# A preliminary study of pollination ecology of *Punica granatum* L (Punicaceae) in Kathmandu valley, Nepal

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## Abstract

The ecological and phenological study on *Punica granatum* L, which is a cultivated and wild species found in outer Himalayan ranges and warm inner valleys (between 700 and 2700m), was carried out during April and May of 2006 and 2007 in Kathmandu Valley, Nepal. The study embraced the blooming time, size of flower, its correlation and interaction with the visitors and pollinators. The prime pollinator was found to be the *Apis cerena* along with *A. mellifera.* The normal range of the length of a full blooming flower (mature flower) was found to be 4.1 to 4.7 cm (in bagged flower) and 3.8 to 4.9 cm (in open flower). The fruiting rate was higher in case of the open flowers than the bagged one. The visiting rate was found higher (most effective) in morning with sunny weather (766 times out of 1365). Similarly, the least effective time was found to be dawn and dusk with cloudy and rainy weather (2 times each out of 1365).

**Key Words:** *Punica granatum***,** Pollination ecology, floral phenology, visitors/pollinators

## Introduction

### *a. Introduction to the species*

*Punica granatum* L. is a member of the family Punicaceae**.** It is a glabrous shrub or small tree of 5-10m height. Branchlets are often spine-tipped. Bark is smooth, dark grey. Leaves are 2 - 8cm long, entire, lanceolate to broadly oblanceolate, opposite, shining, narrowed to a short petiole. Flowers on the tip of axillary shoots, with crinkle petals, blooms between late spring and early summer (May-June). Calyx 2 - 3 cm long, tubular with 5 - 7 triangular fleshy lobes. Petals 5 - 7, bright red, rarely white or

yellowish (Partap 1997, Lama et *al* 2001, Joshi & Joshi 2001). Stamens numerous. Pollen grains 22.6+_- 1.04 µm long and 21.6+_- 1.9 µm broad, yellow in colour, spherical in shape, and tri-colporate with a smooth exine (Partap 1997). Fruits are round or ovoid, 5 cm in diameter, at first greenish then brownish, orange to scarlet, with a semi-woody pericarp, interior with separating membranous wall containing numerous seeds. Seeds have edible fleshy red, pink or whitish external layer (Partap 1997, WHO 1999, Bista *et al* 2001, Lama *et al* 2001, Joshi & Joshi 2001).

The centre of origin of ***Punica granatum*** is claimed controversially as Iran (Kochhaar 1998, *www.herbdatanaz.com/pomeganate.htm*). It grows wild on both shores of the Mediterranean belt, Arabia, Persia, Bengal, China, Japan, Central and Western Asia. There are pocket areas in the Hind Kush Himalayan (HKH) region, where its pure wild forests exist in hot, dry valley areas. This species has been introduced into the East and West Indies. It is cultivated in all countries, where the climate is warm (between the Subtropical and Subtemperate regions) (*www.herbdatanaz.com/pomeganate.htm*) including Asia especially the eastern Himalayas and southern Europe.

In Nepal, only one species of *Punica* (***Punica granatum* L.)** has been reported (Bista *et al* 2001). In Nepal, both cultivated and wild forms grow in open and dry slopes of warm valleys and outer hills ranging between 700 and 2700m (Lama *et al.,* 2001; Joshi & Joshi 2001; Chaudhary, 1998; DMP, 1970). It is locally known as Anar and Darim.

The fleshy layer of seeds is edible**.** The juice is highly nutritious for the patients. In Nepal it is an expensive fruit. However, roots and barks are also used.

***b. Phytochemicals and Uses***

The root and bark contain tannin (20-22%) and alkaloids (0.5-1%). The seeds contain steroidal oestrogen. The fruit pulp contains protein, carbohydrate, fat, fibre, minerals, oxalic acid and vitamins A, B and C (Lama *et al* 2001, Joshi & Joshi 2001, *www.herbdatanaz.com/pomeganate.htm*). In early times Greeks and Romans used *Punica* for tanning leathers, which is obtained from root, bark, stem, leaves and fruit rind (Kochhaar, 1998; Lama *et al.,* 2001; Joshi & Joshi 2001).

