CULTIVATION AND BREEDING OF EGGPLANT

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INTRODUCTION

Eggplant, *Solanum melongena* L., is a common and popular vegetable crop grown in the subtropics and tropics. It is called *brinjal* in India, and in Europe *aubergine*. Eggplant is a perennial but grown commercially as an annual crop. The name *eggplant* derives from the shape of the fruit of some varieties, which are white and shaped very similarly to chicken eggs. Eggplant is essentially a warm weather crop which is grown extensively in India, Bangladesh, Pakistan, China, Japan, and the Philippines. It is also popular in Egypt, France, Italy, and the United States. According to the 1994 FAO Production Yearbook, the world eggplant production areas were 556,000 ha, and the total production was 8,979,000 metric tons. Asia has the largest eggplant production which comprises more than 90% of the world production area, and 87% of the world production. (The data did not include India and Bangladesh). Gill and Tomar(1991) reported 299,770 ha of eggplant production area in India, and 29,150 ha in Bangladesh in 1992-93, bringing the Asian total close to 830,000 ha. Eggplant can be grown in almost all parts of India all the year round except in higher altitudes. Its actual area under cultivation in India in not available due to its seasonal nature of cultivation.

COMPOSITION AND USES

Composition

Eggplant has been a common vegetable on our diet since the ancient time. Its composition per 100 g of edible portion is as below.

Calories	24.0	Sodium (mg)	3.0
Moisture content (%)	92.7	Copper (mg)	0.17
Carbohydrates (%)	4.0	Potassium (mg)	2.0
Protein (g)	1.4	Sulphur (mg)	44.0
Fat (g)	0.3	Chlorine (mg)	52.0

Fiber (g)	1.3	Vitamin A (I.U.)	124.0
Oxalic acid (mg)	18.0	Vitamin B (mg)	
Calcium (mg)	18.0	Thiamine	0.04
Magnesium (mg)	16.0	Riboflavin	0.11
Phosphorus (mg)	47.0	B-carotene (ug)	0.74
Iron (mg)	0.9	Vitamin C (mg)	12.0

It was reported that on an average, the oblong-fruited eggplant cultivars are rich in total soluble sugars, whereas the long-fruited cultivars contain a higher content of free reducing sugars, anthocyanin, phenols, glycoalkaloids (such as solasodine), dry matter, and amide proteins. A high anthocyanin content and a low glycoalkaloid content are considered essential, regardless of how the fruit is to be used. For processing purposes, the fruit should have a high dry matter content and a low level of phenolics. Bitterness in eggplant is due to the presence of glycoalkaloids which are of wide occurrence in plants of Solanaceae family. The glycoalkaloid contents in the Indian commercial cultivars vary from 0.37 mg/100 g fresh weight to 4.83 mg. Generally, the high content of glycoalkaloids (20 mg/100 g fresh weight) produce a bitter taste and off flavor. The discoloration in eggplant fruit is attributed to high polyphenol oxidase activity. The cultivars which are least susceptible to discoloration are considered suitable for processing purposes.

Uses

The unripe fruit of eggplant is primarily used as a cooking vegetable for the various dishes in different regions of the world. It has much potential as raw material in pickle making and dehydration industries. It may contain certain medicinal properties because medicinal uses of eggplant I' ve been reported. For example, white eggplant is good for diabetic patients. It can cure toothache if fried eggplant fruit in til oil is taken. It has also been recommended as an excellent remedy for those suffering from liver complaints.

ORIGIN AND GENERAL BOTANY

Origin

Eggplant, or brinjal/aubergine, is probably a native of India and has been in cultivation for a long time. A wild type with many small fruits, sometimes called as S. *melongena* var. *insanum, is* found on the Bengal plains of India. Various forms, colors and shapes of eggplant are found throughout Southeast Asia, suggesting that this area is an important

center of variation and possibly of origin. Vavilov (1928) felt that its center of origin was in the Indo-Burma region. It originated in India but has a secondary center of variation in China. In China, eggplant has been known for the last 1,500 years.

General Botany

Eggplant, *Solarium melongena L.* belongs to the Solanaceae family (Nightshade family), and has chromosomes 2n=24. There are three main botanical varieties under the species *melongena.* The round or egg-shaped cultivars are grouped under var. *esculentum, common* eggplant. The long, slender types are included under var. *serpentinum,* snake eggplant, and the small and straggling plants are put under var. *depressum,* dwarf eggplant.

Solanum is one of the largest genera of vascular plants, having more than 1,500 described species. There are some relationships between the different solanum species. Studies on interspecific relation and hybridization are of great importance because sometimes interspecific hybridization may be necessary to incorporate desirable genes to cultivated species. Athough the eggplant is a specie presenting wide variability in its morphological characters (color and shape of fruits, growth habit and plant vigor, and prickliness, etc.), physiological attributes (earliness of flowering, water absorption, and transpiration, etc.), and biochemical features (bitterness of fruit, etc.). The resistance to most eggplant pests or pathogens has been found to be partially but often at rather low levels. Obviously, there is a great need for total or very high resistance to the main pests and diseases, and wild genetic resources deserve fuller investigation in this respect. Among the related wild species,S. *sisymbriifolium* and S. *torvum* are particularly interesting on account of their resistance to three of the most serious eggplant diseases (bacterial wilt, *Verticillium* wilt and nematodes). Unfortunately these two species do not give fertile progenies when crossed with S. *melongena.*

Eggplant is a bushy plant and grows to a height of 60 to 120 centimeters. The plant is erect, compact, and well branched. It has a rather fibrous or lignified root system. The leaves are large, simple, lobed and alternate on the stems. The flowers are large, violet- or white-colored, and solitary, or in clusters of two or more. The stems, leaves, and calyx of some cultivars are spined. The fruit is a pendant, fleshy berry. The shape of fruit varies from ovoid, oblong, obovoid, or long cylindrical; the color of fruit varies from (shiny) purple, white, green, yellowish, or striped. The seeds are borne on the fleshy placentae filling the locular cavity completely.

