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Seed-borne and post-harvest diseases of watermelon (*Citrullus lanatus* (Thunb.) Matsum. Nakai) and their management

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ABSTRACT

Watermelon (*Citrullus lanatus* (Thunb.) Matsum. Nakai) family Cucurbitaceae is a popular dessert vegetable available round the year. It is an important multipurpose crop extensively grown in Rajasthan with widely accepted nutrients. It has very high water content (93ml/100g edible portion), carbohydrates (5 mg), calcium (8 mg), phosphorous (9 mg), ascorbic acid (8 mg), vitamins (0.64 g), lycopene and citrulline (per 100 g of edible portion). It is affected by various pre-harvest and post-harvest diseases that limit the marketability or restrict the economic returns to plant growers. In the field, vegetable is infected by various diseases but post-harvest diseases are also posing a great threat. The plant is attacked by various fungi, bacteria, viruses, mycoplasma and insects or diseases of non-parasitic origin.

1. Introduction

India is the second largest producer of vegetables in the world (next to China) accounts for about 15% of the world's total production of vegetables. In the years 2016-17 (2nd Adv Est), the total area under vegetables is estimated at 10.3 million hectares with a production of 175 MT in India. The total vegetable production was highest in Uttar Pradesh (26.4 MT) followed by West Bengal (25.5 MT). The area and production of watermelon was 95 H with 2325 MT respectively in 2015-2016 in India with major growing districts *viz.* Aandra Pradesh, Tamilnadu, Maharastra, Madhya Pradesh and Hariyana. In Rajasthan, it is growing on 2.93 H area with 27.56 MT productions (Anonymous, 2017). India loses about 35-40% of the produce every year due to improper post-harvest management with heavy loss wastes of fruits and vegetables (Anonymous, 2008). In Rajasthan, it is grown in Jaipur, Sikar, Dausa, Nagaur, Ajmer, Chittorgarh and Swai Madhopur on 2422 H area (Anonymous, 2016).

Cucurbits compare a largest group of summer vegetables grown in tropical countries. The important cucurbits are watermelon (*Citrullus lanatus* (Thunb.) Matsum and Nakai), melon (*Cucumis melo* var. *inodorus* and *C.m.*var. *cantalupensis*), cucumber (*C. sativus* L.), summer and snack squash (*Cucurbita pepo* L.), pumpkin (*C. maxima* Duch. ex Lam. and *C. moschata* Duch. ex Poir), snake melon (*Cucumis melo* var. *flexuosus* L.), bottle gourd (*Lagenaria siceraria* (Molina) Stand.), sponge gourd (*Luffa cylindrica* L.), bitter melon (*Momordica charantia* L.), Sechium (*Sechium edule* (Jack.) Swartz) and squirting cucumber (*Ecbalium elaterium* L.) grow worldwide.

Watermelon (*Citrullus lanatus*) of cucurbitaceae is cultivated species (2*n*=22) and bitter fruit in the form of *C. vulgaris* Schrader is the ancestor of watermelon (Mohr, 1986; Mallick and Masui, 1986). *Citrullus lanatus* of genus *Citrullus* consists of 8 species and sub-species. In the New World, cultivation began in Massachusetts as early as 1629 (Mohr, 1986).Watermelon was brought to America by Spanish and quickly became very popular crop (Robinson and Decker-Walters, 1997). The family Cucurbitaceae consists of two well defined subfamilies consist of about 118 genera and 825 species (Jeffrey 1990; Dane and Jiarong, 2007).

Watermelon originated in Africa and India has been in cultivation for more than 4, 000 years. In the drier or warmer parts watermelon grown throughout India; continents as Africa and countries as Asia, Russia, China and Japan (Cobley and Steele, 1976; Mallick and Masui, 1986). Cucurbits are excellent source of vitamins, minerals and carbohydrates used mostly in form of staple food, both fresh and preserved (Paxton, 1981). In India, the fruits are also pickled and candied; seeds are roasted and consumed or used as fodder and medicine. In Africa, it is usually grown in small plots for the market rarely for home consumption.

Many seed-borne and post-harvest diseases affect the production watermelon and cause enormous losses. A review with brief account of the important diseases affecting the crop is given here.

