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Management of insect pests and diseases of jackfruit (*Artocarpus heterophyllus* L.) in agroforestry system: A review

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Abstract
The main aim of this review is to document the insect pests and diseases of jackfruit (*Artocarpus heterophyllus* L.) and their management in Bangladesh compared to other jackfruit growing countries. This article was based on mostly literature review. *A. heterophyllus* being the national fruit of Bangladesh, is widely consumed by most of the rural people. All parts of the fruit and tree are used as human food, animal feed and wood source for furniture. Jackfruit contains anti-bacterial, anti-diabetic, anti-oxidant, anti-inflammatory and anti-helminthic properties. The fruit is rich in carbohydrates, minerals, carboxylic acids, dietary fiber, vitamins and minerals. The seed is rich in manganese, magnesium, potassium, calcium iron and lectins and thus meets up nutritional requirements for the rural people. Despite the importance, a number of insect pests and diseases attack jackfruit plant and fruit. Shoot and fruit borer (*Diaphania caesalis* Walker) and trunk borer (*Batocera rufomaculata* De Geer) have been reported as major insect pests, while stem and fruit rot (*Rhizopus artocarpi*), bacterial dieback, pink disease (*Pelliculana salmonicolor),* leafspot (*Phomopsis artocarpina*), fruit bronzing (*Pantoea stewartia* Smith) and Gummosis (*Phomopsis artocarpi*) have been reported as major diseases. The pruning and training are an effective management technique for the insect pests and diseases. This technique provides well ventilation and reduces relative humidity at tree canopy level. Bordeaux paste is a common fungicide for the management of jackfruit borer pest and rhizopus rot, leaf spot, dieback and gummosis diseases. This paper has heighted the multifarious benefits of jackfruit plant and described the problems and solutions of jackfruit cultivation in agroforestry system of Bangladesh.

Keywords: *Artocarpus heterophyllus,* insects, diseases and medicinal value

Introduction
Bangladesh is a densely populated developing country hosting nearly 161 million people with per capita annual income of US $ 1080, containing more than 1078 persons per square km area (Rahman *et al*., 2017) [1]. Bangladesh is sanctified with a vast diversity of fruits. About 70 different types of fruits are grown in Bangladesh (Hassan *et al*., 2011) [2]. Jackfruit is the national fruit of Bangladesh (Haque, 2009) [3]. It is the most popular fruit in rural areas of Bangladesh. A small quantity of about 60 MT fresh jackfruit and some seeds are exported to UK (INSPIRED, 2013) [4]. It ranks the 4th position as per production volume after banana, mango, and pineapple (BBS, 2018) [5]. Jackfruit ranks the 3rd position with respect to fruit production in Malaysia. The jackfruit is a cross pollinated fruit tree and is mainly propagated by seeds (Hasanuzzaman, 2003) [6]. It is the major fruit tree at Madhupur tract in Bangladesh (Hasan *et al*., 2008) [7].

Taxonomic position

Kingdom	:	Plantae
Order	:	Rosales
Family	:	Moraceae
Tribe	:	Artocarpeae
Genus	:	*Artocarpus*
Species	:	*Artocarpus heterophyllus*

