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Management of *Papaya Ringspot Virus* (PRSV) using Insecticides and bio Rationals under Field Conditions

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ABSTRACT: A field experiment conducted at the Haveli farm, College of Horticulture, UHS Bagalkot, Karnataka, India during 2019-20 to evaluate efficacy of different combination of insecticides and bio rationals (plant based oils and seaweed extract) in reducing *Papaya ringspot virus* (PRSV) incidence in papaya under field conditions. The results indicated that different combination of insecticides and bio rationals differed in their effectiveness in delaying PRSV infection. A combination of insecticides *i.e* tolfenpyrad 15% EC @1 ml/lt, imidacloprid 17.8%SL @ 0.2 ml/lt, thiacloprid 21.7 SC @ 1 ml/lt and dinotefuran 20 % SG @ 0.5g/lt sprayed along with micronutrients at every 30 days internals was the most effective treatment with less PRSV infection. Out of nine treatments complete protection could not be obtained in any of the treatment combinations probably due to the non persistent nature of virus transmission by vectors.

Keywords: *Papaya ringspot virus*, Seaweed extract, Bio oils, Tolfenpyrad 15% EC, Imidacloprid 17.8%, Thiacloprid 21.7 SC, Dinotefuran 20 % SG, Insecticides, Bio rationals, Management

INTRODUCTION

Carica papaya L. belongs to the family Caricaceae, commonly known as "Papaya", is a popular and economically important fruit tree of tropical and subtropical countries in the World. It is also known as paw paw, papaw tree melon, the fruit of angels and poor man's fruit (Nakasone and Paull, 1998). Papaya provides economically important edible fruits and is considered to be one of the most important sources of vitamins A and C. In addition, papaya contains enzyme papain and chymopapain, both of which are widely used in the food industry, medical purposes and for the preparation of value added products.

This crop is badly affected by many biotic factors such as fungi, bacteria, viruses and nematodes. Besides these papaya viruses cause diseases of global significance with serious damage in fruit production as well as the devastation of the entire crop (Akhter and Akanda, 2008). More than 29 different important virus diseases affecting papaya cultivation have been reported worldwide which belongs to different viral groups (Alcala-Briseno *et al.*, 2020). Among the viruses *Papaya ringspot virus*, *Papaya leaf curl virus* have gained global importance in all the papaya growing countries. In India, *Papaya ringspot virus* (PRSV) is one of the greatest concerns, potentially causing a 100 per cent loss in yield (Sharma and Tripathi, 2014). *Papaya ringspot virus* is a member of the genus *Potyvirus* in the family Potyviridae which manly infect papaya, cucurbits and other plants. Particles of PRSV are flexuous rods measuring 760-800 nm × 12 nm (Yeh and Gonsalves, 1984). It consists of positive sense single stranded RNA with 9000 to 10,326 nucleotides in length excluding the poly 'A' tail (Wang *et al.*, 1978) encapsulated by 30-36 kD coat protein.

Management of PRSV is essential for reducing disease incidence and to minimize the yield loss. This can be achieved by controlling disease transmission by insect vector aphids. Further integrated disease management approach is essential for viral management. The present study evaluates four different systemic insecticides *viz.*, tolfenpyrad 15% EC @ 1 ml/lt, imidacloprid 17.8% SL @ 0.2 ml/lt, thiacloprid 21.7 SC @ 1 ml/lt and dinotefuran 20 % SG @ 0.5g/lt, seaweed extract and bio oils either singly or in combination. These are the most promising components against the sucking insects in many crops. The use bio oils lead to loss of water from the cuticle of insects leading to dehydration and death (Najar-Rodriguez *et al.*, 2008) and have repellent properties acting as an anti-feedant (Pundt, 2015). These can also be mixed with insecticides for a broad spectrum and persistence action, as "stylet oils" that interferes with the piercing and sucking mouth parts (stylets) of sucking insects that transmit viruses (Cranshaw and Baxendale, 2011). However, development of resistance to conventional insecticides especially when used continuously is a serious threat to India. In this regard the bio efficacy of selected insecticides on insect pests infesting papaya was carried out.

