PBG 605: (Breeding vegetable crops) 3(2-1)

Session # 1: Tutorial

Introduction and importance of vegetable crops

In the nineteenth and twentieth centuries, humans tried to understand in greater detail the rules and processes of evolution, domestication, genetics, and breeding of plants. In the field of evolutionary biology, background was built by C. Darwin (Darwin 1859), domestication by N. I. Vavilov (see Lo¨ ve 1992) and J. R. Harlan (Harlan 1992), and genetics and breeding by J. G. Mendel (Orel 1996). The Vilmorin-Andrieux family in France pioneered European plant and vegetable breeding in the nineteenth century, as did Luther Burbank in the United States, who gained particular fame for his work with the potato (Stickland 1998). By the 1940s, Darwin's concept of evolution and Mendel's ideas of heredity had been brought together to produce "the modern synthesis" (neo-Darwinism) and this was one of the great intellectual triumphs of the twentieth century (Tudge 2000). These germinal ideas and their combination created the background of modern biology and genetics. Practical application and utilization of this knowledge applied to studies of plant genetic resources has lead to advances in plant breeding. Many vegetables are ancient cultivated plants that have played an important role in human development. In situ cultivation of plants began more than 10,000 years ago as result of changes in human life style from nomadic and semi-nomadic to sedentary life (Hancock 2004). Sauer (1969) outlined the requirement for plant domestication and early cultivation. As a crucial factor, he considered the status of land (i.e., that the first cultivated lands would have been those that required little preparation). Environmental conditions (rainfall and temperatures favorable for growing plants) were considered important. These conditions played a major role in the development of diverse food plants. N. I. Vavilov postulated at least eight centers of origin and diversity of cultivated plants including vegetable crops (Figure 1.1; Vavilov 1950). All of these centers encompassed modern vegetable crops (Rubatzky and Yamaguchi 1997). The diversity of vegetables is considered an international and world heritage (Stickland 1998).

IMPORTANCE OF VEGETABLE CROPS

Cereals are a major source of carbohydrates and fiber, grain legumes supply protein and antioxidants, and oilseeds are an excellent source of dietary fatty acids, whereas vegetable crops are valuable sources of nutrition, including mineral nutrients, antioxidants, and vitamins. The primary vegetable crops included in this volume are potato, tomato, brassicas, okra, pepper, allium, cucurbits, lettuce, eggplant, and carrot. Many legumes, such as common bean, pea, cowpea, pigeonpea, faba bean, chickpea, cowpea, mungbean, azuki bean, and lentil are also used as green vegetables. These legumes are described in Grain Legumes, Volume 1 of this series. Green immature soybean pods (known as Edamame), described in Oilseed Crops, Volume 4, are popular in Japan, Korea, China, and Taiwan. Soybeans are a major source of protein, vitamin A, carbohydrates, and iron, as well as many antioxidants. Maize (sweet corn) is also included in vegetables and is discussed in Cereals, Volume 2 of this series. Vegetable crops belong to the families Alliaceae (onions), Asteraceae (lettuce), Brassicaceae (brassicas), Cucurbitaceae (cucurbits), Malvaceae (okra) and Solanaceae (potato, tomato, pepper, and eggplant) and Apiaceae (carrot, celery), whereas legumes belong to Fabaceae.

Vegetable production provides a way out of poverty for smallholder farmers and the landless. It generates more income and jobs per hectare, on-farm and off-farm, than most other agricultural enterprises.

Vegetables are vital for combating the "hidden hunger" of micronutrient malnutrition:

Over two billion people, most of whom are poor women and children, do not have access to sufficient micronutrients in their diets – and vegetables provide their best source of these. In sub-Saharan Africa the consumption of vegetables is only 43% of that recommended for good health and its diversity has been deteriorating.

Vegetables are essential for a balanced diet and good health:

A past global development emphasis on increasing the production of staples has resulted in reduced dietary diversity and reduced health. Increasing the consumption of vegetables is essential for the good health of rich and poor alike, but vegetable consumption is below the recommended minimum in most countries around the world.