Jackfruit is a tree species of the family Moraceae which is native to Southeast Asia and usually confused with the species *Artocarpus integer* (Harb *et al*., 2015) [8]. The *Artocarpus* is derived from the Greek words *artos* (bread) and *carpos* (fruit) (Bailey, 1942) [9]. The common name of 'jackfruit' is used by the physician and naturalist Garcia de Orta in his 1563 book Colóquios dos simples e drogas da India (Anonymous, 2000) [10]. The jackfruit is also called as jack, an English adaptation of the Portuguese jaca. In Bangla and Hindi, it is called as Kathal; Malayalam Chakke; Canada Halasu; Marati Phanas; French jacquier; Papua New Guinea Kapiak and Samoa Ulu initia (Popenoe, 1974) [11]. It is a multipurpose tree plant bearing great importance for the farmers as fruit, timber, fodder, food, medicine, aroma, timbers, fruits, vegetables and fuel. It is often called poor man's fruit (Rahman *et al*., 1994) [12]. The plant is a source of fire, wood and cattle feed. The fruit provides food and cash (Soetjipto and Lubis, 1981) [13]. The jackfruit fruit is occasionally about 25 cm in diameter. Even relatively thin trees (circa 10 cm diameter) can have the largest edible fruit in the world (Naik, 1949; Sturrock, 1959) [14, 15]. Jagadeesh *et al*. (2006) [16] reported that the fruit weight ranges from 30 to 50 kg, with fruit length of 80 to 90 cm and fruit diameter of 40 to 50 cm. The sweet yellow sheaths around the seeds are about 3 to 5 mm in thick and have a taste similar to that of pineapple but milder and less juicy (APAARI, 2012) [17]. It was identified as an important nutritious crop (Ahmed, 1999) [18]. The fruit yield per hectare is 17 MT. It is a popular and relatively cheaper fruit in Southern part of Asia especially in Bangladesh. In Europe, the fruit is sold with syrup. Away from the Far East, the fruit has never gained good acceptance as of the breadfruit. The ripe fruit contain odor which is chosen for the fruit (APAARI, 2012) [17].

The fruit is indigenous to the rain forests of the India and is cultivated throughout the tropical and subtropical lowland areas of the South and Southeast Asia, and some central parts of Africa. Major jackfruit producing countries are Bangladesh, India, Myanmar, Thailand, Vietnam, China, The Philippines, Indonesia, Malaysia, Sri Lanka and some regions of Brazil and Australia (Rahaman *et al*., 1999) [19]. Mymensingh, Dhaka, Gazipur, Tangail, Khagrachari, Rangamati, Moulvibazar, Narsingdi, Dinajpur and Rangpur are the maximum jackfruit producing districts of Bangladesh. The country cultivates jackfruit in 79 thousand ha of land with about 1,352,000 tons of annual fruit production.

Benefits and uses of jackfruit: Fruits can be eaten at all stages of growth as it can be baked, boiled, roasted, fried or steamed (Ragone, 2003) [20]. The seed is also cooked and used for cooking. The bark and leaves are excellent cattle feed. APCAEM (2007) [21] reported that the fruits have been contributing to about 4% of human nutritional requirement (Ong *et al*., 2006; Saxena *et al*., 2008) [22, 23]. The fruit is enriched with nutrients. The fruit can be consumed when it is ripening. The tree provides food, fodder, fuel wood, timber and 70% of timber, 90% of fuel wood, and 48% sawn (Uddin *et al*., 2002) [24]. It provides nearly 50% of cash flow to the rural poor people (Abedin and Quddus, 1990; Daniel and Dupraz, 1999) [25, 26].