***c. Mode of administration***

It is used singly or with other herbs. Fruit juice, powder of whole fruit and seeds (including its skin) are used. It is slightly sour in taste (WHO 1999). The root, stem bark and rind are used as astringent and antihelmintic (DMP1970, WHO 1999, Lama et *al*

2001, Joshi & Joshi 2001, *www.herbdatanaz.com/pomeganate.htm*).

It is administered especially in tapeworm infections. The rind of fruit combined with clove is used in diarrhoea and dysentery. It is also used in colliquative sweats. More frequently it is used in leucorrhoea, and as a gargle agent in sore of throat. The rind powder has also been recommended in fever (US Pharmacopoeia, 1870). The fruit pulp is beneficial in cardiac disorders, leprosy and stomachic problems. The juice is used as tonic, refrigerant, anti-inflammatory and anti-prostrate cancer (*www.herbdatanaz.com/pomeganate.htm*).

The present article throws light on floral phenology and ecology influencing visitors and pollinators, which has not been previously studied.

***d. Floral phenology and Pollination ecology***

As we all know that, the time and duration of budding, flowering, wilting and fruiting of any plant is essential aspect in the study of pollination as they provide vivid knowledge on the activity of the visitor. (Bawa 1983; Larcher, 1995; Kearns & Inouye, 1993; Kevan, 1983). The role of corolla, which is mainly related to attract pollinators, depends upon its structure, colour and appearance. In some flowers a spot of different color on the corolla directs the insect to the interior of the flower, guiding the pollinators toward their destination. For instance, *Pedicularis dendrothauma* has a corolla with a pinkish spot (Adhikari 2003, Adhikari 2004). These factors are the essence of phenological studies (Augspurger 1978 in Macior 1990).

The length of stamen and gynoecium also play an active role in pollen transfer. Besides these flowers have other floral cues like nectar, sugar, odor and oil to attract the insects, which help in pollination. In some species, insect visit is directly related with plant height (Hainsworth *et al.,* 1984; Heinrich, 1983**;** Larson & Larson, 1990; Andersson, 1988 in Kearns & Inouye, 1993) and also varies with size of the inflorescence (Willson & Bertin, 1979; Thomson, 1988).

Both plants and pollinators are affected by environmental variables (Kearns & Inouye, 1993). Flower development and opening, nectar secretion, anther dehiscence and seed development are all dependent on ambient temperature. Similarly, air temperature affects the activity of flower-visiting insects. Bees, the most important pollinators, can't go outside their hive in cold weather (Adhikari, 2003, Adhikari 2004). Some evolutionary

co-adaptation can be seen between many flowers and their pollinators (Macior, 1990, 1982).

### *e. Conservation and Pollination*

Pollination systems are under increasing threat mainly from anthropogenic sources, including fragmentation and alteration of habitat, changes in land use pattern, modern agri practices, move towards monocultures, use of chemicals such as pesticides, and invasions of alien species (Kearns *et al.*, 1998; Adhikari, 2005). In many places of the world, the 'pollination crisis' is evident in declines of honeybees and native bees and in damage to webs of plant-pollinator interactions. The inevitable and obligate role of pollination makes it clear that the conservation of pollination systems is an important priority for all (Kearns et *al.*, 1998; Adhikari 2003). The declining apple production in the Hind Kush-Himalayas (HKH) region is due to the loss of local /wild pollinators and consequently due to the inadequate crop pollination (Partap and Partap 2001, Ahmad *et al* 2002, Adhikari 2004,Adhikari 2005).

## Historical review of pollination study

The science of anthecology began around 200 years ago. Since then, Kolreuter (1761), Muller (1881), Knuth (1898-1905), Robertson (1929), Miyamoto (1962), and others have accumulated prodigious records of pollinator diversity on flowers. Less than 50 years, however, have elapsed since Kugler and other pollination ecologists, following studies of insect behavior by Frisch and his colleagues, began critical studies on pollination dynamics (Macior, 1971).

