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Floral Biology of Pomegranate (*Punica granatum* L.)

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ABSTRACT

A key member of the family Punicaceae, pomegranate (*Punica granatum* L.), is an ancient and important fruit crop of arid and semi-arid regions of the world. Unlike other perennial fruit crops, it has a characteristically short juvenile period of 1-2 years. In tropical climates, it flowers almost throughout the year whereas in subtropics, flowering is observed only once in a year. In areas where the temperature is low in winter, the plant is deciduous, but in tropical conditions, it is evergreen or partially deciduous. Although evergreen pomegranate cultivars flower throughout the year under subtropical conditions in central and western India, there are 3 distinct waves/seasons of flowering i.e. *ambe bahar* (January-February flowering), *mrig bahar* (June-July flowering) and *hasth bahar* (September-October flowering). The inflorescence is a dichasial cyme possessing hermaphrodite, staminate and intermediate flowers, which are urcerate, campanulate and tubular in shape, respectively. Both pin- and thrum-type flowers are found in hermaphrodite flowers. The sex ratio varies in different seasons and with respect to variety. Both self- and cross-pollination occurs in pomegranate. Cross pollination in pomegranate is due to protogyny. From the point of view of crop improvement through hybridization, pollen viability of the male parent and the number of hermaphrodite flowers of the female parent are of paramount significance.

Keywords: flower type, metaxenia, pollination

CONTENTS

INTRODUCTION

Pomegranate is an important fruit crop of tropical and sub-tropical regions (Jalikop 2003). It belongs to the genus *Punica* and family Punicaceae (Chatterjee and Randhawa 1952; Joshi 1956). It has become an indispensable export-oriented crop for the past decade in India (Chandra and Jadhav 2008). Now, India ranks first in area and production and second in export of pomegranate in the world. More than 25 varieties are grown in different parts of India, but 'Bhagwa', 'Ganesh', 'Mridula' and 'Phule Arakta' are the main cultivars (Jadhav and Sharma 2007). The plant habit, flowering physiology and fruiting change, however, with the habitat (Pareek and Sharma 1993). Most commercially grown varieties in India have an edge over the rest due to their free flowering nature. To tap this beneficial feature, crop regulation is practiced in pomegranate according to the need and choice of growers (Ram Asrey *et al.* 2007). However, it is unfortunate that all the commercial varieties in India are susceptible to major diseases and insect pests, especially bacterial blight and wilt diseases (Jadhav and Sharma 2007) and they have posed a serious threat to the pomegranate industry in Maharashtra and adjoining states over the last decade. Researchers have a challenging task of developing high-yielding, disease-resistant varieties acceptable to the international market (Jadhav and Sharma 2007). As a thorough understanding of floral biology is an inevitable pre-requisite for any crop improvement programme (Babu *et al.* 2009a), it is necessary to review the current state of knowledge on floral biology of pomegranate.

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Invited Mini-Review

JUVENILITY

Singh (1999) reported that pomegranate has a relatively short juvenile period of 1 year compared to other fruit crops viz., budded plants of ber, guava grafts, sapota grafts (3 years); litchi layers (4 years); budded plants of aonla (4-5 years); jack fruit (7-8 years). When seedlings are raised from seeds, a small proportion of them set flowers in their first year of growth and bear fruits in the second year (Terakami *et al.* 2007). In general, the seedlings flower and bear fruit in their second or third year of growth. The ability to flower and bear fruit in very young seedlings was also noted in 'Nana' (*Punica granatum* var. *nana*), a dwarf type (Terakami *et al.* 2007). Among perennial plants, the time required for seedlings to flower is not necessarily identical to the time required for young plants derived through clonal propagation (cutting, grafting, budding and layering). In pomegranates, these two physiologically different periods last for a similar duration, while in other species, the length of time required for flowering varies dramatically.