Vegetable research has the highest rate of return of any agricultural research:

In 2005 a major review of the returns to agricultural research and extension from 375 projects across the world was commissioned by the UK's Department for International Development

(DFID). It found that agricultural research and extension have consistently yielded high rates of return to public investment, with 82% of research case studies yielding returns higher than 20%.

Session # 2 & 3: Laboratory

Study of reproductive biology of important vegetables

Tomato:

Tomato (Lycopersicon esculentum Mill) is an economically important vegetable that is widely used for both basic and applied research. Numerous advantageous features render tomato as a favorable model species for plant research in areas of classical genetics, cytogenetics, molecular genetics, and molecular biology. Its self-pollinating nature, easy crossability to the wild species, simple genome, and vast genetic variation render tomato an ideal species for classic genetic studies. The 12 chromosomes in the tomato genome can be readily identified through analyses of pachytene karyotype, synaptonemal complexes, and chromosome or chromosome arm-specific DNA sequences, making it an excellent species for cytogenetic research. Moreover, its small genome size (w950 Mb), various high-density molecular linkage maps, and numerous genomic databases and DNA libraries—such as expressed sequence tags and bacterial artificial chromosomes— make tomato a model system for molecular genetic and genomic studies. In addition, the ease of cell culture and genetic transformation by Agrobacterium-based vectors render tomato an excellent species for genetic engineering and molecular biology studies. Because of these outstanding features and its economic importance, tomato has been chosen by the recently initiated International Solanaceae Genome Project (SOL) as the Solanaceae model species for genome sequencing. The availability of whole genome sequences in the next decade will likely lead to a better understanding of plant adaptation and diversification. The utilization of potential natural variation discovered from the SOL project will accelerate tomato improvement, and thus improve the health and wellbeing of humans in a more environmentally friendly and sustainable manner.

The tomato and its close wild relatives are believed to have originated in the mountainous regions of the Andes and the Galapagos Islands (Villand et al. 1998). The cultivated tomato became domesticated in the early civilizations of Mexico and then disseminated to the other parts of the world (Rick 1958). Alternative scientific names for tomato have appeared in the literature, such as Solanum lycopersicum L., Lycopersicon lycopersicum (L.) Karsten, or Lycopersicon esculentum (Broome et al. 1983). The last one was first proposed in the middle of the eighteenth century and has become the most frequently used (Taylor 1986).

Tomato (Solanum lycopersicum L.) is one of the most important vegetable crops under solanaceous group which can be grown both under open field conditions and greenhouses. It has become an important commercial crop when we talk about the human nutrition. It has more than 3000 species among solanaceous vegetables. Tomatoes were originated in Peru (South America) and first domesticated in Mexico on the basis of availability of numerous cultivated and wild relatives of the tomato found in this area (Rick. 1969). There are two types of tomatoes that are cultivated and wild form tomatoes. The genetic diversity in the wild type of tomatoes, especially in case of selfincompatible species such as S. chilense and S. peruvianum are very vast. This crop is widely grown throughout the tropical and subtropical areas around the world. Tomato is considered as a protective food because it provides nutrients such as beta-carotene, lycopene, vitamin C and flavonoids. Furthermore, tomato has achieved high popularity especially in recent years because of lycopene's anti-oxidative activities and anti-cancer functions (Fentik et al., 2017).Tomato fruits were very small berry and were considered as poisonous in the ancient times but in 1820, farmer R. G.

