CHAPTER 2

Mango (*Mangifera indica* L.), popularly known as "Aam" belongs to the family Anacardiaceae and is the most economically important fruit crop. The word mango comes from Malayalam “manga” and Tamil “mangai”, and the name *Mangifera* was first given by *Botinus* in 1658, where he referred to it as *Mangifera*. It is a diploid (2N), with 20 pairs of chromosomes having a small genome size of 439 Mb (Arumuganathan and Earle, 1991). Due to its sweetness, unique taste, high-quality fibre content and, vital source of vitamin (A and C). It is considered as ‘The king of fruit’. It is a national fruit of India (Bally, 2006; Singh *et al*., 2016). It is also known as “Food of the God”, the fruit of the tropics and the vernacular name is “*AAM*” in India. It is one of India's most important fruit crops, with approximately 50 % of fruit production in the world (FAOSTAT, 2016). It is widely used in ayurvedic and indigenous medicine and possesses vast anti-diabetic, antiviral, cardiotonic, hypotensive, antioxidant and anti-inflammatory properties (Shah *et al*., 2010).

It is believed that the most grown varieties of mango are originated in India and Myanmar (Mukherjee, 1951; Mukherjee and Litz, 2009). According to Mehta (2017), all the known cultivars of mango are originated from two strains of mango seeds: i) mono-embryonic cultivars from India that are grown in India, Africa, Florida (USA) and South America and, ii) poly-embryonic cultivars from the Indochinese strains that are cultivated South East Asia, Central America, Haiti and USA, Australia and South Africa (Mathews *et al*., 1992; Saran *et al*., 2020b, c). Besides *M. indica*, nearly 26 other species of *Mangifera* bears edible fruits, including other species such as *Mangifera caesia, M. foetida, M. kemang, M. altissima,* and *M. similis* may also bear edible fruit (Litz, 2009).

However, some cultivars of the mango bear low/inferior quality fruits that are considered wild mango (Bally, 2006). Mango is mainly cultivated in dry and wet tropical low land areas 23° 26' North and South equator of the Indian subcontinent, Central and South America (Litz, 2009). For several years, some of the cultivars *viz*. Langra, Chausa and Mallika, have been considered as originated from India and maintained under cultivation through vegetative propagation (Litz, 2009). During the early periods of its origin, very low-quality fruits (small size, lack of sweetness and relatively more minor flavour, vitamins and minerals) were produced. However, due to several years of selections, huge variations were seen in shape and size (Litz, 2009).

The genus *Mangifera* has nearly 69 species, among them approx. 26 species producing edible fruit (Mukherjee, 1997; Mukherjee and Litz, 2009) and more than a thousand varieties are known to occur (Iyer, 1991). However, nearly 30 varieties are grown widely because of their intense aroma, delicious taste, nutritive value and high content of vitamin C, β-carotene, and minerals (Tharanathan *et al*., 2006). However, despite all good qualities and economic importance, mango cultivation suffers from several diseases and disorders. In every stage of development, i.e., from the nursery to fruit development stage; each part of the plant *viz*., trunk, branch, twig, leaf, petiole, flower and fruit are affected by various pathogens such as fungi, bacteria, viruses and some insect and pests (Litz, 2009). These pathogens induce diseases and symptoms like- rot, dieback, anthracnose, scab, necrosis, blotch, spots, mildew (Prakash and Srivastava, 1987; Prakash, 2004).

All these diseases are major problems for mango cultivation and responsible for heavy economic loss in mango production. The powdery mildew is a great problem throughout the country and the whole world, causing up to 90 % loss of fruit crop (Mishra, 2001). Similarly, anthracnose leads to 2-39 % losses from India (Prakash *et al*., 1996) and 30-60 % from other parts of the world (Akem, 2006; Chowdhury and Rahim, 2009). Bacterial canker causes 10- 70 % fruit drop while pre-and post-harvest losses are estimated at 10-85 % and 5-100 %, respectively (Sarwar, 2015). Mango malformation affects the inflorescence and results in the decline of yield from 50-80 % (Kumar *et al*., 2011).