FLOWERING HABIT

The flowering habit of pomegranate is influenced by the prevailing climatic condition of the geographical region where it is grown (Pareek and Sharma 1993). In tropical climates, pomegranate flowers almost throughout the year whereas in subtropics, it flowers once a year. In areas where the temperature is low in winter, the tree is deciduous, but in tropical conditions, it is evergreen or partially deciduous. Evergreen cultivars of pomegranate flower throughout the year (Hayes 1957). Flowering and subsequent fruit set last about one month. During this period, there are three waves of flowering (Ben-Arie *et al.* 1984; Shulman *et al.* 1984; El Sese 1988; Assaf *et al.* 1991; Hussein *et al.* 1994; Mars 2000). In southern India, the flowering season for evergreen cultivars was observed in three periods coinciding with June, October, and March (Nalawadi *et al.* 1973). In the northern hemisphere, flowering occurs in April-May. However, flowering may continue until the end of summer, particularly in young trees. Such flowers are fertile, but the fruit will not mature properly because the plants enter dormancy during the cooler season in Mediterranean regions.

Varieties vary with respect to their flowering season. Under Delhi conditions, 'Dholka', 'Kandhari', 'Muscat White' and 'Patiala' flowered only once a year; 'G.B.1' and 'Japanese Dwarf' flowered twice and 'Double Flower', an ornamental variety bloomed three times a year (Nath and Randhawa 1959a). The varieties having the same number of flowering seasons but differed also in their specific flowering periods. In 'Japanese Dwarf', vegetative growth and flower initiation take place simultaneously. The flowers are formed mostly in clusters, either terminally or in the axils of leaves and are mostly axillary and usually solitary when terminal (Nath and Randhawa 1959a). Singh (1969) reported that pomegranate flowers in spring in north India, but in central and south India, it flowers almost throughout the year. However, the flowers are most profuse early in the monsoon season. Spring flowering (*ambe bahar*) gives fruits in summer. In evergreen cultivars, floral buds of spring flush are borne on mature wood of the first year old shoot, whereas the flowers which appear during July-August are borne on current year's growth. In deciduous cultivars, the flowers are borne on the current season's growth between July and August.

Flower bud development

Flower bud development takes place at varied times under tropical conditions. The time span between the start of flower bud elongation (growth) and anthesis ranges from 14 to 28 days depending on the variety and climatic conditions (Gur 1986). Thus, in subtropical climate of the northern hemisphere, flowering occurs from the last week of March till the second week of May (Singh *et al.* 1978; Fouad *et al.* 1979). Several distinct flushes of flowering on the same tree occur quite frequently. The time required for completion of flower bud development in Indian cultivars is between 20 and 27 days (Nalawadi *et al.* 1973).

Table 1 Weight of flower buds (g) during developmental stages in cv. 'Bhagwa' and 'Ganesh'.

Stage of flower bud development	Bhagwa	Ganesh
S1	0.011	0.011
S2	0.028	0.027
S3	0.060	0.054
S4	0.164	0.124
S5	0.282	0.243
S6	0.685	0.414
S7	1.031	0.694
S8	1.267	1.201
S9	1.526	1.739
S10	2.562	2.398
S11	3.364	3.658
S12	3.680	4.178

Data from HSS, AYODHIAPATNAM.

According to Meena *et al.* (2009), the minimum number of days for flowering was recorded in 'Sur Sakkar' (16 days) whereas, maximum flowering duration was in 'Dholka' (39 days) followed by 'Bedana Sedana' and Muskat (38 days) with an overall population mean of 27 days. The duration of dormancy ranged from 56 days in 'Sur Sakkar' to 67 days in 'Gul-e-Shah Red' followed by 'Kazak Anar' and 'Kali Shirin' (66 days). 'Japanese Dwarf' required the longest period (27 days) for bud development while 'Patiala' required the shortest (14 days). 'Double Flower' took the longest time for petal shed (6-7 days) in comparison to the fertile varieties which took only 1-2 days. There seems to be a positive correlation between the period of bud development and fruit setting.

Regarding the development of flower buds, 12 stages were recognized right from pin-head (stage 1) to ready-to-crack stage (stage 12) based on the weight of flower buds. The weight of flower buds was found to gradually increase from stage 1 to stage 12 (**Table 1**). The time taken for flower bud development was maximum (20.4 days) in 'Ganesh' compared to 'Bhagawa' (19.3 days), 'Mridula' (17.5 days) and 'Arakta' (16.2 days) in June (Babu *et al.* 2009a).

