Papaya Fruit Pests and Development of Integrated Pest Managements: Critical Review

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Abstract
Papaya *(Carica papaya* L.) is one of the most popular fruit plants grown widely under tropical and sub-tropical climates although it is suffering due diseases and few insect pests globally. It is affected by fungal diseases (anthracnose and mildews Black spot), bacteria (wilt) and virus (papaya ring spot virus) and insect pest (papaya fruit fly, webworm, whitefly, mites, aphids, scales, mealy bugs, leafhoppers and hornworms. Of these pests, the papaya fruit fly is especially important because it is difficult to control) like other fruit crops grown in the same or different agro ecology; among them the fungal diseases are the most common one. For those pests, Integrated management strategies have been developed in the way that combining various control measures like cultural, biological and chemicals; since single control method alone is not effective and environmentally friendly. Generally, cultural practices (proper management), sanitation, biological, pesticides as the last option have been developed for proper pest management of diseases and insects pest and sustainable farming. However, no more experiments have been done in combination of these management tactics in Ethiopian context.
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1. Introduction

Papaya *(Carica papaya* L.) is one of the most popular fruit plants grown widely under tropical and sub-tropical climates. It is the most important fruit plant in home gardens, and green papaya is also used as a vegetable. It is one of the few fruit plants which yields throughout the year, gives quick returns and adapts itself to various soil and climatic conditions (Kumara and Rawal, 2007). Papayas are important throughout the tropics where they thrive in frost-free areas below 1500m in elevation. Little fresh fruit is exported since it is highly perishable and requires careful handling to reach distant markets in a saleable condition (De Bac, 2010)

The top ten papaya producers are Brazil, Mexico, Nigeria, Indonesia, India, Ethiopia, Congo, Peru, China and the Philippines. Mexico, Brazil and Belize are the main exporters of papaya to the US market while USA (Hawaii) and the Philippines supply the Japanese market (Mendoza *et al*., 2008). Ethiopia is the sixth important producer of papaya in the world with a share of 2.34 percent and productivity of 14 t/ha under farmers field (Evans and Ballen, 2012).

Papaya is considered one of the most important fruits because it is a rich source of antioxidant nutrients (e.g., carotenes, vitamin C, and flavonoids), the B vitamins (e.g., folate and pantothenic acid), minerals (e.g., potassium and magnesium), and fiber. In addition, papaya is a source of the digestive enzyme papain, which is used as an industrial ingredient in brewing, meat tenderizing, pharmaceuticals, beauty products, and cosmetics (Evans and Ballen, 2012).

Ripe papaya fruits are popularly eaten fresh and can be processed into jam, jelly, marmalade, candy, puree and as a component of tropical fruit cocktails. The green or unripe fruits can be added to viands as vegetable and are made into a pickled product called *achara*. In addition, the latex from green papaya fruits is the source of papain which is used as meat tenderizer, in clarifying beer, in the production of fish concentrates for animal feed and various food processing steps. Papaya is also utilized in the pharmaceutical and cosmetics industries (Mendoza *et al*., 2008).

Papayas grow and produce well on a wide variety of soil types. Under favorable conditions, the root system can penetrate the soil to a depth of 2 m, but most of the roots responsible for nutrient uptake are found in the top 500 mm of soil, with the largest concentration in the top 250 mm (DAISDAFF, 2009). A minimum monthly rainfall of 100 mm and an average relative humidity of 66 percent are suggested as ideal for papaya growth and production. In low rain fall areas supplementary irrigation is possible. Dry climate at the time of ripening is good for the fruit quality (Harnet et *al*., 2015). A windbreak is advisable if the area is subject to high winds since the plants are susceptible to breakage. Papayas are tolerant of drought once established but in areas with a pronounced dry season little fruit will be set except during the wet season. Irrigation will increase yields in low rainfall areas but has a disadvantage in that, if irrigation is excessive, the flavour of the fruits may be poor (De Bac, 2010).

Fruit is harvested at the first signs of yellowing if it is to be sent to distant markets; it may remain on the tree a day or two longer if intended for local markets. Papayas should be stored at temperatures between 10^{o}C and 13ºC for maximum storage life. Lower temperatures will cause chilling injury and fruits will fail to ripen properly. Since the skin is extremely delicate, very careful handling is necessary (De Bac, 2010).

Ethiopia is agro-ecologically diverse and many parts of the country are suitable for growing temperate, subtropical and tropical fruits. For example, substantial areas in the southern and south-western parts of the country receive sufficient rainfall to support fruits adapted to the respective climatic conditions. In addition, there are also many rivers and streams which could be used to grow various fruits. Ethiopia has a potential irrigable area of 3.5 million ha with net irrigation area of about 1.61 million ha, of which currently only 4.6 % is utilized (Amer, 2002).

