Series of Crop Specific Biology Documents

BIOLOGY OF BRINJAL

सत्यमेव जयते

Ministry of Environment and Forests
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CONTENTS

BIOLOGY OF *SOLANUM MELONGENA* L. (BRINJAL)

1. GENERAL DESCRIPTION

Brinjal or eggplant (*Solanum melongena* L.) is an important solanaceous crop of sub-tropics and tropics. The name brinjal is popular in Indian subcontinents and is derived from Arabic and Sanskrit whereas the name eggplant has been derived from the shape of the fruit of some varieties, which are white and resemble in shape to chicken eggs. It is also called aubergine (French word) in Europe.

The brinjal is of much importance in the warm areas of Far East, being grown extensively in India, Bangladesh, Pakistan, China and Philippines. It is also popular in Egypt, France, Italy and United States. In India, it is one of the most common, popular and principal vegetable crops grown throughout the country except higher altitudes. It is a versatile crop adapted to different agro-climatic regions and can be grown throughout the year. It is a perennial but grown commercially as an annual crop. A number of cultivars are grown in India, consumer preference being dependent upon fruit color, size and shape.

The varieties of *S. melongena* L. display a wide range of fruit shapes and colours, ranging from oval or egg-shaped to long club-shaped; and from white, yellow, green through degrees of purple pigmentation to almost black. Most of the commercially important varieties have been selected from the long established types of the tropical India and China.

Brinjal fruit (unripe) is primarily consumed as cooked vegetable in various ways and dried shoots are used as fuel in rural areas. It is low in calories and fats, contains mostly water, some protein, fibre and carbohydrates. It is a good source of minerals and vitamins and is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients. The composition of edible portion of brinjal is given in Table 1.

Table 1: Composition per 100 g of edible portion of brinjal

Calories	24.0	Sodium (mg)	3.0
Moisture content (%)	92.7	Copper (mg)	0.12
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	Folic Acid (µg)	34.0
Calcium (mg)	18.0	Thiamine (mg)	0.04
Magnesium (mg)	15.0	Riboflavin (mg)	0.11
Phosphorus (mg)	47.0	B-carotene (µg)	0.74
Iron (mg)	0.38	Vitamin C (mg)	12.0
Zinc (mg)	0.22	Amino Acids	0.22

Source: *Gopalan et al. (2007)*

It has been 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 (Bajaj *et al.*, 1979). 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 - 4.83 mg/100 g fresh weight (Bajaj *et al.*, 1981). Generally, the high content of glycoalkaloids (20mg/100 g fresh weight) produce a bitter taste and off flavour. 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.

Brinjal is known to have ayurvedic medicinal properties and is good for diabetic patients. It has also been recommended as an excellent remedy for those suffering from liver complaints (Shukla and Naik, 1993).

Brinjal has been cultivated in India for the last 4,000 years, although it is often thought of as a Mediterranean or mid-Eastern vegetable. The global area under brinjal cultivation has been estimated at 1.85 million hectares with total production of brinjal fruit of about 32 million metric tonnes (FAO data, 2005, http://faostat.fao.org/). India accounts for about 8.7 million MTs with an area of 0.53 million hectares under cultivation. Brinjal is also exported in the fresh or frozen form. In 2007-08, 34 million kg worth of Rs. 19 million was exported mainly to UK, Netherland, Saudi Arabia and Middle East countries (DGCIS, 2008).

2. TAXONOMY AND GEOGRAPHIC ORIGIN

2.1 Taxonomy

Brinjal belongs to the family *Solanaceae* and is known under the botanical name *Solanum melongena* L. The family contains 75 genera and over 2000 species, out of which, about 150-200 are tuber bearing and belong to section Tuberarium. The majority of species (about 1800) are non tuber bearing. Cytological studies have indicated that basic chromosomal number 2n = 24 is same in almost all the varieties and species.

There are 3 main botanical varieties under the species *melongena* (Choudhury, 1976a). The common brinjal, to which large, round or egg-shaped fruited forms belong, are grouped under var. *esculentum*. The long, slender types are included under var. *serpentinum* and the dwarf brinjal plants are put under var. *depressum.*

Name	Brinjal
Kingdom	Plantae
Class	Magnoliopsida
Subclass	Asteridae
Order	Solanales
Family	Solanaceae
Genus	*Solanum*
Species	*melongena*

2.2 Geographic Origin and Distribution

Brinjal is considered a native to India where the major domestication of large fruited cultivars occurred. In "Origin of cultivated plants" published in 1886, De Candolle, stated that the species *S. melongena* has been known in India from ancient times and regarded it as a native of Asia. Vavilov (1928) was of the opinion that its centre of origin was in the Indo-Burma region.

Various forms, colours and shapes of brinjal are found throughout South-East Asia, suggesting that this area is an important centre of variation. A centre of diversity is believed to be in the region of Bangladesh and Myanmar (Former India-Burma border). Evidence to this was given by Isshiki *et al.,* 1994 based on the isoenzyme and morphological variation noticed in large germplasm collection from India.

According to Zeven and Zhukovsky, 1975, it originated in India but spread eastward and by the 5th century B.C. was in China, which became a secondary centre of variation. Thus, it has been known for the last 1500 years in China. Arabic traders were responsible for subsequent movement to Africa and Spain. Brinjal cultivation in the Mediterranean region is relatively recent. Portuguese colonies took it to Brazil. It is now widely cultivated for its fruits in the tropical, subtropical and warm temperate zones, especially in Southern Europe and the Southern United States. Sampson, 1936 suggested the African origin of this crop, but there is no evidence that *S. melongena* is native there though there are spiny African brinjal plants.

2.3 Genomic Evolution

As regards affinities and origin of *S. melongena L.*, hybridization experiments between *S. melongena* and other species of *Solanum* have been performed only in few cases and definite conclusions are not available. Efforts have been initiated for studying evolutionary relationship and discerning varieties within crop germplasm (Doganlar *et al.*, 2002 and Singh & Kumar, 2005).

3. REPRODUCTIVE BIOLO GY

3.1 Growth and Development

Brinjal is usually transplanted rather than direct seeded in the field as it provides the best means of establishing a uniform and complete stand of plants. Brinjal seeds germinate one to two weeks after sowing. Seedlings grown in containers are ideal because they allow field planting without disturbing the root system. A main stem with 6-10 leaves develop before the appearance of first flower. Depending on whether the sowing period corresponds to more or less favourable agro-climatic conditions, the first flower appears one and a half to three months after sowing. At the level of each flower, there is dichotomous branching that grows more or less regularly, depending on the species and variety. The sympodia generally consist of two leaves and the axillary bud of the leaf below each flower frequently gives rise to a new branch. Growth and flowering are continuous throughout the life of the plant.