Medicinal significance of jackfruit: The *Artocarpus* species have been used as traditional medicines. The plants have been used as anti-bacterial, anti-diabetic, antioxidant, anti-inflammatory and anti-helminthic (Hwang *et al*., 2017) [27]. It is a major source of carbohydrates, minerals and vitamins (Deivanai and Subhash, 2010) [28]. Abedin and Quddus (1990) [25] reported that the average annual net returns found more than the agriculture system. Gapasin *et al*. (2014) [29] observed that the fruit contains lignans, flavones and saponins which have the properties of anti-cancer, anti-ulcer, anti-hypertensive and anti-aging. It contains immense medicinal values and also considered a rich source of carbohydrates, minerals, carboxylic acids, dietary fiber and vitamins such as ascorbic acid and thiamine (Lin *et al*., 2000) [30]. Manganese and magnesium (Barua and Boruah, 2004) [31], potassium, calcium and iron (Goldenberg, 2014) [32] elements are found in seed. Theivasanthi and Alagar (2011) [33] reported that the seeds contain lectins as jacalin and artocarpin. Jacalin has been shown to be useful for the evaluation of the immune status of patients infected with human immunodeficiency virus (Haq, 2006) [34]. Seed nanoparticles were found effective against *Escherichia coli* and *Bacillus megaterium* bacteria (Theivasanthi *et al*., 2011) [35]. It has anti-oxidant action (Biworo, 2015) [36], and acts against inflammation, malarial fever and skin diseases (Khan *et al*., 2003a) [37], anti-bacterial and anti-helminthic (Soeksmanto *et al*., 2007) [38]. The tree leaves are commonly used as healing for ulcer. Its leaves have the potential of curing diabetics due to the presence of hypoglycemic and hypolipidemic substances (Prakash *et al*., 2009) [39]. The leaves and stems have sapogenins, cyclooctenone, cycloartenol, β-sitosterol and tannins (Sathyavathi *et al*., 1987) [40]. The latex yield artosteron mixed with vinegar promotes healing of glandular swelling and snake bites (Devaraj, 1985; Mukherjee, 1993) [41, 42]. Ferrao (1999) [43] reported that the root extract is a therapy for asthma and skin disorder. The wood has sedative property and believed that it may cause promotion of abortion (Morton, 1987) [44], cure diarrhea and fever (Samaddar, 1985) [45]. The fruits and roots are used for tapeworm infection (Patil *et al*., 2002; Su *et al*., 2002; Khan *et al*., 2003b) [46, 47, 48]. The fruit is rich in carbohydrates, complex B vitamins, and minerals (Rahman *et al*., 1999; Jagadeesh *et al*., 2007; Souza *et al*., 2009) [18, 49, 50]. The freshly fruit is consumed. It can be processed to candies, sweeties, frozen pulps, juices and vegetable in immature fruit. Its seed can be consumed as baked or used in culinary to develop several menus. Now, there are studies concerning the use of seed meal for preparing cookies, sweeties and bread as an alternative source of carbohydrate. The jackfruit contains variable constituents of moisture (6.7%), glucosides (38.0%), lipids (0.7%), protein (1.7%) and cellulose (59.0 %) (Perkin and Cope, 1895) [51]. Elevitch and Manner (2006a) [52] observed that the ripe fruits are rich in nutritive value; every 100 g of ripe fruit contains 287-323 mg potassium, 30.0-73.2 mg calcium and 11-19 g carbohydrates. Chawdhary and Raman (1997) [53] reported that the bark contains betullic acid and a flavone pigment, cycloheterophyllin (C30H30O7). The fruit pulp also contains lycopene (Setiawan *et al*., 2001) [54]. De Faria *et al*. (2009) [55] reported that the fruit contain 18 carotenoids were successfully separated, identified and quantified and 14 were detected. The leaves and stem contain sapogenins, cycloartenone, cycloartenol, β-sitosterol and tannins show estrogenic activity. A root contains β-sitosterol, ursolic acid, betulinic acid and cycloartenone (Dayal and Seshadri, 1974). Jackfruit seed contains a thin brown spermoderm, the

crude fiber (2.36 %) (Singh *et al*., 1991; Swami *et al*., 2012) [56, 57], but the composition of flour depends on nature of seed.

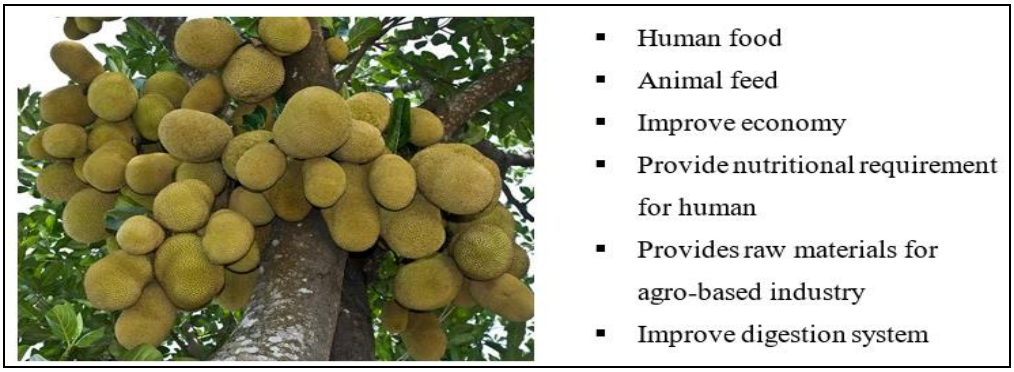

Fig 1: Diversified uses of Jackfruit plant, fruits and byproducts

Despite many health and economic benefits, the farmers of Bangladesh are losing their interest in cultivating jackfruit in agroforestry system due to the attack of insect pests and diseases. Nevertheless, great genetic and morphological variations in jackfruit have made successful jackfruit production in Bangladesh and India (IPGRI, 2000; Reddy *et al*., 2004; Shyamalamma *et al*., 2008; Ullah and Haque, 2008) [58, 59, 60, 61]. In view of the above facts, the review works were carried out and gathered information on insect pests and diseases along with their management in agroforestry system are reviewed as follows.