Despite having numerous production potential, diseases and few insect pests are seriously damage papayas and often accounts for the short life of the tree. Seedlings are very susceptible to damping off and older plants are susceptible to root and collar rots. All of these diseases are most serious in waterlogged soils, therefore the importance of good drainage cannot be under-estimated. Perhaps the most potentially serious disease is bunchy top caused by a virus transmitted by homopterous insects (De Bac, 2010)

Careful management of chemical control options is necessary to minimize the risk of resistance development among pathogen populations and to reduce the impact of chemicals upon the environment. Integrated Pest Management (IPM) is a leading complement and alternative to synthetic pesticides and a form of sustainable intensification with particular importance for tropical smallholders. Global pesticide use has grown over the past 20 years to 3.5 billion kg/year, amounting to a global market worth $45 billion. The external costs of pesticides are $4–$19 (€3–15) per kg of active ingredient applied, suggesting that IPM approaches that result in lower pesticide use will benefit, not only farmers, but also wider environments and human health (Pretty and Bharucha, 2015).

Integrated management strategies have been developed to use chemicals in a sustainable manner by combining them with biological and cultural methods (Reglinski *et al*., 2009). Integrated Pest Management (IPM) is defined as a pest management system that utilizes all suitable techniques in a total management system with the intent of preventing pests from reaching unacceptable levels or to reduce an existing population to an acceptable level. An emphasis is placed on manipulation of the pest's environment to the point that it will not support a pest population. Biological controls may also be used (MDARD, 2013).

This paper is designed to review the major disease and insect pest of papaya with their respective integrated management methods.

2. Papaya Pests and Development of Integrated Pest management

2.1. Papaya Diseases and Insect pest management Methods

Diseases are often the most important constraint to the production of tropical fruit. They indirectly reduce yields by debilitating the plant, and directly reduce the yield or quality of fruit before and after they are harvested. They range from esthetic problems that lower the marketability of the harvested product to lethal problems that devastate local or regional production. Moreover, fruit crops in Ethiopia are attacked by numerous insect pests and diseases which has been one of the challenges in the development sector (Kebede, 2015).

Papaya is affected by different diseases caused by fungi, bacteria and virus like other fruit crops grown in the same or different agro ecology; among them the fungal diseases are the most common one. Diseases like anthracnose and mildews are the major and observed in the papaya growing area (Harnet et *al*., 2015). A serious disease during the seedling stage is seedling rot or phytophthora causing soft rot and wilting of seedling, which also affects mature trees (Medina *et al*., 2010).

Black spot is also the disease is caused by a fungus *Asperisporium caricae was considered* as a minor problem on papaya. However, currently black spot is a very widespread and considered as major disease wherever papaya is grown. The characteristic damage symptoms include numerous black spots on leaves and fruits. During severe infection the whole fruit surface is covered with black spores of the fungus that causes high quality loss and also fruit rotting (Harnet *et al*., 2015). Papaya ring spot virus is serious virus disease and transmitted by several aphid species causes dark green rings on fruit which may be slightly sunken and become less distinct as the fruit ripens; fruits may have uneven bumps; leaves often exhibit a bright yellow mosaic pattern and new leaves are small and plant growth is stunted **Mulwa (2016);** moreover anthracnose has been reported and highly visible in papaya growing area.