The studies on the pollination ecology started with the works on *Pedicularis* in Europe (Knuth, 1898-1905), North America (Macior 1982, 1983, 1986a, 1986b, 1986c) and Japan (Macior 1988). They have demonstrated close correspondence of floral function and pollinator behavior. Recently, such studies have been carried out in Asia (Macior 1990). For example, Deyrup & Menges (1997) studied on *Dicerandra frutescens* (Lamiaceae), Proctor, Yeo & Lack (1996) studied on insect visitors, Adams (1982) studied on *Pedicularis* pollination, Boyle & Menges (2001) studied on *Hypericum cumulicola* (Hypericaceae), and Paulus & Gack (1998) studied on the pollination of *Ophrys* (Orchidaceae). Kearns & Inouye (1993) published a book on 'Techniques for

Pollination Biologists". O'Neill (1997) and Dafni (1984), has significant contribution on the field. Similarly Jones & Little (1983) also published book named "Hand book of experimental pollination biology".

The pollination ecology of *Pedicularis* species in Asia include the contributions of Macior (1990) in Kasmir Himalaya, Macior (1995), and Macior & Sood (1991) in Himachal Pradesh (India), Macior & Tang (1997) in China, Tang *et al.*, (1998), and Macior *et al.* (2001 in China.

Since then till now, many authors have thrown light on pollination biology. However, Nepal has remained virgin in this area.

## Study Area

The study area includes different places of Kathmandu valley, Central Nepal. The Kathmandu valley lies between 27°34' – 27°46" N Latitude and 85°10' – 85°52' E longitude with its unique physiography (altitude ranging between 1350 – 2765 msl) covering an area of 650 sq km. The valley is drained by the rivers Bagmati and Bishnumati and their tributaries The cool subtropical to temperate climate and surrounding ranges (Shivapuri 1910m , Nagarjoon 2500m, Phulchwoki 2765m, and Chandragiri 2220m ), which abound with scenic natural beauty (ever green oak laurel forest, which contain different religious areas and picnic spots of botanical interest (Adhikari 1988) (Fig. no. A – After Adhikari, 2007)..

*Punica granatum* has been cultivated in many places inside and outside valley.

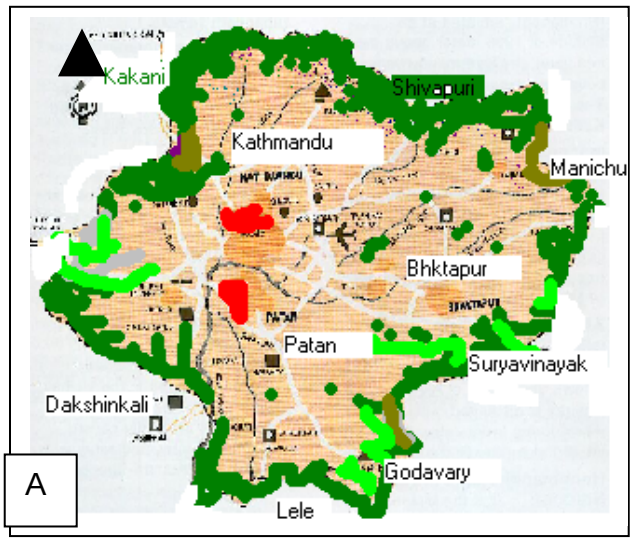



**Fig.no. A - Place in and around Kathmandu valley**

## Materials and Methods

The flowering phenological record of *Punica* along with visit of insects was studied throughout the study period. Flowers with different development stages like tight buds, developing buds, opening buds, mature flowers etc were taken for the study. The photography was done.

***a. Floral phenology***

For the study of floral phenology, flowers were classified into different developmental classes viz.

1 = Tight, unopened bud, 4 = mature flowers,

2 = developing bud/opening bud, 5 = flower (corolla) wilting,

3 = open flower, 6 = corolla fallen off, fruit developing,

7 = Shade off / died out.