Taking into account the competition between the vegetative growth and fruit production, brinjal is capable of indefinite production.

The botanical features of *S. melongena* along with characteristics of three common varieties viz. *esculentum*, *serpentinum* and *depressum* are placed at Annexure- I.

3.2 Floral Biology

Brinjal flowers are large, violet coloured and solitary or in clusters of two or more. Flower consists of calyx: sepals 5, united, persistent; corolla: petals 5, united, usually cup shaped; Androecium : stamens 5, alternate with corolla; Gynoecium: carpels are united, ovary superior. The hypogynus gynoecium is syncarp located obliquely in relation to the median. In most varieties the perfect flowers are borne singly and opposite to the leaves.

In brinjal, heterostyle is a common feature. Four types of flowers have been reported depending on the length of styles, viz. (a) long-styled with large ovary, (b) medium-styled with medium size ovary, (c) Pseudoshort-styled with rudimentary ovary and (d) true short-styled with very rudimentary ovary (Figure 1).

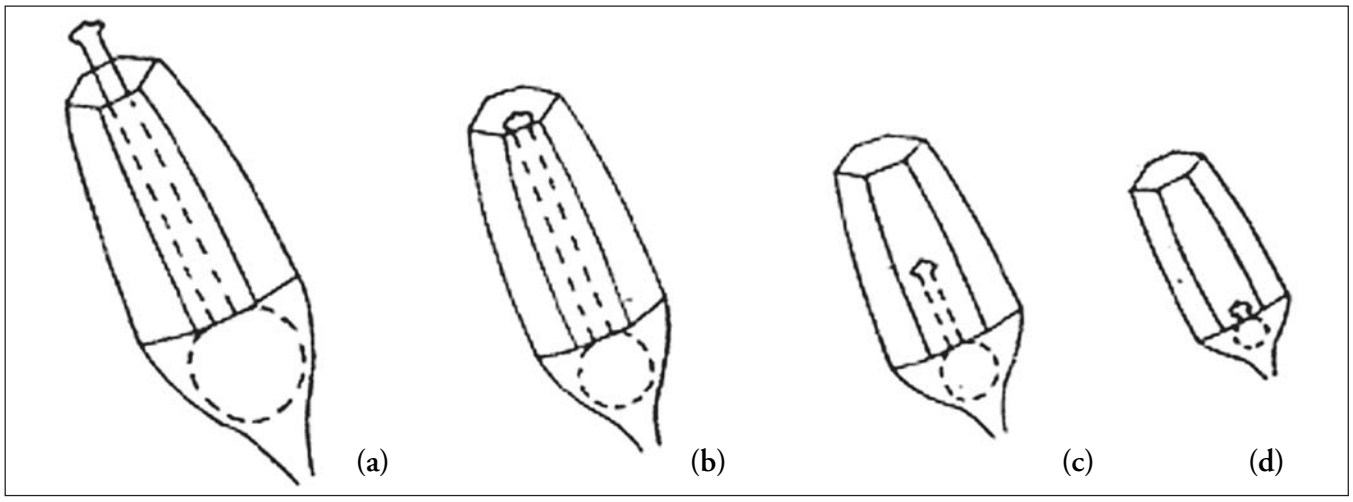


Figure 1: *Types of brinjal flowers on the basis of length of styles*

a. long-styled (big ovary), *b. medium-styled (medium ovary),*
c. pseudoshort-styled (rudimentary ovary), *d. true short-styled (very rudimentary ovary).*
Source: *Krishnamurthi and Subramaniam, 1954*

It has been reported that long and medium-styled flowers produce fruits whereas pseudo-short and short-styled flowers do not set any fruits. Further, chances of cross pollination are more in long style flowers. The percentage of long and medium styled flowers is a varietal character. Fruit setting of long-styled flowers varies from 70% to 86.7% in different varieties. In medium styled flowers, fruit set ranges from 12.5% to 55.6%. All varieties have flowers with different style length. The position of the stigma in relation to stamens varies with the cultivars and can also vary in different flowers of same cultivar. Stigmas are either found above, on the same level as or below the stamens and the highest

percentage of fruit set is found where the stigma is above the stamens. In short-styled flowers the androecium is fertile but the stigma is smaller with underdeveloped papillae and lower sugar content than that in long-styled flowers. There is no pollen germination on the stigma or penetration of pollen tube into short styles (Rylski *et al.,* 1984).

3.3 Pollination

Brinjal is usually self-pollinated, but the extent of cross-pollination has been reported as high as 48% and hence it is classified as cross-pollinated crop. The cone-like formation of anthers favours self-pollination; but since the stigma ultimately projects beyond the anthers, there is an ample opportunity for cross-pollination. The rates of natural cross-pollination may vary depending on genotype, location and insect activity. The extent of outcrossing has been reported from 3 to7% in China and from 0 to 8.2% (with a mean of 2.7%) at Asian Vegetable Research Development Centre (Chen & Li, 2000); however the Indian researchers have reported 2 to 48% outcrossing in brinjal varieties in India as indicated in Table 2. Outcrossing primarily takes place with the help of insects.

Table 2: Reported cross-pollination in brinjal in India

% Cross pollination	Reference
0.00 - 48.00%	Agrawal (1980)
6.00 - 20.00%	Choudhary (1971)
6.70%	Sambandam (1964)
30.00 - 40.00%	Daskalov *et al.* (1937)
0.14 - 1.99%	Choudhary *et al.* (1970)

Flowers generally emerge 40-45 days after transplanting. The anthesis and dehiscence in brinjal are mainly influenced by the daylight, temperature and humidity and therefore the exact timing for every area should be determined by observation and experience. Usually anthesis starts from 6 to 7.30 AM and continues up to 11 AM. Peak time for anthesis is 8.30 to 10.30 AM. The pollen dehiscence starts from 9.30 to 10 AM. Stigma receptivity is highest during anthesis. The receptivity of the stigma could be observed from the plump and sticky appearance which gradually turns brown with the loss of receptivity. The stamens dehisce at the same time stigma is receptive so that self pollination is a rule, although there is some cross-pollination by insects also. The period of effective receptivity ranges from a day prior to flower opening. Pollen is most fertile immediately after the anther dehiscence. Pollen remains viable for a day. Opening of anthers is mostly by pore or slit at or near the apex. Repeated pollination and pollen from different plants increases both fruit and seed set.