2. Review of literature

Watermelon attacked by several diseases caused by fungi, bacteria, virus and mycoplasma which effected yield and marketable value of watermelon. The range of diseases and pests on watermelon corresponds closely with that of round gourd. Alternaria leaf spot/blight (*Alternaria cucumerina*), anthracnose on stem, leaf and fruit (*Colletotrichum orbiculare*), belly rot (*Rhizoctonia solani*), black root rot (*Thielaviopsis basicola*), fusarium fruit rot (*Fusarium equiseti*) (Martyn et al., 1993; Roberts and Kucharek, 2006), gummy stem blight and black rot (*Didymella bryoniae* (Auersw.) (Rehm, 1881) and Fusarium wilt (*Fusarium oxysporum* f. sp. *niveum*) are important fungal diseases (Zhou and Everts, 2007; Zhou et al., 2010).

Watermelon attacked by bacterial diseases *viz.* angular leaf spot (*Pseudomonas syringae* pv. *lachrymans*), bacterial fruit blotch/seedling blight (*Acidovorax avenae* subsp. *citrulli* = *P. pseudoalcaligenes* subsp. *citrulli*), bacterial leaf spot

(*Xanthomonas campestris* pv. *cucurbitae*), bacterial rind necrosis (*Erwinia* spp.) and bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*) (Noble and Richardson, 1968; Neergaard, 1977; Richardson, 1979; Agrios, 1978, 2005).

Richardson (1990) reported an annoted list of seed-borne microflora as *Colletotrichum* sp., *Didymella bryoniae, Colletotrichum lagenarium, Fusarium oxysporum* f. sp. *niveum, F. moniliforme*, *F. oxysporum, F. solani, Glomerelia lagenaria* as *G. oingulate* var. *orbicutare, Pythium aphanidermatum, Pseudomonas pseudoalcaligenes* ssp. *citrulli, Pseudomonas* sp., *Alternaria* and *Cladosporium*.

Agrobacterium tumifacience (Smith & Townnsend) Conn., *Erwinia caratovora* subsp. *caratovora* (Jones) Bergey et al., *E. tracheiphila* (Smith) Bergey et al., *Pseudomonas chichorii* (Swingle) Stapp., *P. pseudoalcacaligenes* subsp. *citrulli* Schaad, Sowell, Goth, Colwell & Webb, *P. soalanceaarum* (Smith) Smith, *P. syringae* pv. *lachrymans* and *Xanthomonas campestris* pv. *cucurbitae* are reported to be seed-borne (Bryan) Dye (Bradbury, 1986). Some fungal diseases include *Alternaria* leaf spot/blight (*Alternaria cucumerina*), anthracnose (stem, leaf and fruit) (*Colletotrichum orbiculare*), belly rot (*Rhizoctonia solani*), black root rot (*Thielaviopsis basicola*) and *Fusarium* fruit rot (*Fusarium equiseti*) are important diseases of watermelon (Martyn et al., 1993; Roberts and Kucharek, 2006). Seed-borne disease caused by *Lasiodiplodia theobromae* reported on watermelon, squash and bottle gourd (Sohi and Maholay, 1974; Maholay and Sohi, 1976; Sultana and Ghaffar, 1992).

3. International and national status

The common pre- and post-harvest diseases of cucurbits including watermelon are as Alternaria leaf spot (*Alternaria cucumerina*, *A. alternate*), leaf spot (*Clasdosporium herbarium, Cercospora citrullina, Colletotrchum capsaci, Phyllosticta citrullina*), downy mildew (*Pseudoperenospora cubensis*), powdery mildew (*Podosphaera xanthi*), anthracnose (*Colletotrichum orbiculare*), scab or gummosis (*Cladosporium cucumerinum*), septoria leaf spot (*Septoria cucurbitacearum*), gummy stem blight (*Didymella bryoniae*), charcoal rot (*Macrophomina phaseolina*), damping-off of seedlings and fungal root rots (species of *Pythium*, *Rhizoctonia, Fusarium*), angular leaf spot (*Pseudomonas syringae pv. lachrymans*), bacterial leaf spot (*Xanthomonas campestris* pv. *cucurbitae*), mosaic viruses (Watermelon mosaic virus (Type 1 and 2), papaya ring spot virus and zucchini yellow mosaic virus) (Richardson, 1990; Khare and Bhale, 2000; Mehrotra and Aggrawal, 2005; Singh, 2005; Watson and Napier, 2009).