ADAPTATION

Climatic Requirements

A. relatively long growing season of about 120 days is required for successful production of this crop. Eggplant is a warm-weather plant, and the optimum temperatures for growth and fruit development are 21° to 29°C. It is intolerant of frost, and the growth of young plants will be retarded when night temperatures are below 16°C. On flowering plants, both cool temperatures and light low-intensity can cause pollen viability and failure of fruit set. Eggplant, though more resistant than tomato in the sense that it can tolerate drought and excessive rainfall, shows relatively slow growth under a high temperature which results in stunting. When both temperature and relative humidity are high, eggplant becomes more vegetative.

Soil Requirements

Eggplant production can be successful on any good agricultural soil by using appropriate management methods. A deep, fertile and well-drained sandy loam or silt loam soils, with a pH of 5.5 to 6.8, and a high organic content are desirable for eggplant growth and development . Studies have indicated that lower or higher soil pH results in low yields because pH is closely related to the availability of soil nutrients. A sandy loam soil is ideal especially when an early yield is desired. For longer and later yields, heavier soils are preferable. Eggplant is susceptible to root rotting fungi, so saturated soil conditions and heavy clay soils should be avoided. Nematode problems are more likely to happen on very sandy soils. Choose the land after paddy rice in order to reduce bacterial wilt and nematode incidence.

CULTIVATION AND CULTURAL REQUIREMENTS

Seed Germination

The optimum temperature for eggplant seed germination is at 24° to 29°C. At this temperature, seedlings should emerge in 6-8 days. The number of days required for emergence at various soil temperatures from seed sown at 1.2 cm deep are given below:

Soil temperature (°C)	20	25	30
Days to emeence	13	8	5

Germination conditions can be improved by covering the seeded flats or containers with a sheet of clear polyethylene, which must be removed as soon as emergence begins. For rapid and homogeneous germination, it is important to maintain a temperature range between 28°C day temperature and 20°C night temperature. Do not go beyond 30°C. Avoid using seeds older than 2 or 3 years according to the storage conditions, otherwise the germination rate may be substantially lower.

Raising of Seedling

Eggplant is usually transplanted rather than direct seeded in the field. The use of transplant makes the most efficient use of land and provides the best means of establishing a uniform and complete stand of plants. Sow seeds in seedling flats, beds, pots or modules. The seed beds should be fertile and well drained. The bed area can be incorporated with fertilizers at 40 g/oo2 ammonium sulfate, 50 g/m^2 superphosphate, 30 g/m^2 potassium chloride, and 2kg/m^2 of compost. Prepare seed beds of 15 cm high and 0.0zn wide, and sow the seed in rows o{6 cm apart and 0.5 cm deep. Apply a thin layer of compost on the bed before mulching with rice straw and cover them with a mesh screen net. Thin seedlings at the first true leaf stage. They will be ready for transplant in about 5-to6-weeks depending on the sowing season.

Seedlings grown in cells or containers are ideal because they allow field planting without disturbing the root system. Bare-rooted seedlings could be successful if the field is irrigated and no drying oftbeyozzog root system during the planting process. The most recent technique is the use of cuecbazdcaloovv' The seeds are mechanically dispersed into cells or plugs of a PE tray by the seeder. The plug seedlings are raised under greenhouse condition. Fertilize the plug seedlings weekly after two weeks, preferably with avvater-aoluble fertilizer solution. Plug seedlings will be ready to set in the field 4 to 5 weeks after sowing.

Land Preparation

Land preparation is done to create a favorable condition for seedling establishment and subsequent crop management. I[prop^{p}rh/dono.it eliminates most of the weeds and soil-borne pathogenic microorganisms. It also improves the water holding capacity, drainage, and aeration of the soil. Likewise, it facilitates field operations, such as furrow irrigation and mechanized weed control.

Choose land with fertile, good drainage, and accessible to irrigation water. Avoid the land that is previously planted with Solanaceous crops such as potato, tomato, pepper, etc.

The land after paddy rice is ideal because of the reduction of nematodes and soil-borne pathogens.

1. Soil is dry, irrigate it 3-4 days before land preparation. Temporary furrows can facilitate irrigation.
2. Rototill the soil. If the soil is plowed rather than rototilled, harrow it to achieve a fine tilth prior to bed formation.
3. Apply compost and basal fertilizers and incorporate them into soil by rototilling. Suggested fertilization rates are given in fertilization section.
4. Form the bed of 1.5 m wide and 20-25 cm high. The distance between centers of two adjacent furrows is about 1.5 rn. Beds are mulched with rice straw or PE sheets to control weed and conserve soil moisture.

Transplanting

A cloudy, cool weather condition and moist but not wet soil are ideal for transplanting. During sunny days, transplanting is best done in the late afternoon to allow the seedlings to recover at night. However, seedlings that are adequately hardened with slightly damaged roots could recover well when transplanted in a well-irrigated field, even on a hot day.

1. About 6-9 *days* before transplanting, harden seedlings by slightly withholding water and exposing them to strong sunlight by removing the netting. This will decrease the transplanting shock. Thoroughly water seedlings 12 to 14 hours before transplanting to the f~eld.
2. The ideal seedlings to be transplanted are those with 3-4 true leaves, stocky and diseease-free. Generally, seedlings are ready to set in the field 4-6 weeks after sowing.
3. Transplant seedlings by digging a hole deep enough to bury a plant so that its first true leaf is just above the soil surface. Press the soil firmly around the root. Irrigate furrows immediately after transplanting.
4. Planted crop on raised beds with a single row of plants in the middle of the bed (75-150 cm). In-row spacing varies from 50 to 70 cm, depending upon the vigor of the variety, the climate, and the soil productivity. These spacings require 9,524 to *26,666* plants per hectare.
5. In order to save the labors, eggplant is also mechanically transplanted by the transplanter.

Fertilization

Adequate application of manures and fertilizers is very important for successful crop production. Being a long duration crop, eggplant requires a good quantity of fertilizers. The following fertilization rates are generally recommended for growing eggplant in Taiwan. These rates may be used as a guide, and adjustment may be necessary according to information from a soil test.

