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RUGOSE SPIRALING WHITEFLY INFESTATION ON COCONUT: THREATS AND REMEDY

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ABSTRACT

Rugose spiraling whitefly (RSW) *Aleurodicus rugioperculagus* (Hemiptera: Aleurodidae) is an invasive pest causing severe damage to coconut plant, having higher percent of infestation (70.2% to 165.4%). The nymph and adults suck cell sap from the underside of the leaves and secret honeydew that develop sooty mold fungi and interfere the growth of the plants. It was first identified in Bangladesh in 2019 on coconut plants in Jashore.Then it has spread to almost all other districts in Bangladesh. Highest coconut tree infestation was observed in south-western part (97.5%) and lowest (68.0%) was in central part of the country and there was no significant difference among locations. In the coastal regions, the highest percent (97.0%) of infested coconut tree, infested fronds (96.2%) and leaflet area (84.0%) was recorded in Bagerhat district while the lowest percent infested tree (68.0%), fronds per tree (67.2%) and leaflet area (48.0%) was in Cox's Bazar. The abundance of RSW increases as the number of leaves increased. Higher percent tree infestation (85.7%) was noticed in native while it was lower(81.2%) in dwarf coconut plants although no significant difference was observed.Low abundances of adult RSW were also found in dwarf coconut plants than that of native ones. The highest incidence of whitefly of coconut was observed in summer months of April-May andthe lowest was in June-July. Biological control is an effective measure where *Encarsia guadeloupae,* lady bird beetleand lacewings are common predators and entomopathogenic fungi *Isaria fumosorosea* reduces the incidenceof RSW from 77.8 to 75.1%. Various cultural and mechanical practices also significantly reduce the pest incidence, infestation, abundance of egg, nymph and adult by 50.0%, 49.9%, 49.7%, 50.1% and 49.8% respectively. Different systemic neonicotinoid insecticides also showed successful result in controlling rugose spiraling whitefly

Keywords: *Aleurodicus rugioperculagus*, *Cocusneucifera*, infestation, damage, management

Introduction

Coconut *Cocos nucifera*belonging to the family Arecaceae, is one of the most significant palm crops in tropical, subtropical and warm temperate areas. Both coconut water and endosperm are refreshing and very nutritious and can be used to make different food items. Coconut oil and other products are also useful as natural foods and in cosmetic industries. Its dried copra is used for the preparation of vegetable oil and the pressed oil cake is used for livestock and crop production.Coconut husk and leaves can be used to make various household products, shells are used for ornaments. Coconut is grown in more than 93 countries. Among themIndia, Indonesia, Philippines and Sri Lanka account for 78% of the total worldproduction (Kumara *et al.* 2015). In the year 2020-2021, the area under cultivation of coconut in Bangladesh was 36.15 thousand ha and total production was 402.85 thousand Mt (BBS, 2021).Bangladesh ranked 12thin coconut production in the world (FAOSTAT 2022).In Bangladesh, the plant is an important plantation crop and is cultivated as a homestead plant for fruits and multipurpose uses.

Agriculture in Bangladesh is frequently in danger due to the invasion of various foreign insect species in addition to the native insect species due to its warm, humid environment and commerce with other nations for agricultural products. Exotic creatures that appear outside of their natural habitat and dispersal potential are considered alien species (Das *et al.* 2023).When foreign species are accidentally introduced into new environment and are capable of causing significant ecological, environmental or economic damage they are said to be

invasive (Raghubanshi *et al.* 2005). Recently rugose spiraling whitefly *Aleurodicus rugioperculatus* Martin has been identified as an exotic invasive pest in our country, which is believed to be introduced from India.

Invasive rugose spiraling whitefly has become a serious threat to coconut production in Bangladesh (Ullah *et al*. 2021). This insect was first identified on coconut in Belize, in 2004 (Martin 2004). Then in 2009 it was identified in Florida, United States of America from gumbo limbo. Since then, its geographic range has significantly increased inside the state, and as a result, it has spread to 22 more countries in Central and South America.In India the pest was identifiedinPollachi, Tamil Nadu 2016 (Sundararaj and Selvaraj 2017). Around 3 years later in Bangladesh this pest was first identified by Bangladesh Agricultural Research Institute (BARI) on coconut plants at Regional Agricultural Research Station (RARS), Jashore (BARI 2019) in April 2019.Subsequently, the whitefly population increased greatly and spread across the neighboring districts. The insect sucks out sap from under the leaves, inducing stress on the host plant from the loss of water and nutrients that reduce photosynthesis of the plant that results in heavy yield loss (Ullah *et al.* 2021).