There is variation in the size of pollen grains also (Prasad *et al.,* 1968). Popova (1958) reported that pollen remained viable for 7-10 days and stigma remained receptive for 6-8 days. Maximum fruit set was observed when stigma received pollen from many different plants.

The extent of cross pollination has been reported as high as 48% and depends on the presence of pollinating insects such as bumblebees (*Bombus* sp.), wild bees *(Exomalopsis* sp., *Xylocopa* sp.*, Anthophora* sp.) and domestic bees*(Apis* sp.).

Pal and Osvald (1967) observed that the fruit set of insect pollinated plants is much higher then that of self pollinated ones. Flower abortion is favoured by natural day light reduction and high (30°C) night temperature as reported by Saito and Ito (1973). Pal and Taller (1969) opined that the number of seeds per fruit is closely related with the type of pollination. It is highest with free pollination, lower in selfed plants and lowest in exclusively artificially crossed plants.

3.4 Methods of Reproductive Isolation

Since there is considerable amount of cross-pollination in eggplant, isolation is essential for seed production in case of brinjal. As per Indian minimum seed certification standards, an isolation distance of 300 meters is required for production of foundation seeds of varieties/hybrids in case of brinjal (Tunwar and Singh, 1988). Accordingly requirements of 300 meters as the isolation distance has been adopted for conducting confined field trial of genetically engineered brinjal varieties/hybrids.

4. CROSSABILITY BETWEEN *SOLANUM SPP.* AND HYBRIDISATION

Solanum is a very large genus. It includes both tuberous and non tuberous group of species. The chromosome number of many species under non tuberous group is fairly stable as 2 x = n = 24. There are 38 Asian species which include 22 Indian species (listed in Box 1). There is a group of 5 related ones, namely *S. melongena L., S. incanum L.,* (often considered synonymous to *S. coagulans L.), S. xanthocarpum, S. indicum L.* and *S. maccani*. (Choudhary, 1976b).

Box 1: *Solanum spp.* in India

1.	*Solanum aethiopicum L.*	12.	*Solanum marginatum L*
2.	*Solanum americanum Miller*	13.	*Solanum melongena L.*
3.	*Solanum anguivi Lam.*	14.	*Solanum nigrum L.*
4.	*Solanum blumei Nees*	15.	*Solanum sisymbriifolium Lam.*
5.	*Solanum dulcamara L.*	16.	*Solanum stramonifolium L.*
6.	*Solanum ferox L.*	17.	*Solanum torvum Swartz*
7.	*Solanum incanum L.*	18.	*Solanum trilobatum L.*
8.	*Solanum indicum L.*	19.	*Solanum undatum Jacq. non Lam.*
9.	*Solanum lasiocarpum Dunal*	20.	*Solanum viarum L*
10.	*Solanum macrocarpon L.*	21.	*Solanum violaceum Ortega*
11.	*Solanum mammosum L.*	22.	*Solanum xanthocarpum* Schrad. et Wendl

Source: *Indian Institute of Vegetable Research (IIVR), 2009. Personal communication*

Crossability among some of the important species has been reviewed by Rao, 1979. He studied crossability among ten species and reported that *S. melongena* cultivar as female parent hybridized with *S. melongena* variety *S. insanum, S. incanum, S. integrifolium* and *S. gilo* and resulted in viable seeds. It produced only shrunken seeds with *S. khasianum* and did not hybridize with *S. indicum, S. zuccagnianum* and *S. sisymbrifolium*. *S. melongena* as male parent hybridized with *S. indicum* and produced a number of hybrids. Rajasekharan (1969) studied the interrelationship of some common *Solanum* species occurring in South India. Eight *Solanum* spp. were crossed in all possible combinations out of which *S. indicum* x *S. melongena*; *S. xanthocarpum* x *S. trilobatum* crosses were successful. Schaff *et al.* (1980) produced interspecific hybrids in reciprocal crosses by using 11 *S. melongena* types and an African accession of *S. macrocarpon*. Nishio *et al.* (1984) classified 11 *Solanum* species into three groups on the basis of their inter specific compatability: (1) *S. melongena*, *S. incanum*, and *S. macrocarpon*; (2) *S. integrifolium*, *S. gilo* and *S. nodiflorum*; and (3) *S. indicum*, *S. mammosum*, *S. toryum*, *S. sisymbriifollium*, and *S. toxicarium*. Crosses were compatible within and between the first and second groups, but were otherwise incompatible. From various reports, it appears that *S. melongena* is more closely related to *S. incanum* than to any other species.

5. ECOLOGICAL INTERACTIONS

5.1 Organisation of Species Complexes and Gene Flow

The species of *S.melongena, S. aethiopicum* and *S.macrocarpon* are interfertile with their respective wild ancestors (Lester *et al.*, 1986; Hasan, 1989; Daunay *et al.*, 1991). For each of these, the wild ancestor constitutes the primary gene pool according to Harlan and de Wet (1971). In nature, the morphological continuum observed between the primitive forms of each cultivated species, its semi-cultivated forms and the wild species indicates spontaneous gene exchanges. However, these exchanges, which are frequent between primitive forms of each cultivated species and wild species, are much less frequent between advanced forms and wild species.

5.2 Potential for Gene Transfer from Brinjal

5.2.1 *Gene transfer between different brinjal species*

Based on the available information on crossability among different species of brinjal, it is evident that as such there is no natural crossing among cultivated and wild species of brinjal. Further under forced crossing situations, even if crossing was possible. The resultant hybrids were either not viable or the progenies could not be established.

5.2.2 *Gene transfer from brinjal to other plants*

There are no reports of any gene transfer from brinjal to unrelated plant species. Further, it may be noted that such a transfer of any gene is highly improbable because of pre-and post-zygotic genetic incompatibility barriers that are well documented for distantly related plant groups. No evidence for transfer of genes from brinjal to other plant taxa has been identified.

5.2.3 *Gene transfer from brinjal to other organisms*

Horizontal gene transfer from plants to animals (including humans) or microorganisms is extremely unlikely. No evidence has been identified for any mechanism by which brinjal genes could be transferred to humans or animals, nor any evidence that such gene transfer has occurred for any plant species during evolutionary history, despite animals and humans eating large quantities of plant DNA. The likelihood of brinjal genes transferring to humans and other animals is therefore effectively zero. Similarly gene transfer from brinjal, or any other plant, to microorganisms is extremely unlikely. Horizontal gene transfer from plants to bacteria has not been demonstrated experimentally under natural conditions (Nielsen *et al*., 1997; Nielsen *et al*., 1998; Syvanen, 1999) and deliberate attempts to induce such transfers have so far failed (Schlüter *et al.,* 1995; Coghlan, 2000).