Fertlizer	Total amt. k /h	Basala I /ha.	1st side-dress[b] kg/ha	2nd side-dress[c] kg/ha
Compost	1,500	1,500		
N	168	84	42	42
P_2O_5	72	72		
K20	180	180		

Application time: [a]preplanting; [b]3 weeks after transplanting; [c]5weeksaftertransplanting

An adequate amount of compost is essential to improve the efficiency of chemical fertilizers and to retain optimum soil physical/chemical conditions. If a longer harvesting period is preferred, an additional N application of 20 kg/ha is required at 7 weeks after transplanting or the amount of side-dressing can be equally devided and applied 3 times. Urea can be used to replace ammonium sulphate for side-dressing, however, only one-half of the amount of ammonium sulphate is needed at each application.

Macro-eiement fertilizer application has pronounced effects on the vegetative growth, development, yield and fruit quality of eggplant. Application of minor elements is not a high requirement, and deficiencies are seldom a problem. However, the effects on the improvement of flowering and fruiting have been reported by adding micronutrients such as Cu, Yin, and Zn.

Irrigation

Irrigation is essential for eggplant cultivation in the region where only little or no rain is available during the growing season. The frequency and amount of water application are determined by the weather, soil conditions, the development stage, and depth of the root zone specific for the variety. The waterholding capacity of the soil is a major factor that determines the frequency of irrigation. A sandy soil must, therefore, be watered more frequently than a clay soil. Eggplant is a medium-rooted crop with a root-zone depth of about 90 cm in well drained soil. Irrigate soil of at least 45 cm deep. The method of applying irrigation water depends on soil texture, topography, and water supply.

Generally, furrow (surface) irrigation is used in eggplant production. Mulching with black polyethylene will maintain a more uniform soil moisture between irrigations.

Weed Control

Eggplant is one of the initially slow growing crops which is incapable of competing with the aggressive weeds. Weed infestation also increases insect pests and diseases of eggplant. Therefore, the weeds should be controlled at the "critical period" when the maximum weeds are tolerable but without affecting the crop yield. Weeds are controlled either by physical/mechanical methods or chemical control. Physical methods, such as hand weeding, use of tools (hoe), cultivation and mulching, are quite common in small vegetable farms. Only shallow cultivation is necessary to remove weeds. Mulching with black polyethylene will effectively control weeds and greatly lessen labors. Natural organic mulches not only help conserve moisture, but also add organic matter to the soil.

Chemical weed control has developed rapidly and gained importance in vegetable production because of the selective properties of herbicides; that is, they destroy some plants but do not harm others. Chemical weed control is also popular in places where labor is very expensive or not readily available. Herbicides, Lasso (1.5 kg a.i./ha), Enide 5OWP (dil. 1:300), Sancor 70WP (dil. 1:4,000), Paraquat 24EC (dil. 1:250), etc. are recommended for use in eggplant production.

Disease and Insect Control

Diseases

The eggplant is subjected to the attack of many diseases.which cause damages in all growth stages. Only the most common diseases are mentioned with their possible control measures.

Damping off *(Pythium spp.; Phytophthora spp.; Rhizoctonia spp.)*

The fungus attack usually starts on the germinating seed, sppreading to the hypocotyl, basal stem, and developing tap root. The affected seedlings are pale green, and a brownish lesion is found at the basal portion of the stem that girdles the stem. The affected tissue rots and the seedling collapses. The disease is soil-borne. The disease may be controlled by soil sterization and seed treatment with fungicides or hot water.

Phomopsis blight (Phomopsis vexans)

Phomopsis blight or fruit rot is probably the most serious and widespread eggplantdisease. It occurs in the stems, leaves, and fruits. The fungus attacks the stems of the young plants at the soil line, often girdlies the stem and causes the plant to break off, or at least to wilt and die. The fungus could also attack the stems of older plants at any point, causing sunken, oval, dark-brown cankers. Leaf infection first appears as round, brown spots; the centers of the spots later turn gray. Fruit spots are pale and sunken. The spots frequently orignate on the calyx and expand into the fruit pedicel and then into the fruit. Fruit decay is soft and spongy and may penetrate rapidly throughout the fruit. To control this disease, use clean seeds, as the fungus may be carried on the seed; adopt a three- to four-year crop rotation; use resistant varieties such as Florida Market and Florida Beauty; and spray regularly with a protective fungicide such as maneb or zineb.

Leaf spot *(Alternaria spp.; Cercospora spp.)*

There are four different types of leaf spot in eggplant caused by *A. melongenae, A. solani, C. solani-melongenae, and C. solani.* The *Alternaria* leaf spots produce the characteristic leaf spots with concentric rings. The spots are mostly irregular, 4-8 mm in diameter and may enlarge and cover a large area of the leaf blade. The leaves may drop off due to severe infection. The *Cercospora* leaf spots are characteristically chlorotic lesions, angular to irregular in shape, and later turn grayish brown with profuse sporulation at the center of the spot. Severely infected leaves drop off prematurely resulting in the reduction of yield. The leaf spot disease may be primarily controlled by maintaining proper field sanitation. If the general control measures suggested *for Phomopsis blight* are followed, the leaf spots should be much reduced.

Verticillium wilt *(Verticillium dahliae; Verticillium alboatrum)*

The most characteristic symptoms of *Verticillium* wilt. are found on the stems and *roots.* The infected plants become stunted in growth and generally, do not flower and set fruit. If the infection takes place after the flowering or fruit setting, the flowers and fruits are deformed, flaccid and finally drop off. The lengthwise cut of the infected stem shows dark-brown discoloration in the vascular tissue. The affected leaves turn yellow and then brown between veins followed by wilting and dropping off. After the plant is thoroughly invaded, the roots and the base of the stem may decay. The pathogen is soil-borne and the primary inoculum usually comes from the soil. Soil sterilization and crop rotation in which crops other than potatoes, tomatoes, and peppers are grown are recommended as a control measure. Grafting eggplants on suitable rootstocks also provides an effective method to minimize the disease infestation. Use of resistant varieties, however, control the

disease permanently. It was reported that eggplant cultivars,Black Beauty, Pusa Purple Long, K-2282, Florida Market, Harris 468 Special Hibush, and Harris Hybrid 77631 are less affected by *Verticillium* wilt. A relatively high degree of resistance was also observed in the related *Solanum* species such as S. *acu.leatissimin , S. sca.brum,* and S. *sisymbriifolium*.