FLOWERING PERIOD

There are two flowering seasons in North India whereas Nalawadi *et al.* (1973) reported three flowering seasons in western India. In subtropical central and western India, there are 3 distinct seasons of flowering i.e. *ambe bahar* (January-February), *mrig bahar* (June-July) and *hasth bahar* (September-October). *Ambe bahar* is most commonly preferred by growers because of high yield consequent to profuse flowering compared to other flowering seasons (Singh *et al.* 1967; Prasanna Kumar 1998). In Karnataka, flowering was observed for 80-87 days in June-August (Nalawadi *et al.* 1973). In Punjab, only one flowering season was observed from April-June (Josan *et al.* 1979a). Under Delhi conditions, depending on the cultivar, flowering may occur once or twice a year (Nath and Randhawa 1959a). In the temperate climate of Himachal Pradesh, flowering takes place during the middle of April (Parmar and Kaushal 1982) and in Bihar, flowering occurs twice during February-March and July-August.

INFLORESCENCE

The pomegranate inflorescence is a cyme (dichasial cyme). Flowers can appear solitary, in pairs or in clusters. The solitary flowers appear on spurs along the branches in most cases, while the clusters are terminal. Due to heavy drop of secondary and tertiary buds, the dichasial cyme appears to

be solitary in clusters (Nath and Randhawa 1959b). In the evergreen pomegranate cultivar, inflorescences of the spring flush are borne on mature wood of one-year-old shoots whereas the flowers which appear during July-August are borne on the current year's growth. In deciduous cultivars, flowers are borne on the current season's growth between July and August.

KINDS OF FLOWERS

The flowers are short peduncled or subsessile. There are three kinds of flowers (**Fig. 1**) borne on the same pomegranate plant viz., staminate, hermaphrodite and intermediate which occur about 1 month after bud break on newly developed branches of the same year, mostly on spurs or short branches (Babu *et al.* 2009b). The male flowers are campanulate (bell-shaped) whereas the bisexual flowers are urcerate (vase-shaped). The intermediate ones are tubular in shape. If fruit set takes place in such flowers, they may drop before reaching maturity, even if some fruits which reach maturity become misshaped. The ovary of the male flower is rudimentary whereas that of intermediate flowers are of the degenerating type. The bisexual flowers possess a well developed ovary with a broad base.

During the early balloon stage, the flower resembles a small pear with a greenish color on its basal part and reddish colour on its apex or entirely dark red (**Fig. 2**). As the flower matures, it develops an orange-red to deep red sepal color, which varies among different varieties. The petals are orange-red or pink and rarely white (Feng *et al.* 1998; Wang 2003; Levin 2006; Beam Home 2007).

The sepals, 5-8 fused in their base, form a red fleshy vase shape (**Fig. 3**). The sepals will not drop with fruit set but will stay as an integral part of the fruit as it matures, generating a fruit crowned with a prominent calyx. The flower has 5-8 petals. Their number usually equals the number of sepals. The petals, which alternate with the sepals, are separated and have a pink-orange to orange-red colour depending on the variety. The petals are obovate, very delicate, and slightly wrinkled. The multiple long stamens are inserted into the calyx walls in a circle and frequently number more than 300 per flower. They have an orange-red filament and yellow bilocular anthers that remain attached to the prominent calyx. Nectaries are located between the stamens and the ovary base (Fahan 1976). The carpels vary in number but are usually 8 superimposed in two whorls. They form a syncarpic ovary and are arranged in two layers.

PETALOIDY

Several pomegranate cultivars from India, Russia, China, and Turkmenistan were reported as ornamental pomegranates that are double flowered (Iskenderova 1980, 1988; Feng *et al.* 1998; Wang 2003; Levin 2006). 'Multiplex' (double, creamy white bloom), 'Chico' (double orange red), 'Chico' (double red), 'Pleniflora' (double red), 'Rubra Plena' (double red), 'Mme. Legrelle', 'Variegata' (double scarlet flowered, streaked with yellowish white) are some of the cultivars with ornamental value. These cultivars have an unusually high petal number and strong petal color. Some of these cultivars are fertile and produce edible fruit while others are infertile. An ornamental variant of pomegranate known as 'Double Flower' produces attractive large rose-like flowers due to the phenomenon of petaloidy wherein the stamens are modified into petals. Trees with such flowers are incapable of setting fruits on their own. When the double flowers were pollinated with the pollen of cultivated pomegranate, they produced fruits suggesting that the absence of fruit set in 'Double Flower' is due to functional male sterility (Jalikop and Kumar 2009). No studies exist on the fragrance of these pomegranates.