MATERIALS AND METHODS

Experimental layout. The investigation was done to study the effect of insecticides, bio rationals (plant based oils and seaweed extract) against PRSV under field conditions. The experiment was conducted in Randomized Block Design having nine treatments with three replication in a plot size of 4.5 m × 3 m which was laid out in Haveli farm of College of Horticulture, UHS, Bagalkot, Karnataka, India, during 2019-20. The papaya hybrid Red Lady was planted at spacing of 1.5m × 1.5m.

Treatment details: There were nine treatments replicated three times. Each treatment was having eight sprays at 30 day interval. Treatment details are given in Table 1.

Observations recorded. The observations on disease incidence were recorded at 30, 60, 90, 120, 150, 180, 210, 240 and 270 DAT and were computed and tabulated which were further angular transformed before analysis.

RESULTS

Results showed that at 30, 60, 90 DAT there was no incidence of disease in any of the treatments. At 120, 150, 180, 210, 240, 270, 300, 330 and 360 DAT treatments differed significantly with respect to PRSV incidence. At 120 DAT, T_9 (63.89 %) recorded significantly highest disease incidence followed by T_8 (11.11 %), while all the other treatments recorded zero incidences. At 150 DAT, the same trend was followed wherein T_9 and T_8 recorded 94.44 per cent and 25.00 per cent respectively, while all other treatments being zero. At 180 DAT, T_9 reached 100 per cent incidence which was significantly superior, followed by T_8 (50.00 %), T_6 (27.78 %) T_2 (16.67 %), T_3 (8.33 %) and T_7 (2.78 %). Still at this stage T_1, T_4 and T_5 recorded zero incidence. At 210 DAT, T_4 (13.89 %) and T_5 (8.33 %) recorded disease incidence for the first time, while T_1 still continued with zero incidence. At 240 DAT, T_1 (2.78 %) recorded the first incidence of disease. At 270 DAT, both T_9 and T_8 (100 %) were significantly highest followed by T_2 (77.78 %), T_3 (72.22 %) and T_6 (72.22 %) which were on par. T_7 recorded 50.00 per cent while T_1 (22.22 %) was significantly least than all other treatments. The same trend continued at 300 DAT. At 330 DAT, except T_1 (80.56 %) all other treatments recorded 100 per cent incidence. At 360 DAT all the treatments recorded 100 per cent incidence. The data is presented in the Table 2 and Fig. 1.

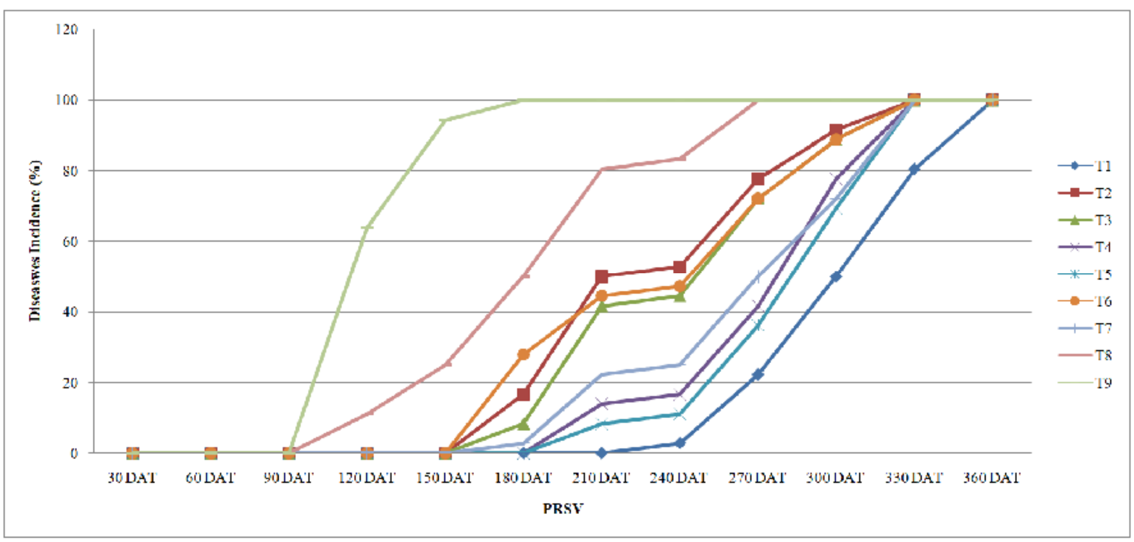

Fig. 1. Effect of insecticides and bio rationals on disease incidence.