Mukerji and Bhasin (1986) reported microflora on the *Citrullus* spp. namely Alternaria leaf spot (*Alternaria cucumerina*, *A. alternate),* leaf spot (*Clasdosporium herbarium, Cercospora citrullina, Colletotrchum capsaci, Phyllosticta citrullina, Myrothecium roridum Gleosporium* sp.), fruit rot (*Curvularia lunata, Fusarium equisetai, F. oxysporium, Geotrichum candidum, Pythium aphanidermatum, Trichothecium roseum*), rust (*Puccina citrulli*), white rot (*Sclerotium rolfsi*), leaf, stem and fruit gall (*Synchitrium legenariae*), leaf gall (*S. trichosanthidis*), powdery mildew (*Erysiphae cichoracearum*), anthracnose (*Colletotrichum capsici*), wilt (*Fusarium oxysporium* f. sp. *niveum*), charcoal rot (*Macrophomina phaseolina*), soft rot (*Erwinia caratovora*), mosaic viruses (Watermelon mosaic virus (Type 1 and 2), papaya ring spot virus and zucchini yellow mosaic virus).

On *Citrullus* spp. several diseases have been reported from various parts of country as Alternaria leaf spot disease caused by *Alternaria cucumerina* and *A. alternate* from (Jobner) Rajasthan (Khandelwal and Prasad, 1970; Goyal et al., 1971); Maharastra (Poona) and Punjab (Rao, 1955; Chahal et al., 1970). Leaf spot disease is caused by *Phyllosticta citrullina* from Maharastra (Rao, 1964, 1965); by *Myrothecium roridum* from Allahabad. U.P., Delhi (Munjal, 1960); *Gleosporium* sp. from Maharastra (Rao, 1966), *Cercospora citrullina* in Pusa, Bihar (Mundkar and Ahmed, 1946), *Clasdosporium herbarium* in Maharastra (Rao, 1966), *Colletotrchum capsaci* from Karnataka (Amin and Sohi, 1979; Amin and Ullasa, 1981) was reported respectively. Anthracnose on leaf and stem disease caused by *C. lagenarium* reported from Banglore Karnataka (Sohi and Prakash, 1972). The fruit rot disease caused by *Curvularia lunata* from Maharastra (Rao, 1966), by *Fusarium equisetai* from M.P. (Chaurasia, 1980; Jhamaria and Patel, 1971), by *F. oxysporium* from Kota, Rajasthan (Mathur and Mathur, 1958), U.P., Punjab (Suryanarayan and Nath, 1963), by *Geotrichum candidum* and *Trichothecium roseum* from Maharastra (Rao, 1966) on stored fruit, *Pythium aphanidermatum* from Poona, Maharastra (Rao, 1966; Narayanan, 1962). The rust disease is caused by *Puccina citrulli* reported from Coimbator, Tamil Nadu (Sundaram, 1963) and white rot caused by *Sclerotium rolfsi* reported from Maharastra (Uppal et al., 1935). Leaf, stem and fruit gall caused by *Synchitrium legenariae* from Poona Maharastra and Lucknow (Karling, 1966), leaf gall caused by *S. trichosanthidis* from Pusa, Bihar (Matre and Mundkar, 1945) was reported. Other diseases were powdery mildew (*Erysiphae cichoracearum*), wilt (*Fusarium oxysporium* f. sp. *niveum*), Charcoal rot (*Macrophomina phaseolina*) from all over country (Shaw, 1912; Shaw and Ajrekar, 1915; Butler, 1918; Anonymous, 1925; Ashby, 1927; Anonymous, 1930; McRae, 1934; Anonymous, 1950; Bhide et al., 1955; Tilak and Rao, 1970). Controlling measures for the control of Alternaria leaf spot diseases were studied (Pareek and Ahir, 2010).

Fungal diseases

Downy mildew of cucurbits- The diseases is caused by *Pseudoperonospora cubensis* (Berkeley and Curtis) Rostow. It is commonly found in north India and become severe just after ending of rainy season. It produced oospores as resting state. In India, oospores on certain cucurbits reported from Madhya Pradesh, Punjab and Rajasthan (Mahrishi and Siradhana, 1984). The pathogen infects mostly watermelon, round melon and some other species of cucurbitaceae but Pumpkin and vegetable marrow are less affected (Bains and Jhooty, 1976; Bains and Vidyaprakash, 1985). To control the disease treatment with fungicide Dithan M-45 (Mancozeb), Dithane Z-78 protect the leaves for 9 days after spraying while Tricop-50 give protection only for 5 days (Bains and Jhooty, 1978; Mehrotra and Aggrawal, 2005).