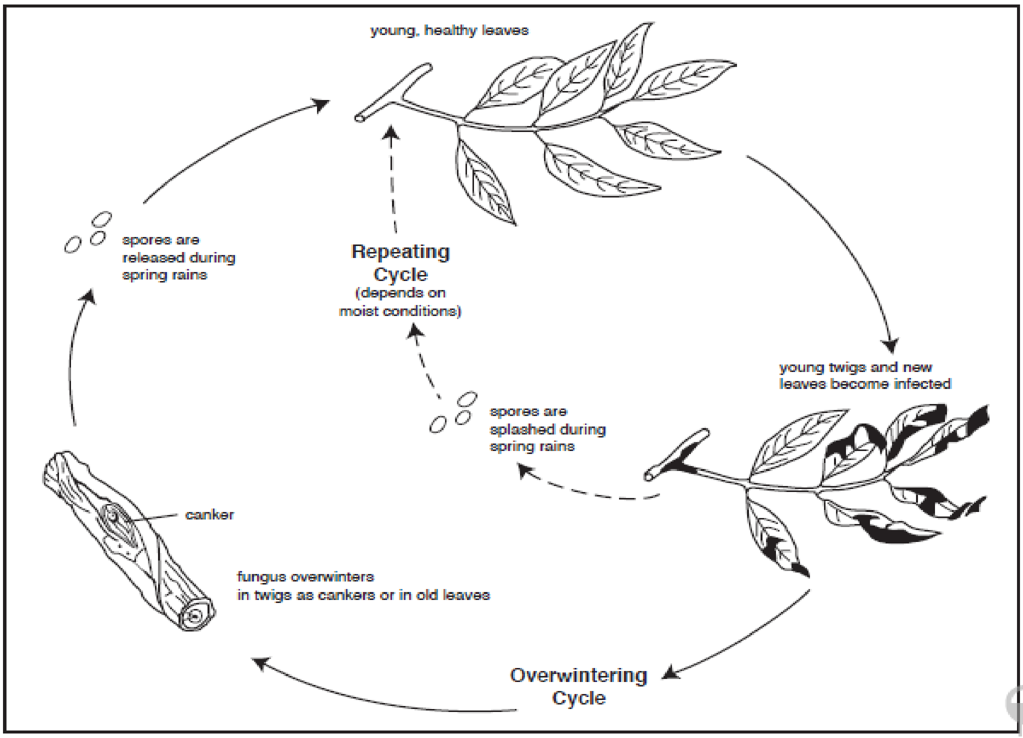
2.1.1. Anthracnose (Colletotrichum gloeosporioides)

Papaya fruit has a very thin skin and therefore rough handling leads to heavy losses due to a diseases caused by different pathogens. Commercial papaya production has been hampered worldwide due to the high susceptibility of the crop to various diseases. Of the important diseases, anthracnose caused by *Colletotrichum gloeosporioides* Penz. and Sacco is the most serious disease that affects the ripened fruit. The disease is prevalent wherever papaya is grown' and becomes more prominent during marketing and at consumer level (Kumara and Rawal, 2007). This pathogen infects about 470 different host genera. The pathogen also causes post-harvest problems and also act as endophytic strains which are isolated from symptomless plant parts (Cannon and Simmons, 2002).

2.1.2. Biology and Life cycle of Anthracnose

Anthracnose *is belongs to Colletotrichum* genus of ascomycete fungi in which the major pathogens of fruit crops causing economically important losses in temperate, subtropical and tropical regions of the world also belong. It has a wide range of hosts including cereals, legumes, vegetables and fruits (Mekonnen *et al.*, 2015) and this fungus infects monocotyledons (turf grass) to higher dicothyledons (cashew trees); thus, *C. gloeosporioides* is widely distributed and common plant pathogen in the world (Cannon *et al*., 2000). This pathogen is inactive in dry season and switches to active stages when encountered favorable environmental conditions. It involves hemibiotrophic mode of infection where both phases, biotrophic and necrotrophic phases occur sequentially. Various medium preparations were employed for the growth and sporulation of *C. gloeosporioides* including Potato dextrose agar, lima bean agar, malt extract agar and oat meal agar (Sharma and Kulshrestha., 2015).

Anthracnose, which usually attacks the ripe fruits and is caused by the fungus *Colletotrichum gloeosporioides*, was formerly the most important pawpaw disease (Medina *et al*., 2010). Anthracnose fungi occur primarily on leaves and twigs. On deciduous trees these fungi overwinter in infected twigs or dead leaf litter (Figure 1).



Source: (Crump, 2009)

Figure 1. Anthracnose disease life cycle

In spring, the fungi produces numerous microscopic spores that spread via splashing rain or sprinkler water to new growth where they germinate, entering leaves and newly expanded twigs. If moist conditions prevail, a successive generation of spores occurs in the infected parts of new leaves. On evergreen species such as Chinese elm, the fungus can occur year-round on leaves and twigs, but on most deciduous trees the progress of the disease slows and becomes negligible during hot, dry weather (Crump, 2009).

2.1.2.1. Identification and damage Anthracnose

Anthracnose caused by a fungi *Colletotrichum gloeosporioides* is a major production threat of papaya in all growing areas of Ethiopia (Mohammed *et al*., 2009). *Colletotrichum* infects fruits throughout the period of fruit growth but remains quiescent for weeks or months while the fruit is immature. Quiescent infection appears to be a fungal response to adverse physiological conditions temporarily imposed by the host (Prusky and Lichter, 2007). The damage and symptoms vary with the plant host, weather, and the time of year infection occurs. The fungi affect developing shoots and expanding leaves (Crump, 2009). The fungus can infect immature green fruits attached to the plant and remain quiescent until the fruit begins to ripen (Liberato, 2012).