Methodology

To assess the current state of the research on insects and diseases of jackfruit, a review of the existing journal literature, books, report, blogs and newspaper were carried out. Keywords: (*Artocarpus heterophyllus*, insects, diseases and medicinal value) search in the google, google scholar, research gate (www.researchgate.net), web of science database (www.thomsonreuters.com/web-of-science) and a full-text search of the Science Direct (www.sciencedirect.com) database were carried out. Information was also collected from government organization and NGO's by personal communication.

Reviews on Insect Pests and Diseases of Jackfruit

Every plant has its own specific insect pests and diseases in open and confined conditions. The weather parameters play key role in multiplication, growth, development and distribution of pest population on crop plants (Dhaliwal and Arora, 2001) [62]. Temperature is the most influential weather parameter that greatly affects the population dynamics of insect pests (Arun, 2003) [63]. Baker *et al*. (2012) [64] observed that the abundance of the insect pest and disease is correlated with weather factors (Khan *et al*. 2020) [65], showing the lowest population density in winter season when air temperature usually goes down. Seasonal population dynamics of any pest provide insight into the relationships of weather factors with insect pests and diseases. It indicates that the farmers of a particular area or region must be aware of the management techniques of the pest. More than 250 species of insect pests, eight species of mites and seven species of nematodes have been reported to attack jackfruit trees all over the world. Butani (1979) [66] observed 39 species of insects attacking jackfruit in India. In Bangladesh, 35 species of insect pests and diseases attack jackfruit plant (Alam, 1974) [67]. Insect pests and diseases are one of the key constraints in jackfruit production. Shoot and fruit borer (*Diaphania caesalis* Walker), jackfruit trunk borer (*Batocera rufomaculata* De Geer), bud weevil (*Ochyromera artocarpi*), mealybug (*Drosicha mangiferae*), spittle bugs (*Cosmoscarta relata)*, bark-eating caterpillar (*Indarbela tetraonis*), caterpillars of leaf webbers (*Perina nuda* and *Diaphania bivitralis*), aphids (*Greenidea artocarpi* and *Toxoptera aurantii*), thrips (*Pseudodendrothrips dwivarna*), and scale insects (*Ceroplastes rubina*) have been found among the insect pests, while stem and fruit rots (*Rhizopus artocarpi*), bacterial dieback, pink disease (*Pelliculana salmonicolor)*, leafspot (*Phomopsis artocarpina, Pestalotia quepini, Colletotrichum lagenarium, Septoria artocarpi*), gray blight (*Pestalotia elasticola)*, anthracnose, rust (*Uredo artocarpi*) and fruit bronzing (*Pantoea stewartia* Smith) have been found among the diseases (Table 1).

Khan and Islam (2004) [68] observed that the larvae of *D. caesalis* are voracious feeders, because the cause 27.44% damage in jackfruit plantations in Bangladesh. According to Murad and Zainudin (2017) [69] and Friel and Ford (2015) [70] crop losses persistently reach up to 20% of the world harvest due to plant diseases. As an underutilized crop, jackfruit has runaway attention for intensive selection and cultivation. The most serious insect pests of jackfruit in Mymensingh and Gazipur districts are fruit borer and trunk borer (Hassan, 2010) [71]. The half to three-fourth growers faces problems with fruit borer, whereas one-fourth to half of the growers faces problems with the trunk borer infestation. The other parts of growers face the disease problem in jackfruit cultivation. The common insect pests and diseases are described below:

a). Jackfruit borer (*Diaphania caesalis* Walker): It is the major pest of jackfruit (Tandon, 1998) [72]. All the three local types of jackfruit viz. Khaja, Dorsa and Gola are equally susceptible and frequently infested by jackfruit borer (Khan *et al*., 2003a) [37]. An average of 27.44% jackfruits is infested by *D. caesalis* in Bangladesh (Khan and Islam, 2004) [68]. Evaluation of available jackfruit germplasm to *D. caesalis* results in identification of resistant germplasm which further helps in the development of insect resistant rootstocks, which culminates into development of rational pest management strategy for fruit and shoot borer. Keeping this in view, screening studies were carried out to know the relative resistance level among 65 accessions of jackfruit against *D. caesalis.* Shoot and fruit borer also

attack in other fruits like eggplant, tomato, brinjal and many other crops (Soumya *et al*., 2015) [73]. The pest *D. caesalis* attacks the fruits where fruit growth is influenced by weather factors such as temperature, relative humidity, wind speed and rainfall (Kallekkattil and Krishnamoorthy, 2017) [74].

b). Jackfruit trunk borer (*Batocera rufomaculata* De Geer): Jackfruit trees are attacked by 35 species of insect pests, of which, the jackfruit trunk borer, *Batocera rufomaculata* De Geer is the most destructive one (Alam, 1974; Azad, 2000; Rasel, 2004; Haq, 2006) [67, 75, 33]. The borer bores the tender shoots and buds. The pest is internal feeder and difficult to control. The target of pest reduction is unpredictable because insecticides cannot reach the infested trees (Poland and McCullough, 2006) [76] and asynchronous larval development allows insect pests to avoid treatment effect. In Bangladesh, there is no effective management practice against the trunk borer. According to Bebber and Gurr (2015) [77], fungal and oomycete pathogen has been found as the chief global problem in yield reduction of jackfruit. Fisher *et al*. (2012) [78] observed that the plant epidemics caused by fungi and the fungal like oomycetes has been happened since 19th century. A healthy plant can endure physiological activity at the best of its genetic and morphological potential. The potential plant can be disrupted due to the presence of insect pests and or pathogens in field or garden (Ghiasi *et al*., 2017) [79]. In Sreepur Upazila, 25.3% infested jackfruit trees were found in research areas of Bangladesh (Rasel, 2004) [80].

Management of the borer pest: Ahmed *et al*. (2013) [18] noted that 83.33 % control of borer in Gazipur by placing aluminum phosphide and sealing the hole with Bordeaux paste. Alam (1974) [67] recommended the following method for the management of trunk borer pest.

i. The infested shoots and buds should be examined, collected and destroyed the beetles and grubs.
ii. In holes of the borers may be sealed with mud and used paradichlorobenzene introduced into the holes of shoot and buds.

Table 1: Review of literature on the insect pests and diseases of jackfruit

Insect pests	Status	References
Shoot and fruit borer	Major	Little and Hills, 1978; Karim, 1995; Tandon, 1998; Gullan and Cranston, 2014; Rahman *et al*., 2005; Hassan *et al*., 2011; Soumya *et al*., 2015; Kallekkattil and Krishnamoorthy, 2017 [81, 82, 72, 82, 84, 2, 73, 74].
Trunk borer	Major	Beeson 1941; Singh, 1969; Alam 1974; Butani, 1979; Maniruzzaman 1981; Hill, 1983; Gupta and Panday, 1985; Nayar *et al*., 1989; Soepadmo, 1992; Azad, 2000; Dickmann *et al*., 2001; Rasel, 2004; Yang, 2005; Haq, 2006; CABI, 2007; Hasan *et al*., 2008; Ahmed *et al*., 2013. [85, 86, 67, 66, 87,88, 89, 90, 75, 92, 80, 93, 34, 94, 7, 18]
Bud weevil	Minor	APAARI, 2012 [17]
Mealybug	Minor	Morton, 1987; Agounke *et al*., 1988; Ragone, 1997. [44, 95, 96]
Spittle bugs	Minor	NIPHM, 2014 [97]
Bark-eating caterpillar	Minor	Tandon, 1998, Azad, 2000 [72, 75]
Aphid	Minor	Prakash *et al*., 2009 [39]
Scale insects	Minor	NIPHM, 2014[97]
Diseases	**Status**	**References**
Stem and fruit rots	Major	Karim, 1995; Tandon, 1998; Shamim *et al*., 2011; Kallekkattil and Krishnamoorthy, 2017 [82, 72, 98,74]
Bacterial dieback	Major	Mohammed *et al*., 2012 [99]
Fruit bronzing	Major	Hassan, 2010; DAM, 2012; Gapasin *et al*., 2014; Zulperi *et al*., 2017 [70, 100, 29, 101]
Dieback	Major	Gupta and Panday, 1985 [89]
Gummosis	Major	Elevitch and Manner 2006; Rahman and Afroz, 2016 [52, 102]
Pink disease	Major	Ferreira and Alfenas, 1977; Sharma *et al*., 1984; Sharma *et al*., 1985 [103, 104, 105]
Leafspot	Minor	Gupta and Panday, 1985 [89]
Gray blight	Minor	Morton, 1987[44]
Anthracnose	Minor	Gupta and Panday, 1985[89]
Rust	Minor	Morton, 1987; Banks, 1987; DAM, 2012; TFNet, 2012 [44, 106,100, 107]