Floral biology:

The cultivated tomato has been used in genetic studies because of the ease with which it can be easily manipulated and also its diversity present within the population. Tomato has perfect flowers, having viable male and female parts. In tomato anthesis starts around 6 a.m and finally the flower opens around 11 a.m, dehiscence of anther occur between 8 to 11 a.m. Pollen remain viable from 2 to 5 days. Stigma of the flower remains receptive 16 to 18 hours before anthesis upto 6 days after anthesis (Cheema et al., 2004). The reproductive biology and production of appreciable quantity of seeds per fruit provide ample opportunity for manifestation of heterosis in tomato (Singh and Singh, 1993). Under the favourable environmental condition more than 250 seeds may be obtained from a single pollination. In tomato emasculation for controlled pollination must be done nearby one day prior to opening of the flower in order to avoid the self-pollination. Making controlled pollinations under greenhouse is more efficient than under field conditions environments. The stigma appears to be fully receptive at this stage, thus allowing pollination immediately after emasculation. Emasculation of flower is done between

55 and 65 days after planting. Pollen grains are collected before it is shed. When the corolla of the emasculated flower turns bright yellow the stigma is ready for pollination. For 3-5 weeks repeat the pollination 2-3 times a week. Usually, fruit starts to enlarge after successful pollinations are visible within one week (Fentik et al., 2017).

Objectives of plant breeding:

Needs of producers, consumer and processors include breeding for processing (TSS, color, total acidity and viscosity) Panchal et al., (2017) evaluated tomato genotypes in order to estimate the extent of heterosis and quality traits like, TSS, lycopene content, ascorbic acid content (vitamin-C), average pulp content, pulp: skin ratio, solid: acid ratio and titrable acidity and cross JTL-12-12× JT-3 followed by NTL-1 × AT-3, JTL-12-12 × GT2 shown positive significant heterosis for all the traits., fresh market (shelf life for distance transport, round fruit and large size), home gardens (high fruit quality, appropriate disease resistance and earliness) and green house production of tomatoes (high yielding for several successive markets and indeterminate), are the general breeding objectives. Some of the major specific objectives are Fruit yield, Earliness, Growth habit, Fruit quality, Resistance to diseases and pest, Resistance to abiotic stresses and Suitability to post harvest storage and transport. The fruit quality now days becoming one of the important breeding objectives which include following studies (Ramachandaran, 2013).

Session # 4: Tutorial

Importance of vegetable crops

Vegetables, the cheapest and nutrient-rich food sources within the economic reach of the poor, play a vital role in the human diet since they provide carbohydrates, protein, fat, minerals, vitamins, fibres, and phytochemicals (nonnutrient bioactive compounds), which are essential for making the body’s immune system strong, detoxifying carcinogens, reducing muscular degeneration, and protecting the body from infectious ailments. The importance of eating vegetables for the maintenance of good health is now well recognized all over the world.

Vegetables are grown worldwide in almost 200 countries and make up a major portion of the diet of humans in many parts of the world and play a significant role in human nutrition, especially as sources of vitamins (C, A, B1, B6, B9, E), minerals, dietary fiber and phytochemicals [1]. They can be also a major source of protein for the poor. Vegetables in the daily diet have been strongly Vegetable crops include crucifers (cabbage, cauliflower, kale, and brussels sprouts), tuber bulbs and root crops (potatoes, onions, garlic, turnip, leek, carrot, beet root, and radish), vegetable fruits (tomato, eggplant, okra, and cucurbits), salad crops (spinach, lettuce, amaranth, and celery), and protein-rich grain legumes (common bean, cowpea, faba bean, chickpea, and mungbean). Beans and peas have been excluded from this volume on Vegetable Crops because they have been included in the volume Grain Legumes of this series. The majority of the vegetable crops originated in the Old World, particularly in Asia, while potato and tomato originated in the New World—South America. Today, potato and tomato are important vegetables throughout the world. They are considered a miracle gift of the New World and are grown worldwide in a wide range of agro-eco-climatic conditions on a commercial scale as well as on a small scale, often known as “kitchen gardening.” Potato production alone accounts for 44% of all the vegetable crops production listed by the Food and Agriculture Organization (FAO) (http://faostat.fao.org). It is ranked as the fourth most important food crop of the world. Furthermore, more than one-third of all the potatoes are now grown in the developing countries (http://www.cipotato.org). The intensive varietal improvements of vegetable crops for high yield and improved nutritional quality are primary breeding objectives of various national and international programs. Three international centers for vegetable crops have been established: (1) The International Potato Center [Centro Internacional de la Papa (CIP)] was founded in 1971 in Lima, Peru (http://www.cipotato. org); its primary mandate was to deliver high-yielding potatoes. (2) The Asian Vegetable Research and Development Center (AVRDC) was established in 1971 in Shanhua, Taiwan (www.avrdc.org); its mandate is to improve tomato, brassicas, alliums, cucurbits, peppers, eggplant, okra, and legumes including edamame (edible vegetable soybean). (3) Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia (www.ciat.cgiar.org) works on beans as one of its primary mandates (described in Grain Legumes, Volume 1 of this series), and also works on sweet potatoes. The Indian Institute of Vegetable Research (IIVR) in