On ripe fruits, anthracnose causes dark depressed lesions, which then become soft, dark coloured and unattractive (Medina *et al*., 2010). Later, lesions on the surface of ripening fruit expand to 5 cm diameter, become rounded, sunken (from 3 to 5 mm deep) and brown to black in colour. The lesions can be water-soaked or dried and hard. In the centre of the lesions, the fungus produces dark acervuli, frequently in a concentric pattern and orange to pink gelatinous mass of conidia can be observed. The whole lesion can be easily separated from the flesh of the fruit as a corkscrew, using a knife, leaving a well-defined hole in the fruit (Liberato, 2012).

Anthracnose diseases appear in both developing and mature plant tissues giving rise to two distinct types of diseases i.e. those affecting developing fruit in the field (pre-harvest) and those damaging mature fruit during storage (post-harvest) (Mekonnen *et al.*, 2015). Generally, mature leaves are resistant to infection, but when conditions are favorable, spotty lesions can occur. Heavily infected leaves fall prematurely throughout the growing season, and sometimes trees become completely defoliated. New leaf growth usually occurs after an early drop **(**Crump, 2009).

2.1.3. Integrated Management Methods of Anthracnose

The foundation for pest management in agricultural systems should have an understanding and shoring up of the full composite of inherent plant defenses, plant mixtures, soil, natural enemies, and other components of the system. These natural built in regulators are linked in a web of feedback loops that are renewable and sustainable. The use of pesticides and other treat the symptoms approaches are unsustainable and should be the last option rather than the first line of defense (Ehi-Eromosele et al ., 2013). Pesticides are used to protect food and non-food crops, pets, homes and ourselves from pests. Public concern about health and environmental risks associated with the application of pesticides has been an issue for many years. In order to address this concern, pest managers and regulatory agencies are promoting the use of effective alternative pest control methods. Managers with pest control decision-making responsibilities should become aware of the pest control options available to reduce exposure to potentially harmful pesticides (MDARD, 2013).

Due to key principle of sustainable intensification, use of methods and practices that maintain or improve agricultural productivity whilst both reducing negative impacts and increasing positive outcomes for natural capital and ecosystem services, IPM is considered as advancing and promising methods of pest management (Pretty and Bharucha, 2015).

While IPM programs intended to used, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment (Ehi-Eromosele et al., 2013). With careful management, some cultivars of susceptible landscape plants can be grown at a high level of aesthetic quality, despite the presence of anthracnose (Crump, 2009).

2.1.3.1.Cultural Practices

Avoid planting highly susceptible species including Modesto ash (*Fraxinus velutina* variety *glabra*), American sycamore (*Platanus occidentalis*), and the London plane tree (*P. acerifolia* or *P. hybrida*). Although anthracnose doesn't affect California sycamore (*P. racemosa*) in the southern part of the state, it does infect this tree in the north, so it is better to avoid planting it in this region. The ash varieties Moraine and Raywood and the Evergreen (Shamel) ash are more resistant to anthracnose than other varieties. For evergreen Chinese elm, plant the more resistant Drake cultivar instead of True Green or Evergreen. Table 1 shows the relative susceptibility of some landscape trees to anthracnose (Crump, 2009).

Space the plants far enough apart to maximize air circulation, increase sunlight and Rake sanitation measures like removal of infected and dropped leaves fallen leaves and twigs during the growing season and in fall; eve which facilitate faster drying of leaf surfaces when trees are fully grown (Harnet *et al.*, 2015). To stimulate vigorous growth of trees suffering from anthracnose, fertilize after the leaves open and avoiding irrigation systems that wet leaves are important to reduce the intensity and severity of the disease (Crump, 200**9).** Planting papaya as a multi-crop that is interspersed with non-hosts of C. *gloeosporiodes* such as citrus and coffee can help to minimize anthracnose disease incidence and severity; dipping fruits in hot water at 48°C for 20 minutes reduces the incidence of the disease after harvesting **(Mulwa , 2016).**

While pollarding severe pruning that removes all of the previous year's growth isn't recommended for most trees, you can use this method on some papaya varieties like London plane trees to control anthracnose, because it removes pathogen infected shoots **(**Crump, 2009).

2.1.3.2.Biological control

Lima *et al*. (2014) experimented by using two killer yeasts that were isolated from papaya and identified as *Wickerhamomyces anomalus* (strain 422) and *Meyerozyma guilliermondii* (strain 443). As he found, the electron micrographs showed that all application vehicles provided the necessary adhesion of yeasts to the fruit surface, which is a key feature to ensure disease control, as competition for space and nutrients are the main mechanisms involved in biological control. The adherence of yeasts to the fruit surface was indispensable to ensure occupation of the site and delayed growth of the phytopathogen.