5.3 Seed Dormancy

Some wild species of brinjal germinate much slower than cultivated species. Seed dormancy is sometimes observed, which varies according to cultivars and harvest conditions. Storage for a few months at an ambient temperature, or a few weeks at chilled conditions lessens this dormancy (Daunay *et al.,* 1991). Seed dormancy was reported in some of the cultivated brinjal species also. Yogeesha *et al*., 2006 have reported seed dormancy in fresh seeds of eggplant cultivars. The germination of two month old seeds of two brinjals varieties cv. Arka Keshav and Arka Neelkanth was 0 % and 2 % respectively, revealing the presence of dormancy. However, there was a gradual decline in the seed dormancy with the ageing of seeds under ambient conditions and complete breakdown of dormancy occurred after 12 months of storage.

5.4 Free Living Populations of Brinjal

The term “free living” is assigned to plant populations that are able to survive, without direct human assistance, over long term in competition with the native flora. This is a general ecological category that includes plants that colonize open, disturbed prime habitat that is either under human control (weedy populations) or natural disturbed areas such as river banks and sand bars(wild populations). There are no such free living populations of brinjal in India.

5.5 Weediness of Brinjal

No reports of *Solanum melongena* as a weed are available.

6. HUMAN HEALTH CONSIDERATIONS

In brinjal, no endogenous toxins or significant levels of antinutritional factors have been found till date. It is so not considered a pathogen and is not capable of causing any disease in humans, animals or plants.

7. BRINJAL CULTIVATION IN INDIA

7.1 Climatic and Soil Requirements

Brinjal is a warm season vegetable and susceptible to severe frost. Climatic conditions especially low

temperature during the cool season cause abnormal development of the ovary (splitting) in flower buds which then differentiate and develop into deformed fruits during that season (Nothmann and Koller, 1973). The optimum temperature for growth and fruit set is 20-30°C. However, the high night and day temperature condition of 22-24°C to 33-35°C markedly reduce fruit set and yield (Kalloo *et al*, 1990; Kumar *et al*., 2000; Mohanty and Prusty, 2000; Thapa, 2002). Many of the round varieties set fruits at slightly lower temperature but are highly susceptible to frost. The long fruited varieties set fruit at higher temperature and show tolerance to frost. The growth of the crop is severely affected when temperature falls below 17°C. It can be successfully grown as a rainy season and summer season crop.

The brinjal can be grown practically on all soils from light sandy to heavy clay. Light soils are good for an early crop, while clay loam and silt-loam are well suited for high yield. Generally, silt-loam and clay-loam soils are preferred for brinjal cultivation. The soil should be deep, fertile and well-drained. The soil pH should not be more than 5.5 to 6.0 for its better growth and development. It is moderately tolerant to acidic soil. Several cultivars are grown successfully under high pH level with a rich application of farmyard manure or green manuring practiced before transplanting.

7.2 Varietal Testing System

As brinjal is grown all over India and round the year, like other similar vegetable crops, brinjal is tested in the All India Coordinated Vegetable Improvement Programme (AICVIP), spread in selected location in the country. State Universities and Research Stations test the locally preferred varieties in the jurisdiction. The AICVIP promotes R&D and breeding of improved varieties of vegetable crops including brinjal. Vegetable growing states in India are classified into eight different zones, mainly on the basis of agro-climatic conditions and these are listed below:

Zone I: Jammu & Kashmir, Himachal Pradesh and Uttarakhand
Zone II: West Bengal and Assam
Zone III: North East States and Andaman and Nicobar Islands
Zone IV: Punjab, Uttar Pradesh, Bihar and Jharkhand
Zone V: Chhattisgarh, Orissa and Andhra Pradesh
Zone VI: Rajasthan, Gujarat, Haryana and Delhi
Zone VII: Madhya Pradesh and Maharashtra
Zone VIII: Karnataka, Tamil Nadu and Kerala

7.3 Pests and Diseases of Brinjal

Insect pests infestation is one of the most limiting factors for accelerating yield potential of brinjal. The crop is prone to damage by various insects, although there is wide variability in their degree of infestation. Some of the important insects are fruit and shoot borer, jassids, mites, etc. The brinjal is also subjected to the attack of many diseases affecting roots, leaves, stems and fruits. The severity in any particular disease depends on the season and the region in which the crop is grown. Many of the diseases have caused

damage only in exception years, but a few are prevalent in many areas each year and cause varying levels of damage. The major insect pests, disease and predators of brinjal in India are detailed in Annexure II to IV.

7.4 Breeding Objectives

Breeding activities in brinjal have been targeted at the development of high-yielding, early, better quality and disease resistant varieties. The colour, size and shape of the fruit, proportion of seeds to pulp, short cooking time and lower solanine levels are important traits in assessing quality. As brinjal is susceptible to several pests and diseases such as wilt, *Phomopsis* , little leaf and root-knot nematodes and to insects such as shoot and fruit borer, jassids, epilachna beetle, etc. the development of pest resistant varieties is a major challenges. Plants are susceptible to both low and high temperature; therefore attempts are being made to develop chilling or frost- tolerant and heat-tolerant varieties (Singh and Kumar, 2005).

Specific breeding objectives in brinjal in Indian context are:

i. Exploitation of heterosis for increasing productivity
ii. Incorporation of resistance against insect pests including fruit and shoot borer
iii. Breeding wilt and other disease resistance-host plant resistance
iv. Development of cultivars of better quality and yield
v. Development of locally preferred cultivars which are distinct in appearance

7.5 Importance of Heterosis Breeding

Brinjal continues to be a choice of breeders for exploitation of heterosis due to hardy nature of crop, comparatively large size of flowers and large number of seeds in a single act of pollination. Highly varied consumer acceptance from region to region also demands for development of a large number of high yielding F_1 hybrids. Exploitation of hybrid vigour has become a potential tool for improvement in brinjal (Pal and Singh, 1949; Mishra, 1961; Chadha and Sidhu, 1982).

In India, several reports are available on hybrid vigour in brinjal. Pal and Singh (1949) reported that hybrid in brinjal showed 48.8-56.6% increased yields over the better parent. Mishra (1961) also observed increased yields in brinjal hybrids. The cost of hybrid seed production is not high as compared to other vegetables and this can be further reduced by the use of male sterile lines.

