INTRODUCTION

*Fagopyrum*, economically the most important genus of the family Polygonaceae, is represented by fifteen species distributed in the temperate regions of the world. Despite the fact that some species of *Fagopyrum*, commonly called as buckwheats, are grown as minor cereals in many parts of the world, the taxonomy of its cultivated taxa is still very confusing. While some workers recognize *Fagopyrum esculentum* and *F. tataricum* as the two cultivated species, others are of the view that the cultivated taxa are either *F. sagittatum* or *F. tataricu.m* or it is a mixture of all the three species.

The chromosomes of all the five species are very small in size thereby restricting detailed karyotypic analysis of the *Fagopyrum* species. Comparison of growth and yield characteristics of the four cultivated species has shown that in *F. esculentum* grain yield is low despite vigorous vegetative growth. This is due to a high incidence of grain abortion. Grain is high in *F. kashmirianum* and *F. sagittatum*. Harvest index of *F. tataricum* is low due to profuse grain shattering. Comparative study of grain composition suggests that grains of *F. esculentum* are distinct from those of the other three species. Based on chromosome studies, growth characteristics and grain composition, it is concluded that *F. esculentum* is distinct from *F. kashmirianum, F. sagittatum and F. tataricu.m*. The last three species, although distinct in many respects, bear a good deal of resemblance.

Five species of buckwheat are found in the Himalayan ranges. Four of these namely *F. esculentum, F. kashmirianum, F. sagittatum* and *F. tataricu.m* are cultivated and one (*F. cymosum*) grows wild. All
the four cultivated species are diploid with normal meiosis and the wild species is tetraploid in which despite normal pairing of chromosomes into bivalents at earlier stages, the subsequent course of meiosis is highly irregular because of stickiness of chromosomes at metaphase I.

Recently, Munshi (1982) has raised another species of this genus namely *F. kashmirianum* Munshi from amongst the types grown in the Kashmir Himalayas. According to Munshi (1982), this new species is allied to *F. tataricum*.

In view of the economic importance of this genus, it is of primary importance to have a clear picture of the taxonomic status of its cultivated taxa. During the course of present investigation the four cultivated taxa namely *F. esculentum*, *F. kashmirianum*, *F. sagittatum* and *F. tataricum* have been analyzed for cytological details and growth characteristics so as to (i) understand the relationships, and (ii) gain an insight into their growth patterns and performance under experimental conditions. The results thus obtained would help in planning future work on this genus. In addition, detailed cytological investigations were also made in the wild tetraploid species *F. cymosum* because of its importance as the productive good ancestors of the cultivated buckwheat and its perennial nature. Based on all the investigations thus made, the taxonomic aspects of the four cultivated taxa are discussed at the end.

The plants of these four cultivated species, are although similar in many aspects, differ in some morphological characters of which the most characteristic and diagnostic feature is their nut character.
Morphological details of these species have been described by Marshall (1969), Govil and Rathar (1981) and Munshi (1982). These details clearly show that in respect of plant and grain morphology, the five species differ from each other. The four cultivated and one wild species in Kashmir Himalayas can be easily identified on the basis of their grain characters.

The name buckwheat, first coined by Scotch, seems to be a distorted version of the word “beech wheat” (‘Buckweizen’ in German) as its seeds have a close resemblance with beechnuts. The beech tree - *Fagus sylvatica* which belongs to the family Fagaceae has a German name “Buche”.

Buckwheat, a name which seems similar to bread wheat (*Triticum aestivum*) has botanically nothing in common with it as the two belong to two different groups of seed plants; wheat to the family Gramineae (monocots) and buckwheat to the family Polygonaceae (dicots). Whereas the wheat is a true cereal, buckwheat with some other plants such as amaranths and chenopods belonging to unrelated families is classified as the pseudocereal or minor cereal.

As far as the center of origin of buckwheat is concerned, most of the investigators believe that the genus *Fagopyrum* originated in the Himalayan region either in western China or northern India. The common buckwheat *F. esculentum* along with tartary buckwheat (*F. tataricum*) and *F. segittatum* has a wide distribution, especially in the northern hemisphere. According to Kreft (1983) buckwheat is grown mainly in India, Nepal, Afghanistan, Brazil, Canada, China, Hungary, Iran, Japan, Korea, Pakistan, USA, USSR, Yugoslavia and to some
extent in Austria, France, Great Britain, Italy and Switzerland. At present USSR leads all other countries in buckwheat production.

According to De Candolle (1883) the common buckwheat was not cultivated in ancient times and there is no name for any *Fagopyrum* species. De Candolle (1883) was of the opinion that buckwheat reached Europe through Russia during the middle ages and spread to the other parts of Europe, China and mountains of India during 17th century. From Europe it was brought to USA and it was grown by Dutch colonies along the Hudson River before 1605. According to Airy-Shaw (1973) the buckwheat is distributed in the temperate regions of the world.