The current incidence of RSW in Bangladesh is alarming due to its polyphagous nature and hence it has a great potential to extend its host range and spread all over the country. Because of the rapid proliferation and easy dispersal of whitefly through wind, they spread to the neighboring garden at faster rate causing serious threat to the economy of the coconut growers. Until now the severity of infestation is pronounced on coconut but it may cause economic loss to other horticultural and field crops as well within its host range, if not managed properly. Sincerugose spiraling whitefly has recently introduced in Bangladesh, no work on its population dynamics and yield loss of coconut has been conducted. Very limited research was done on the pest status and proper management of this insect.This review aims to report on the infestation status, seasonal abundance and current control measuresas well as provide information on the appropriate management practicesofrugose spiraling whitefly of coconut.

Bioecology of rugose spiraling whitefly

Rugose spiraling whitefly lay eggs in a spiraling pattern which is not seen in other common whiteflies. Thus, it's called the spiraling whitefly. It mostly infests palms, gumbo limbo, and other landscape plants. Thus, it was previously also known as the gumbo limbo spiraling whitefly. Adult rugose spiraling whiteflies are three times bigger (about 2.5 mm), more sluggish in naturethan typically encountered whiteflies and hastwo irregular light brown wavy markings on the forewings with greyish eyes (Stocks and Hodges 2012). This insect has an incomplete metamorphosis. So, it has three stagesin lifenamely egg, nymph (1^{st}, 2^{nd}, 3^{rd} and 4^{th} nymphal stage- called puparium) and adult. Saranya*et al*. (2021) reported that total developmental period of RSW from egg to adult was 36.23 ± 1.51 days andtotal life cycle was 56.23 ± 2.20 days. Developmental period of egg, nymphal, pupal and adult period was 8.47 ± 0.26, 17.46 ± 0.76, 10.30 ± 0.29 and 20.00 ± 1.00 days, respectively (Saranya*et al.* 2021).

Symptoms and nature of damage

Presence of egg spirals with heavy white waxy material on the underside of the leaflets is the main characteristic symptom of rugose spiraling whitefly which later coalesce and extend to the entireleaflet in due course of time.Although this whitefly does not kill large or healthy trees, smaller or unhealthy plants may succumb to very high infestation levels. Both adult and immature stages of RSW suck coconut sap by feeding on the undersides of the leaflets which cause withdrawal of water and nutrients and stress the palms (Mohan *et al.* 2017).

Extensive feeding of the insect leads to the excretion of honey dew, a sticky, glistening liquid substance, which subsequently gets deposited on the upper surface of the leaves. Honey dew promotes the growth of the fungus *Capnodium* sp., which forms sooty mold, dries to form thick dark coatings on the leaves, decreasing the plant's ability to photosynthesize, which in turn creates physiological problemsandinterfere with the normal growth. The ants and wasps are attracted to the honeydew andtheydefendthe whiteflies from their natural enemies. In the event of serious attack, egg spirals could be seen on leaf petioles and tender coconuts. Irrespective of the climatic conditions the pest can be found active round the year (Mohan *et al.* 2017).

Host plants of rugose spiraling whitefly

Polyphagous insect RSW,attacks about 120 plant species belonging to 43 plant families including many economically important horticultural crops worldwide (Nandiniand Srinivason 2022). In Bangladesh about 63 host plants were identified including various fruits (49.2%), flowers and ornamentals (21.3%), forest (8.2%), field crops (8.2%) and others (13.1%). Among these, coconut was found to be the most preferable host followed by banana and guava respectively (Das *et al.* 2023). All the life stages (egg, nymph, pupa and adult) were found in coconut, banana, guava and areca nut (Khan 2022). Nowadays, rugose spiraling whitefly is an emerging and devastating pest of coconut plants in the coastal area in Bangladesh (Dutta *et al.* 2019).