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*. However, the biotechnological tools could be useful in overcoming the crossability barrier between the *Solanum melongena* and *Solanum tuberarium.*

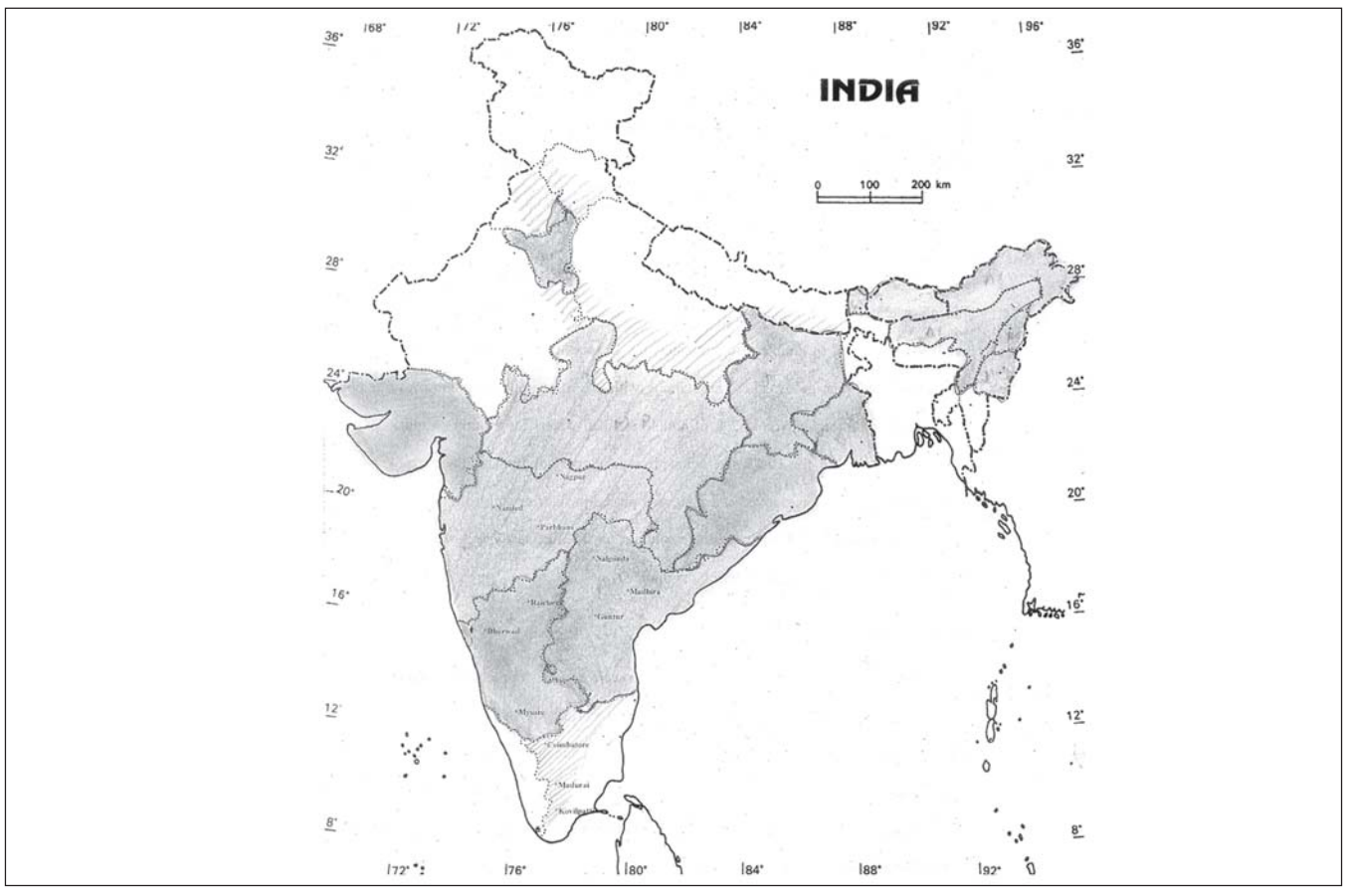
Keeping in view the above, the main objective of inter specific hybridization has been to transfer resistance characteristic(s) of wild species to commercial varieties. The related species of *S. melongena* L. have been

used in breeding for insect and disease resistance. Two other species, *S. khasianum* and *S. aviculare*, having the same chromosome number, have gained importance as sources of solasodine used for synthesis of steroid hormones (Choudhary, 1976b).

