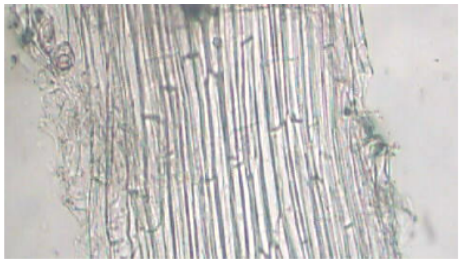

xxi) *Mallotus philippensis*

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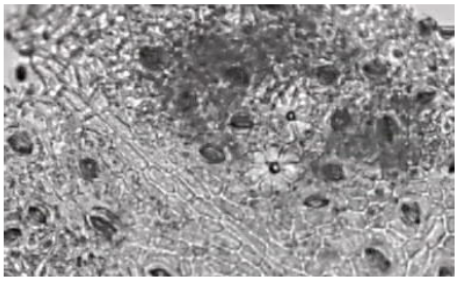
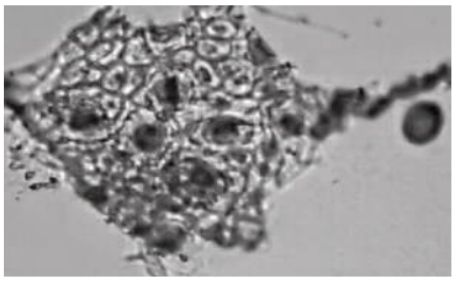

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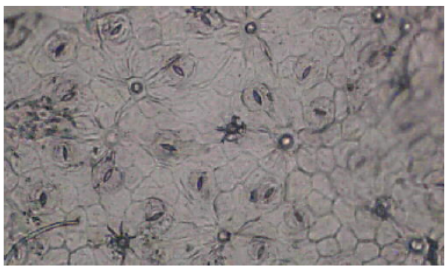
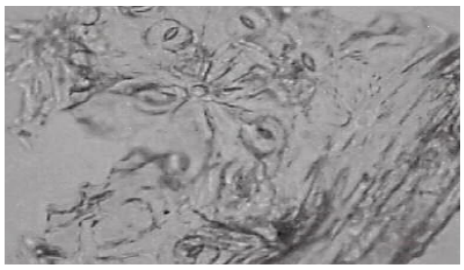

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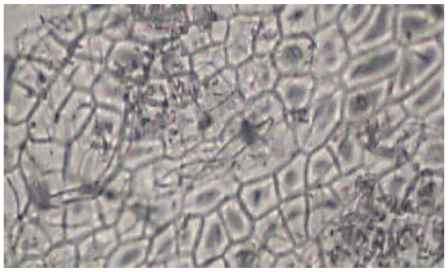
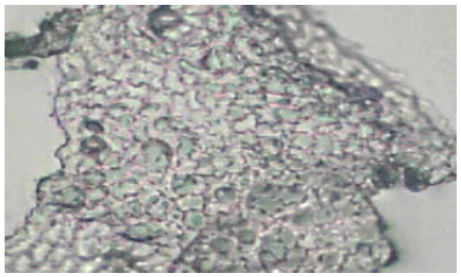

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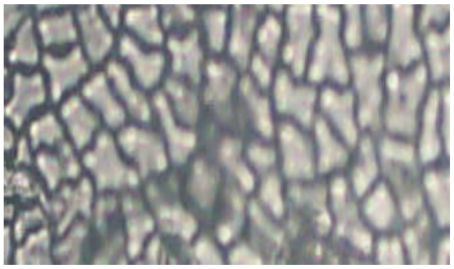
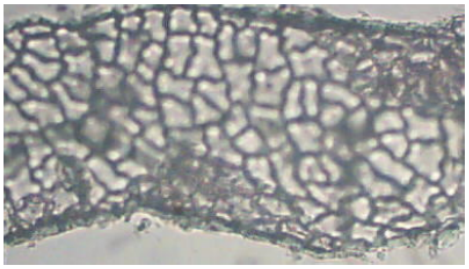

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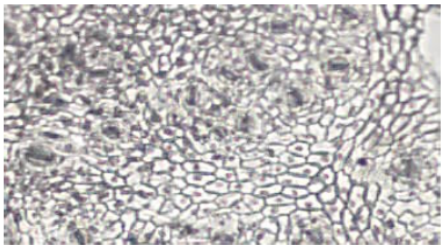
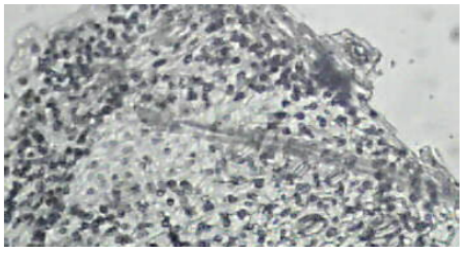

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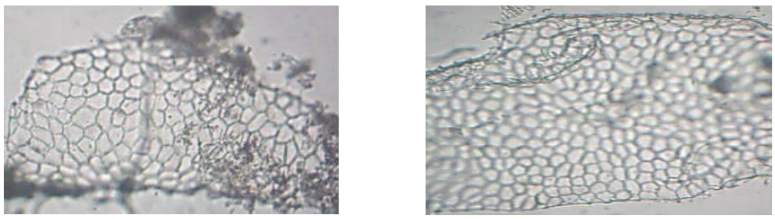

xxvii) *Zizziphus mauritiana*

Supplementary Fig. 1. Tissues in leaves.
(i) *Acacia modesta*, (ii) *Acacia nilotica*, (iii) *Albizia lebbek*, (iv) *Anagallis druens*, (v) *Asparagus officinalis*, (vi) *Bauhinia variegata*, (vii) *Bambusa arudinasia*, (viii) *Brachiaria ramosa*, (ix) *Broussonetia papyrifera*, (x) *Buxus papilossa*, (xi) *Lepidium sativum*, (xii) *Carissa opaca*, (xiii) *Cassia fistula*, (xiv) *Cynodon dactylon*, (xv) *Dalbergia sissoo*, (xvi) *Elusine indica*, (xvii) *Ficus bengalensis*, (xviii) *Ficus carica*, (xix) *Ficus religiosa*, (xx) *Ficus virgata*, (xxi) *Mallotus philippensis*, (xxii) *Maytenus roylena*, (xxiii) *Morus alba*, (xxiv) *Phyllanthus emblica*, (xxv) *Punica granatum*, (xxvi) *Pyrus pashia*, (xxvii) *Zizziphus mauritiana*.