c). Bud weevil/leaf eating weevil (*Ochyromera artocarpi* M., *Onychocnemis careyae* Mshll, *Teluropus ballardi* Mshll): The bud weevil is a precise pest of jackfruit. The small whitish grubs bore into tender flower buds and fruits, and induce premature drop. These greyish brown adult weevils are found nibbling the leaves and the weevil feeding on leaves in South India (APAARI. 2012) [17].

Management of bud weevil: Removing and destroying the pretentious fallen shoots, buds and fruits. Application of carbaryl (3 g/L) of water.

d). Aphids (*Greenidia artocarpi* Westw. and *Toxoptera aurantii* Bd.F.): The aphid is serious pest of many vegetables and fruits plant (Khan *et al*. 2020) [108]. Its colonies feed on the tender leaves and shoots which get wrecked and devitalized (APAARI. 2012) [17].

Management of aphid: Aphids can be controlled through applying the neem oil (1%) or spray Dimethoate (0.03%).

e). Mealy bug (*Drosicha mangiferae* Gr.): The bugs observed in clusters on tender shoots and inflorescence cause damage by sucking vital sap (APAARI. 2012) [17].

Management of Mealy bug: The orchard should plough during summer to depiction eggs to natural enemies and sun heat, and remove and burn all the weeds which are alternate hosts of the mealy bugs. Application of crude garlic oil (1%) on tree trunk below band to kill the bug, and conserve natural enemies like Coccinellids and spiders by avoiding application of broad-spectrum pesticides during top activity period.

f). Rhizopus rot (*Rhizopus artocarpi*): The Rhizopus rot is the most serious disease of jackfruit. It mainly infects inflorescence of the plant. Up to 80% of the growers in the surveyed areas have problems with Rhizopus rot caused by *Rhizopus artocarpi*, which results in premature fall of young fruit. It also attacks other fruit crops such as peach, papaya and tomato (Murad and Zainudin, 2017; Ghosh *et al*., 2015) [69, 109]. The fungi cause fruit disease as peaches is phylum Ascomycota whereas fruit rot is caused by anamorphic pathogen and a few other pathogens (Murad and Zainudin, 2017) [69]. The causal organisms of the disease for such symptoms are mostly the species *Rhizopus artocarpi* and some species of the genus *Rhizopus* (Nelson, 2005) [110]. They reported about 15–32% crop loss due to this disease.

Management of Rhizopus rot: Remove, destroy and clean up the diseased fruit from trees and ground have been found as some of the effective management techniques. Azad (2000) [75], Ghosh (1994) [111] and McMillan (1974) [112] recommended that copper hydroxide (53%), Bordeaux mixture (0.5%), copper oxychloride (0.2%) and 2,6-dichloro-4-nitroaniline (DCNA) 75 WP can be used to manage the fungal pathogen.

g). Fruit bronzing (*Pantoea stewartii* Smith): Symptoms of the disease are reddish discoloration in affected fruit pulp and rags, which could reduce the fruit quality and discourage purchasers (Ibrahim *et al*., 2019) [113]. Bronzing disease of jackfruit has been formally reported in Mexico (Hernández-Morales *et al*., 2017) [114] and the Philippines (Gapasin *et al*., 2014) [29]. It affects in jackfruit, pepper, tomato, strawberry, corn (Cluever *et al*., 2015; Gapasin *et al*., 2014; Mergaert *et al*., 2015) [115, 29, 116]. Mergaert *et al*. (2015) [116] stated that the biotic agent that had caused fruit bronzing on jackfruit is *P. stewartia*.