Several fungal pathogens have been identified and reported to cause a different kind of diseases on mango throughout the world. The pathogens that affect the fruit production are *Alternaria* black rot caused by *Alternaria alternata* (Prusky, 1998), pink disease by *Erythricium salmonicolor* (Lim, 1998), stem-end rot caused by *Lasiodiplodia theobromae* or *Dothiorella dominica* (Johnson, 1998) and mango anthracnose caused *by Colletotrichum gloeosporioides* or *Colletotrichum acutatum* (Ploetz, 1998). These diseases and pathogen cause both qualitative and quantitative reduction in the crop yield (Arauz, 2000). Besides these, several other microscopic fungi have also found to be associated with mango trees, including sudden death disease including; *Ceratocystis fimbriata*, *Alternaria alternata*, *Cladosporium* sp., *C. gloeosporioides*, *Dothiorella dominicana*, *Fusarium* spp., *Lasiodiplodia theobromae*, *Penicillium* spp., *Pestalotiopsis* spp. and *Phomopsis* spp. (Ploetz, 2004). Therefore, it is believed that mango trees always remain under different threats, which may be either biotic or abiotic

that can influence the health status of the tree (Prakash, 2004). A brief summary of various diseases is mentioned as follows:

2.1 *Anthracnose*:

Anthracnose appears as an oval or irregular vinaceous brown to deep brown areas/spots of variable sizes irregularly distributed over the leaf surface. Under damp conditions, the fungus proliferates and form elongated brown necrotic lesions that are 20-25 mm in diameter. Subsequently, these lesions get blighted and rupture. It is caused by *Colletotrichum gloeosporioides*. It was first reported from Puerto Rico by Collins, (1903), which was later confirmed by Dodd *et al*. (1997) from several other biogeographic regions.

Anthracnose, variously called as blossom blight / leaf spot or fruit rot and is a destructive and prevalent disease in all the mango growing states of India (Cook, 1975; Dodd *et al*., 1997; Ploetz and Prakash, 1997). Kelkar and Rao (1962) reported that *C. mangiferae* was also responsible for causing mango anthracnose. Fitzell (1979) and Prakash (1990) reported *that Colletotrichum acutatum* is the primary causal organism of mango anthracnose from New South Wales and India, respectively. It causes unsightly blemishes on fruit, and it is a main pre-and post-harvest problem (Jeffries *et al*., 1990).

This disease can also damage foliage, while under crowded and moist conditions, it causes severe problems in nurseries and young orchards (Bose *et al*., 1973). The disease affects leaves, twigs, petioles, panicles and fruits (Nelson, 2008). It also damages panicles. Anthracnose is reported from several countries like Brazil, British Guiana, Cuba, Columbia, Congo, Dominican Republic, Dutch East Indies, French Guiana, Fiji, Guatemala, India, Jamaica, Mozambique, Mauritius, Morocco, Philippines, Portugal, Pakistan, Peru, Sierra Leone, Sri Lanka, South Africa Trinidad, Taiwan, Uganda, USA (Prakash and Srivastava, 1987), Malaysia (Lim and Wai, 1986), Australia (Fitzell and Peak, 1984), Bangladesh (Alam *et al*., 1989), Thailand (Mendoza and Wills, 1984), Costa Rico (Arauz and Umana, 1986) and Barbados (Simons, 1991).

It has also been reported as a widespread fungal disease on mangoes and avocados in South Africa (Swart, 1998) and said to cause significant loss in yield, which is estimated to be 2-39 % in India, 41-72 % from Ethiopia (Prakash and Raoof, l991; Prakash *et al*., 1996; Tucho *et al*., 2014; Uddin *et al*., 2018). According to Bose *et al.* (1973), young plantation of cultivar *Bombay Green* was utterly wiped out in Tarai region of Uttar Pradesh (India) due to severe wither tip.