In India, buckwheat is cultivated over a very limited area in the moist and temperate belts of Himalayas. It is grown mainly in Jammu & Kashmir, Himachal Pradesh, hilly tracts of Uttar Pradesh, Assam, Sikkim and to some extent on South Indian hills particularly in Tamil Nadu and Kerala. In Yugoslavia, buckwheat has been grown at least from the beginning of the 15th century (Kreft, 1980). Later in 16th and 17th centuries it became widely spread and one of the most important crops. Japanese culture has a deep relationship with buckwheat (Nagatomo, 1983). Nagatomo (1983) reports that in Japan there are many mountains, places, stations, folksongs, folk stories and proverbs based on buckwheat. For a long time Japanese have a taste for buckwheat. Nodules made of buckwheat are one of the popular items of traditional foods of Japan.

The majority of *Fagopyrum* species are diploid with \(2n=16\) chromosomes with the basic chromosomes number i.e. \(x=8\) whereas *F.*
*F. cymosum* is a natural tetraploid (2n=32). *F. cymosum*, an Asian wild species is believed to be a progenitor of cultivated buckwheat. The taxonomy of the cultivated species is still very confusing. While some workers recognize *F. esculentum* (common or Japanese buckwheat) and *F. tataricum* (tartary buckwheat) as the two common cultivated species, others hold the view that the cultivated taxa include *F. segittatum, F. tataricum, F. esculentum* and *F. kashmirianum*.

**BUCKWHEAT CULTIVATION IN INDIA**

![Map of India with buckwheat cultivation highlighted]
The chromosome number reported for the various species are as follows:

*F. kashmirianum* 2n=16 (Govil and Rathar, 1981)

*F. esculentum* 2n=16 (Stevens, 1912; Jarotzky, 1928)

*F. cymosum* 2n=32 (A tetraploid species) (Jarotzky, 1928)

*F. tataricum* var. notch seeded 2n=16 (Quisenberry, 1927)

Mansurova (1948), while studying the karyology, observed that the translocation involving chromosomes V and VI may be responsible for an additional satellite in *F. emerginatum*. Almost all of induced tetraploid plants have proved to be of little practical utility due to the low fertility (Adachi *et al.*, 1983). According to Muntzing (1936), the low fertility in induced autotetraploid buckwheats is caused by the irregularity of meiosis and disturbance of genetic balance.

The *Fagopyrum* has typical Polygonum type of Embryo sac consisting of three cells of egg apparatus at the micropylar end, the three antipodals at the chalazal end, and a large binucleate primary endosperm cell (Mahoney, 1935). Mahoney (1935) further reported typical crucifer type of embryo sac in buckwheat as in the two celled embryo of *F. esculentum* the apical cell gives rise to the embryo and the basal cell forms the suspensor. The inheritance of various characters in buckwheat is not very well known.

The common buckwheat is known in different regions of India by different names such as Hindi - Kotu, Garhwali - Phaphar, oggal and Kumaoni - oggal.
It is a herb of moderate height which ranges from about 50 cm to 150 cm. The hollow angular greenish-brown stem bears many branches. The leaves are heart shaped, 4-7 cm in length and 3-5 cm width. While the lower leaves bear long petioles, the upper leaves are nearly sessile. Flowers are white pinkish in colour, have five partite persistent perianths and are arranged in dense clusters in axillary and terminal cymes.

In buckwheat plants, Sugawara (1958) described a strong correlation between the incidence of retarded pistil development, giving rise to female sterility and unfavourable photoperiodic conditions (long-day). Under long-day conditions, most varieties produced frequent abnormal stigmas. Pausheva (1965) noted a succession in opening of the flowers, the short-styled flowers remaining open for a shorter period than the long-styled and considerable differences between individual plants. The short-styled flower and long-styled flower have different photoperiodic requirements.

It is a well known phenomenon that flowers of many plant species do not remain constant in form or color when legitimate pollination or fertilization occurs; following pollination or fertilization, they fade and become unattractive to pollinators. It is also shown that with legitimate pollination of long-styled flowers effected at different times of the day, the best set is obtained with pollen collected and applied immediately after dehiscence of the anthers. Naumova (1976) observed that the ratio of long-styled (L) to short-styled (S) plants in varieties varied between 1:0.88 and 1:1.37, and L and S plants differed in their grain yield, namely a shortage of legitimate pollen led
to poor fruiting in both forms and especially poorer in the case of L plants. It is believed that under the condition of a lack of pollinators, the long period of opening and poorer seed fruiting in the long-styled pin flowers are quite common in both the species *F. esculentum* and *F. kashmirianum* (Namai, 1990).

Gorina and Anokhina (1978) clearly reported that there were great intervarietal differences in nectar production of buckwheat, and environmental conditions, especially low temperature, had a greater effect on nectar production in early varieties than in mid-season and late ones. Kopeljkievskii et al. (1978) described that nectar production was correlated with grain yield \( r=+0.92 \), number of fruits per plant \( r=+0.83 \) and the frequency with which bees visited the flowers \( F=+0.64 \), and Kopeljkievskii et al. (1979) also described that nectar production proved to be correlated with leaf area \( r=+0.79 \) and yield \( r=+0.67 \).