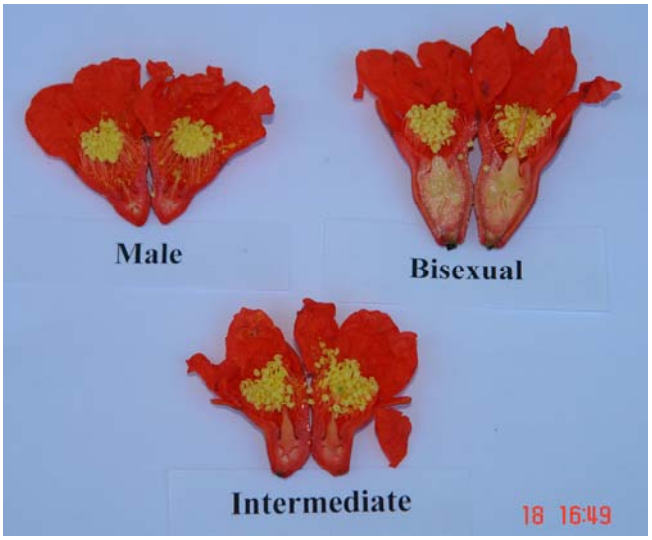

Fig. 1 Kinds of flowers showing petals, stamens, pistil and sepals. Male flower with rudimentary pistil; bisexual flower with long pistil; intermediate flower with medium pistil.

Fig. 2 Flower bud development stages of pomegranate. Stages 1-5: top row; Stages 6-9; middle row; Stages 10-12: bottom row (from left to right).

Fig. 3 Persistant calyx with stamens. Sepals fused at their base with stamens (top), sepals fused at base (both sides).

FLOWER BIOMETRY

According to Babu *et al.* (2009a), the individual flower weight of 'Ganesh' ranged from 1.7 to 4.8 g. Hermaphrodites were found to be the heaviest (4.8 g), staminate (1.7 g) being the lightest and intermediates weighing in between

(2.6 g) the hermaphrodite and staminate. The number of flowers borne in a cluster arising from the leaf axil usually ranged from 1 to 7. However, this varied with variety. The total number of flowers from a 2-year-old plant was 124/ plant which was relatively higher than 'Arakta' (95/plant) and 'Mridula' (111/plant) and lower than 'Bhagawa' (133/ plant). The total number of flowers in 2-year-old 'Bhagawa' plant ranged from 117 to 149 (Babu *et al.* 2009b).

SEX RATIO

Three conditions of sex are generally present in pomegranate viz., male, hermaphrodite and intermediate (Nath and Randhawa 1959b; Nalawadi *et al.* 1973; Singh *et al*. 1978; Josan *et al*. 1979a; Parmar and Kaushal 1982; Shulman *et al.* 1984; El Sese 1988; Assaf *et al.* 1991; Hussein *et al.* 1994; Mars 2000; Babu *et al.* 2009b). Male flowers are those in which the style is present but remains in a rudimentary state. However, the stamens are well developed. The hermaphrodite or perfect flowers have long styles, protruding distinctly beyond the staminal column and also have well developed stamens. The intermediate type of flowers represent a compromise between these two conditions and have a style reaching up to or just below the staminal column. These also have well developed stamens (Nath and Randhawa 1959a).

The percentage of hermaphrodite flowers was highest in 'Japanese Dwarf' (53.8%) and lowest in 'Kandhari' (25%) followed by 'G.B.1' and (25.4%). No hermaphrodite flowers were found in 'Double Flower'. The percentage of hermaphrodite flowers was highest during the early part of the flowering season and it decreased as the flowering season advanced (Nath and Randhawa 1959b).