7.6 Status of Brinjal Cultivation

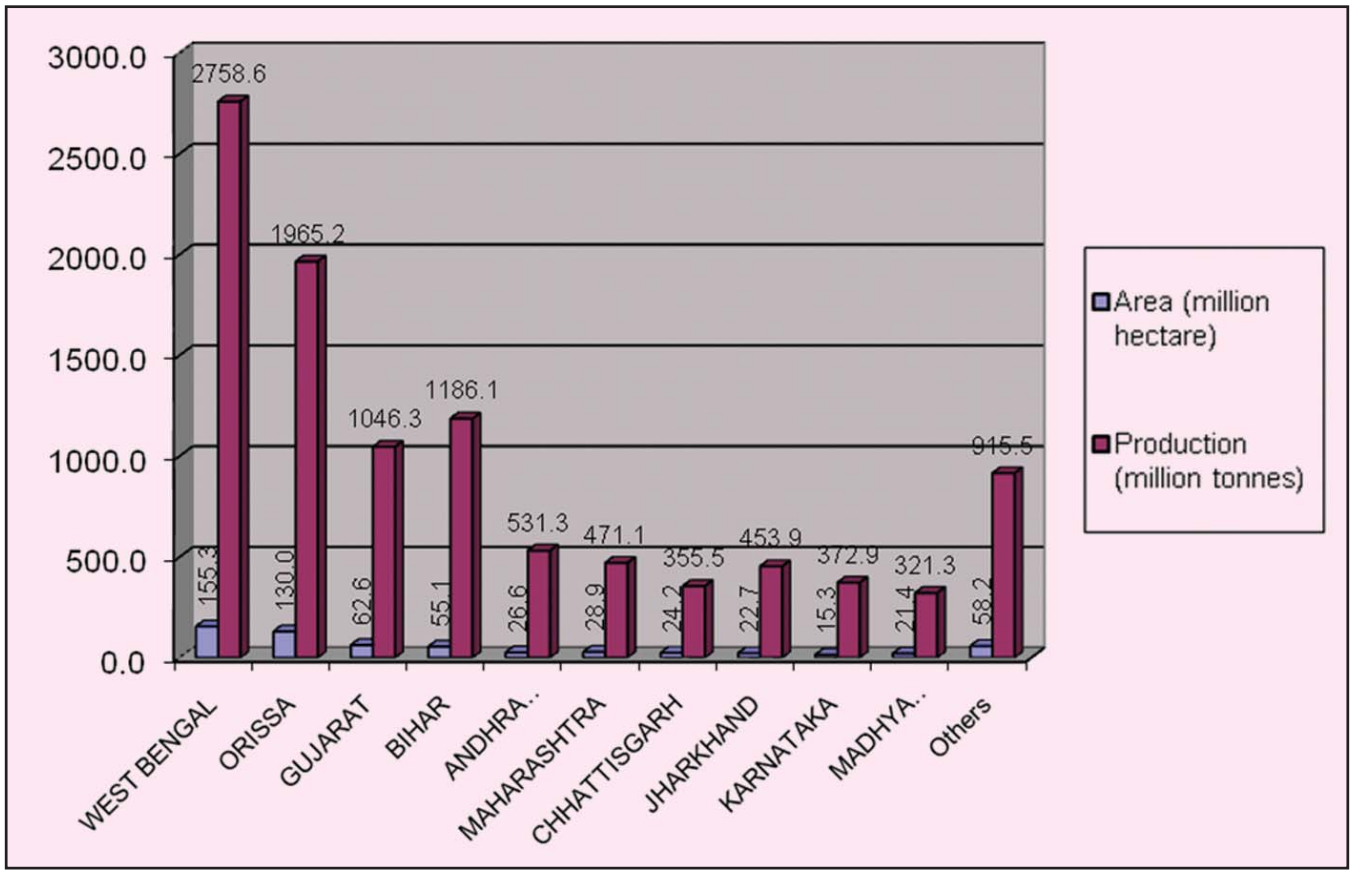
As mentioned earlier, brinjal can be grown in almost all parts of India except higher altitudes all the year round. A number of cultivars are grown throughout the country depending on the yield, consumer's preference about the colour, size and shapes of the various cultivars. There is huge diversity in Indian germplasm ranging from long to round fruits, white fruited to black fruited, thorny to non thorny and bushy plant habit to erect plant habit. It is a versatile crop adapted to different agro-climatic regions.

Brinjal cultivation in India is estimated to cover about 8.14% vegetable area with a contribution of 9% to total vegetable production. The crop is largely grown in small plots or as inter crop both for cash and domestic consumption by farmers all over India. The major brinjal producing states are West Bengal, Orissa, Bihar, Gujarat, Maharashtra, Karnataka, Uttar Pradesh and Andhra Pradesh. A map of India showing brinjal cultivation area is placed in Figure 2. Area and production data in major brinjal growing states in 2008-09 is placed in Figure 3.



Solid shading indicates a traditional brinjal growing area while light feathering indicates sparsely spread area under brinjal.

Figure 2: *Map of India showing brinjal cultivation area*
Source: *Fakrudin,B.UAS Dharwad, Personal Communication*



Source: *http://nhb.gov.in*

Figure 3: State wise area and production of brinjal for the year 2008-09

7.7 Status of Biotechnological Interventions

Fruits and shoot borer i.e. *Leucinodes orbonalis* being the most destructive pest in brinjal crop, efforts have been made to develop insect resistant brinjal varieties by incorporating *cry1Ac* gene in brinjal from a bacterium mainly *Bacillus thuringiensis*, commonly known as Bt brinjal. The Bt brinjal developed by M/s Maharashtra Hybrid Seeds Company Limited containing *cry1Ac* gene (Event EE1) is in the advanced stages of regulatory consideration. MAHYCO has also transferred Bt brinjal technology to public sector institutions viz. Tamil Nadu Agricultural University (TNAU), Coimbatore, University of Agricultural Sciences (UAS), Dharwad and Indian Institute of Vegetable Research (IIVR), Varanasi, who have successfully backcrossed Event EE1 into locally adopted open pollinated brinjal varieties. The technology has been also transferred to Institute of Plant Breeding of the University of Philippines, in the Philippines and Bangladesh Agricultural Research Institute and East West Seeds Limited in Bangladesh. National Research Centre on Plant Biotechnology (NRCPB), New Delhi has also developed Bt brinjal by incorporating *cry1Fa1* gene into brinjal and transferred to the same to few seed companies for further biosafety studies and field evaluation. The Indian Institute of Horticultural Research (IIHR), Bangalore is also developing Bt brinjal using *cry1Ab* gene construct in two important brinjal varieties.

ANNEXURE - I

BOTANICAL FEATURES

Brinjal or eggplant is a herbaceous annual with erect or semi spreading habits. It is a perennial plant but cultivated as annual. It develops into bushy plants with large, fuzzy leaves that grow to a height of about 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 stems, leaves, and calyx of some cultivars are spined.

The botanical features of various plants parts of brinjal are as under:

Leaves

The leaf pattern is mostly opposite, large, single lobed and the underside of the most cultivars is covered with dense wool like hairs. The leaves may be with or without spines at the midrib portions. The leaf blade and tip angle is very acute to very obtuse (Figure 4). Inflorescence is often solitary but sometimes it constitutes a cluster of 2 - 5 flowers. This character is dependent on the variety or hybrid.

Figure 4: *Brinjal Leaves*
Source: *http://pestnet.org*

Flower

The flowers are large, violet-colored and either solitary or in clusters of two or more (Lawande and Chavan, 2000). Flower is complete, actinomorphic and hermaphrodite (Figure 5). Calyx is five lobed, gamosepalous and persistent with or without spines depending on the cultivar types. It forms a cup like structure at the base. Corolla is five lobed gamopetalous with margins of lobes incurved. There are five stamens which are free and inserted at the throat of corolla. Anthers are cone shaped, free and with apical dehiscence. Ovary is hypogynous, bicarpellary, sycarpous and with basal placentation.

Figure 5: *Brinjal Flower*
Source: *http://susveg-asian.nri.org*

Four types of flowers have been reported depending on the length of styles, viz. (i) long styled with big ovary, (ii) medium styled with medium sized ovary, (iii) pseudoshort styled with rudimentary ovary and (iv) true short styled with very rudimentary ovary.