All together 20 days were spent for the study of flower development. Flower conditions were recorded in every five days. The measurement of each flower size/ length of corolla tube was taken at a five-day interval, for a total of five times. In addition, flowers were sectioned in order to observe the construction, arrangement and origin of all parts. A time table of morning, day and evening including dawn and dusk was prepared to watch the visit of pollinators in different flowers.

**b. *Pollination ecology***

Measurement of flowers and observation and collection of pollinators -The pollination ecology and development of flower in Punica granatum was studied within a month period in each year. The main blooming period was found to be 20 days. Altogether 77 hours of patient watching was carried out. While watching the visitors or pollinators, the insects' behavior on the flowers, number and species of visitors, their frequency of visit during different day times and weather conditions, date, no. of flowers on plant, whether the flower was shaded or sunlit during the observation as well as their visiting period were observed and recorded. Weather conditions were also recorded at regular time intervals. Visitors and pollinators were collected from the *Punica granatum* flowers. The insect visitors were trapped and preserved for identification. Extensive non-timed flower observations for their development and visitors were made over 3 yrs (2005, 2006 & 2007)

***c. Bagging Studies***

Some fifteen healthy and unopened flowers (buds) were bagged in order to

exclude the visitors/pollinators. The conditions of all buds and flowers were studied on the same day or interval as that of the flowers with no bagging (5 times in each five days of interval).

## Result and discussion

The bee flora of Nepal have been surveyed by Kafle (1984; 19920), Maskey (1989; 1992), and Partap & Verma(1996). These surveys have found that mixed types of bee forage occur in different ecological zones of the country.

Normally, a bud of *P. granatum* takes 20 days for its complete maturation (Table B,C-Annex). A young bud (condition - 1) measures up to 0.9 cm (in bagged condition) and upto1cm (in open condition). The bagged flowers were seen to mature first than the open flowers (Table B,C-Annex). The normal range of the length of a full blooming flower (mature flower) was found to be 4.1 to 4.7cm in bagged flower, while 3.8 to 4.9cm in open flower (Table B,C-Annex). *A. cerena and A. mellifera* visit *P. granatum* flowers mainly for pollen. Pollen grain feature is(length=20-25µm Breadth=20-25µm , Aperture Number=3 , Aperture Type=Colporate, ,Exine Sculpture= psilate, faveolate, fossulate , and Aggregation=1 ). (Partap 1997). Nectar and pollen potential of *P. granatum* is $N^3$ $P^1$ i.e. minor nectar source and major pollen source (Partap 1997).

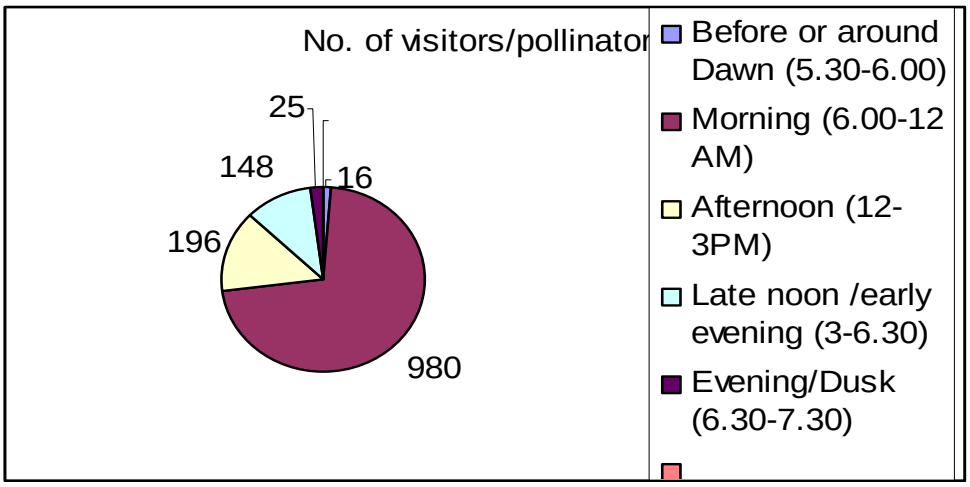
Among cultivated crops, *P. granatum* is one of the important sources of both pollen and nectar. *P. granatum* produces more pollen then nectar and the pollen plants are important in beekeeping, especially at the time of colony build-up, when bees need large amounts of protein for brood rearing. Pollen from *P. granatum* is among the best. Pollen is the sole source of proteins, lipids, minerals, and vitamins needed to feed the brood and immature adult bees. Pollen from different plant species differs greatly in nutritive value and attractiveness to bees. According to Macior (1986) *P. granatum* is obligately dependent upon animal pollinators