2.2 *Alternaria rot* (black spot):

In India, McRae (1924) reported the disease for the first time and later studied by different researchers (Prusky, 1998). The highest symptoms of the disease can be seen during the transportation of fruits and storage incidence of the disease increases in the presence of gall midge in certain areas. Symptoms appear as brown to deep brown or black spot in angular or in irregular shape that coalesces and forms big and wide lesions on the leaf surface (Prakash and Srivastava, 1987). Young leaves are brutally attacked as compared to old leaves and often show a shot-hole appearance. Commonly, these symptoms found at the terminal portions and leaf margin. The tip of very young branches gets dried from the top to downwards. On panicles, the disease symptoms emerge as brown to black spots and subsequently become large and kill the flowers, resulting in fruit yield reduction (Arauz, 2000). The fruits also show dark brown lesions that coalesce and finally enter into fruits resulting in fruit drop (Nelson, 2008).

2.3 *Bacterial Canker*:

Bacterial canker is one of the most important diseases of economic loss in mango. It appears as small water-soaked lesions on the surface of leaves. These lesions may coalesce to form large necrotic patches, which are often rough and raised. A similar type of lesion appears on fruits and turn into dark brown colour. As the lesions enlarge, they become raised, black and angular, are limited by veins and surrounded by chlorotic haloes (Ploetz and Freeman, 2009; Prakash and Mishra, 2001). The mango canker initiates its infection on twigs and fruits during dry weather of April month while the disease remains in dormant condition during November-March. With the arrival of the rainy season, the disease spread rapidly, and it became severe in post-monsoon (Shekhawat and Patel, 1975).

Apart from India, this disease has been identified in many countries and is said to be caused by *Xanthomonas campestris* pv. *mangiferae indicae* (Patel *et al*., 1948). A gram-negative rod, motile by monostichous flagella and three to four pathotypes have been identified (Kishun, 1995). It causes 10 to 100 % loss to the mango crop in the field and storage conditions (Shekhawat and Patel, 1975; Kishun, 1981). Several mango varieties are found severely infected with disease, but available literature indicates that poly-embryonic varieties are highly susceptible to this disease (Prakash and Raoof, 1985a).

2.4 *Mango Malformation*:

Mango malformation is one of the major problems, and it is a severe disease that leads to significant economic loss throughout the world (Ploetz, 2001). Summanwar (1967) found the yield losses up to 50 to 60 % and reached up to 100 % when the disease becomes severe, whereas Kumar *et al*. (2011) reported 50 to 80 % yield loss from India. Though mango malformation did not kill the plant, it infects inflorescence (panicles) that reduce the fruit yield. In India, mango malformation was reported for the first time from Darbhanga (Bihar) and then from different states of India *viz*. Maharashtra, Gujarat, Uttar Pradesh, Punjab, Jammu and Kashmir, Madhya Pradesh, Himachal Pradesh, and Haryana (Kumar *et al*., 2011). Mango cultivation is severely affected by malformation in many countries worldwide (Kumar *et al*., 1993, 2011; Ploetz and Freeman, 2009).

Malformation generally affects inflorescences, but the vegetative parts of the plant are also affected by malformation resulting in a delay in canopy development. Generally, three distinct types of symptoms can be seen on mango plant as described by earlier researchers, including bunchy top of seedlings, vegetative malformation and floral malformation. Later, these symptoms were divided into two distinct groups, i.e., vegetative and floral malformation (Varma, 1983). The vegetative malformation is found chiefly in young developing seedlings (Nirvan, 1953). Due to this, several small flushes come out from the apical branches that disturb shoot growth. Floral malformation commonly occurs on panicles and is a more severe problem than vegetative malformation (Mahrous, 2004).