Anthracnose- The disease is caused by the fungus *Colletotrichum lagenarium* (Pass.) Ellis and Halsted restricted

to plants of cucurbitaceae. Heavy loss on fruits of watermelon is occurs in temperate countries. The spots on the foliage begin as small yellowish or water-soaked that enlarger rapidly and turn black in watermelon. The disease can be controlled by seed treatment or eradicate the surface inoculums of pathogen using bavistin or benlate (2.5 g/kg) as systemic fungicides. Fungicides like mancozeb (dithan M-45) @ 2 kg/ha, difolatan (0.2%), benlate (0.5-1.5k g per ha) or blitox-50 (0.2%) should be used for spraying on the crop (Singh, 1987; Mehrotra and Aggrawal, 2005; Agrios, 2005).

Fusarium wilt- The disease is caused by *Fusarium oxysporum* f. sp. *niveum* (E.F. Sm.) W.C. Snyder & H.N. Han. in watermelon and widely spread in growing regions in the world last more than 85 years. In the United States, the disease was first described by Smith in 1894 in South Carolina and Georgia. *F.oxysporum* f.sp. *niveum* is host specific and causes disease only on watermelon (cucurbits), although a few exceptions have been reported in studies conducted under greenhouse conditions (Hegde and Bidai, 1958; Martyn, 1987, Bruton et al., 1988; Zhou and Everts, 2007; Zhou et al., 2010).

Recently it occurs in many states of the country. Hegde *et al.* (1955) reported the disease from Dorli village, district Thane of Maharashtra. Jhamaria and Patel (1971) reported *F. o.* f.sp. *niveum* a serious wilt disease of watermelon widely distributed in Rajasthan. McMillan (1986) studied cross pathogenicity with isolates of *F. oxysporum* from either cucumber or watermelon pathogenic to both crop species. Bruton (1988) in Oklahoma observed *F. o.* f.sp. *niveum*, race-2 to cause watermelon wilt. Thirty six plants of different groups (cucurbits, beans, pulses, cereals, oilseed, vegetables, etc.) were selected on the basis of their susceptibility to different *Fusarium* spp. and availability (Thakare and Gaikwad, 2010). In cucurbits, highest disease incidence (100%) was observed in bottle gourd and watermelon followed by cucumber (93.3 %) and snake gourd (80.0 %).

It is seed-borne and persistent soil-inhabitant concentrates in the xylem vessels (Singh, 2005). In wet weather the dead stem contains whitish-pink fungal mass. The plant is attacked by pathogen in all stages of its growth in high frequency (Mclaughlin and Martyn, 1982). Germinating seeds may rot in the soil, young seedlings showed damp-off and die or best stunted in growth after attack of pathogen. The cotyledon show wilting symptoms and hypocotyls is girdles by a soft rot. The wilting progress is slow by tip and margin showed inward rolling symptoms on leaves (Hegde and Baidai, 1958; Singh, 1987, 2005; Mehrotra and Aggrawal, 2005; Agrios, 2005).

A study was conducted to examine fungal diseases on watermelon in Morogoro urban, Tanzania. Forty eight samples of watermelon with necrotic symptoms collected from randomly selected home gardens. These samples were tested for infection using the Blotter method, identify on the basis of morphological characters and found infected. *Alternaria alternata* (96.7%), *Cercospora citrullina* (93.3%), *Fusarium oxysporum* (40%), *Microphomina phaseolina* (38.3%) and *Cladosporium cucumevicum* (14.2%) reported first time from Tanzania (Mbega and Mabagala, 2012).

In another survey, conducted to determine the frequency of phyto-pathogenic fungi infected and associated with watermelon plants cultivated in different fields from Saudi Arabia. Incidence of damping off disease in watermelon root samples which naturally infected with *Fusarium solani* and *Rhizoctoina solani* were 43.2 and 50.5% and found most prevalent fungi with 48.4 and 52.6%, respectively. Two Trichoderma species (*T. harzianum* and *T. viride*), three Pseudomonas species (*P. chlororaphis, P. eruginosa, P. florescence*) beside the fungicide Rizolex were used to study their effect on the root rot fungi in laboratory and greenhouse conditions and found that treatment with Rizolex-T resulted in great inhibitions of both the pathogen followed by treatments with *P. florescence, P. chlororaphis, P. aruginosa, T. harzianum* and *T. viride*. At same treatments significant decrease in disease incidence (pre & post-emergence damping-off) followed by treatments with *T. harzianum, T. viride, P. chlororaphis* and *P. aruginosa*. All treatments enhance dry weight of shoot and root systems and showed a significant increase in total chlorophyll content as compared to check (Alharbi, 2015).