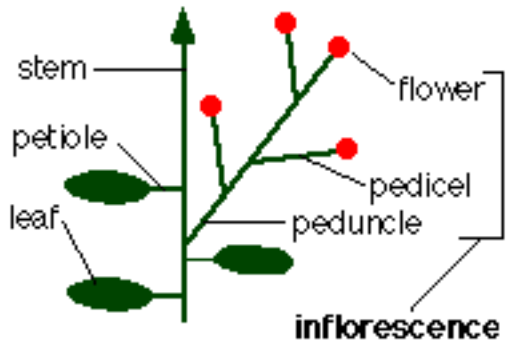
Varanasi, Uttar Pradesh, India (www.icar.org.in) is a national institute; it concentrates on multidisciplinary research approaches for the improvement of the major vegetable crops grown in India. These and other centers around the world collect, maintain and preserve germplasm resources as potential sources of genes for high yield, resistance to various biotic and abiotic stresses, and for improving nutritional, storage, and shelf life qualities. In Europe, Warwick Horticulture Research Station (HRI) (a part of the University of Warwick, Warwick, UK; formerly known as National Vegetable Research Station (NVRS) and then HRI in Wellesbourne, UK) is a leading world center of vegetable research and breeding. Since its days in Wellesbourne in the middle of the twentieth century, this institution has contributed substantially to progress in several areas (breeding, plant protection, and disease management, plant nutrition and physiology, seed and growing technology, germplasm preservation and characterization, and biotechnology of vegetable sciences). Most genetic improvements of vegetable crops have been accomplished by conventional breeding assisted by germplasm resources, cytogenetics, plant pathology, entomology, agronomy, cell and tissue cultures, and molecular biology. Because there is no consolidated account of germplasm resources, cytogenetic manipulations, biotechnological approaches, and breeding of vegetable cops, it was important to bring out this book, Volume 3 in the series Genetic Resources,Chromosome Engineering, and Crop Improvement. World-renowned scientists were invited to contribute chapters on the vegetable crops of their expertise. This volume consists of 11 chapters dealing with vegetable crops of great economic importance for the developed and the developing countries of the world. These chapters give comprehensive and authoritative accounts of genetic resources and their utilization for improving yields, disease and pest resistance, other agronomic traits, and nutritive quality of the most widely grown and consumed vegetable

Session # 5 & 6: Tutorial

Reproductive systems of important vegetables.