Infestation severity in different regions of Bangladesh

In the year of 2019,RSW infestation was observed only in 4 regions of Bangladesh: Magura Sadar (68.3%), Jashore Sadar (63.3%), Boalmari (57.3%) and Isurdi, (46.6%) (Dutta *et al.* 2019).In the year of 2021-22 it was found by Das *et al*. (2023) that the RSW infestation was spread to all the regions of Bangladesh. To know the infestation severity on coconut plants, Das *et al*. (2023) divided the whole country into nine regions *viz.* north, south, east, west, north-east, north-west, south-east, south-west and central andfound the infestation rate of coconut treeranged from 97.5% (Southwest region) to 69% (Central region) but there was no significant difference of the infestation rate among the locations (χ^2 = 8.7, df = 8, p = 0.37). It means that the climatic condition or the natural enemies of those locations did not affect the infestation rate (Figure 1). The coconut plants of 11 coastal areas in Bangladesh was surveyed by Khan (2022) and found that the highest percent (97%) of infested coconut plants was recorded in Bagerhat district, while the lowest percent was recorded in Cox's Bazar (68%).

The infestation percentage of coconut fronds and leaflet area by RSW was also separately studied by Khan (2022). The highest percent infested fronds per tree (96.2%) andpercent leaflet area (84%) was recorded in Bagerhat district and the lowest percent was recorded in Cox's Bazar (67.2% frond and 48% leaflet area) (Table 1). The infestation rate of the tree and fronds per tree had no significant difference among the locations (Tree: χ^2 = 9.8, df = 10, p = 0.46; Frond: χ^2 = 9.7, df = 10, p = 0.47),but the leaflet showed significant difference (χ^2 = 20, df = 10,p < 0.05).

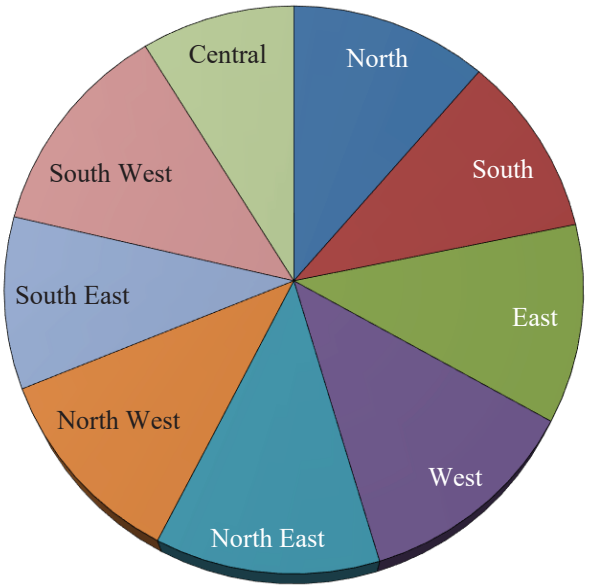


Figure 1. Infestation rate (%) of coconut plant by rugose spiraling whitefly in different geographical regions of Bangladeshduring 2021-22.

Approximately 12000 native and 8500 dwarf coconut plants were investigated randomly by Das *et al*. (2023) in different districts to know the scenario of infestation caused by rugose spiralingwhitefly. They have noticed different level of infestation (20-100%) across the country. They reported that tree infestation was higher (85.7%) in native and lower (81.2%) in dwarf variety andtherewas 5.3% variation (Table 2) but there was no significant difference (χ^2 = 9.8, df = 10, p = 0.46). Das *et al.* (2023) showed that comparatively low leaf area encrustation by sooty mold fungus and lower frond infestation (69.2%)in dwarf variety compared to native (75.7%) with a variation of 8.6% but there was no significant difference (χ^2 = 9.7, df = 10,p = 0.47). The reported that leaflet infestation (65.3%)was lower in dwarf variety compared to native (78.1%) with a variation of 16.4% (Table 2) and the results differed significantly (χ^2 = 20.0, df = 10, p < 0.05).