Bacterial wilt *(Pseudomonas solanacearum)*

Bacterial wilt disease causes a severe problem in eggplant cultivation in the subtropics and tropics. Once it has become well established, it can be one of the most destructive pathogens known. The symptoms of bacterial wilt on susceptible plants are yellowing, curling and wilting of leaf; disintegration 6f stem and root; and dying of the plant. When newly infected stems or roots are cut crosswise and left for a short time or are pressed strongly, a dingy gray to yellowish ooze appears from the darkened circle. Crop rotations with immune species, eradication of weeds, good drainage, growing healthy seedlings, and grafting plants on the suitable resistant rootstocks are important control measures. Resistant genes are found in eggplant germplasm and wild species. A number of resistant accessions have been identified at AVRDC. The wild eggplant S. *melon gene* var. *insanum, S. integrifolium* and S. *torvum* have also been reported to be highly resistant to bacterial wilt.

Little leaf

I_yttle leaf disease of eggplant is caused by mycoplasma. It is a serious eggplant disease throughout India. The infected plant is generally shorter but possesses a large number of branches, leaves and roots than a healthy one. The leaves are malformed into tiny chlorotic structures. Many lateral shoots develop in the axils leaf and with the shortened internodes give the plant a bushy appearance. The mycoplasma is transmitted by leaf hopper *Hishimonus phycitis* and also transmitted artificially by grafting. The suggested control measures are the complete eradication of all solanaceous weeds, the chemical control of leaf hopper, the roguing out of the diseased plants in the earlier stage of infestation, and the use of resistant cultivars such as Pusa Purple Cluster and Kartain.

Mosaic virus

There are several viruses which can infect eggplant under natural conditions and produce mosaic symptoms. They are cucumber mosaic virus (CMV), potato virus Y (PVY), potato virus X (PVX), tobacco ringspot virus (TRSV), etc. Plants infected with the virus are generally stunted in growth and show mosaic symptoms on leaves. The use of resistant or tolerant cultivars are the only control measure for these virus diseases.

Insect Pests

Insect infestation is one of the most limiting factors for accelerating yield potential of eggplant. The crop is prone to damage by various insects, although there is wide variability in the degree of infestation. Some of the important ones are briefly described below.

Fruit and shoot borer *(Leucinodes orbonalis)*

Eggplant fruit and shoot borer is a very destructive pest in southeast and south Asia. It has been reported that the insect caused a loss up to 70% in yield. The larva attacks the terminal shoots and bores inside, resulting from withering and drying of the shoots. It also bores into the young fruit and feeds inside which makes the fruit unmarketable. Insecticides, Soznicidbz2OBC, Lannate 9OWP, Decis 2.8EC, Sevin 50VVI", etc. are effective in controlling this pest. An increased emphasis has been given to develop resistant varieties which seem to be the only solution to reduce the hazards caused by the use of toxic chemicals. Several eggplant accessions have been screened against this insect pest, for example, Pusa Purple Long, H-128, H-129, Azcabey,Thorn Pendy, Black Pendy, H '\/Il-195, Shyamla Dhepa, Banaras Long Purpple, etc., have been reported to be tolerant or resistant.

r hrtms (mainly *Thrips palmi)*

Thrips have become *serious pests* of many vegetable crops. They attack eggplant mostly in dry season. Certain insecticides seem to cause resurgence in thrips population. Therefore, do not spray the crop until it haabben identified that thrips are the cause As damage. Insecticides Oxamyl 24BC,Carbosulfan 48EQ,and Cyhalothrin 2.8BCare recommended for controlling thripaby spraying once a week until infestation stops.

Cotton leafhopper or Tasoidm (Amrasca biguttula bigi , *Hish/n«ouus phycitis)*

Cotton leafhoppers feed mainly on the underside of eggplant leaves. The infested leaves curl upwards along the *margin.* Their feeding results in small yellow patches on the foliage. They also transmit mycoplasma disease like little leaf. Fruit setting is adversely affected by the infestation. Spraying with Cazboaulbao4BEC or Bifentbriu2.8EC once a week is recommended for controlling the insect. Eggplant varieties, TnzaagadbSel. 1, Aushey, R-34, H-4 and T-3 have been reported to be resistant to cotton leafhopper.

Two-spotted spider mite (Tetranychus urticae)

These small, polyphagous insects feed on the underside of eggplant leaves in large colonies. Resulting from white specks that appear on the leaves. These specks coalesce and appear as white patches. Ultimately, the entire affected leaf are discolored and withered. The damage is more pronounced during the warm and dry season. Spraying vviLb8Ucotbrin]OVVP or Cyhalothrin 2.8EC are effective in controlling the insect.

Aphids (Aphis gossypii)

The aphid is small, soft, yellowish green or greenish brown found in colonies on the tender shoots and the mndersurface of young leaves. They feed on leaves and stems by sucking the plant juice. Black sooty mould develops on the honeydew excreted by the aphid and covers on the leaves and adversely affects the photosynthesis. As a result, infested plants appear weak. These insects occur in the cool dry season. Spraying with Bifenthrin 10 WP or Carboaolban48EC once avveek is suggested to control the aphids.

Epilachna beetle *(Eoi/ochnn vigintioctopunctata, E. indica)*

The beetle is brown to red, small, spherical and mottled with black spots. They feed voraciously on the leaves and tender parts of eggplant and often cause serious damage when they appear in numbers. As a result of their feedingekeletonized,lacelike patches are developed on leaves and later the leaves dry away. They can be controlled with Carbaryl 50N7[p] orMalatbioo5QBC.