Tomato:

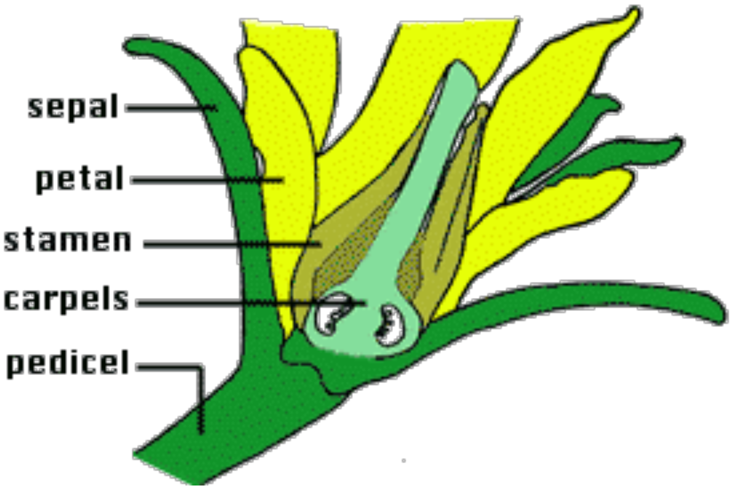
Tomato plants have yellow flowers that, in full bloom, are generally less than an inch in diameter. The flowers can occur in a simple or a complex inflorescence. The diagram to the right depicts a typical inflorescence.



There are different types of inflorescences. To the right, two types have been shown. A raceme inflorescence is one in which the flowers branch off laterally from a main shoot that grows indefinitely. In a cyme inflorescence, the shoot apex differentiates into a flower, subsequent growth occurs due to activity in an axillary branch which will eventually terminate in a flower.

The tomato flower occurs in the three organizational patterns drawn below. Simple flowers can appear as well as simple cymes and branched cymes. The number of flowers that occur in an inflorescence is dependent upon environmental factors such as temperature.

If we take a look at a longitudinal section through a tomato flower we can see that the tomato flower is organized in four whorls of organs which are labelled below. The pedicel is the stem that supports the flower.



Okara:

The cultivated okra [Abelmoschus esculentus L. (Moench)] is an important vegetable crop throughout tropical and subtropical low altitude regions of Asia and Africa. It is valued very highly for its mature, tender, and green fruits. Okra fruits are rich in calcium (90 mg per 100 g fresh weight) and provide a valuable supplementary item in the tropical diet. The young fruits are consumed as cooked vegetable, mostly fresh but sometimes sun dried or frozen. The fruit is fairly rich in protein and minerals. Its seed contains 13–22% edible oil and 20–24% edible protein, and is viewed as alternative source for edible oil. Stem fiber of some wild Abelmoschus species is used for making rope. Edible roots are used as food and for medicinal purpose. In Papua New Guinea and the Solomon and Fiji Islands, some forms of A. manihot are used as a leafy vegetable. The roasted and powdered seed of okra is substituted for coffee in parts of China and Africa, while in Japan, okra pods are pickled.

Botany and Floral Biology

Bailey (1969) described the morphology of A. esculentus in detail. Okra is an erect, herbaceous annual, 1–2 m tall with green stems or with a reddish tinge. Leaves alternate, broadly cordate, palmately 3–7 lobed, hirsute, serrate. Flower solitary, axillary with about 2 cm long peduncle; epicalyx up to 10, narrow hairy bracteoles that fall before the fruit reaches maturity; calyx split longitudinally as flower opens; petals 5, yellow with crimson spot on claw, 5–7 cm long; staminal column united to the base of petals with numerous stamens; ovary superior, stigma 5–9 deep red. Fruit is a capsule, light green, or sometimes red in color, pyramidal-oblong, beaked, longitudinally furrowed, 10–30 cm long, dehisces longitudinally when ripe. Seeds are green to dark brown, rounded, or sub-reniform. The greatest increase in fruit weight, length, and diameter occurs during 4–6 days after pollination. Generally, the fiber formation in the fruit starts from the fifth to sixth day of fruit formation, and a sudden increase in fiber content from the ninth day is observed. Okra flowers occur singly in the leaf axils and the flowers are hermaphrodite. Flowers take about 22 days to fully develop. Anthesis takes place in the morning, and most flowers open between 9:00 and 10:00 a.m. During August high temperature and low humidity hasten anthesis. Anther dehiscence begins when the flowers are opening and is completed before flowers are finished. Dehiscence occurs from 6:00 to 11:00 a.m. and is at a maximum between 8:00 and 9:00 a.m. Pollen grains are round in shape. Pollen fertility is optimum between 6:30 and 8:30 a.m. Stigma receptivity varies in duration and is maximally recepetive on the day of anthesis.