Table 1. Infestation rate (%) of coconut tree, leaflet area and frond by rugose spiraling whitefly in different coastal districts of Bangladesh

District	Infestation rate (%)		
	Tree	Leaflet	Frond
Bagerhat	97	84	96.2
Noakhali	96	75	95.8
Khulna	94	78	94.4
Bhola	93	72	94.3
Barguna	92	70	94.6
Cox's Bazar	68	48	67.2
Jhalokathi	77	50	75.5
Pirojpur	78	65	86.1
Patuakhali	84	55	88.8
Laxmipur	86	62	90.9
Barishal	89	67	85.5

Table 2. Infestation rate (%) of rugose spiraling whitefly on native and dwarf varieties of coconut tree, frond and leaflet

Observation parameters	Infestation rate (%)		Variation (%)
	Native variety	Dwarf variety	
Tree	85.7	81.2	5,3
Frond	75.7	69.2	8.6
Leaflet	78.1	65.3	16.4

The percentage of coconut tree infestation by rugose spiraling whiteflyin different locations of Bangladesh ranged from 69% to 97.5% which was shown by Das *et al*. (2023), while Khan (2022) reported 68% to 97% and Dutta *et al*. (2019) reported 46.7 to 68.3%. Kityo *et al*. (2017) reported up to 100% coconut tree infestation in different districts of Mozambique. Elango *et al*. (2019) found that the incidence was high in Coimbatore (62.9%) district followed by Tiruppur (56.1%) and Erode (54.4%) while Rao *et al*. (2018) showed infestation ranged between 40-60% on coconut in India.

Abundance of rugose spiraling whitefly in coconut plants

Abundance of adult rugose spiralingwhitefly was studied in the leaflets of coconut plant in India byFousiya*et al*. (2019) and revealed that 70,99, 103, 136 and 165 adults were found in 10, 20, 30, 40 and 50 leaflets respectively. Here we showed that the abundance of adult rugose spiraling whitefly is increased as the number of the leaflet per tree increases (Figure 2).

Seasonal abundance of rugose spiraling whiteflyoncoconut tree

The weather parameters play an important role in the incidence of RSW on coconut. The population of

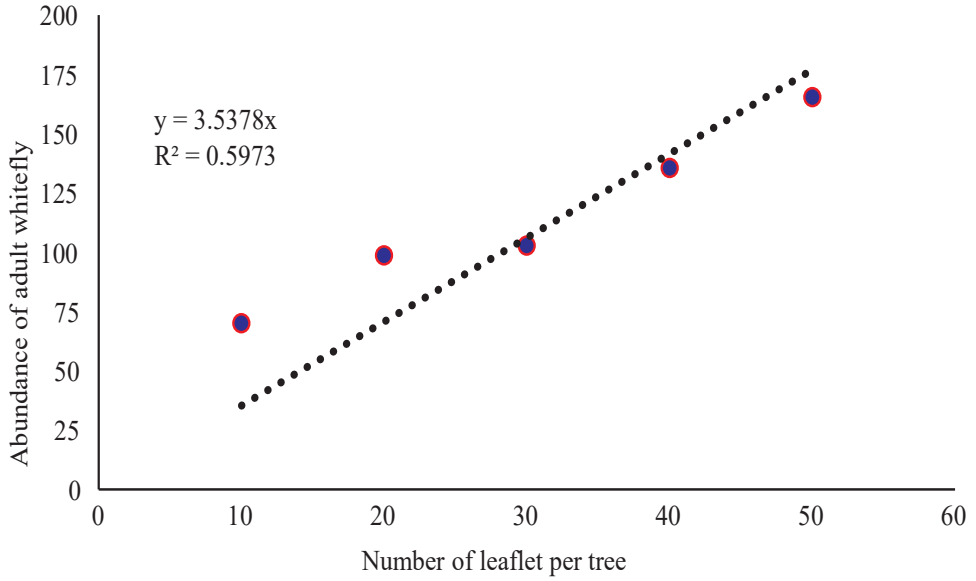


Figure 2. Relationship between the abundance (number of adults/ leaflet) of adultrugose spiraling whiteflyand the number of leaflets of coconut plant.

RSW present throughout the year on the coconut palm andthe population is high during summer, low in the rainyseasonand moderate during post rainyseasonand winter. The population of RSW has a positive correlation with maximum temperature, bright sunshine hours and evaporation (Chavan *et al.* 2022, Elango and Nelson 2020). Khan (2022) in Bangladesh showed that the incidence of rugose spiraling whitefly egg spirals per leaflet was high in with increasing temperatureduring April-May followed by September-October, November while the low with increasing of rainfall in July followed by June, January, February and December. In India Chavan *et al*. (2022) also found that the population of RSW was relatively low during the June-July and maximum during the second week of April (Figure 3). In another report, it was observed that the peak infestation of RSW per leaflet of coconut was in September and population was lowest in December- January (Sushmitha *et al*. 2020).