Furthermore, in addition to maintaining the population stability, an increase in the initial yeast population was observed in the formulation of *M. guilliermondii* strain 443 and starch (2%). This finding is important because the concentration of the agent is directly related to its efficiency. It is also noteworthy that in addition to ensuring the survival of the biocontrol agent, the application vehicle must not be a food source for the organism, which could lead to increased population. After 10 days of incubation under conditions favorable to disease development (28°C and 95% relative humidity - RH), fruits treated with the yeast-based formulations showed lower rates of disease compared with untreated fruits. The best results were obtained with a mixture of *W. anomalus* (strain 422) and starch (2%), a formulation that reduced the disease severity by approximately 48.3%; other functional formulations contained *M. guilliermondii* (strain 443) in liquid carnauba wax (2%) and in gelatin (2%), which reduced the postharvest disease severity in papayas by 50% (Lima *et al*., 2014).

2.1.3.3.Chemical Application

According to Ademe *et al*. (2014), mycelial growth of *C. gloeosporioides* was significantly (P<0.05) inhibited by methanol extracts of nine plant species (Table 1). The effect of the extracts ranged from weak to strong (shown on 0-4 scale). Strong antifungal activity was exhibited by both leaves and twings methanol extracts of *Echinops* sp. and *Thymus serrulatus*. Growth inhibition score of four was recorded for extracts of these plants, indicating complete inhibition of growth and sporulation of the fungus. *Echinops* sp. had the highest inhibition zone diameter of 13.5 mm, which was then followed by that of *Ruta chalepensis*, *Thymus serrulatus*, *Vernonia amygdalina* and *Zingiber officinale.* Similarly to mycelial growth, there were significant differences among treatments on germination of spores (P<0.05). Among the nine methanol extracts, *Echinops* sp., *Thymus serrultus* and *Ocimum lamifolium* showed strong inhibition with only 1.1%, 2.0% and 2.3% spores germinated, accounting for 98.7, 97.7 and 97.3% inhibition of spore germination over the control, respectively (Table 1).

Table 1. Antifungal activity of methanol extracts of selected plant species against *C. gloeosporioides*

Plant species	Plant family	DI (mm)[a]	IE[b]	Spore germination (%)[c]
Artemisia afra	Asteraceae	4.3	3	10.5
Echinops sp.	Asteraceae	13.5	4	1.1
Lantana viburnoides	Verbenaceae	2.2	1	18.9
Ocimum lamifolium	Lamiaceae	3.8	3	2.3
Ocimum sp.	Lamiaceae	2.2	1	47.7
Ruta chalepensis	Rutaceae	6.8	3	7.4
Thymus serrulatus	Lamiaceae	6.8	4	2.0
Vernonia amygdalina	Asteraceae	6.2	1	32.6
Zingiber officinale	Zingiberaceae	5.7	2	12.6
Control		0.0	0	86.5
LSD (0.05)		1.27		3.70

a = diameter of inhibition zone in mm measured after 4 days of incubation
b = inhibition effect on a 0-4 scale, where 0=none and 4=strong inhibition
c = spore germination 24 h after treatment
Source: Ademe *et al.* (2014)

Siqueira Junior *et al*. (2012), used Purified castor bean essential oil and its major constituents like, oleic acid, linoleic acid, and ricinoleic acid and examined for their antimicrobial activity against the anthracnose agent in the papaya fruits, *C. gloeosporioides*. The result shown, significant differences were observed in the fungal growth, when the fungi were added to the PDA micro plates containing the castor bean oil. The growth inhibition was effective with as low as 1% concentrations of the oil when compared to fungal growth in the control plates (in absence of oil) (Figure 3). Higher concentrations of the oil imposed higher inhibitions and modifications on the mycelial growth.

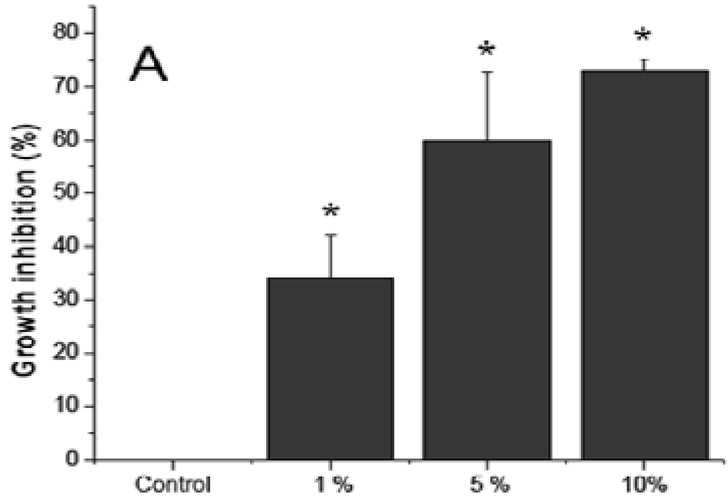


Figure 2. Percentage inhibition of mycelial growth of C. gloeosporioides in concentrations of the castor oil. The values represent the means in triplicates obtained from three independent experiments. Asterisks denote significant difference t P < 0.05 (Student's *t-test*) from control.