Fruit

The fruit is pendent and is fleshy berry borne singly or in clusters. The shape of fruit varies from ovoid, oblong, obovoid, or long cylindrical. The colour of the mature fruit varies from mono-coloured purple, purple black, yellowish, white, green and variegated types of purple with white stripes, green with light green / white stripes or even combination of three colours (Figure 6).

Figure 6: *Brinjal Fruit*
Source: *http://susveg-asia.nri.org/*

Seeds

The seeds are borne on the fleshy placenta and the placentae with the seeds completely fill the locular cavity. The number of seeds per fruit varies from few (50) to many. The seed color is white, light yellow, brownish yellow, brown to black brown for different varieties.

ANNEXURE - II

KEY INSECT PEST OF BRINJAL

Brinjal is attacked by a number of insect pests and nematodes during various stages of crop growth in most of the tropical countries including India. The extent of losses caused by these pests depends on season, variety, soil and other factors (Dhamdhere *et al.*, 1995; Roy and Pande, 1995). Some of the important ones are briefly described below.

1 Brinjal Fruit and Shoot Borer (*Leucinodes orbonalis*)

Fruit and shoot borer *(Leucinodes orbonalis)* is the most destructive pest of brinjal. It is widely distributed in the Indian sub-continent and also in Thailand, Laos, South Africa, Congo and Malaysia. It also damages potato and other solanaceous crops. This pest is active through out the year at places having moderate climate but it is adversely affected by severe cold.

The damage by this insect starts soon after transplanting of the seedlings and continues till harvest of fruits. Eggs are laid singly on ventral surface of leaves, shoots, and flower-buds and occasionally on fruits. In young plants, appearance of wilted drooping shoots is the typical symptom of damage by this pest; these affected shoots ultimately wither and die away (Figure 7).

Figure 7: *Plant showing shoots damage (Drooping Shoot) and insect inside the shoot*
Source: *http://ikisan.com*

At later stages, the caterpillars bore into flower buds and fruits, entering from under the calyx. They have no visible sign of infestation, but the caterpillars feed inside. The damaged flower buds shed without blossoming whereas the fruits show circular exit holes (Figure 8). Such fruits, being partially unfit for human consumption, lose their market value considerably.

Figure 8: *Fruit damaged by Brinjal fruit and shoot borer (Leucinodes orbonalis)*
Source: *http://ikisan.com*

ii) Brinjal Fruit Borer (***Helicoverpa armigera***)

The pest is polyphagous in nature. The full grown larvae are greenish with dark broken grey lines along the side of body. They measure about 35-45 mm long. The moth is large and brown with V-shaped speck and dull black border on the hind wings. The larvae are fed first on leaves and fruiting bodies and later on, they bore into the fruits, completely eating away the internal contents.

Figure 9: *Brinjal Fruit Borer (Helicoverpa armigera) Larvae*
Source: *http://zipcodezoo.com*

iii) Brinjal Stem Borer (***Euzophera perticella***)

Full grown caterpillars are creamy white with a few bristly hairs and measure about 20-22 mm in length. The moth is small having pale straw yellow fore wings and whitish hind wings. The moth measure about 32 mm across the spread wings. The caterpillar causes the damage and feed exclusively in the main stem. It enters the main stem and make tunnel which results either in stunting of growth or withering of plants (Figure 10). Its infestation is seen usually in the later stage of crop.

Figure 10: *Infected Brinjal Stem with Brinjal Stem Borer (Euzophera perticella)*
Source: *http://.ikisan.com*

iv) Hadda Beetle (***Epilachna vigintiopunctata***)

The grubs are almost 6 mm long, yellowish in colour and have six rows of long branched spines (Figure 11). Beetles are 8-9 mm in length and 5.5 mm in width. Beetles are deep red and usually have 7-14 black spots on each elytra whose tip is somewhat pointed (Figure 12). The damage is caused by the beetles as well as by the grubs by feeding on the upper surface of leaves. The leaves are eaten between the veins, sometimes being completely stripped to mid-rib. The leaves present a lace like appearance; turn brown, dry up and fall off. Thus, the plant is completely skeletonized.

Figure 11: *Hadda Beetle (Epilachna vigintiopunctata)*

Figure 12: *Grub of Hadda Beetle (Epilachna vigintiopunctata)*

Source: *http://brisbaneinsects.com*

v) Sucking Pests

1. Aphids (***Lipaphis erysimi***)

The nymphs and adults are louse like and pale greenish in colour (Figure 13, 14). This pest is very active from December to March when various cruciferous and vegetable crops are available in the fields. The damage is caused by nymphs and adults by sucking cell sap from leaves, stems, inflorescence or the developing plants. They are seen feeding in large numbers, often covering the entire surface. Owing to feeding on cell sap, the vitality of plants is greatly reduced. The leaves acquire a curly appearance.

Figure 13: *Adults of Aphids (Lipaphis erysimi)*

Figure 14: *Nypmhs of Aphids (Lipaphis erysimi)*

Source: *http://backyardnature.net*

2. Jassids (***Amrasca bigutella***)

The nymphs and adults are very agile and more briskly forward the side ways (Figure 15, 16). Adults are about 3 mm long and greenish yellow during summer, acquiring a reddish tinge in the winter. Nymphs and adults remain in large numbers and suck the sap from the undersurface of the leaves. While feeding, they inject the toxin saliva into the plant tissues. The leaves shows symptoms of hopper burn such as yellowing upward curling, bronzing and even drying of leaves. The crop becomes stunted and often in highly susceptible varieties it cause complete mortality of the plants.

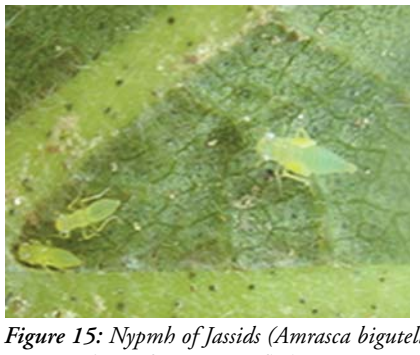


Figure 15: *Nypmh of Jassids (Amrasca bigutella)*
Source:- *http://farm3.static.flickr.com/*

Figure 16: *Adult of Jassids (Amrasca bigutella)*
Source: *http://ikisan.com*

3. White Fly (*Bemisia tabaci*)

Winged nymphs are 1.0-1.5 mm long and their yellowish bodies are slightly dusted with a white waxy power. They have two pairs of pure white wings and have prominent long hind wings (Figure 17). The nymph on emergence, look elliptical and soon fix their mouthparts in the plant tissues (Figure 18). They feed on cell sap causing damage in two ways: (a) the vitality of plant is lowered through the loss of cell sap, and (b) normal photosynthesis is interfered with due to the growth of a sooty mould on the honey dew excreted by the insect. From a distance the attacked crop gives a sickly, black appearance.