Progenies better able to withstand cold and drought and containing 15-40% more sugar in the nectar were obtained by selecting for high nectar production. Chepik (1979) described that the sugar content in the nectar of 100 florets was 13.2 mg in short-styled and 11.4 mg in long-styled forms, the coefficient of variation in sugar content of the nectar was 53.0% in the long-styled and 20.2% in the short-styled form, and nectar production was correlated with yield \( r=+0.91 \) and with number of florets per plant \( r=+0.77 \). Chepik (1981a) described that forms obtained by selecting seedlings with a well-developed root system were found to have a higher nectar production rate and nectar content than normal forms under low temperatures and under drought conditions. Chepik (1981b) also
noted that tetraploids contained more sugar in the nectar than diploids and the nectar content, as the amount of sugar/100 flowers was about 20 mg in tetraploid varieties and 10 mg in diploid ones. Jablonski et al. (1986) reported that the quality of the homostylous variety for beekeeping is similar to that of heterostylos one.

Komenda et al. (1986) studied 120 varieties from different countries and noted that pistil length differed among plants of the same variety, and that perianth size in pin types was generally smaller than in thrum types, but 1000-seed weight tended to be greater in the latter. Ren and Liu (1986) reported that the mean flower number/plant differed among the varieties from 700 to 1070, and this figure varied with locality. The percentage fruit set varied from 5.3 to 9.0% and was in general inversely related to the number of flowers.

In spite of the general description that buckwheat is a typical dimorphic heterostylos plant, long-styled pin type with short stamens and short-styled thrum type with long stamens, there are actually wide inter- and intra-varietal variations in length of pistil and stamen in each flower. Sobolev (1988), therefore, recommended a new system for exactly classifying pistils and stamens in buckwheat flowers, as for example, very short (b), short (B), long (l) and very long (L), and combining these classes gives 16 types of hermaphroditic flower so that the symbol for pistil length is followed by that for stamen length; hermaphroditic flowers are divided into two major groups, heteromorphic and homomorphic, with the former further divided into 3 subgroups (heteromorphic, subheteromorphic, and semiheteromorphic) and the latter into 4 (homomorphic, subhomomorphic, semihomomorphic and intermediate) according to
similarities in pistil and stamen length. In each subgroup, there are 2 types (long-styled and short-styled).

Samborska-Ciania et al. (1989) studied buckwheat flowers just after opening, over a 24-day period, in connection with the flower position on the raceme and stage of flowering, and concluded that the first 3 flowers on the raceme and the size of their flower components were largest in the opening sequence. Pistil length and stigma cell size were greater while filament length and pollen grain size were less for pin than thrum flowers. In general, pistil and filament length, stigma cell size and pollen grain size decreased with each successive flower in the raceme. Pollen grain cell size decreased as flowering progressed in pin type flowers while in thrum type flowers it reached a peak at full flowering and had the same, lower value at the beginning and end of flowering. Stigma cell size decreased as flowering progressed but it tended to level off towards the end of flowering. Pistil and filament length were relatively constant as flowering progressed except for pistil length which decreased in thrum flowers after full flowering.

Flowers are white pinkish in colour, have five partite persistent perianths and arranged in dense clusters in an axillary and terminal cymes. Each flower has eight stamens, the bases of which alternate with eight honey secreting glands. This is an arrangement to ensure insect pollination and makes the plant immensely useful for honeybee keepers. The gynoecium is tricarpellary, ovary unilocular with single erect ovule. Style is tripartite, each with a knob like stigma.

The 'pin' flowers have their styles projecting above the anthers i.e. longer than anthers while the 'thrum' type flowers have style
shorter than their anthers. In this way the flowers are dimorphic. *F. esculentum* shows self-sterility, i.e. it is cross pollinated. Flowers which have styles and anthers of the same length are sterile.

In common buckwheat, the number of fruits set is much smaller in comparison to the number of flowers on the plant. The main pollinating agents of the buckwheat are honeybees. Hartley (1964), Elagin (1968) and Free (1970) have shown that if the honey combs are kept in the buckwheat fields, the yield increases considerably. An alternate pollinating agent of the buckwheat is the alfalfa leaf-cutter bee (*Megachile rotundata*) (DeJong, 1972; Jay, 1971). Some pollination may also be facilitated by wind (Marshall, 1969).

The fertility of flowers also depends upon their position on the plant. The pollen grains obtained from the base of the inflorescence are large and have maximum fertility (Pausëva, 1960).

The fruit of the common buckwheat is a brown, black or mottled, one seeded, dry, triangular nut or achene which measures about 6 mm x 3 mm. The surface of the fruit is hard, smooth and convex. The nuts of *F. esculentum* var. *emerginatum* also possess a kind of outgrowth at each of the three borders of the fruit known as wing. According to Morris (1947), the winged condition of the seed is dominant over non-winged and the inheritance is complex as many intermediate types appear in the cross between the two extreme types.