It is one of the complex diseases of mango, which has always created ambiguity in the causal organism. Initially, researchers isolated several microorganisms and claimed them as causal agents (Ploetz, 2001; Kumar *et al*., 2011). *Fusarium mangiferae* is considered as a causal organism of mango malformation worldwide (Kumar *et al*., 2011). In India, the causal organism of floral and vegetative malformation of mango was reported for the first time as *Fusarium moniliforme*, later recognized as *F. subglutinans* by Summanwar *et al.* (1966) and Varma *et al*. (1972). The disease has also been associated with physiologic disorders and hormonal imbalances (decreased level of auxins and increased level of cytokinin) (Iyer *et al*., 2009; Kumar *et al*., 2011).

2.5 *Die Back*:

It is one of the severe diseases in which the plant dies completely. In this disease, the plants start to dry and die from top to bottom. Therefore, it is also known as stem-end rot of mango. The disease shows drying of twigs from top to bottom with discolouration, wilting of leaves and, leaf drop. In advanced stages of the disease, apical branches start to dry one by one, and consequently, all twigs become bare and lead to the decline of trees. The complete wilting or death of the tree takes within few weeks to months after the infection by the causal organism.

In general, the disease symptoms are seen throughout the year, but it appears during October and November (Prakash and Raoof, 1985b). If the stem and branches are split open, it shows internal browning in the wood tissue along the axis. Several pathogens have been reported as causal organisms of dieback of mango throughout the world. Ramos *et al.* (1991) reported *Botryospaeria ribis* from United State. Recently, Coelho *et al*. (2018) reported *Lasiodiplodia theobromae* and *Neofusicoccum parvum* from Brazil as a causative agent of mango dieback. In India, *Botryodiplodia theobromae* Pat. was reported as the causal organism of dieback of mango (Rath *et al*., 1978; Prakash and Raoof, 1989; Sireesha and Reddy, 2018).

2.6 *Powdery Mildew*:

Powdery mildew is a distressing disease that affects almost every cultivar of mango. The severity of the disease mainly depends on the climatic conditions, and it becomes severe when the temperature is low and the humidity is high (Prakash and Srivastava, 1987). The disease usually manifests from January to March (flowering time), but at elevations above 600 to 1200 meters, it is known to persist for more extended periods. White superficial, the powdery appearance of fungal growth on leaves, inflorescences, stalks of the inflorescences and young fruits is a characteristic symptom of the disease. Powdery mildew was attributed to *Erysiphe cichoracearum* (Wagle, 1928). Kaur (2019) reported that powdery mildew is caused by *Pseudoidium anacardii* (formerly known as *Oidium mangiferae* Berthet).

Recently, Atsushi *et al.* (2020) reported *Erysiphe quercicola* as a causal organism of powdery mildew for the first time from Japan. In Maharashtra, the yield losses have been estimated up to 20 per cent (Cheema *et al*., 1954), whereas in Lucknow, it varies from 30 to 90 per cent (Prakash and Srivastava, 1987; Mishra, 2001). A similar loss in the fruit yield is also reported in Iran by Zakii *et al*. (1993) and in Pakistan by Ihsan *et al*. (1999).

Besides these abovesaid diseases, some more diseases are also recorded on mango tree from different part of India. These diseases are under new diseases of unknown aetiology including stem bleeding, fiat limb in young as well as full-grown tree's leaf crinkle, woody gall, fruit tumour, fruit size reduction and deformation, fruit chimaeras and clustering are recorded (Mishra and Prakash, 1999).

2.7 Mango Burl:

From these, one of the critical and lesser-known diseases named "**Mango Burl**" has been studied from India (Prakash and Srivastava, 1987; NHM, 2012; Saran *et al*., 2011, 2020a, b, c; Choudhary and Rajput, 2018; Choudhary *et al*., 2020a, b, c, d). It is also known to occur in other parts of the world with different names like crown gall, scaly bark and ball formation etc., (Malaguti and de Reyes, 1964; Cook *et al*., 1971; Angulo and Villapudua, 1982; Hafiz, 1986; Jiskani *et al*., 2007; Ploetz and Freeman, 2009). Malpighi (1675) defined galls in his book "De galls" as "an abnormal growth of plants" caused by different organism. The abnormal growth of any part of plants formed due to active mitosis and morphogenesis of affected cells.