Table 1: Details of treatment combination of insecticides and bio rationals for the management of PRSV under field condition.

Treatment	1st Spray at 30 DAT	2nd Spray at 60 DAT	3rd Spray at 90 DAT	4th Spray at 120 DAT	5th Spray at 150 DAT	6th Spray at 180 DAT	7th Spray at 210 DAT	8th Spray at 240 DAT
T_1	Tolfenpyrad 15% EC 1 ml/lt followed by micronutrients*	Imidacloprid 17.8%SL 0.2 ml/lt followed by micronutrients	Thiacloprid 21.7 SC 1 ml/lt followed by micronutrients	Dinotefuran 20 % SG 0.5g/lt followed by micronutrients	Tolfenpyrad 15% EC 1 ml/lt followed by micronutrients	Imidacloprid 17.8% SL 0.2 ml/lt followed by micronutrients	Thiacloprid 21.7 SC 1 ml/lt followed by micronutrients	Dinotefuran 20 % SG 0.5g/lt followed by micronutrients
T_2	1% Neem oil 10 ml/lt followed by micronutrients	Honge oil 10 ml/lt followed by micronutrients	Groundnut oil 10 ml/lt followed by micronutrients	Mineral oil 10 ml/lt followed by micronutrients	1% Neem oil 10 ml/lt followed by micronutrients	Honge oil 10 ml/lt followed by micronutrients	Groundnut oil 10 ml/lt followed by micronutrients	Mineral oil 10 ml/lt followed by micronutrients
T_3	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient	Seaweed extract 4ml/lt followed by micronutrient
T_4	Tolfenpyrad 15% EC 1 ml/lt followed by micronutrients	1% Neem oil 10 ml/lt followed by micronutrients	Imidacloprid 17.8% SL 0.2 ml/lt followed by micronutrients	Honge oil 10 ml/lt followed by micronutrients	Thiacloprid 21.7 sc 15% EC 1 ml/lt followed by micronutrients	Groundnut oil 10 ml/lt followed by micronutrients	Dinotefuran 20 % SG 0.5g/lt followed by micronutrients	Mineral oil 10 ml/lt followed by micronutrients
T_5	Tolfenpyrad 15% EC 1 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Imidacloprid 17.8% SL 0.2 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Thiacloprid 21.7 sc 1 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Dinotefuran 20 % SG 0.5g/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients
T_6	1% Neem oil 10 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Honge oil 10 ml/lt followed by micronutrients	Seaweed extract- 1gm/lt followed by micronutrients	Groundnut oil 10 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Mineral oil 10 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients
T_7	Tolfenpyrad 15% EC 1 ml/lt followed by micronutrients	1%Neem oil 10 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Imidacloprid 17.8% SL 0.2 ml/lt followed by micronutrients	Groundnut oil 10 ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients	Seaweed extract- 4ml/lt followed by micronutrients
T_8	Micronutrients*	Micronutrients	Micronutrients	Micronutrients	Micronutrients	Micronutrients	Micronutrients	Micronutrients
T_9	Control (No spray)							

* Zn-3.0%, Fe-2.0%, Mn-1.0%, B-0.50%, Mg-2.0%

Table 2: Effect of insecticides and bio rationals on PRSV disease incidence.