Session # 7& 8: Tutorial

Breeding objectives of important vegetable crops

Breeding objectives are those specified agronomic parameters of any crop set by breeders for improving genetic make up of crop more suitable for their use by the consumers for ex. early maturity, resistant varieties for biotic (diseases & pests) and abiotic (drought, cold, salinity), quality (colour, shape and size of vegetables) etc.

Breeding Objectives of okara:

The genetic improvement of the following traits should result in increased productivity in terms of time and area of cultivation.

1. To develop high-yielding varieties capable of an inceased marketable yield of darkgreen, tender, long, smooth pods. High yield of seed would be an added advantage.

2. To breed early-maturing and late-senescing varieties.

3. To develop varieties resistant to virus diseases such as okra mosaic virus, YVMV, and leaf curl; fungal diseases such as vascular wilt, Cercospora blight, powdery mildew, fruit rot, and damping off; root-knot nematodes; insect pests such as shoot and fruit borer, leafhopper, aphids, red spider mite, flower beetles, white fly, etc.

4. To develop varieties with multiple resistance to diseases and insect pests, with special emphasis on combining yellow vein mosaic virus resistance with resistance to okra mosaic virus, leaf curl, fruit and shoot borer, jassids and leafhopper, and rootknot nematodes.

5. To develop the most suitable ideotype possessing characters such as short plant with more

nodes and short internodal length, which is more productive than tall plant with long internodal distance. Plants and fruits should be devoid of conspicuous hairs. Fruits should snap easily from the stalk, facilitating easy and economic harvest. Photoinsensitive type would be more desirable.

6. To breed varieties with optimum seed-setting ability for rapid multiplication.

7. To evolve varieties tolerant to abiotic stresses, especially tolerance to low temperature, drought, excessive rain, saline and alkaline soils, and damage by fungicides, insecticides, and other environmental pollutants.

8. To develop varieties suitable for export market.

9. To evolve varieties with better nutritive attributes and also varieties suitable for dehydration, canning, and freezing.

10. To develop the most economic hybrids.

11. To evolve varieties and hybrids for wider adaptibility.

BREEDING OBJECTIVES TOMATO

- **Earliness**
- **Increased fruit yield**
- **Fruit quality:** Large round fruit with adequate firmness and shelf life, uniform fruit size, shape, red colour and freedom from external blemishes or abnormalities for fresh market Large fruit size, high fruit quality and continuous production for home garden

tomatoes Deep, uniformly red coloured tomatoes, pH below 4.4, high TSS (4.5-7%) and high alcohol insoluble solids (AIS) in processing tomatoes

Indeterminate cultivars for greenhouse production:

Resistance to diseases:

Fusarium wilt (Fusarium oxysporum f.sp. lycopersici (Sacc.) Verticillium wilt (Verticillium albo-atrum Reinke & Berth) Late blight (Phytophthora infestans) Early blight (Alternaria solani) Septoria leaf spot (Septoria lycopersici) Anthracnose (Colletotrichum phomoides) Bacterial wilt (Pseudomonas solanacearum) Bacterial canker (Corynebacterium michiganense) Tomato mosaic (Tobacco mosaic virus) Root knot nematode (Meloidogyne incognita)

Resistance to insects:

Fruit borer (Heliothis armigera) White fly(Bemisia tabaci) □ Resistance to abiotic stresses: Cold set varieties Hot set varieties

Drought tolerance, Salt tolerance, Low temperature germination and growth Chilling injury tolerance Herbicide tolerance

Session # 9 & 10: Tutorial

Breeding and hybridization constraints of vegetables of vegetables and possible improvement strategies

Although yield and adaptability are the primary concerns of most tomato breeding programs, efforts have also been taken seriously to develop cultivars with improved fruit quality (Berry and Uddin 1991), fruit color (Chalukova and Manuelyan 1991), and attributes suitable for processing and machine harvesting (Berry and Uddin 1991; Lukyanenko 1991b).