Burls may be solitary or maybe several and scattered over the twigs, branches, trunk and exposed roots of an affected individual (White and Millington, 1954; Peterson, 1961). The mango burl is typically the proliferation of cells on the trunk and lower or main branches. In any stage of the growth and development, trees may get infected with burl disease, which may be visible as single or in groups (White and Millington, 1954; Peterson, 1961).

The burl has different shapes and sizes (Peterson, 1961; Barnard and Freeman, 1982; Teas and Meewa, 1982; Saran *et al*., 2011, 2020a, b, c; Choudhary and Rajput 2018, Choudhary *et al*., 2020a, b, c, d). They are also reported on red mangrove and their bark tissues show dark color with rough surface and seems globular to irregular in shape (Barnard and Freeman, 1982). Similar to burl, crown gall disease of mango was reported from Pakistan. These galls were large in size with different texture however, galls were smaller on roots comparative to crown or collar and always hard on stems (Hafiz, 1986).

It is typically an abnormal swelling and uncontrolled growth of the primary stem and also appeared as warty and corky on main and subsidiary branches of mango (White and Millington, 1954; Saran *et al*., 2011; Choudhary and Rajput, 2018; Choudhary *et al*., 2020a, b, c, d). These burls showed variation in colour, surface, site of formation, presence of gum formation and canopy of tree.

According to Prakash and Srivastava (1987), burl first appear as scaly or corky bark and subsequently it deforms an entire stem portion and may penetrate the phloem and become necrotic. Similar reports are also available on mango seedlings from Hawaii (Cook *et al*., 1971). Comparable disease symptoms resemble scaly bark disorder reported in 'Cuarteado', from Colombia (Cook, 1975). In Mexico, the burl disease on mango is known as 'nanahuate', 'bolas' or 'Buba of mango' (Angulo and Villapudua, 1982). The symptoms of burl with sizable galls are also reported from Puerto Rico, Miami and University of Florida (Ploetz *et al*., 1996b).

Trees of all ages can be affected by burl and occur as single or in groups and the range of burls on branch and trunk may have from 6-10 burls per branch (Mishra and Prakash, 1999). Highly affected plant shows poor vegetative growth and stumpy flowering and consequently leading to reduction in fruit yield (Saran *et al*., 2011; Kumar and Saran, 2018; Choudhary and Rajput, 2018; Choudhary *et al*., 2020a, b, c, d). As per available information, it is difficult to detect the appearance of burl during early stages of disease development and they become visible only after the plant attains certain age (Saran *et al*., 2011, 2020a, b; Choudhary and Rajput, 2018; Choudhary *et al*., 2020a, b, c, d). The number of burls on individual mango tree may vary and totally depends on the variety and the plant part where it occurs.

2.7.1 *Burl Shape and Size*:

Mango burls show significant variation in their shape and size, and these variations are associated with the mango variety. White and Millington (1954) reported that burls were irregular in size and shapes with bigger size (i.e., one meter or more in diameter) on the aged trees. Peterson (1961) also mentioned that burl can grow from small to huge size along with the growth of the tree. Barnard and Freeman (1982) observed that burls have variation in size ranging from 10 to 20 cm in diameter. Angulo and Villapudua, 1982) also reported that burl ranging from 5-10 cm in diameter in mango trees growing in Mexico.