Nematodes

Root-knot nematodes UNe*/cnoogyncspp.,*

Eggplant is highly susceptible to the nematode. Attacked plants become stunted, reduced growth, and their leaves show yellowing or cblorotic symptoms. The infestation is also easily recognized by the characteristic root galls. Proper crop rotation with other crops resistant to root-knot nematodes such as marigold, will help in reduction of nematodes population. Terbufos (10%) orI]ClP 80EC is recommended for controlling the root-knot nematodes.

Harvest and Postharvest

The time required from flowering to market-fruit size is about 3-4 weeks, but fruit can be harvested and eaten at any earlier stage of the development. Fruit should be harvested while it still glossy vvitba desirable color. When the color dulls, the seeds become dark and the flesh becomes spongy and bitter. At market maturity, the fruit stem is tough and hard, so a sharp knife or hand-priming clipper is needed to remove the fruit from the

plants. The calyx and a short piece of the stem are left or, the fruit, but care should be taken to prevent the stem from injuring other fruits in the package.

Eggplant yields are commonly in the range of 30 to 40 tons/ha of marketable fruit, although higher yields can be achieved. With the normal annual cropping practice, 6 to 12 marketable fruit may be expected per plant for the large-fruited type, weighing in the range of 300 to 400 gm each. The elongated oriental varieties may produce twice of that many fruit quantity, with individual fruit weighing in the range of 100 to 150 gm each.

Eggplant does not have a long storage life and should be marketed immediately after harvest. The fruit should be handled and packed carefully to avoid puncture or abrasion damage to the skin.. Fruit are packed toa fiberboard carton or a special crate or other containers. Eggplant can be stored *safely for 7* to 10 days at 71 to 10' C and 90-95% relative }ozozidUt ın It is subject to chilling injury when stored at temperatures below 7' C for several days.

EGGPLANT BREEDING

Reproductive Biology

The eggplant flower normally perfect cuavzo* functional male (aoroena) and female (pistil) parts. Most of the eggplant cultivarabear a flower cluster along with a solitary flower. There are three types of flowers depending upon the length of styles, viz., (i) long-styled with large size ovary, (ii)ruediuzn-otyledwith medium size ovary, and (iii) short-styled with rudimentary ovary. The ratio of the three flower types varies with the cultivars and the stage of plant development. It has been reported that the long-styled flowers are always appreciably more in number (52-90%) than the medium-styled (8.5-28%) and short-styled ones (1.5-25%). At AVRDC, a large variation was found among the genotypes in terzasof percentages of long-styled (defined as the stigma is either above or on the same level as the stamen) and short-styled (defined as the stigma is below the stamen) flowers on the same plant. The ratio of the long-styled flowers ranged from 30 to 95%, while the short-styled flowers ranged from 5 to 70%. The proportion of long-and short-styled flowers also varied with the stages of plant development in each genotype.
It was reported that fruit set in eggplaotcudtbrars with long-styled flowers varied from 70 to 86%, while those with short-styled flowers did not set fruit.

Eggplant is normally highly self-pollinated; flowers are large and easily emasculated and pollinated; and individual cross may yield as many as several hundred seeds. Rates of natural cross-poDinatioomay vary depending on genotype, location, and insect activities. A considerable outcrossing rate of 20-60% in eggplant cuitivars has been reported by Indian researchers. However, 2.7% and 6.7% of natural outcrossing rates have also been reported io7aivvan(A\/RI]C field) and China, respectively.

In most eggplant-growing areas, anthesis and dehiscence in eggplant flowers occur between 6:00 and 11:00 in the morning. However, anthesis and dehiscence are mainly influenced by the daylight; temperature, arllhumidity, the exact timing for every area should be determined by observation. Pollen viability is retained for 8-10 days at a temperature of 20^0-22' C and with a relative humidity of 50-55%. Emasculation for the purpose of controlled pollination must be done approximately one or two days prior to anthesis or *flower* opening to avoid accidental self-pollination. With favorable environmental conditions, 400 or more seed may be obtained from a single fruit. The first flower opens at 6-8 weeks after seeding, and an additional 6-8 weeks elapse from first flower to harvestable stage. Seed is physiologically mature when the fruit reaches full ripeness.

Breeding Goals

Effective crop improvement programs require clearly defined objectives and a well-conceived breeding strategy to accomplish established goals. The following are important goals for eggplant breeding.

Stable and High Yield

Improved yield or high productivity is one of the major goals of eggplant breeding. However, selecting for yield per se is seldom very effective because yield is genetically complex and invariably influenced by environmental factors. The yeild genetic control is polygenic in nature. Also, additively and nonadditively acting genes are known to condition yield. As a result, selection for high yield demands a rigorous control of environmental effects to insure that the phenotypic expressions of the breeding materials correspond to their true genetic potential.

The genetic potentialities of yield contributing components and their interrelationship should be properly assessed for improving the crop. In eggplant, it has been reported that yield per unit area is a product of several components: number of branches, number of

fruit per plant, and fruit weight. Among these components, number of fruit per plant exhibits the maximum direct effect on yield. It is, therefore, considered useful to select the best eggplant genotype based of number of fruit per plant for effective improvement in. this crop.

Disease Resistance

Most of eggplant cultivars are susceptible to a number of diseases. Biotic stresses refering to all disease and pest factors affecting the productivity of eggplant are among the maj or yield- and quality-limiting constraints, if not the most important. Breeding for disease resistance is one of the maj or objectives of eggplant improvement.

There are a number of economically important diseases for which control is either absent or prohibitively costly (e.g.,soilbooe wilt diseases such as bacterial wilt, verticillium wilt, etc,and little leaf). Exploitation of host-plant resistance in breeding give rise to resistant cultivars which will make production in infected fields economically feasible. In collaboration with plant pathologists, eggplant breeders have successfully developed increasingly higher disease-resistant level of breeding lines.