Wide Hybridization

Interspecific Hybridization

Due to limited variation in the cultivated tomato, breeders have been repeatedly forced to use exotic germplasm to find genes of interest for tomato improvement. Wild Lycopersicon species possess great genetic variation and many agriculturally important traits (see discussion above). Moreover, all these wild species can be crossed to tomato with varying degrees of difficulty; therefore, all of the germplasm in the genus is transferable to the cultivated tomato. In fact, many traits of economic importance have been bred from wild Lycopersicon species and many cultivars possess various combinations of such resistances (Rick 1986; Rick et al. 1987). Most notably, resistances to over 40 major diseases have been detected in wild accessions, at least 20 of which have been bred into horticultural tomatoes (Rick and Chetelat 1995). Improvements have also been made in fruit quality traits, tolerance of abiotic stresses (e.g., drought, temperature extremes), and resistance to insect pests. Examples of successful incorporation of genes from wild species into tomato cultivars include resistance to Fusarium wilt, root knot nematodes, and tomato mosaic virus. Recently, resistance to Begomoviruses have also been incorporated into tomato from L. hirsutum (Hassan et al. 1984), L. pimpinellifolium (Kasrawi 1989), L. peruvianum (Pilowsky and Cohen 1990), and L. chilense (Pilowsky and Cohen 1990; Zamir et al. 1994; Griffiths and Scott 2001; Ji and Scott 2005).

Intergeneric Hybridization

In addition to wild Lycopersicon species, potential genetic resources for tomato improvement can also be found in the huge ancestral genus Solanum, which possesses vast amounts of genetic variation. Of special interest to tomato breeders is the array of traits in Solanum species not found in Lycopersicon, including resistances to certain diseases and tolerance of extreme aridity or chilling stress (Rick 1988). Four nightshade species in this genus—S. juglandifolium, S. ochranthum, S. lycopersicoides and S. sitiens, all members of series Juglandofolia within subsection Potatoe of section Petota—display close resemblance to members of Lycopersicon in respect to chromosome number and morphology (Rick et al. 1979b; Rick 1988). Although they have many features in common, these four species are extremely diverse in their growth habit, fruit characteristics, and autoecology. Among those species, S. juglandifolium and S. ochranthum are closely related to each other in many respects, but they are distinct from the other two species, S. lycopersicoides and S. sitiens. The latter two are closely-related sister taxa, as evidenced from classical and molecular systematics, ecology, and crossing relationships (Rick 1988; Peralta and Spooner 2001). In fact, the only successful cross between the four species is between S. lycopersicoides and S. sitiens. The resulting interspecific F1 hybrids are easily synthesized and displayed normal meiotic behavior and high fertility (Rick 1979; Pertuze et al. 2002; Ji et al. 2004). A comparative linkage map of the S. lycopersicoides and S. sitiens genomes revealed that all chromosomes were collinear with the tomato map, except for chromosome 10, where a paracentric inversion on the long arm was detected (Pertuze et al. 2002).

Session # 11 & 12: Laboratory

Selfing techniques in major vegetables

Tomatoes:

Tomatoes are **self**-fertile, which means each flower can **pollinate** itself. Nevertheless, the presence of bees and/or wind dramatically improves **pollination** by nudging the flowers just enough to help dislodge the pollen from the stamens.

- Anthesis starts in morning around 6 am and continues till 11 am.
- Maximum flower opening – 7 to 9 am .
- Stigma receptivity – 16 to 18 hrs before anthesis to 5 to 6 days after anthesis
- Pollen viability – 2 to 5 days (18 - 25°C) & upto 6 months in a dessicator (5°C) 18
- Essentially a Self Pollinated crop as stamens form a solid cone enclosing the pistil • Self pollination varies between 94 - 99% 19

SELFING •

Self pollinated crop as stamens form a solid cone enclosing the pistil. For selfing just cover the flower with butter paper bag.