The result received after watching the pollinators or visitors in selected flowers are tabulated below. A great attempt was made to watch all flowers from dawn to dusk and from rainy to sunny days.

**Table1:** Time **spent on different days** for pollination studies

| Time of day/periods | Duration (time spent) (hrs) | No. of visitors/pollinators | Relative percentage of duration | Average Visitor/hr | Date |
|---|---|---|---|---|---|
| Before or around Dawn (5.30-6.00) | 3 | 16 | 3.89 | 5.33 | 20th, 25th, 28th, 4th , 6th, 9th of April and May-2007 |
| Morning (6.00-12 AM) | 36 | 980 | 46.75 | 27.22 | 21st, 25th, 30th, 4th , 7th, 10th of April and May-2007 |
| Afternoon (12-3PM) | 18 | 196 | 23.38 | 10.88 | 20th, 25th, 29th, 2nd , 5th, 10th of April and May-2007 |
| Late noon /early evening (3-6.30) | 14 | 148 | 18.18 | 10.57 | 24th, 26th, 30th and 8th of April and May-2007 |
| Evening/Dusk (6.30-7.30) | 6 | 25 | 7.79 | 4.16 | 20th, 25th, 1st, 4th , 5th, 9th of April and May-2007 |
| Total | 77 hrs | 1365 | 100 | - | - |

***(Note- visitors include both the pollinators and visitors themselves in these tables and the total flowers included to watch visitors were more than 100)***




## b) Hours spent on different weather conditions

**Table 2:** Time schedule for pollination studies in different weather conditions

| Weather condition | Duration of time(hrs) | No. of visitors/pollinators | Relative percentage % of duration | Average Visitor/hr | Remarks |
|---|---|---|---|---|---|
| Clear, no sun, no rain, no cloud/fog | 8 | 115 | 10.39 | 14.37 | Among **1365,** 1008 are *A. cerana*, 278=*A. mellifera*, 40=*Bombus* sp., 10=*Helina* sp., *7=Meliscaeva* sp., 5= *Fannia* sp., 7= *Formica* sp. Unidentified sp=4, & *Vespula* sp.=6 |
| Clear-sun | 48 | 943 | 62.33 | 19.65 | |
| Partly cloudy-sun | 16 | 286 | 20.78 | 17.87 | |
| Cloudy/ Foggy -rain | 5 | 21 | 6.49 | 4.2 | |
| Total | 77 hrs | 1365 | 100 | - | |

*(Note: Time spent on flowers by visitors is generally (10 secs-5 min.))*

**Table -3: Visitors or Pollinators and their frequency of visit to flowers**

| S N. | Visitor | Visits per watch hour | Relative % of all visits | Type of Interaction |
|---|---|---|---|---|
| 1 | *Apis cerena* (fam. Apidae : Honey Bee) Indigenous bee of Nepal | 13.09 | 73.85 | Primary Pollinator |
| 2 | *A. mellifera* (fam. Apidae : Honey Bee) | 3.61 | 20.37 | Major Pollinator |
| 3 | *Helina* sp., (fam.–Muscidae:Dark fly) | 0.13 | 0.73 | Possible Pollen robber |
| 4 | *Meliscaeva* sp., (fam. – Syrphidae:Hover fly) | 0.09 | 0.51 | Pollen/ nectar robber |
| 5 | *Bombus* spp (Apidae:Bumblebee) | 0.52 | 2.93 | Nectar/ pollen robber or Possible pollinator |
| 6 | *Fannia* sp., (fam.– Fanniidae:Small Dark grey fly) | 0.06 | 0.37 | Nectar and/or pollen robber |
| 7 | Unidentified sp., (fam.–Sepsidae: Small ant like fly) | 0.05 | 0.29 | -- |
| 8 | *Formica* sp. ( fam-Formicidae: Ant) | 0.09 | 0.51 | Causal visitor |
| 9 | *Vespula* sp. (Vespidae:Wasp) | 0.08 | 0.44 | Bee killer/eater |