Source: Siqueira Junior *et al*. (2012)

Anthracnose of papaya can be controlled by fungicide treatments like Mancozeb, Ridomil Gold and Agrolaxyl but application of higher concentrations of chemicals in an attempt to overcome anthracnose increases the risk of high levels of toxic residues, which is particularly serious since papaya fruit is consumed in relatively short time after harvest and plant extracts are emerging as safer alternatives to conventional fungicides for the control of plant diseases (Hernandez-Albiter et al .,2007 and Harnet *et al*., 2015). Some fungicides provide a degree of control anthracnose of papaya, if thoroughly spray all new growth as buds begin to open in spring. Apply the spray before rainy periods, because fungicides can protect only healthy tissue and don't eradicate existing infections. If no rains are predicted, you can delay this application. If moist weather prevails, the plant might require additional applications at intervals of about 2 weeks to protect newly exposed growth. Complete spray coverage is crucial in preventing the disease (Crump, 2009 and **Mulwa , 2016).**

Percentage inhibition on the sporulation of *C. gloeosporioides* by the castor bean essential oil ranged from 65 to 70% in comparison to the control (Figure 4); the major inhibitory activity in castor oil was due to ricinoleic acid (Siqueira Junior *et a*l ., 2012).

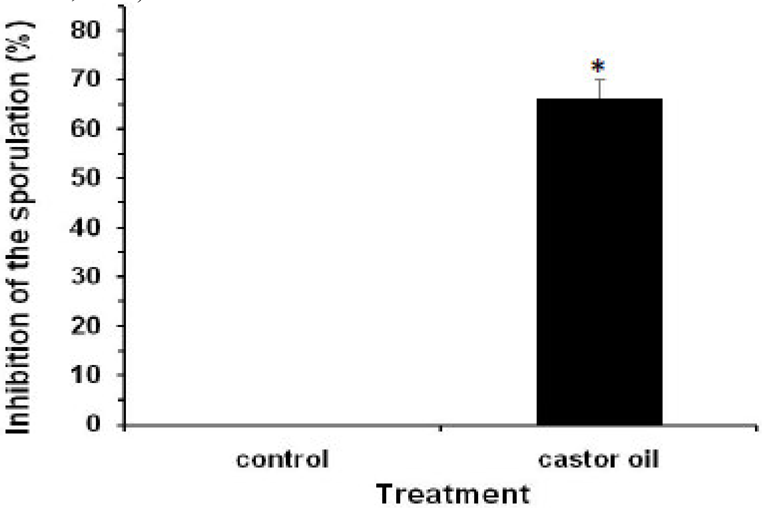


Figure 3. Percentage inhibition of spore production in C. gloeosporioides by castor oil at 10% concentration. Data are means of triplicates obtained from three independent experiments. Asterisk denotes significant difference at P < 0.05 (Student's t test)

Source: Siqueira Junior *et al*. (2012)

2.2. Papaya Insect pests and Integrated management Methods

Insects may be a limiting factor in growing papayas, especially from fruit set until harvest. Among those likely to be a problem are the papaya fruit fly, webworm, whitefly, mites, aphids, scales, mealybugs, leafhoppers and hornworms. Of these pests, the papaya fruit fly is especially important because it is difficult to control and requires some preventive control measures (Pena and Johnson, 2006).

2.2.1. Papaya Fruit Fly (*Toxotrypana curvicauda*)

The most serious of the pests are the fruit flies, sucking pests such as aphids and mites which cause damage to the fruits (Medina *et al*., 2010). These are sometimes called wasps, because of the long ovipositor of the female fly as well as similarities in size and color. This long egg-laying organ, which is as long as the body proper, penetrates the flesh of the fruit and enters the seed cavity. Eggs are usually laid in small fruit, about two to three inches in diameter, but they may be deposited in smaller and larger fruit, especially during high populations of the fly (Pena and Johnson, 2006).