Similar studies have also been reported by Prakash and Shrivastava (1987) from Uttarpradesh (India) in different varieties of mango. Ploetz *et al*. (1996b) also reported that the size of mango burls was 45 cm in diameter with rough and scaly exteriors in *Langra* variety. The size of burl also depends on location of affected trees. The size of burl ranging from 25-37.5 cm in diameter but sometime may be bigger in size and rough in surface (Mishra and Prakash, 1999). The age of the tree plays major role in the

development of burl size because as the tree age increases the size of the burl also increases, particularly in *Langra*, *Rajapuri*, and *Chausa* etc., from 10 to more than 40 years of age (Saran *et al*., 2011, 2020b, c; Choudhary and Rajput, 2018; Choudhary *et al*., 2020a, b, c, d). Different variation in burl shape and size are given in Table 3.

Table 3. Variation in size and shape of different germplasms/varieties of mango (*Mangifera indica*). Source: Saran *et al*. (2011, 2020b, c)

S. No.	Name of variety	Burl size	Shape	Surface	Source
1.	*Langra*	31.8 cm	Globose or globose to elongated	Rough	Saran *et al.* 2011, 2020b, c;
2.	*Chausa*	16.4 cm	Globose	Rough	Saran *et al.* 2011, 2020b, c
3.	*Gulab Jamun*	4.0 cm	Globose to semi elongated	Smooth	Saran *et al.* 2011, 2020b, c

Kumar and Saran (2018) reported the range of variations from 5-62 cm in diameter in Langra and Chausa variety. The largest burl nearly 26 ft (7.9 m) was found on *Sequoia sempervirens* stem that covers whole plant trunk whereas the world's second largest burl is documented in British Columbia (https://en.wikipedia.org/wiki/Burl, site visited on 10/03/2021).

2.7.2 *Incidence and Fruit Yield Loss*:

Generally, the burl disease incidence and yield loss can be seen in mature mango tree. In India, the incidence of burl was reported in three varieties including *Langra*, *Chausa* and *Gulab Jamun* and it has been observed that the incidence reduces fruit yield up to 30% over 2 years (Saran *et al*., 2011). Among these three varieties, the highest effect of incidence and yield loss was examined in *Langra* variety (80.3 % incidence, 25.46 % yield loss approximately) while it was minimum in *Chausa* and *Gulab Jamun* (Saran *et al*., 2011).

García-López *et al*. (2016) reported that the incidence ranged from 10 to 50 % in cv. "Puntica" in Peravia province of Dominican Republic. Kumar and Saran (2018) noted incidence and yield losses in two mango variety *Langra* and *Chausa*. The *Langra*

variety is highly infected with burl comparative to *Chausa*. The yield losses were also found maximum in *Langra* (25.13 %) and minimum in *Chausa* (11.07 %). A similar study was conducted, and maximum incidence was observed in various mango varieties including *Mahuvas*, *Seedlings*, *Arka Aruna*, etc. whereas several mango varieties have minimum incidence including *Neelam* and *Desi* (Saran *et al.* 2020b, c). They also observed fruit yield loss in several mango varieties where highest fruit yield loss was noted in *Mahmood Vikarabad*, *Langra* and it was lowest in *Olour*.

2.7.3 *Histological Examination of Burl Infected Stems*:

The effect of burl formation in wood tissue was also examined using histological tools. Anatomical studies revealed that wood tissue lost its polarity and there was no specific orientation in complex tissues of burl infected wood (Saran *et al*., 2011). Similarly, the anatomical examination was also conducted in other varieties, which showed the deformed xylem with irregular orientation of conducting elements of secondary xylem (Saran *et al*., 2020a).

2.7.4 *Relationship Studies of Burl*:

Several studies have been conducted to correlate the incidence of burl, their size and shape with plant age, habitat and environmental factors. Olexa and Freeman (1978) reported that distribution of disease is limited by temperature and in further study concluded that development of galls, their size depends on plant age, location and temperature (Barnard and Freeman, 1982). Similar report on the relationship of burl incidence was carried out on different mango varieties (Saran *et al*., 2011, 2020b, c) and reported that the size of the burl increases with tree age. Kumar and Saran (2018) studied that, plants less than 15 years old were not affected with burl but more than 15 years old were severely affected. Saran *et al*. (2020b) documented that incidence of burl formation is associated with climatic factors such as relative humidity, temperature and rainfall in plants growing at different locations. These studies observed that high rainfall and relative humidity favors the burl development increase the incidence of burl, whereas the high temperature and low rainfall and humidity suppress the burl development.