Progress in developing disease-resistant eggplant would not have been possible without the genetic resources to sustain the breeding efforts. Fortunately, the genus *5olanmnis a* trove of genetic variability. Genes for resistance to various diseases have been uncovered from cultivated and wild relatives of eggplant. And in many cases, their underlying inheritance are also studied. Early progress was fostered by the efforts to screen germplasm collections for reaction to major eggplant diseases. For example, efforts were made at the Indian Agricultural &esearchInstitute (IARI), New Delhi, to find out the sources of resistance against various diseases. As a result, sources of resistance to major diseases such as bacterial wilt, verticUlhozzvvUt, phomopsis blight, and little leaf, have been identified either from the cultivated *S.rnelongonnor* from the related So/o-nunzspecies. Recently, there are more resistant sources of bacterial wilt identified at AVRDC, and some of them are being used in the breeding program for bacterial wilt resistance.

Insect Resistance

Breeding for insect resistance receives considerably less attention than disease resistance, and very few commercial cultivars have been developed. Traditionally, a low priority is given to insect resistance breeding, programs because the use of pesticides can effectively control most of the maj or eggplant insect pests. Also, it is difficult to develop the

breeding and selection procedures to exploit the existing genetic variability for insect resistance.

Eggplant fruit and shoot borer *(Leucinodes orbonalis)* and cotton leafhopper or jassid *(Amrasca biguttela biguttela)* are important insect pests. Resistance or tolerance has been reported to both pests. Fruit and shoot borer is the most destructive pest which limits successful eggplant cultivation, particularly under high temperature and humidity. Both insects are borer pests and in general getting resistance to borers has proven to be difficult in most crops. Breeding for fruit and shoot borer resistance in commercial cultivars will not be easy. However, progress in host-plant resistance has been made by for the Plant Biotechnology, IARI, to transfer Bt crystal protein genes in eggplant to combat fruit and shoot borer. A collaborative research on the use of Bt-biotechnology for the control of eggplant fruit and shoot borer has been proposed by AVRDC's entomologist. Resistance to cotton leafhopper reported by earlier workers was due to long hairs and a high density of hairs on the leaves that hinder the oviposition of insects.

Improved Fruit Quality

Breeding for improved quality initially requires a definition of the major parameters that contribute to quality. Moreover, the criteria of good quality vary among consumer groups. The subjectiveness of quality introduces a great deal of complications in its genetic improvement. Therefore, quality is often a secondary priority in the breeding program.

Size, shape, external color, smoothness, uniformity, and freedom from defects are the major concern for the appearance of eggplant fruit. The biochemical constituents such as anthocyanins, total phenols, polyphenol oxidase activity, and glycoalkaloid content are important for eggplant quality. Genetic variabilities of these chemical costituents are observed among the eggplant cultivars. On the average, the elongated-type varieties are rich in dry-matter, crude protein, anthocyanin, phenolics, and glycoalkaloid contents; while the oblong-type varieties are rich in total sugars. It is also observed that glycoalkaloid content is not associated with bitterness, but both discoloration and bitterness increase with increasing percentage of total phenols.

Inheritance of Qualitative and Quantitative Characters

Genetic architecture and the mode of inheritance of characters are important considerations while determining the breeding procedures. The inheritance of various characters of eggplant has been extensively studied. The results are summarized in the following tables.

'Inheritance o ualitative characters.

Characters	Gene dominance	References
Fruit color	Purple > green	Tatebe 1944; Khan and Ramzan 1954
	Green > white	Swam Rao 1970; Choudhuri 1972,1977; More and Patil 1982; Gopinath et al. 1986; Joshi 1989
	Monogenic	Nolla 1932; Jannaki and Ammal 1933; Swamy Rao 1970; More and Patil 1982; Patil and More 1983
	Two genes in complementation	Thakur et al. 1969
	Complex	Fukusawa 1964;Gopinath et al. 1986
	Interaction of three non-allelic genes	Khapre et al. 1988
Plant color	Purple > green	Thakur et al. 1969; Sharif and Habib 1977; Mmbalkar and More 1980; Patid and More 1983
Sterm color	Purple > green	Wanjarl and Khapre 1977, Patin and more 1983
	Duplicate gene	More and Patil 1982; Nimbalkar and More 1980
H'-,7)ocotyl/ seedling color	Purple > green Monogenic	Wanjari and Khapre 1977; Khapare et al. 1986
	Duplicate gene	Rangaswamy and Kadam Bavanasundram 1973
Corolla color	Purple > white or light purple monogenic	Wanjari and Khapre 1977; Khapre et al. 1986; Rangaswamyand Kadam Bavanasundram 1973
	Interaction of three or more non-allellic genes	Khapre et al. 1986
Leaf color	Monogenic two complementary genes	Sharif and Habib 1977; Patil and More 1983
Leaf vein color	Purple > green three or more enes	Khapre et al. 1986; Patil and More1983

Continued.

Characters	Gene dominance	References
Fruit flesh color	Green flesh white monogenic	Wanjari. and Khapre 1977, Khapre et al. 1986
Fruit shape	Elongated > found	Swamy Rao 1970; Choudhuri 1977
	Round > oval	Patil and More 1983
	three genes control	Nimbalkar and More 1980
	four genes control	
Bearing habit	Cluster > single	Swamy Rao 1970
	Single gene	Rangaswamy and Kadam Bavanasundram 1973
	Trigenic	Fukusawa 1964
Plant spread	Erect > spreading	Vijay Gopal and Sathumadhavan 1973
	Two complementary genes	Wanjari and khapre 1981; Khapre et al. 1985
Plant height	Tall > dwarf monogenic	Choudhuri 1972,1977
Prickle presence onpetiole/ leaf/stem	Prickle presence absence monogenic	Rangaswamy and Kadam Bavanasundarm 1973
Male sterility	Two recessive nuclear genes, msi andms2	Chauhan 1984
Style erectness	Incurved style erect monogenic	Rangaswamy and Kadam"avanasundram 1973

tnh522ance of *tiantitative characters.