The hermaphrodite flowers are vase-shaped, while male flowers are bell-shaped (**Fig. 4**). The bell-shaped flower has a poorly developed or no pistil and atrophied ovaries contain few ovules and are infertile. Therefore, bell-shaped flowers are referred to as male flowers and drop without fruit set. Vase-shaped flowers are fertile with a normal ovary capable of developing fruit. The stigma of the hermaphrodite is at the anthers' height or emerges above them. This position allows for self-pollination as well as pollination by insects. The factor that determines the capacity to set fruit is the number of vase-shaped flowers. Therefore, cultivars with a higher vase-to-bell shape ratio will have a higher fruit yield potential. The percentage of vase-shaped flowers among Israeli cultivars is 43.66% (Assaf *et al.* 1991b). Some other studies were also conducted in India indicating a 53.80% vase-shaped flowers for local Indian cultivars (Nalawadi *et al.* 1973). An intermediate third type of flower has been described that has a short style and a developed ovary which is sometimes fertile (Goor and Liberman 1956; Nalawadi *et al.* 1973; Assaf *et al.* 1991b).

ANTHESIS

The appearance of cracks at the apex of the bud (where the calyx lobes unite) is the first sign of unfolding of the floral bud. Then, the sepals gradually separate, exposing the crumpled scarlet petals which start to bulge out. The sepals grow continuously by the pressure of the bulging petals inside, from an incurved form to straight, and from straight to slightly out-curved. After full bloom, the corolla takes about 3-4 hours to open and stretch completely from the inflated and crumpled stage.

In 'Ganesh', anthesis commenced at 7 am and finished at 6 pm (Babu *et al.* 2009a). The opening of the maximum number of flowers occurred between 10 am and 12 noon in June. Hence, the peak period of anthesis for 'Ganesh' is 10 am to 12 noon. Nath and Randhawa (1959b) reported that maximum temperature has some effect on the time of anthesis and with an increase in temperature, anthesis was hastened. As the time of anthesis varies in different varieties, it is possible that the optimum temperature favouring anthesis may also vary according to variety. As the flowers in a bunch are in different stages of development at any point in time, the anthesis of some flowers may synchronize with flower bud development and fruit set of some other flowers. Babu *et al.* (2009b) reported that in 'Bhagwa', anthesis commenced at 9 am, which is comparatively later than 'Ganesh' and finished at 6 pm with the peak period of anthesis between 10 am and 12 noon.

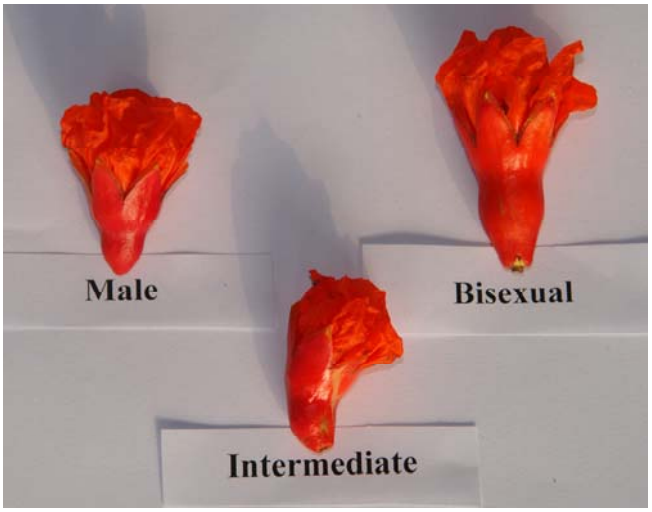

Fig. 4 Male, bisexual and intermediate flowers. Bell-shaped male flowers; vase-shaped bisexual flowers; tubular shaped intermediate flowers.

In 'Muscat White', the corolla takes about 3-4 hours to open and stretches completely from the inflated and crumpled stage, after full bloom. The opening of flowers was observed in all varieties except for 'Dholka', for one week in June. In 'Muscat White' observations were also made in April to note the possible effects of season on anthesis. Maximum temperature influenced the time of opening of flowers. Optimum temperature favouring maximum anthesis of flowers in 'Muscat White' was 37-38°C (Nath and Randhawa 1959b). There was no sharp peak period of anthesis in 'Double Flower', which occurred between 7 am and 12 noon. Few flowers opened before 7 am and after 12 noon. In 'GB 1', anthesis peaked between 11 am and 12 noon while in 'Kandhari' it was between 9 and 10 am and was completed by 12 noon during each of the seven days when observations were recorded. In 'Patiala', however, the time of anthesis was earliest i.e., between 7 and 8 am in comparison with other varieties. No difference was observed in the time and mode of anthesis among the hermaphrodite, male and intermediary flowers.