Management strategies

Being a non-native species in Bangladesh, RSW can achieve invasive pest status due to absence of their natural enemies (Duan *et al.* 2015). Mohan *et al.* (2017) reported different types of strategies for effective management of RSW. The strategies include quarantine of foreign products, regular survey and monitoring of coconut plants, awareness campaign and the Integrated Pest Management (IPM) approaches is the best tactics to be done. It is the combination of all management practices like cultural, mechanical, biological and chemical, which is environment friendly and also preserves the biodiversity.

Cultural control

By avoiding transplanting of affected coconut seedlings, adopting proper spacing as per the recommendation, application of optimum doses of fertilizers, by cutting and burning of severely infested coconut leaves. Host plants which favor the development and shorten the developmental time of RSW should be avoided as intercropped with coconut (Pradhan *et al.* 2020).

Mechanical control

At the initial stage of infestation, water can be sprayed forcedly to remove the eggs and immature stages ofRSW. Combination of the installation of light traps @ 5/ ha, fixing yellow sticky trap sheets @ 25/ ha, spraying three rounds of 0.5% neem oil at 15 days interval on the under surface of leaves, three rounds of jet water spray at 10 days interval about 15 days after spraying of neem oil and stapling of leaflets containing *Encarsia guadeloupae*parasitereduce the incidence (%), infestation (%), abundance. of egg, nymph and adult to 50.0%, 49.9, 49.7%, 50.1% and 49.8% respectively (Table 3) (Alagar *et al.* 2022).

Biological control

Biological control includes the use of living organisms to control the rugose spiraling whitefly infestation. Many natural enemies of rugose spiraling whitefly have been identified by a number of researchers, which are

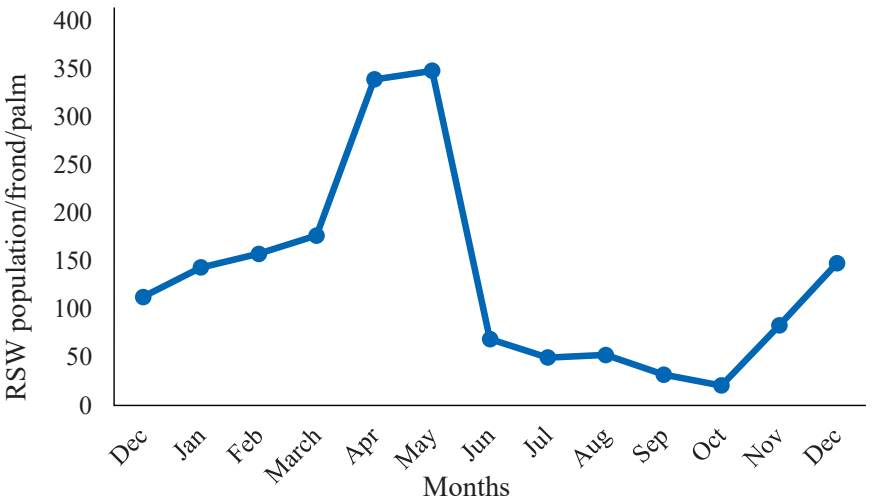


Figure 3. Population dynamics of rugose spiralingwhiteflyon coconut plant in different months of a year.

Table 3. Combination effect of light trap, yellow sticky trap, spraying neem oil, and jet water on different life parameters of rugose spiraling whitefly of coconut

Observation parameters	Pretreatment	Post treatment	Reduction (%)
Incidence (%)	66.1	33.0	50.0
Infestation (%)	75.0	37.6	49.9
Abundance of egg	19.7	9.9	49.7
Abundance of nymph	26. 5	13.2	50.1
Abundance of adult	10.9	5. 5	49.8

used to control the whiteflies. Using parasitoids, re-introducing parasitized pupae,and through conservation and augmentation of predators the infestationof RSW can be controlled.