Management of fruit bronzing: High relative humidity around the plant has also been reported to be associated with increased maturity bronzing in fruit tree. For this reason, regulations of temperature and relative humidity though training and pruning of old jackfruit trees at canopy level have been found as effective pest management approach.

h). Leafspot (*Phomopsis artocarpina, Pestalotia quepini, Colletotrichum lagenarium, Septoria artocarpi*): The leafspot is one of the most damaging serious diseases of jackfruit. It reduces timber quality and fruit yield. The disease symptom is visible mainly on stem or branches in several conditions attract a number of insect pests in the trees. The infested trees show turns brown, dries up and later death of the tissues. As a result, the plant becomes weak with low timber quality in Bangladesh (Anonymous, 2010) [117]. In India, *P. artocarpi* causes leaf spot disease in damaging trees (Elevitch and Manner, 2006b) [118]. The leafspot infection was ranged from 45 to 87% in jack trees by gummosis disease caused by *Phomopsis atrocarpi* in the study area (Rahman and Afroz, 2016) [102].

Management of leafspot: According to Rahman and Afroz (2016) [102], the use of Bordeaux paste or coal tar can cure the plants from the disease. The mixture was used before or after the rainy season at 0 day interval because wet condition and less interest of plant might have lessened the effectiveness. The treatment controlled around 90% leafspot in the study area of Bangladesh.

i). Dieback: It is caused by *Colletotrichum gloeosporioides*. The die back was observed in the jackfruit plantation in Mymensingh and Gazipur districts Awasthi *et al*. (2005) [119]. It is very serious disease in the many fruits plant (Khan *et al*. 2020) [120]. The borer mainly damaged portion of the fruit is scrapped out followed by the application of lime paste to prevent the further spread of the damage and subsequent rot. Juan *et al*. (2011) [121] stated that the fruit has a short shelf life (2-3 days ripe fruit) mostly because of losses due to postharvest diseases caused by pathogenic fungi. They identified the fungi that cause diseases in jackfruit in order to develop new post-harvest practices for the future. Five fungi, consistent to the genus *Aspergillus* and *Penicillium* were isolated from deteriorated jackfruit. The pathogenicity trial was positive only for *Aspergillus* sp. which after PCR analysis was identified as *Aspergillus niger*.

Management of dieback: It can be controlled by pasting Bordeaux mixture (0.5%) and block the hole with mud. The spraying of carbendazim (0.1%) or thiophenate methyl (0.2 %) or chlorothaloni (0.2%) is more effective to manage the borer than control the dieback of jackfruit tree (PAT, 2012) [122].

j). Gummosis (*Phomopsis artocarpi*): In Bangladesh, about 45- 87% of jackfruit was infected by gummosis caused by *P. atrocarpi* irrespective of age of the trees (Rahman and Afroz, 2016) [102]. It is very common disease in jackfruit. It reduces fruit yield, wooden quality and life span of the tree. This disease was first noticed in 2006 in Narasingdhi. The symptoms are mainly visible in stem or branch. There is making small split of bark in center of infection from where brown gummy exudation is coming out attracting various insects. As a result, the plant becomes weak, the timber quality reduces and ultimately yield also decreases (Anonymous, 2010) [117]. Elevitch and Manner (2006b) [118] reported that *P. artocarpi* causes leaf spot disease in India without much damaging to the crop.

Management of gummosis: Use of Bordeaux paste or coal tar is the effective for the control of gummosis of disease in jackfruit (Rahman and Afroz, 2016) [102]. Rahman and Afroz (2016) [102] found that at first the infected tissues of jackfruit plant are to be chiseled properly and then Bordeaux paste or coal tar is to be pasted on the chiseled area to cure the plants. Use of Bordeaux paste and Ridomyl gold is also effective against another group of fungus.