Josan *et al.* (1979b) studied anthesis and receptivity of the stigma and reported that the time taken by flowers to complete anthesis was 3 to 5 hours. The stigma became receptive one day before anthesis and remained in a receptive state up to the second day after anthesis.

DEHISCENCE

In most varieties, dehiscence starts after the flowers are in full bloom. Generally, it begins with the opening of the flowers but sometimes is delayed by 2-3 hours. The time of dehiscence varies in different varieties and no general sequence is found with regard to the time of anthesis. In 'Patiala', dehiscence started prior to anthesis whereas in 'Muscat White', it started afterward. There was virtually no dehiscence at night. Dehiscence was affected by maximum temperature as well as by atmospheric humidity. No difference was observed in time of anthesis and in the mode and time of dehiscence among hermaphrodite, intermediate and male types of flowers in all the varieties under study (Nath and Randhawa 1959b).

The time of dehiscence of anther varies in different cultivars and no general sequence was found at the time of

anthesis (Nath and Randhwa 1959b, Josan *et al.* 1979a). In 'Patiala', dehiscence starts prior to anthesis whereas in 'Muskat White', it starts afterward. Dehiscence was found to be affected by temperature and atmospheric humidity.

POLLEN VIABILITY AND GERMINATION

Pomegranate produces profuse pollen grains in its flowers. Pollen viability is a vital phenomenon that decides fruit set. With 1.0% acetocarmine, the viable pollen grains became deeply stained whereas the non-viable pollen grains remained unstained; pollen viability of 'Ganesh' ranged from 84.0 to 95.0% (Babu *et al.* 2009a).

The fertility of pollen grains in hermaphrodite flowers was higher than in male flowers (Nath and Randhawa 1959c). In the varieties studied, the pollen grains had different sizes, but their general shape was the same except for 'GB 1' in which the presence of a ring-like band on the pollen surface was noticed. Pollen grains of all varieties were highly fertile. Evreinoff (1957) reported that the development of stamens is normal and pollen is fertile in both hermaphrodite and male flowers. A definite seasonal variation in pollen fertility was noticed. Different media for artificial pollen germination were tried and 12.5% sugar and 12.5% sugar + 0.5% agar were found to be most suitable for pollen germination.

HETEROSTYLY

Heterostyly is also a common phenomenon in pomegranate; in this case hermaphrodite flowers are pin eyed and male flowers are thrum type. Pomegranate flowers exhibit heterostyly which denotes the presence of 2 or more kinds of flowers with respect to pistil length. Interestingly, the pistil is present in all 3 kinds of flowers including staminate (male flower). But, the pistil in staminate flowers is rudimentary. Based on heterostyled, flowers are categorized into 2 types (**Fig. 5**) viz., pin type (the pistil is higher than or equal to that of stamens e.g., hermaphrodite flowers) and thrum type (the pistil is lower than that of stamens e.g. intermediate flower). In 'Ganesh', pistil length was 2.00, 1.55 and 0.65 cm in hermaphrodite, intermediate and staminate flowers, respectively (Babu *et al.* 2009a). Pistils were comparatively longer in 'Ganesh' than in 'Bhagawa' irrespective of the type of flower. Karale *et al.* (1993) also reported heterostyly in pomegranate.

STIGMA RECEPTIVITY

In pomegranate, the stigma attains maturity one day before anthesis and receptivity remains at a peak on the same and second day after anthesis but gradually decreases until the third day after which it abruptly becomes non-receptive (Nath and Randhawa 1959b). Josan *et al.* (1979b) noted that stigmas remained receptive from 1 day before anthesis to 5 days after the completion of anthesis and that pollen germination was over 90%. Cross pollination in pomegranate is due to protogyny.

POLLINATION

Both self and cross-pollination occur in pomegranate. The percentage of fruit set observed by hand pollination and pollination under natural conditions (Nath and Randhawa 1959b; Josan *et al.* 1979b). Gammie and Patwardhan (1924), Nalawadi *et al.* (1973) and Bavale (1978) indicated that pomegranate is a cross pollinated crop. According to Singh (1977), pomegranate is often cross-pollinated crop whereas Pross (1938), working with four pomegranate cultivars in central Asia, considered it to be a self-pollinated crop.