Entomopathogenic fungi: Entomopathogenic fungi are identified as promisingbiocontrol agents for regulation of invasive insectpest population without harming the natural enemies.Table 4 showed that application pf entomopathogenic fungi *Isaria fumosorosea* reduced the incidence and colony/leaflet of RSW 77.8% and 66.5%, respectively, while combination of *Isaria fumosorosea* and *Encarsia guadeloupae* reduced incidence and colony/leaflet 75.1% and 77.9%, respectively. Mohan *et al. (*2017) found that *Encarsia guadeloupae* caused 60 to 70% parasitism of RSW, while Alagar *et al.* (2022) found the range from 40.4 to 82.5%. *Encarsiadispersa*, was also found to parasitize this whitefly to about 5% (Mohan *et al.* 2017). The findings of Elango *et al*. (2022) are presented in table 5. They showed that under laboratory condition *Isaria Fumosorosea* caused maximum 34.5%, 37.4% and 48.3% egg, nymphalandadult mortality, respectively. They also reported that *Isaria fumosorosea (Pfu-5*caused 44.0% and 44.8% mortality of egg and nymph, respectively. In laboratory condition, mortality rates of egg, nymph and adult by *Lecanicillium lecanii* were 24.5%, 30.8% and 28.0%, respectively. Themortality rates of egg, nymph and adult by *Metarhizium anisopliae* were 20.6, 32.5 and 42.9%, respectivelyand by *Beauveria bassiana were* 16.6, 28.7 and 36.98,respectively (Table 5).

Boopathi *et al*. (2015) reported 37.3 and 22.6% of egg mortality with *Metarhizium anisopliae* (M2 Strain) and *Paecilomyces fumosoroseus* (P1 strain), respectively. Similarly, Sandeep *et al*. (2022), Ali *et al*.

Table 4. Field efficacy of Isaria fumosorosea (NBAIR-Pfu-5) and Encarsia guadeloupaeon colony parameters of rugose spiraling whitefly of coconut

Treatment	Observation			
	Parameter	Pretreatment	Post treatment	Reduction (%)
Isaria fumosorosea	Incidence (%)	59.1	18.6	77.8
	Colony/leaflet	49.4	17.0	66.5
Isaria fumosorosea+ *Encarsia guadeloupae*	Incidence (%)	67.6	16.7	75.1
	Colony/leaflet	45.6	10	77.9

Table 5. Effect of entomopathogenic fungi on the mortality rate (%) of different life stages of rugose spiraling whitefly of coconut at different days after treatment

Fungi treatment(5ml/L)	Mortality rate (%) at different days after treatment		
	Egg	Nymph	Adult
Isaria fumosorosea	34.5	37.4	48.3
Isaria fumosorosea (Pfu-5)	44.0	44.8	-
Lecanicillium lecanii	24.5	30.8	28.0
Metarhizium anisopliae	20.6	32.5	42.9
Beauveria bassiana	16.6	28.7	37.0

(2016), Sumalatha *et al*. (2020) stated that RSW can be controlled effectively by *Isaria fumosorosea* alone and in combination withnovel insecticides at a reduced rate, which showed better toxicity, ovicidal action and preserve natural enemiesand reduced environmental load of chemical pesticides. The egg mortality is one of the important attributes of entomopathogenic fungiby which pest are suppressed at initial stageand crop damage isreduced.

The compatibility of two different types of biological control agent is very important for successful pest management. Dias *et al*. (2020) tested the entomopathogenic fungi, viz*., Beauveria bassiana*, *etarhizium anisopliae* and *Metarhizium rileyi* with the larvae of *Chrysoperla externa* (Neuroptera: Chrysopidae) and reported that these three fungi may be used inassociation with *C. externa* for sustainable management of sucking insect pests.

Botanical insecticides

Botanical insecticides namely Fizimite, Bioclean, Natrasoap, Neemtech and Canola oil are effective to control RSW. Active ingredient, dose, spray schedule and mode of action of these insecticides have been presented in Table 6. It has been reported by Alagar *et al.* (2022) that spraying three rounds of 0.5% neem oil at 15 days interval on the under surface of leaves, three rounds of jet water spray at 10 days interval about 15 days after spraying of neem oilcan reduce the rugose spiraling whitefly infestation to a great extent. Fizimite or Bioclean @ 1ml/L at 15 days interval, Neemtach@ 30ml + oil 2ml/L water,Natrasoap@ 20ml + Oil 2ml /L water, Canola/vegetable oil at three days interval can be used to effectively control the rugose spiraling whitefly infestation (Chin *et. al*. 2023.).