Gummy stem blight- Black rot or gummy stem blight is caused by *Didymella bryoniae* Auersw. produced foliar blight and canker (Rehm, 1881). The disease occurs universally on *Cucumis melo* subsp. *melo*, *Citrullus lanatus* var. *lanatus*, *C. sativus, Cucurbita maxima, C. pepo* and *C. moschata* (Keinath et al., 2010; dos Santos et al., 2009; Jensen et al., 2011; Keinath, 2011) commonly in humid, temperate, semi-tropical and tropical regions (Bala and Hosein, 1986; Sitterly and Keinath, 1996). The fruit of butternut squash, pumpkin, ornamental gourds, muskmelon and greenhouse cucumber are the most susceptible to the disease (Babadoost and Zitter, 2009; van Steeklenburg, 1982; Zhang et al., 1999; Zitter, 1996). Black rot also affects watermelon when foliar blight is severe (Zitter, 1996). The symptoms of diseases produced above-ground vegetative and reproductive parts as leaves, petioles, vines, stems, tendrils, pedicels, flowers, peduncles, fruits and seeds (Chester, 1891; Keinath, 2011, 2013). Initially leaf spots appear round or triangular (leaf margins), or sometimes rhomboid; expand, coalesce finally results in leaf blighting and used to diagnose the disease. Expanding of lesions on leaves, petioles and pedicels often are water-soaked due cell wall degrading enzymes produced by pathogen particular polygalacturonase (Zitter, 1996). Leaf spots are dark brown on loofah and watermelon frequently displays alternating rings of dark and light brown necrosis.

Cankers produced on crowns, main stems, or vines of melons and other hosts (Keinath et al., 2010) by the pathogen as cankers expand become dry and rough resulting surface cracks. Drops of gummy, amber plant sap appear on cankers under certain undefined conditions (due to exudates disease name is given). The disease occurs on young plant or blight can see on seedlings of watermelon, muskmelon, and other cucurbits grown in greenhouses for use as transplants (Koike, 1997; Keinath, 2011). Black rot on watermelon appears as a large, expanding rot that starts at the blossom end of the fruit.

It has wide host range attack on cucurbits and other non-cucurbits *viz. Momordica charantia, Lagenaria siceraria*, *Luffa*

cylindrica and *Sechium edule* (Wiant, 1945; Bala and Hosein, 1986; Keinath et al., 2010; Tsai and Chen, 2012), *Citrullus lanatus* var. *citroides* (Keinath et al., 2010), *Bryonia alba, B. cretica* (Corlett, 1981) and *Benincasa hispida* (Wiant, 1945). The fungi *D. bryoniae* is distributed universally.

Phtophthora fruit rot-The disease is caused by soil borne fungus *Phtophthora capsaci* Leonian. The fruit rot is appearing as gresy blotches on fruit rind. The disease occurs after excessive rains when the field has moisture or wet soil. The disease can be controlled by using systemic fungicide like Ridomil (Anonymous, 2003).

Stem-end rot disease-The disease is caused by *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl and first seen as shriveling and drying of stem. The disease develops rapidly at the temperature 25^{o}C but slowly at 10^{o}C (Anonymous, 2003).

Bacterial diseases

Bacterial blotch- The disease is caused by *Pseudomonas pseudoalcaligenes* Stanier (=*Acidovorax avenae*) in watermelon. Bacterial fruit blotch and leaf blight is an important yield-reducing disease of watermelon reported first time in the Mariana Islands in 1988 (Latin, 2000) on commercial watermelon fields in Floroda. The cultivated cucurbits susceptible to infection are significant losses reported (Latin, 2000; Anonymous, 2008). Amadi et al. (2009) from Ilorin, Nigeria reported that plant infected with both leaf and fruit blotch occurred together in watermelon.