Pollination bag: Flower conditions on different dates of the bagged plant (Table B,-Annex )

Fruiting is found higher in open flower (12/15) than in caged or bagged flower (8/15). The pollinators have their preferences for flower colours. In general, fly-pollinated flowers tend to be white (Lubbock, 1881; Muller 1881) and have low food rewards. The "bee flowers," many of which are blue, provide large rewards (in Heinrich, 1983; Kevan, 1983). The flowers, which are scarlet red are pollinated by bees. In case of nocturnal pollinators like moths, the colour has no effect.

Although some flower visitors (birds, mammals, and some insects) are homoeothermic or capable of endothermic temperature regulation, others (e.g. many Diptera, solitary bees) are dependent on solar radiation to achieve the body temperature required for flight. The present studies have proved that the visit rate of pollinators is higher in the sunny period (19.65 visits per hour) or on the flowers which are exposed to sun rather than in shade (Table -2). The visit rate (visit/hr) increased with flower density

(in flower/$m^2$) indicates that the visit rate to different flowers may be positively density-dependent. Similar observations were found in *Hypericum cumulicola* (Boyle & Menges, 2001).

Cloudy and or foggy rain period has least number of visit rates (4.2/hr). However, visit rate is more in partly cloudy - sun (17.87/hr) and in clear weather condition (14.37/hr). The microclimates have an important effect even in the shade (Adhikari, 2001; Kearns & Inouye, 1993; Deyrup & Menges, 1997). In the morning time (27.22/hr) with sunny days (19.67 visits per hour) are the most preferred time and weather (56.11% of total visits) for the pollinators (table-1, Table A-Annex). Even the sunlit flowers were more visited by visitors than the shaded flowers. The duration of the longest pollinator visit decreases as the morning progresses. It is probably due to the depletion of pollen supplies (Boyle & Menges, 2001) and foraging become less profitable. Also in later days the visit rates were quite low. The dawn (5.33/hr) and dusk (4.16/hr) with cloudy- foggy rain (1.5% each of total visits) are the least preferred time for the pollinators (table -1, Table A-Annex). The dawn and Dusk with sun (0.15% and 0.29% of total visits respectively) have shown a very low visit rate even in a favorable weather condition (sunny weather). It is probably due to a very limited sunny time in the dawn (normally before sun rise) and dusk (normally after sun set) periods. Moreover, Flower density in many cases but not the flower height affected the visitation rate as in case of the previous study of Deyrup & Menges (1997).

*P. granatum* is adapted for bee pollination rather than fly pollination. *Apis cerena*, which made 13.09 visits per hour, is the main/prime pollinator (includes 73.85% of total visits) of *Punica* (Table-3). Assuming 12 hr of visitation, each flower would be visited by about 157 *Apis cerena*, so pollinator limitation for seed production in *P. granatum* is unlikely. *A. mellifera* is also a major pollinator of *Punica* (20.37%). The lower value of *A. mellifera* is may be due to the less number of *A. mellifera* in the vicinity of study area. The bumble bees (*Bombus* sp.) are the other important pollinators or may be the pollen robbers having 2.93% of all visits (table-3). Some other insects (having less than 3% of all visits and having less than 0.1 visits per hour) like *Helina* sp., *Meliscaeva* sp., *Fannia* sp., *Formica* sp. and *Vespula* sp. have also been reported as a visitor of the *Punica* flower

(table-3). However they are not the true pollinators and probably most of them are pollen/nectar robbers.