According to Nath and Randhawa (1959b), in 'Muscat White', 46% fruit set was obtained by bagging the flowers and effecting self pollination. Cross pollination, however, improved the fruit set to 67.9%. The concentration of pollen in the atmosphere was found to be quite low for wind pollination. Cross pollination was effected by three insects, namely *Camponotus* spp., *Apis* spp. and *Papilio demoleus*.

Fig. 5 Pin and thrum type flowers. Pin type (long pistil and short stamens); thrum type (short pistil and long stamens).

The percentage of fruit set was high in 'Japanese Dwarf', 'Dholka' and 'Muscat White', 26.9, 20.8 and 25.5%, respectively. Fruit set was low in the remaining three varieties ('Kandhari' 7.3%, 'G.B.-1' 5.4% and 'Patiala' 4.7%). In 'Dholka' and 'Muscat White', the percentage of seed production was high, 37.4 and 42.9% in comparison to other varieties where values ranged from 25.5 to 29.1% (Nath and Randhawa 1959c).

Pomegranate is both self- and cross-pollinated by insects, mainly bees. Wind pollination (anemophily) is reported to occur, but infrequently (Morton 1987). Emasculation and bagging studies on Indian, Turkmen, Israeli, and Tunisian pomegranate cultivars indicate that pomegranate flowers can self-pollinate and produce normal fruit (Nalawadi *et al.* 1973; Karale *et al.* 1993; Mars 2000; Levin 2006; Holland *et al.* 2007). It was noted, however, that the degree of fruit set by self-pollination varies among different pomegranate cultivars (Levin 1978; Kumar *et al.* 2004). In hermaphrodite flowers, 6 to 20% of pollen may be infertile while in male flowers, 14 to 28% are infertile. The size and fertility of the pollen varies with the cultivar and season (Morton 1987). Yazici *et al*. (2009) reported that higher levels of GA_3 affected barren flower formation in pomegranate.

METAXENIA

The immediate effect of foreign pollen on maternal/ovular tissue is referred as '*metaxenia*'. The phenomenon of metaxenia was also reported in pomegranate (Levin 2006). Occasionally, several seeds of different colours occurring within an individual pomegranate fruit is due to metaxenia.

FRUIT

Pomegranate has a persistent calyx at the top of fruit. When the calyx is cut away on ripe fruit, it shows numerous stamens. The fruit is technically a leathery-skinned berry containing many seeds, each surrounded by a juicy, fleshy aril. The fruit develops from the ovary and is a fleshy berry. The nearly-round fruit is crowned by a prominent calyx. The apex of this crown is almost closed to widely opened, depending on the variety and on the stage of ripening. The fruit is connected to the tree by a short stalk (Nath and Randhawa 1959c).

There are some exceptional cultivars, such as the black pomegranate which acquires its black skin very early and remains black until ripening time. The skin (leathery exocarp) thickness varies among pomegranate cultivars (Fahan 1976). The multi-ovule chambers (locules) are separated by membranous walls (septum) and fleshy mesocarp. The arils contain a juicy edible layer that develops entirely from outer epidermal cells of the seed, which elongate to a very large extent in a radial direction (Fahan 1976).

The arils vary in size and the seeds vary in hardness among different varieties. Seedless varieties actually contain seeds that are soft. The fruit ripens 5-8 months after

fruit set, depending on the variety. Josan (1979a) reported that the colour of the sepals and the final colour of the fruit skin are correlated. The cultivars with deep red fruit skin will have a darker red flower.

PERSPECTIVES

There is an urgent need to explore information on the following aspects of floral biology of pomegranate which is an indispensable requirement for developing disease-resistant/-tolerant cultivars:

- Floral biology of commercial cultivars viz., 'Bhagwa', 'Ruby', 'Jyothi', etc. under Solapur conditions;
- Floral biology of bacterial blight disease-resistant/-tolerant genotypes viz., *Punica granatum var. nana*, daru, Kalpitiya, Nayana;
- Floral biology of hybrids resistant/tolerant to bacterial blight;
- Pollen viability and germination of male, intermediate and bisexual flowers;
- Fruit set due to crossing with pollen of male, intermediate and bisexual flowers;
- Sex ratio during different season and methods to increase the proportion of bisexual flowers.

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