The disease appeared as oily, water-soaked lesions on the top side of the developing fruit (Jett et al., 2002; Egel, 2007). At low (60 F in nights and up to 77 F in the day) temperatures, rainy season and continuous high humidity favors the diseases (Isakeit, 1993). Mohamad (2002) reported bacterial fruit blotch of watermelon from United States. The disease is reported to be seed-borne (Jett et al., 2002; Anonymous, 2006, 2008) and first symptoms appear as small water-soaked lesions on seedlings. The seedlings grow from infected seeds and out of these some seedlings will collapse and die immediately from infection while some can retain the bacterial infection exhibit symptoms until fruit set (Latin and Hopkins, 1995). Fruit symptoms appear first at flowering and early fruit set as a small water-soaked area which but rapidly expands to cover the fruit surface in 7-10 days (Latin, 2000). The pathogen survives on alternate host and transmits and provides for the spread of disease and many other diseases uninfected plants (Anonymous, 2008). Jett et al. (2002) reported that disease infection not extend into red flesh of the fruit but will cause the rind to rupture which enabling infection of saprophytes or secondary pathogens that cause the fruit to rot. Once a wax layer develops, it is more difficult for the bacteria to invade the fruit. The seed may be contaminated externally or internally and such contaminated seed serve as secondary inoculums by infecting the seedlings (Anonymous, 2005). Primarily the pathogen spreads from diseased to healthy plants and secondary infections occur through natural openings like stomata. Lesions on leaves were serving as a source of inoculums or reservoir for fruit infection. Losses by bacterial blotch directly linked to reduced quality and quantity of the crop (Agrios, 1978, 2005; Anonymous, 2008).

Angular leaf spots- The diseases caused by seed-borne bacterium, *Pseudomonas syringae* pv. *lachrymans* (Smith & Bryan) young, Dye and Wilkie is commonly occurs on pumpkin, muskmelon, cucumber and watermelon in regions of cold climate (Singh, 1987, 2005; Mehrotra and Aggrawal, 2005; Agrios, 2005). The disease occurs on all parts of plant as leaves, young green stems and fruits. On the leaf surface water-soaked, irregular and angular lesions occurred. In wet weather with high humidity bacterial ooze (droplets) appears on the water-soaked areas. When the disease portion dies the tissues become white and crack. On the fruit, lesions are only superficial due to cracking of skin and due to this cracking the soft rot bacteria enter easily. *P. syringae* is rod-shaped, Gram-negative, motile (more than one polar flagella), grow on iron-deficient media, produce a diffusible yellow green fluorescent pigment, non-starch hydrolyzing, produce slime in media with 2-5% sucrose, strict aerobes, nitrate non-reducing bacteria which easily grow at 26 to 30^{o}C (Bredbury, 1986). It can survive in soil and on crop debris. The diseased seeds from the diseased fruits carry the bacterium in the seed coat and attack on cotyledons after seed germination. Penetration of pathogen occurs through stomata as natural opening.

The bacterium in the seeds is killed by hot water treatment but this method reduces germination in the seeds. Mercuric chloride (1:1000) for 5-10 min is a good seed dip method. To control the diseases it is better to obtain seeds grown in dry areas. Spraying of copper fungicides reduces spread of the disease in the field leaves (Singh, 1987, 2005; Mehrotra and Aggrawal, 2005; Agrios, 2005).

Bacterial soft rot- The soft rot disease is common in cucurbits. It is mainly a fruit disease and occurs due to injury to fruits during transit and storage conditions. Subspecies of *Erwinia carotovora* are main bacteria associated with soft rot disease in watermelon (Patel, 1972; Singh, 1987, 2005; Mehrotra and Aggrawal, 2005).

Bacterial Rind Necrosis- The disease occurs sporadically caused by *Erwinia carnegieana* on watermelon fruits. Brown, dry and hard necrosis of the rind (rarely extends up to the flesh) were observed after attack of pathogen. In cross section of fruit, a corky layer appears between the outer rind and red flesh fruit tissues. There are no external or visible symptoms appear so disease cannot be estimated easily and reduce the losses of yield and market value of fruits even generally looking healthy. When severely diseased melons are sliced showed necrosis and become unmarketable (Anonymous, 2009). For the control of disease, there is no chemical treatment and control via varietal resistance is controversial. The only effective measure to control this disease is to avoid planting watermelon in fields where rind necrosis has been encountered (Anonymous, 2009).