According to Partap (1997) in addition to the honey bees (*Apis cerena* and *A. mellifera*), *P. granatum* is also visited by the other insects like butterflies, moths, beetles, bee-eating wasps and hornets

The bees vibrate the anther of the flower, or sometimes the whole flower. Then the powdery pollen detaches from the anthers and was collected on the head-thorax region of the bee. When the bee forages on another flower, the exerted stigma from the curved rostrum touches the thoracic region of bee and picks up the pollen, previously deposited there by another flower. This case is same with the Bumblebee pollinators of *Pedicularis* (Macior, 1986; Adhikari, 2003).

Using the latest technologies and methods for the further exploration especially regarding the co-evolution of Punica granatum with its prime pollinators needs a more detailed study.

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*www.herbdatanaz.com/pomeganate.htm*

# *Annexes*

## *No-1*

**Mode of administration**

**Dose (WHO 1999)**

***For adults***

**Fruit juice: 12 teaspoonfuls (60ml) three to four times per day**

**Seed powder: One teaspoonful (5ml) three times per day.**

**Whole fruit powder: One teaspoonful (5g) three times per day.**

**If there is blood in the stool, the juice of one average *P. granatum* should also be taken**

***For babies***

**Give 1 g of the paste or powder of a mixture of equal amount *Punica granatum* (entire fruit including the skin, three times per day adding jaggery or honey**

**Whole fruit powder is preferred for the treatment of acuter form of diarrhoea.**

**(WHO 1999)**

***Dadimastaka curna*: one teaspoonful with hot water, after food, 2 times per day is used in indigestion**

***Dadimastaka curna*: one teaspoonful (5g) with water, 3 times per day is used in Vomiting.**

## *No-2*

### Table-A Two way contingency table between time of day and weather condition

| **Time (below)** | **Weather condition ( right)** | Clear, no sun, no rain, no cloud/fog (**8 hrs)** | Clear-sun **(48 hrs)** | Partly cloudy-sun (**16 hrs)** | Cloudy/ Foggy -rain (**5 hrs)** | **Total no. of visitors (77 hrs)** |
|---|---|---|---|---|---|---|
| Before or around Dawn (5.30-6.00) **(3hrs)** | | 7 | 2 | 5 | 2 | **16** |
| Morning (6.00-12 AM) **36 (hrs)** | | 64 | **766** | 142 | 8 | **980** |
| Afternoon (12-3PM) **(18hrs)** | | 27 | 84 | 81 | 4 | **196** |
| Late noon /early evening (3-6.30) **14 (hrs)** | | 10 | 87 | 46 | 5 | **148** |
| Evening/Dusk (6.30-7.30) **6 (hrs)** | | 7 | 4 | 12 | 2 | **25** |
| **Total no of visitors (77 hrs)** | | **115** | **943** | **286** | **21** | **1365** |

***No. -3***

## Table- B Floral phenological changes (in bagged flower)

| Fl. no. | Time-6.15 AM | | 6.15 AM | | 6.15 AM | | 6.15 AM | | 6.15 AM | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Date-20 - 4- 2005 | | 25 – 04 - 2005 | | 30 – 04 -2005 | | 05 –05 –2005 | | 10 – 05 -2005 | |
| | **Size of Flower (cm)** | **Flower Condition** | **Flower size (cm)** | **Condition** | **Flower Size (Cm)** | **Condition** | **Flower size (cm)** | **Condition** | **Flower Size (cm)** | **Condition** |
| 1 | 1.8 | 2 | 2.3 | 3 | 4.2 | 4 | - | 7 | - | 7 |
| 2 | 2.2 | 2 | 2.9 | 3 | 4.3 | 4 | - | 7 | - | 7 |
| 3 | 2.8 | 2 | 4.0 | 3 | - | 7 | - | 7 | - | 7 |
| 4 | 1.5 | 2 | 1.6 | 2 | 3.2 | 3 | - | 7 | - | 7 |
| 5 | 2.7 | 2 | 3.2 | 3 | 4.1 | 4 | - | 7 | - | 7 |
| 6 | 1.5 | 2 | 1.7 | 2 | 2.4 | 2 | 3.8 | 3 | - | 7 |
| 7 | 2.6 | 2 | 2.8 | 2 | 3.7 | 3 | - | 7 | - | 7 |
| 8 | 1.5 | 2 | 1.9 | 2 | 3.4 | 3 | 4.7 | 4 | - | 7 |
| 9 | 2.2 | 2 | 3.2 | 3 | 4.4 | 4 | - | 7 | - | 7 |
| 10 | 3.0 | 2 | 4.3 | 3 | - | 7 | - | 7 | - | 7 |
| 11 | 2.4 | 2 | - | 7 | - | 7 | -- | 7 | - | 7 |
| 12 | 0.7 | 1 | 0.9 | 1 | 1.7 | 2 | - | 7 | - | 7 |
| 13 | 0.4 | 1 | 0.7 | 1 | 1.2 | 2 | 3.0 | 3 | - | 7 |
| 14 | 0.9 | 1 | 1.9 | 2 | 3.4 | 3 | - | 7 | - | 7 |
| 15 | 0.5 | 1 | 0.5 | 1 | 0.9 | 1 | 1.3 | 2 | - | 7 |