2.2.2. Biology and Life Cycle of Fruit Fly

The female is capable of producing 100 or more eggs. The female fruit fly oviposits in the green immature fruit by thrusting her ovipositor through the flesh of the fruit. She then deposits a group of 10 or longer, slender eggs in the papaya's central cavity where the young larvae feed on developing seeds and the interior parts of the fruit (Selman *et al*., 2012). The initial larvae are small and delicate said first instar (or first stage) larvae. They moult into slightly more robust second instar larvae, and these in turn moult into quite stout and tough third instar larvae. When the third instars have finished feeding they leave the fruits, fall to the ground, and crawl away to a sheltered spot (usually in the soil) where they pupate. The larval skin becomes barrel shaped, tanned brown and hard, and is known as the puparium. The true pupa is formed inside this puparium shell‖. The pupa turns into an adult fly, which escapes from the puparium by splitting open the anterior end and squeezing out (Kumar *et al.,* 2011).

2.2.2.1.Damages, crop loses and symptoms

The damage starts when the female fruit fly punctures the fruit with its long and sharp ovipositor. The fruit skin is breached, and bacteria enter and the fruit starts to decay. The larvae that hatch from the eggs feed on the decaying fruit tissue, and on the yeasts and bacteria that multiply in it. It is believed that some fruit fly females carry bacteria with them that they inject into the fruit at oviposition so that the fruit decays faster (making it more nutritious for the larvae) (Kumar *et al.,* 2011).

Papaya Fruit Fly (Toxotrypana curvicauda) Lays eggs through the papaya fruit peel into the fruit cavity where the larvae feed. Eventually emerge from the ruined fruit and result show yellow areas and drop from the tree prematurely (http://www.itfnet.org/v1/2016/05/papaya-pest-disease-management/, 2016). However, unripe papaya juice is fatal to the larvae so the fruit must be ripe before the larvae begin to eat their way out of the inner cavity. Eggs hatch approximately 12 days after oviposition and larval development in the fruit lasts about 15 to 16 days (Selman *et al*., 2012).

Fruits with fruit fly larvae in them decay quickly. It is sometimes possible to cut out the damage for home consumption of the remaining part of the fruit, but infested fruits are generally unsalable, and can certainly not be exported. Crop losses can vary from a few per cent up to 100%, and losses of 90% or over are common. In some cases losses can be reduced by other treatments applied by the farmers in an area, e.g. against another orchard pest, or in another crop intercropped in the orchard (Kumar *et al.,* 2011). Symptoms are not easily detected until the adult stage when infected individuals are sluggish, have dropping wings and distended abdomen, and poor to no flying ability. Death primarily occurs during late pupation. This pathogen also affects the melon fly, *Bactrocera cucurbitae*, and the Mediterranean fruit fly, *Ceratitis capitata* (http://www.itfnet.org/v1/2016/05/papaya-pest-disease-management/, 2016).

2.2.3. Integrated Management Methods of papaya Fruit fly

Like that of anthracnose, applying Integrated pest management tactics from its advantages point of view and as the process coordinates multiple tactics for control of all classes of pests in an ecologically and economically sound way, for controlling Fruit fly is also important. Crop pests pose a substantial challenge to global food security, poverty alleviation and agricultural livelihoods. Approaches of IPM provide an array of methods by which damage can be reduced. Farmers across Asia and Africa, IPM projects have been able to deliver substantial reductions in pesticide use coupled with increased yields. Reduced reliance on synthetic pesticides delivers a range of on and off farm benefits, including savings, improved public health and improved natural capital on and around farms (Pretty and Bharucha, 2015).

2.2.3.1.Cultural control

Each fruit can produce up to 400 fruit fly adults. Removal and destruction of fallen fruits/old crops is very import for Fruit fly IPM; collected fruits should be buried 6 inches deep in soil; some part of China achieved good success in reducing population of Fruit fly using sanitation. Growing of less susceptible varieties and early harvesting of fruits before fruit fly attack specifically for fruit fly species that infest almost ripe fruits (Kumar *et al.,* 2011).

Use of resistant varieties and field sanitations are considered as the principal cultural methods of controlling papaya fruit fly; even the latter method is also important practice for reduction of re-infestation pressure by removing all unmarketable and infested fruits must be destroyed. Crops should be plowed and disked under as soon as harvest has been completed (http://www.itfnet.org/v1/2016/05/papaya-pest-disease-management/, 2016). Crop hygiene and sanitation are accomplished by preventing old infested fruits lying on the ground that are acting as reservoir of fruit flies from infesting crops in the next fruiting cycle (Kumar *et al.,* 2011).