Characters	I ter itabiit	Genetics advance	References
Yield	High	High.	Dhesi et al. 1964; Singh et al. 197i
	Low		Sidhu et al. 1980; Borikar et al. 1981; Dixit et al. 1982 Naulsri et al. 1986a
	Low	Low	Chadha and Sidhu 1983
Number of fruits perplant	High		Hiremath and Rao 1974; Dharmegowdaetal.1979; Sidh-uetal.1980
	Low	Low	Chadha and Sidhu 1983
Fruit weight	High	-	Hiromath and Rao 1974; Mital et al. *1976;* Sidhu et al. *1976;* Sidhu et al. 1980; Dixit et al. 1984
	Low	Low	Chadha andSidhu 1983
	Low	-	Singh et al. *1974*
Seed weight per fruit	High	-	Hiremath and Rao 1974
Rind thickness	High		Hiremath and Rao *1974*
Fruit girth	High		Sidhu et al. 1980
Plant height	High		Sidhu et al. 1980
	High	High	ChadhaandSidhu *1983*
Number of days to first harvest	High High		Mital et al. *1976;* Chadha and Sidhu. 1983
Insect incidence breadth of fruit	Low	Low	Chadha and Sidhu 1983

Gene effects of various attributes

Characters	Gene effects	References
Number of *days* to flowering	Additive	Mital et al. 1976; Bajpai 1977; Gill et al. 1976
	Nonadditive	Singh et al. 1979; Singh and Mital 1988
	Overdomtnance	Peter and Singh 1973,1976; Hani. et al. 1977
	Dominant	Sidhu et al. 1980
Fruit weight	Additive	Singh et al. 1982; Dixit et al. 1984; Mital et al. 1976; Peter and Singh 1973,1976; Salehuzzaman and Alam 1983; Randhawa 1987
	Both additive dominance	Dharmagowda *1977*
Number of fruits per plant	Additive	Gilletal. *1976;* Singh et al. 1979; Salehuzzaman and Alam 1983; Randhawa 1987; Singh and Mital 1988; Chadha and Sharma 1989
	Both additive	Dixit et al. 1984
Early yield	Additive	Kumar and Ram 1987
Yield	Additive	Gill et al. 1976; Sharma 1985; Gill et al. 1976; Madalageri 1986; Randhawa 1987; Kumar and Ram 1987; Chadha and Sharma 1989
	Additive and nonadditive	Borikar et al. 1981; Dixil et al. 1984; Dharmagowda 1977; Hani et al 1977; Singh et al. 1979; Singh and Mital 1988
	Dominance	Mital et al- 1976; Sidhu et al. 1980; Salehuzzaman and Alam 1983
	Overdomtnance	Singh et al. 1982
Fruit length	Additive e	Peter and Singh 1973, 1976 Singh et al. 1979; Sidhu et. al. 1980; Dixit et al. 1984; Singh and Mital 1988

Continued.

Characters	Gene effects	References
Fruit width—	Additive and nonadditive	Singh and Mital 1988
Fruit size index	Additive	Gill et al. *1976*
Fruit circumference	Additive	Dixit et al. 1984
Plant height	Additive	Gill et al. 1976; Bajpai 1977; Singh et al. 1979; Borikar et al. 1981.
	Both additive/ nonadditive	Dharmagowda, 1977; Dixit et al.,1984; Singh and Mital, 1988
Number of flowers	Dominant additive	Sidhu et al. 1980; Peter and Singh 1973,1976
Seed per fruit	Overdominance	Dharmagowda 1977
Number of branches	Additive	Gill et al. 1976; Borikar et al. 1981
	Dominance	Bajpai 1977; Singh and Mital 1988.
Plant s • read	Dominance	Ba' sai 1977

Hybrid Vigor

Experiments conducted in japan and India have shown distinct hybrid vigor in eggplant. It was observed that yields of F_1 hybrids exceeded the parental mean by *62%* and the high yield was due to more fruits produced rather than bigger fruit size. In India, it was reported that hybrids in eggplant showed. 48-56% yield increases over the better parent. It was also observed that West Bengal hybrid had aouarkedly higher yield than both the parents, Kalyani Green and Blokesbi,by about 164% and 134%, respectively. High yield of the hybrid was attributed to the increase in branches, fruit size, fruit number and weight. Pusa Anmol, abvbzid cultivar, was developed by IARI from a cross between Pusa Purple Long aod}{yderpur. It showed early and increased yield of about 80-100% more than Pusa Purple Long.

Breeding Techniques

The common breeding techniques to improve eggplant include introduction, mass selection, pure line selection, pedigree selection, single seed descent, bulk method, and backcross method. In some breeding programs, combinations of methods have been found a useful approach. These breeding techniques are further discussed below.

Selection Methods for **Natural Variation**

Old landrace varieties or even local cultivars that have been for quite a long time under a certain environment without conscious selection are considered as populations. Plant breeders must first explore the genetic materials on hand before any long-range breeding program is conceived. Old local cultivars which have well-proven adaptability under certain conditions are often available. Sometimes, introduced cultivars which do well under aI)articular condition may exhibit some degree of variation. Breeders need to examine these materials closely to see if simple selection procedures can bring in further ¡mprovement. When substantial variation is available, mass selection will allow the elimination of undesirable individuals and, at the same time, preserve the typical cbaracte^-abca of these cultivars. A pure-line selection could also be applied to further identify the most superior, homozygous lines for release to the growers.

A. **Mass** selection

The main purpose of mass selection is to obtain a high frequency of superior genotypes within the variety or population. Mass selection may be achieved by simply growing the variety in the field and roguing out the undesirable types. At maturity, the remaining plants are bulked. Sometimes, it is tagging only the best plants in the field and bulk-

harvesting them at maturity. Modern plant breeding usually employs mass selection to preserve the characteristics of established varieties.