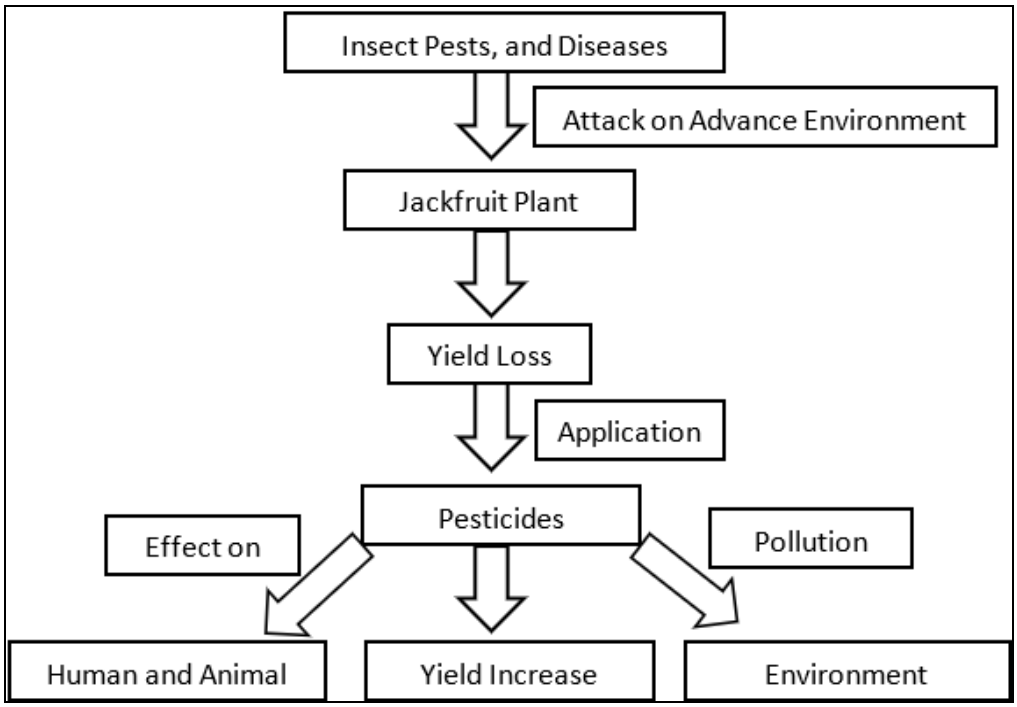

Fig 2: Unsustainable management apprises pesticide (Khan *et al*., 2020) [123]

Unsustainable management apprises pesticide: According to data from the Bangladesh Government, consumption of pesticides increased from 7,350 metric tons in 1992 to 16,200 metric tons in 2001, more than doubling in the past decade (Meisner, 2004) [124]. The chemical insecticides applied in jackfruit plants which were hazard for the animal, plant, environment and the chemical composition found in the river water (Figure 2). The pesticides increased because the rapid growth of population, food security needs, land scarcity and agricultural intensification are quickly becoming issues of pressing importance i.t. the farmers used pesticides in the land to increase crops and fruit yields (Rasul and Thapa, 2003) [125]. Many researchers and doctorates influence the farmers to use botanical, bio-rational and microbial pesticides in the field. Those pesticides managed insect pests and diseases in the jackfruit plant, fruit and eventually increase the fruit yield. The new generation pesticides and IPM tactics save environment, beneficial animal, and save the human life.

Conclusion

The jackfruit tree is very important for rural people who usually suffer from nutritional deficiency. Consumption of jackfruit fulfills the nutritional requirements for human and animals. The insect pests and diseases are the main problems for cultivation of jackfruit trees. There are eight diseases and ten insect genera attack on jackfruit plant and fruit. The use of pruning and training technique and Bordeaux paste or coal tar are the most effective techniques for the management of common insect pests and diseases of jackfruit trees. Development of insect and disease resistant variety and upscaling of IPM and INM approach are necessary for increasing the productivity. More effective bio-rational, botanical ana microbial management methods of controlling insect pests and diseases of jackfruit need to be developed in future.

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