Figure 17: *Adults of White Fly (Bemisia tabaci)*
Source: *http://bcpcertis.com*

Figure 18: *Nypmhs of White Fly (Bemisia tabaci)*
Source:- *http://plante-doktor.dk/*

vi) Root Knot Nematodes

These are the most common plant parasitic nematodes (*Meloidogyne* spp.i.e., *incognita, javanica*) in India and infestation of these nematodes is common in brinjal. The root knot nematode damage is more harmful to seedling than to older plants. These nematodes infest the roots and cause root galls (Figure 19). The affected plant becomes stunted and the leaves show chlorotic symptoms. Infestation of these nematodes greatly hampers the yield of the crop.

Figure 19: *Infestation of Root Knot Nematodes in Brinjal*
Source: *http://vuatkerala.org*

vii) Red Spider Mites (*Tetranychus urticae*)

It is minor and irregular non insect pest of the crop. The nymph and adults are red in color (Figure 20). Its infestation is severe in dry and warm atmosphere. The nymph and adult suck the cell saps from under surface of the leaf. The leaf dries and droppes away incase of severe infestation. Colonies of red mites are found feeding on ventral surface of leaves under protective cover of fine silken webs, resulting in yellow spots on dorsal surface of leaves.

Figure 20: *Red Spider Mites (Tetranychus urticae)*
Source: *http://uspest.org/*

ANNEXURE - III

MAJOR DISEASES OF BRINJAL

Important fungal and bacterial diseases affecting the brinjal crop in India are as follows:

i. Fungal diseases of Brinjal

1. Alternaria Blight (*Alternaria spp.*)

Causes characteristic spot on the leaf with concentric rings (Figure 21). Affected leaves may drop off. It may also infect fruits that turn yellow and may drop off prematurely.

Figure 21: *Alternaria Blight in Brinjal*
Source: *http://ikisan.com*

2. Late Blight *(Phythophthora spp.)*

Symptoms appears as small watersoaked lesions on the fruit to later enlarge in size considerably. The skin of infected fruit turn brown and develops white cottony growth (Figure 22).

Figure 22: *Late Blight in Brinjal (Phythophthora spp.)*
Source: *http://knowledge.allianz.com/*

3. Fusarium Wilt (*Fusarium solani*)

In *Fusarium* wilt, the underground stems become dry and brown as a result of cortical decay while roots may have soft and water soaked appearance (Figure 23). It causes stunted growth, withering of immature fruits, yellowing of lower leaves, drooping of the apical portion, browning of vascular bundles and ultimately drying of the whole plant. Wilting of seedlings is also a common characteristics of the disease.

Figure 23: *Fusarium Wilt (Fusarium solani) in Brinjal*
Source: *http://ohioline.osu.edu/*

4. Phomopsis Wilt (***Phomopsis vexan)***

A serious disease infecting the foliage and the fruits. The infected leaves show small circular spots which later become grey to brown with irregular blackish margins (Figure 24). Dark brown lesions on stem and branches and pale sunken spots on fruits which later merge to form rotten areas. The flesh of severely infected fruits rot.

Figure 24: *Phomopsis Wilt in Brinjal*
Source: *http://vegdis.cas.psu.edu*

5. Damping Off: (***Pythium*** spp., ***Phytophthora*** spp., ***Rhizoctonia*** spp., ***Sclerotium*** spp., ***Sclerotinia*** spp.)

Both the pre-emergence and post-emergence damping-off symtopms are seen in diseased state. The germinating seeds are infected by fungi at the initial stages. The infection later spreads to hypocotyls basal stem and developing roots. The post-emergence damping off phase is characterized by infection of the young, juvenile tissues of the collar at the ground level. The affected seedlings become pale green and brownish lesions are found at the collar region, resulting in botting and topple over of seedlings.

6. ***Cercospora*** Leaf Spot (***Cercospora egenula***)

The disease is favoured by high relative humidity. The leaf spots are characterized by chlorotic lesions, angular to irregular in shape, later turning grayish brown with profuse sporulation at the centre of the spot. Severely infected leaves drop off prematurely (Figure 25).

Figure 25: *Cercospora Leaf Spot Symptoms in Brinjal*
Source: *http:// ikisan.com*

ii) Bacterial diseases of Brinjal

1. Bacterial Wilt (***Pseudomonas solanacearum)***

The characteristic symptoms include wilting of the foliage followed by collapse of the entire plant. The wilting is characterized by dropping and slight yellowing of leaves and vascular discolouration. Drying of the plants at the time of flowering and fruiting are also characteristic to the diseased condition. The infected cut stems pieces when dipped in water, a white milky stream of bacterial oozes coming out which is the diagnostic symptom for bacterial wilt (Figure 26).

Figure 26: *Pseudomonas solanacearum oozing out of the infected Brinjal Stem*
Source: *http:// infonet.biovision.org*

iii) Viral diseases of Brinjal

1. Little Leaf of Brinjal (*Phytoplasma sp.)*

A serious viral disease of brinjal, transmitted by leaf hopper (*Hishimonus phycitis* and *Amrasca biguttula biguttula*). The infected leaves show a reduction in size and are malformed into tiny chlorotic structure (Figure 27).

The flower buds take an upright position instead of being pendulous. All the flowers become phylloid, leaves become smaller. In severe cases, excessive crowding of short branches and production of smaller leaves give plant a rosette appearance. The infected plants generally do not bear any fruit or either the fruit becomes hard and tough.

Figure 27: *Little Leaf of Brinjal (Phytoplasma)*
Source: *http://susveg-asia.nri.org/*

ANNEXURE - IV

NATURALLY OCCURRING PREDATORS

Naturally occurring predators that offer control of pests in brinjal crop are spiders, dragonfly and ladybirds as indicated below.

Figure 28: Spider
Source: *http://susveg-asia.nri.org*

Figure 29*: Dragonfly*
Source:- *http://www.discoveryofdesign.com/*

Figure 30*: Ladybird larva*
Source: *http://audilab.bmed.mcgill.ca/*

Figure 31*: Ladybird adult*
Source: *http://www.garden.org/*

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