Nematode diseases

Root-knot disease of cucurbits is caused by *Meloidogyne incognita* and *M. javanica*. The symptoms are not visible due to extensive growth of the plants effects susceptibility of the plant

roots and other root pathogen increased. Synergism between *M. incognita* and *Fusarium* spp. in watermelon is reported (Singh, 1987, 2005). Cucumber cultivar GY-5937-587 is reported as resistant to Race 3 of *M. incognita* and cv. Improved Long Green to *M. javanica*. Reniform nematode disease has been reported from throughout the country (Khan, 1939; Khan et al. 1964; Seshadri, 1970; Singh, 2005; Mehrotra and Aggrawal, 2005)

Viral diseases

Mosaic disease- In India, the mosaic disease is common on all cucurbit and often recorded heavy losses. Cucumber mosaic virus, Cucumber green mottle mosaic virus and Water melon mosaic virus are common mosaic on cucurbits and cause significant losses. When the plant is attacked by mosaic virus soon after emergence the cotyledons they emerges yellow and seedlings showed wilting symptoms. The diseased leaves are mottled, deformed, and small; sometimes curled downward, veins, veinlets turn yellow. If watermelon mosaic virus is the cause of mosaic the above symptoms will appear but leaves deformed or become filiform, entire lamina destroyed except the adjacent tissue to the veins and veinlets, poor flowering and defoliation occurred. This virus is most dangerous among the cucurbit viruses (Mehrotra and Aggrawal, 2005).

Cucurbits are very much sensitive to viral infection and virus complex (Zitter et al., 1996). Cucumber mosaic virus (CMV), squash mosaic virus (SqMV), watermelon mosaic virus (WMV), zucchini yellow mosaic virus (ZYMV) and papaya ring spot virus (PRSV) are important viruses which transmitted by aphid (except squash mosaic virus) (Tobias and Tulipan 2002). Squash mosaic virus (SqMV) is seed-borne virus which spread by beetles. The symptoms are similar produced by different cucurbit so it is very difficult or even impossible to identify the causal virus. Enzyme-linked immunosorbent assay is used for the detection of plant viruses (Clark and Adams 1977). The other viruses (not so common) are cucumber green mottle mosaic virus and melon necrotic spot virus.

Cucumber mosaic virus- CMV is widely distributed and common virus disease of cucurbits (Ferreira and Boley, 1992) infects all cucurbit, the natural host and non-cucurbit and weeds of different families. Symptoms appear on about 6-week-old plants at vigorous growth stage; on young leaves initial symptoms appear as mottled mosaic leaf pattern and curl downward of leaf edges. Yellow colored mottling, leaf distortion and stunted plant produced due to shortening of stem internodes. Dead leaves either fall off or droop; wilting of the petioles occurs leaving the older vine mostly bare (MacNab et al., 1983).

It has wide host range includes watermelon, muskmelon, cucumber and bottlegourd but not vegetable marrow (*Cucurbita pepo*). In cucumber, approx 8% seeds carry the virus one month after harvest but it reduces up to 1% after 5 months of seed storage. In watermelon 5% seeds are contaminated, mostly external. Species of dodder including *Cuscuta campestris* also can transmit the virus. CMV is transmitted by aphids namely *Aphis gossypii* and *Myzus persicae*; or sap transmitted adhered on the hands and clothes of workers harvesting fruit or through seeds, several weed hosts or overwinters in many perennial weed hosts sources especially attractive to aphids in spring. The entire field of cucurbits sometimes turns yellow due to CMV immediately after the first harvest (Agrios, 1978).

Squash mosaic virus- SqMV is seed-borne and spread by beetles (*Acalymma* and *Diabrotica*) and infects cultivated wild or native cucurbits but does not infect non-cucurbitaceous crops or weeds. The virus causes stunting, chlorotic leaf mottling, green vein banding and leaf distortion of infected seedlings. There are two strains of this virus namely strain 1 (more effect on melons than squash) and strain 2 (reverse action of strain 1) (Haudenshield and Palukaitis 1998). Older infected plants develop distorted margins, blistering, hardening and mild to severe dark-green mosaic pattern on leaves.

Infected fruits may have mottling on the skin and become malformed or distorted (Dukic et al., 2002). The beetles transmit the virus through its saliva by injecting virus during feeding or spread by a mechanical injury. The virus carried within the seed and cannot be eliminated by hot water or chemical treatment (Zitter and Banik, 1984).