2.7.5 *Causal Organism*:

Perusal of literature indicates that there is no unanimous agreement about the causal organism responsible for this disease. There are many assumptions about the

causal organism of burl disease, and it is caused by fungi, bacteria, insects, and maybe some stress or genetic predisposition (Peterson, 1961; Sinclair, 1993; Crane and Hiratsuka, 1994; Kumar and Saran, 2018). The use of farming equipment that scrap lower branches and make wounds on tree that provides the path for the entry of the causal organism. In contrast, Peterson (1961) concluded that insects and pathogens are responsible to induce burls in hardwoods.

Martin (1957-58) isolated *Agrobacterium* from soil and injected to healthy young plant and proved the development of burl symptoms. The soil bacteria could enter into the stem through wounds caused due to agricultural practices or pruning of the plants. The same species of bacterium, i.e., *A. tumefaciens* was recorded as a causal agent for the crown gall formation in giant *Sequoia* and coast redwood seedlings (Bega, 1964). *A. tumefaciens* was also examined for such type of disease from Miami and Hawaii but the bacterium could not be identified in affected tissues (Cook, 1975).

Malaguti and de Reyes, (1964) reported that the stem gall of mango and cacao in plants growing in Venezuela are caused by *Calonectria regidiuscula*. In contrast, Angulo and Villapudua (1982) reported the formation of tumour and gall of mango in response to *Fusarium decemcellulare* infection. It is also reported as a causal organism for corky bark, gall and canker disease on woody plants in the tropic and sub-tropic region (Holliday, 1980, Farr *et al*., 1989; Alfieri *et al*., 1994), but *F. decemcellulare* was tested on mango, and it was failed to cause gall and scaly bark disorders. In contrast, Crane and Hiratsuka (1994) reported that it occurs in response to the fungus *Phellinus tremulae* because it was found associated with aspen tree responsible for gall formation.

According to Ploetz *et al*. (1996b), *F. decemcellulare* isolates are mildly aggressive and require wounding for infection and burl formation. Ploetz and Prakash (1997) reported *A. tumefaciens* strain as a causal organism for inducing gall on stem and leaves of mango after artificial inoculation. Smith (2012) and Kumar & Saran (2018) reported that burl formation occurs due to bacteria, virus, fungi or may be due to some infestation of insect, environmental stress, and genetic mutation are also some of the reasons. Despite these opinions or concepts, no real consensus has ever been reached by the scientific community and failed to recognize the procedure behind the establishment of burls experimentally.

2.7.6 *Biochemical Changes in Burl Infected Fruit and Stem Bark*:

Mango is a rich source of vitamins, dietary fibre and various sugars and other constituents. The bark and secondary xylem of mango also composed of cellulose, lignin, fibre and many other compounds. However, trees infected with burl diseases show alteration in the composition of these compounds (Saran *et al*., 2020b). According to these studies, plants infected with burl disease showed an increase in TSS percentage, total sugar, reducing sugar, nonreducing sugar and ascorbic acid content compared to burl free mango trees. Shaheen *et al.* (2015) also reported that pathogens induce alterations in the sugar metabolism in a diseased mango tree and change the sugar content.

On the basis of the above background information of mango burl disease, the present study is undertaken with the following **objectives**:

1. Survey and screening of different mango germplasm against burl disease
2. Identification of the causal organism
3. To study the effect of burl disease on fruit yield
4. Biochemical changes in fruit and stem bark
5. Histopathological study of burl and alterations induced in response to infection