Note: - 1=Tight, unopened bud, 2=developing bud/opening bud, 3= open flower, 4=mature flowers, 5=flower (corolla) wilting, 6=corolla fallen off, fruit developing, 7=Shade off/died out

## Table -C Floral pphenologycal changes (in open flower)

| Fl. no. | Time-7.15 AM | | 7.15 AM | | 7.15 AM | | 7.15 AM | | 7.15 AM | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Date-20 - 4- 2005 | | 25 – 04 - 2005 | | 30 – 04 -2005 | | 05 –05 –2005 | | 10 – 05 -2005 | |
| | **Size of Flower (cm)** | **Flower Condition** | **Flower size (cm)** | **Condition** | **Flower Size (Cm)** | **Condition** | **Flower size (cm)** | **Condition** | **Flower Size (cm)** | **Condition** |
| 1 | 2.1 | 2 | 2.9 | 3 | 4.3 | 4 | - | 6 | - | 6 |
| 2 | 2.2 | 2 | 2.9 | 3 | 4.6 | 4 | - | 6 | - | 6 |
| 3 | 1.9 | 2 | 2.3 | 2 | 3.9 | 4 | - | 5 | - | 7 |
| 4 | 1.0 | 1 | 1.7 | 2 | 3.2 | 3 | 4.3 | 4 | - | 6 |
| 5 | 1.8 | 2 | 2.2 | 2 | 3.4 | 3 | 4.9 | 4 | - | 5 |
| 6 | 0.2 | 1 | 0.9 | 1 | 1.4 | 2 | 2.7 | 3 | 3.1 | 4 |
| 7 | 0.7 | 1 | 1.7 | 2 | 2.8 | 3 | 4.2 | 4 | - | 7 |
| 8 | 2.2 | 2 | 3.1 | 3 | 4.7 | 4 | - | 7 | - | 7 |
| 9 | 0.4 | 1 | 0.7 | 1 | 1.0 | 1 | 1.9 | 2 | 2.4 | 3 |
| 10 | 2.0 | 2 | 3.4 | 3 | 4.7 | 4 | - | 5 | - | 6 |
| 11 | 0.4 | 1 | 0.6 | 1 | 0.9 | 1 | 1.3 | 2 | 2.5 | 3 |
| 12 | 2.2 | 2 | 3.9 | 3 | 4.4 | 7 | - | 7 | - | 7 |
| 13 | 1.7 | 2 | 1.8 | 2 | 2.2 | 2 | 3.4 | 3 | 4.0 | 4 |
| 14 | 1.9 | 2 | 2.5 | 2 | 3.8 | 4 | - | 6 | - | 7 |
| 15 | 2.5 | 2 | 3.8 | 2 | 4.9 | 3 | 6.5 | 4 | - | 6 |

Note: - 1=Tight, unopened bud, 2=developing bud/opening bud, 3= open flower, 4=mature flowers, 5=flower (corolla) wilting, 6=corolla fallen off, fruit developing, 7=Shade off/died out