Poty virus- Watermelon mosaic virus or poty viruses group (Syn. Melon mosaic virus, Muskmelon mosaic virus, and Watermelon mosaic virus 1 and 2, Cucumis virus 3, Marmor citrulli falvidanum) invades on cucurbits including watermelon. Potyvirus included WMV, PRSV and ZYMV transmitted by different aphid or insects' species as *Aphis gossypii*, *A. fabae, Brachycaudus* spp., *Cavariella* spp., *A. myzus, Liriomyza* spp. in 17 plant families. High activity of aphids in the field often spread very fast the potyvirus. Particles of watermelon mosaic virus (WMV) are filamentous tubes with single stranded RNA as genetic material. It has wide host range attack on watermelon, vegetable marrow, pumpkin, cucumber, bottlegourd and sponge-gourd. *A. gossypii* can acquire the virus after one minute of feeding and without any incubation period it can infect a healthy plant. Transmission by seeds not confirmed. The thermal inactivation point of Indian isolates is reported to be 55-60^{o}C (Raychaudhuri, 1977).

Zucchini yellow mosaic virus- All wild and cultivated cucurbitaceous crops are susceptible to ZYMV or it infects certain non-cucurbitaceous weeds. Melon fruits get discolored with hardening of flesh, seed deformation or external cracks on fruit surface (Blua and Perring 1989; Desbiez and Lecoq 1997). This virus is transmitted by a wide range of aphid. The symptoms initate about 6-week-old plants at vigorous growth stage (MacNab et al*.,* 1983).

The stem end portion of the infected fruits becomes mottled with yellowish-green, darkgreen spots and this mottling pattern gradually covers the whole fruit. The infected plants usually produce few runners, flowers, and fruits as compared to healthy plant (Agrios 1978).

Papaya ring spot virus- PRSV biotype "W" infects many cucurbit crops but does not infect non-cucurbitaceous crops (Bateson et al., 2002). Characteristic mosaic symptoms appear as profuse mottling, puckering and deformation of crown

leaves, while the symptoms do not occur on lower mature leaves. Zucchini squash was the most susceptible to PRSV on cucurbits including watermelon and cucumber (Mansilla et al., 2013). Watermelon fruits may develop uneven surface or typical ring spot patterns on the skin after the attack of this virus. This virus is spread by a number of aphid species including the green peach and melon aphids (Jensen, 1949).

Watermelon mosaic virus-The virus infects almost all cucurbit crops, mainly *Cucurbita pepo*, *C. maxima* and *C. moschata* (Greber et al., 1987) and wild cucurbits bearing a typical petunia-like appearance. The tips of vines and a proliferation of shoots around the crown extend beyond the general level of the vines. It produces less severe symptoms on cucurbit leaves and fruits than PRSV, ZYMV, and SqMV (Coutts, 2006). On severity of disease the flowers become abnormal in size, shape, and color, resulting in mottled, misshapen small fruits.

Tobacco ring spot virus and clover yellow vein virus are another viruses attack on plant. Tobacco ring spot virus is mainly affects melons and cucumbers; transmitted by nematodes (*Xiphinema americanum*). The young infected leaves show a very bright mosaic with stunted plant growth. Clover yellow vein virus is transmitted by aphids and infects summer squash.

Mycoplasma disease

Aster Yellow is disease caused by Mycoplasma and transmitted by leafhoppers. The disease showed symptoms appear as yellowing of plants with stunted growth which is usually confused as viral disease (Dana and Lerner, 2000; Jones, 2009).

4. Conclusion

Watermelon is attacked by various diseases that reduced the quality and cash value of crop. So it is very important to reduce the incidence of pathogen and control these diseases. To control of various diseases of using watermelon resistant verities; removal and burning plant debris, eradicate the weed and alternate hosts of pathogen to reduce disease incidence and survival of pathogen. The production of cucurbit is being challenged by many new diseases as well as earlier described diseases which appearing in new areas. Plant disease management is necessary to reduce the economic damage and maintain the quality of produce though multifaceted or integrated disease management approach. IDM consists of scouting and management strategies include, site selection, field preparation, use of resistant cultivars, altering planting time, optimum plant density, optimum irrigation, proper drainage, mulching, optimum use of nutrients, judicious use of pesticides and monitoring environmental factors.

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