P. Pure line selection

This is a refinement of mass selection. The method also involves tagging the best plants of the variety. However, instead of bulk-harvesting the plants as in mass selection method, are harvested separately and evaluated as distinct progeny rows (pure lines) in the next year. Only the superior pure line is bulked as an improvement of the variety. The pure line may be released as a new variety if it is sufficiently different from the original variety.

Selection for Variation Through Controlled **Hybridization**

Following hybridization, a tremendous burst of variation is released after selfing the immediate hybrid progeny of the cross. Successive self-pollination of the hybrid progenies of self-pollinated crops leads to the progressive decay of the variability within individuals, but with concomitant accentuation of the variation among individuals. The variability can be managed by different methods, and their application depends upon a number of factors such as manpower, land and financial resources, level of expertise, timetable, objectives, and crop species.

A. **Pedigree** method

Pedigree method involves keeping the record of descent of a line of or pedigree of individuals or lines selected in each generation. It offers the plant breeder an opportunity to sample families of diverse descent. In using pedigree selection, the breeder must keep the changing architecture of variability in mind. The greatest range of variability will be expressed in the F2 generation; thereafter, the level of herozygosity in the population will decrease rapidly upon selfing with a concomitant increase in proportion of homozygosity. Based on this trend, selection in early generations (F2, F3 or even F4) will be concerned mainly with single-plant performance. Selection in later generations (F5 and on) must shift towards line or family performance as the within-line variability becomes increasingly dissipated.

Pedigree method is widely used for the development of new varieties in eggplant. In the process undesirable progenies are eliminated as soon as they become visiible. A combination of pedigree record and visual evaluation should lead to a substantial reduction in population size. Single-plant selection is practiced until they reach the F6 and beyond that are considered nonsegregating. Selection is shifted from single plant to

family performance. Selected uniform families are harvested in bulk to provide sufficient seed stocks for the subsequent replicated trials.

Pedigree method offers the following advantages: it permits elimination of a great number of unpromising materials in early generations; it allows evaluation of selections on the basis of several year's performance; and it enables sampling more diverse materials from each cross. However, the method is time consuming, very tedious and, therefore, severely limits the number of crosses that can be exploited as sources of superior genotypes.

B. Bulk method

Bulk method is simple and less time consuming in handling segregating progenies from hybridization. It involves growing them in mass from F2 and succeeding generations until the desired homozygosity is achieved. The method allows natural selection, with the aid of a breeder, to gradually weed out the undesirable types within the population so that after a few generations only the most adapted forms are remained. At the time, when certain forms are already genetically stable (homozygous) single-plant selection is made and evaluated in a series of trials. Only the best lines are released. Since very little work is required, the bulk method allows several crosses to be handled at one time, and large populations of each cross can be grown in each generation, thereby increasing the possibility of greater gene combinations.

C. Backcross method

The procedure of backcross method is carried c- 't using one of the original parents as a constant parent and the selected progenies from a segregating backcross generation as the oti er parent, depending upon the behavior of the gene(s) under consideration. The constant parent is technically termed "recurrent parent, " while the other original parent which contributes the gene(s) under transfer to the recurrent parent is called the "donor parent."

The objective of the backcross method is to transfer a gene or genes from the donor to the recurrent parent, recovering as much of the genetic background of the latter as desired. The recurrent parent is generally a successful variety, lacking only the gene(s) available from the donor to be truely outstanding. The backcross method is especially applicable when the donor parent is a commercially unadapted type so that straight hybridization and selection will not reasonably lead to superior genetic combinations. Often, the donor parent carries along with the desired gene, a number of undesirable genes. Assuming no

unfavorable linkage, the backcroeamethod will allow the transfer only of the desirable gene(s) , eliminating the undesirable traits in the backcrossing process. The method has been very useful in disease-resistance breeding dealing with a few genes.

Backcrossing a character determined by a single dominant gene is relatively easy. When a recessive gene is under transfer, it is necessary to grow the backcross generation to F_2 to identify the homozygous recessive genotypes prior to making the next backcross. Backcross method is very effective on simply inherited characters (high heritability). However, its use is not precluded for complex quantitative traits.

Backcross method offers the following advantages (i) previous gains are not lost because improvements are made in a stepwise fashion; (ii) the program may be independent of the breeder's target environment; (iii) evaluations of the backcross varieties may not be necessary; and (iv) it is relatively rapid, predictable and repeatable. One disadvantage is that the method does not create unusual gene combinations which may be better than the recurrent parent.

Hybrid Development

In most cases, the breeder's goal is to develop improved standard, open-pollinated cultivars. However, in the last decade or so, the use of hybrid cultivarahas increased dramatically. The major role played by the private seed sector in developing and distributing improved eggplant cultivars has encouraged the trend towards increasing use of hybrids. Irrespective of the final type of cultivar to be developed, the breeding tecozu cuey that are used to develop the improved standard cultivars and/or inbred parents for hybrid varieties are one and the same. In developing hybrid varieties, however, is further extended to select from those inbred stocks that nick well (good combining ability) with each other to produce superior hybrid progenies. These parental stocks are built-up, often in a stepwise fashion, to cure the possible defects such as disease susceptibility, poor quality, etc. of their hybrids. The use of backcross method in improving the parental inbreds is common. Once the improved parental stocks are available, the original combinations that nicked well are repeated to form the Fl hybrid varieties.

It is true that Fl hybrids exhibit favorable traits such as uniformity and, to some extent, better resistance to diseases, but their advantages over the standard cultivars have not been as great as cross-pollinating species. The popularization of Fl hybrids among self-

fertilized species owes much to the variety rights theyimpart to their developer. By releasing Fl hybrids, nobody outside the company can duplicate them since the company are the sole prossessor of the parental stocks.

The use of Fl hybrid cultivars in eggplant is likely to increase, and efforts should be emphasized to facilitate economical and efficient production of hybrid seed. The cost of hybrid seed production in eggplant is not high as compared with other vegetables and this can be further reduced by the use of male sterile lines. Exploitation of hybrid vigor in eggplant is economical as each fruit contains more seeds compared to other vegetables such as tomato, pepper, etc.

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