Okra:

Because the predominant breeding system prevalent in okra is autogamous accompanied by allogamy and breeding, methods common to self-pollinated crops can be employed for improvement. The methods commonly employed are plant introduction, pure line selection, intraspecific and interspecific hybridization using backcross techniques, mutation, and polyploidy breeding.

Session # 13 & 14: Tutorial

Possible strategies for vegetable improvement.

Useful information has been generated on economic uses of wild species. There has been an emphasis to collect and introduce the existing variability in Abelmoschus species available, particularly in southern/southeast Asia. Chromosomal variability within A. esculentus needs to be explored, collected, and conserved. Landraces, wild and weedy relatives including different forms in polytypic Abelmoschus species, need to be augmented. For efficient and effective management of genetic diversity in okra including utilization, emphasis needs to be laid on the following aspects:

1. The spread of high yielding varieties caused genetic erosion in most of the accessible areas. Still variability has been found to exist in temperate, subtropical as well as tropical agro-climates for different Abelmoschus species. In India, the primitive locally adapted types in cultivated and semi-cultivated forms are available only in areas difficult to reach particularly in eastern and northeastern region. These possess desirable characteristics associated with sustainable agriculture, such as adaptation to stresses. These materials need to be collected.
2. Wild relatives of okra are important for their inherent resistance to one or more biotic and abiotic stresses. A vast diversity present in wild okra in India, other parts in Asia, and in Africa is yet to be collected. Further, intermediate forms resulting from natural hybridization do occur and such materials are easy to utilize; these should also be

collected. Some important traits for which germplasm should also be introduced along with source country are shade tolerance, short day types, resistance/tolerance against leaf hopper, aphid and cotton bug from the Philippines; Fusarium, wilt and nematode resistance, short day types adapted to cool weather (up to 228C) from Senegal; A. caillei, drought tolerant types with YVMV resistance and long duration from Sudan and other drier parts of Africa; multiple/prolonged fruiting and tolerance to high humidity from West Africa and adaptation to high altitudes in Nepal. With the change in the concept of plant type from nonbranching habit to upright branching, accessions with these traits need to be introduced. Germplasm resources for intercropping under partial shade, arid conditions and for cooler climate will help in introducing cultivation of okra in nontraditional areas.

3. Studies on seed dormancy and regeneration of wild relatives, and strengthening germplasm enhancement activities to promote the use of wild relatives through conventional as well as biotechnological methods.
4. The variability created through interspecific hybridization utilizing A. manihot and A. tetraphyllus needs to be fully exploited. The existing germplasm accessions need detailed evaluation for various traits by multidisciplinary team of scientists. In the breeding programs the characters that need to be given emphasis include medium plant height, upright branching, high number of fruiting nodes, low position of first fruiting node, short internode and deeply lobed medium sized leaf for enhanced productivity; smooth as well as 5-ridged fruits of

medium to short size, dark green color, early maturity, low fiber content, and low mucilage content for enhanced fruit quality and appearance, tolerance to abiotic stresses (water logging, drought, and high and low temperatures, salinity/alkalinity), and resistance/tolerance to biotic stresses (YVMV, wilt, powdery mildew, rhizoctonia, leaf hopper, borers, and red spider mite) for stable and sustainable production.

5. Further, developing suitable cultivars for canning, freezing, and dehydration for home consumption and export and cultivars having high seed oil and protein for their use as an alternative source of edible oil and protein are also important breeding objectives. Germplasm needs to be evaluated for these traits to identify accessions to feed the breeding programs.

6. Development of core collection and its systematic evaluation in multilocation testing

Session # 15:

Tutorial: Course/Discussion from session 1 to 14 (Mid Term Exam)