Chemical control

Complete destruction of adult and immature stages of rugose spiraling whitefly on coconut seedlings can be done by spraying (foliar, soil or trunk applications) of systemic insecticides. Commonly used insecticides along with their active ingredients, doses, spray intervals and mode of actions are presented in Table 7. Insecticides are applied either on soil by drenching granular formulations with water on the soil surface, or burying pellets or on the trunk by basal bark sprays and trunk injection. Insecticides can be used either alone or in rotation with biopesticides. Mannion (2010) reported that the insecticides of neonicotinoid group viz., Acetamiprid @ 1g/L of water, Clothianidin @ 0.1g/L of water,Dinotefuran @ 0.25g/L of water,Imidacloprid @ 0.5-0.8ml/L of waterat 15 days interval significantly reduced the incidence and infestation of RSW on coconut.Application of chemical insecticides

Table 6. Botanical insecticides suggested for effective management of rugose spiraling whiteflyof coconut

Trade name	Active ingredient	Dose	Spray interval	Mode of action
Fizimite	Vegetable oils, water, KOH	1ml/L water	15 Days	Contact
Bioclean	Vegetable oils, water, KOH	1ml/L water	15 Days	Contact
Natrasoap	Potassium salts + Fatty acids of natural oils	20ml + Oil 2ml /L water	3 Days	Contact
Neemtech	Azadirachtin	30ml + oil 2ml/L water	3 Days	Contact
Oil (canola or vegetable oil)	-	20ml/L + oil 2ml/L water	3 Days	Contact

Table 7. Synthetic insecticides suggested for effective management of rugose spiraling whiteflyof coconut

Trade name	Active ingredient	Dose	Spray interval	Mode of action
Tundra 20SP,	Acetamiprid	1g/L of water	15 Days	Systemic
Platinum 20SP	Acetamiprid	1g/L of water	15 Days	Systemic
Dantop 50WDS	Clothianidin	0.1g/L of water	15 Days	Systemic
Token 20G,	Dinotefuran	0.25g/L of water	15 Days	Systemic
Osheen20G	Dinotefuran	0.25g/L of water	15 Days	Systemic
Admire 70 WG	Imidacloprid	0.5-0.8ml/L of	15 Days	Systemic

as a component of Integrated Pest Management (IPM) with cultural, mechanical and biological methods will be more effective and environment friendly.

Conclusion

Adult and nymph of rugose spiraling whitefly suck sap from the coconut leaves and reduces photosynthetic ability of the plants and thus reduce the coconut production. The rugose spiraling whitefly has become a serious invasive pest of coconut tree compared to other host plants which showed higher infestation and lower parasitizinglevel.It has been infested more than 97% coconut trees in different regions and spread to almost all regions in Bangladesh. Highest infestation was observed in south western part (97.5%) and lowest (68%) in central part of our country. In coastal districts, highest infestation (97%) was observed in Bagherhat district and lowest (68%) in Cox's bazar. The native coconut plants are more infested (85.7%) than the dwarf ones (81.2%) although both are susceptible to RSW. Rugose spiraling whitefly severity is usually high during the summer months (Apri-May), low during rainy season (June-July) and moderate during post rainy and and winter season.

Still now, no suitable management option is available against this invasive pest in Bangladesh. The best long-term solution for rugose spiraling whitefly is biological control, by natural enemies i.e., *Encarsia Guadeloupae* that can control 60-70% or entomopathogenic fungi i.e., *Isaria Fumosorosea* which can reduce the RSW 77.8 to 75.1%. Besides, some cultural and mechanical practices (yellow sticky trap, light trap, neem oil, jet spray) reduced the infestation by 49.9% and systemic neonicotinoid insecticides also showed successful result in controlling rugose spiraling whitefly.

As RSW is a new invasive pest, so very limited researches have been conducted on it in Bangladesh. More researches are needed for effective control measures of rugose spiraling whitefly of coconut.

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