2.2.3.2.Mechanical control

Mechanical methods of controlling the oriental fruit fly include the use of traps for destruction of adults. Shrubs within 100 yards of larval hosts may be used advantageously in placing traps. The use of protective coverings is more effective and costly than the use of traps (http://www.itfnet.org/v1/2016/05/papaya-pest-disease-management/, 2016). The recent resurgence of interest in trap cropping as an IPM tool is the result of concerns about potential negative effects of pesticides on human health and the environment, pesticide resistance, and general economic considerations of agricultural production (Shelton and Badenes-Perez, 2006). According to Shelton and Badenes-Perez (2006), among the 10 successful cases of trap cropping at a commercial level, the orders of the targeted insect pests involved three cases of Coleoptera, three cases of Hemiptera, three cases of Lepidoptera, and one case of Homoptera. The cases of Coleoptera, Hemiptera, and Lepidoptera involved insects that directed their movement and tended to aggregate on a highly attractive trap crop. Although lacking the characteristics to make it amenable for trap cropping (i.e., dispersal by passive movement and inability to redirect flight), the successful case of control of a virus carried by a homopteran pest (aphids) was possible because of the combination of a perimeter trap crop acting as a barrier crop (intercepting aphids moving passively into the field) and genetically engineered papaya plants acting as a sink for the virus carried by the aphids. Generally they reported, in the condition in which trap cropping has been successfully implemented, it has provided sustainable and long-term management solutions to control difficult pests. Successes have occurred in both developed (e.g., lygus bugs on cotton) and developing countries (e.g., use of push-pull trap cropping to control stem borers in corn).

Fruit bagging is the practice of covering the fruits with some sort of protective layer that prevents fruit flies from laying eggs in the fruits. Various kinds of cheap bagging materials may be used and oftentimes, fruit bagging increases fruit quality and consequently increases also its selling price (Kumar *et al.,* 2011). Bagging is effective and environment friendly control measure for the fruit fly in small plantings area of papaya. Bagging should begin when the fruit is small, shortly after the flowers have fallen off. Each fruit should be enclosed in a paper bag or rolled tube of newspaper and tied around the stem. This method can be very practical and successful if enough labor is available (Medina *et al*., 2010 and Selman *et al*., 2012).

2.2.3.3.Biological control

Very little research has been done on the biological control of papaya fruit fly, considering its economic importance. However, one parasitic wasp, in particular, *Doryctobracon toxotrypanae* Marsh (Hymenoptera: Braconidae), from southern Mexico and Costa Rica, may have potential for control (Selman *et al*., 2012). As eggs and larvae are main stage, Hymenopteran parasitoids are commonly employed; nevertheless biological control alone does not provide high degree of control on sustainable basis (Kumar *et al.,* 2011).

Diachasmimorpha longicaudata or Opius longicaudatus var. *malaiaensis* (Fullaway), *O. vandenboschi* (Fullaway), and *O. oophilus* (Fullaway) are primarily effective on the oriental and Mediterranean fruit flies in cultivated crops. *O. longicaudatus* is a parasite of the second and third instar fruit fly larvae; *O. vandenboschi* is a parasite of the first instar fruit larvae; and *O. oophilus* is an egg-larval parasite. *O. longicaudatus* females are commonly seen on over-ripe fruits than on the ripe fruits trees where *O. oophilus* females are primarily associated with fruits on the trees (http://www.itfnet.org/v1/2016/05/papaya-pest-disease-management/, 2016).

2.2.4. Insecticides

Not recommended in IPM as there are other robust tools available; however, in citrus fruits FF can be suppressed by a single spray; limited use of pesticides in protein baits (Kumar *et al.,* 2011).

3. Summary and Conclusion

Papaya *(Carica papaya* L.) is one of the most popular fruit plants grown widely under tropical and sub-tropical climates. It is the most important fruit plant in home gardens, and green papaya is also used as a vegetable. Despite having numerous production potential, Commercial papaya production has been hampered worldwide due diseases and few insect pests are seriously damage papayas and often accounts for the short life of the tree. Papaya is affected by different diseases caused by fungi (anthracnose and mildews Black spot), bacteria (wilt) and virus (papaya ring spot virus) and insect pest (papaya fruit fly, webworm, whitefly, mites, aphids, scales, mealy bugs, leafhoppers and hornworms. Of these pests, the papaya fruit fly is especially important because it is difficult to control) like other fruit crops grown in the same or different agro ecology; among them the fungal diseases are the most common one. For those pests, integrated management strategies have been developed to use chemicals in a sustainable manner by combining them with biological and cultural methods; since single control method alone is not effective and environment friendly. Generally, cultural practices (proper management), sanitation, biological, pesticides as the last option have been developed for proper pest management of diseases and insects pest and sustainable farming. However, no more experiments have been done in combination of these management tactics in Ethiopian context rather than report found about the existence of pests on papaya fruits, as well as no information about percentage losses, threshold level of those pests.

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