Treatment	Disease incidence (%) at											
	30 DAT**	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT	210 DAT	240 DAT	270 DAT	300 DAT	330 DAT	360 DAT
T_1	0.00 (0.00)*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.78 (5.59)	22.22 (28.03)	50.00 (45.05)	80.56 (68.57)	100 (90.00)
T_2	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	16.67 (23.62)	50.00 (45.05)	52.78 (46.80)	77.78 (66.49)	91.67 (76.38)	100 (90.00)	100 (90.00)
T_3	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.33 (13.62)	41.67 (39.63)	44.44 (41.60)	72.22 (63.40)	88.89 (73.94)	100 (90.00)	100 (90.00)
T_4	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.89 (18.03)	16.67 (23.62)	41.67 (39.79)	77.78 (62.65)	100 (90.00)	100 (90.00)
T_5	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.33 (13.62)	11.11 (19.22)	36.11 (35.59)	69.44 (56.81)	100 (90.00)	100 (90.00)
T_6	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	27.78 (31.75)	44.44 (41.80)	47.22 (43.40)	72.22 (58.46)	88.89 (74.41)	100 (90.00)	100 (90.00)
T_7	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.78 (5.59)	22.22 (27.03)	25.00 (29.46)	50.00 (45.37)	72.22 (58.57)	100 (90.00)	100 (90.00)
T_8	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	11.11 (16.06)	25.00 (29.79)	50.00 (45.16)	80.56 (68.25)	83.33 (70.21)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)
T_9	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	63.89 (53.25)	94.44 (78.81)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)
S Em ±	NS	0.00	0.00	3.08	2.15	3.88	6.91	5.41	8.7	5.66	3.89	NS
C D @ 5 %	NS	0.00	0.00	9.23	6.44	11.64	20.72	16.20	26.2	16.97	11.67	NS

* Figures in parentheses are arc sine transformed values, **DAT-Days After Transplanting,

DISCUSSION

The result of 2019-2020 showed that T_1 (8 sprays of four different insecticide and micronutrients at 30 days interval) is the significantly best treatment in managing the PRSV which recorded zero disease incidence up to 210 DAT. It has taken 360 DAT to reach 100 per cent.

The T_1 treatment contains micronutrients with four different insecticides which belong to two classes namely pyrazole (tolfenpyrad) and neonicotinoid (imidacloprid, thiacloprid and dinotefuran). These two classes of insecticides are very effective in controlling sucking pests like aphids. All these compounds have different mode of action on insects. Pyrazole acts mainly through the inhibition of the mitochondrial electron transport system (Das, 2013), whereas neonicotinoids target insects' nervous systems *via* nicotinic acetylcholine receptors (nAChRs), exhibiting high selective toxicity (Ihara and Matsuda, 2018).

Neonicotinoids are the most widely used insecticides in the world. They are systemic in action, traveling through plant tissues and protect the crop from sucking pests and safer to natural enemies compared to conventional insecticides. Ahmed *et al.*, (2001) reported that two applications at four rates of confidor, an imidacloprid insecticide (47.6, 71.4, 95.2, and 119 g a.i./ha) indirectly controlled *Tomato yellow leaf curl virus* (TYLCV) in field plantings of tomato. Similarly, Csinos *et al.*, (2001) reported that imidacloprid (Admire 2F) at 67.2 g a.i./7,000 plants is significantly effective in reducing the *tomato spotted wilt virus* (TSWV) disease on Tobacco. Further, a study conducted by Patel *et al.*, (2018) reported that dinotefuron @ 0.2 per cent was significantly effective in controlling the insect vector population (94%) and decreasing the rice tungro disease infection to 75 per cent under glasshouse condition. Mahalakshmi *et al.*, (2015) recorded the significant reduction in whiteflies population and incidence of *Yellow mosaic virus* in blackgram when treated with neonicotiniods such as imidacloprid 200 SL @ 0.3 ml/lt, thiamethoxam 25 WG @ 0.2 g/lt and thiacloprid 21.7 SC @ 1.25 ml/lt.

The second best treatment is T_5 (8 sprays, combination of four different insecticide and seaweed extract with micronutrients at 30 days interval) in controlling disease incidence. However, T_5 is the combination of micronutrients with insecticide and seaweed extract where seaweed extract is sprayed at two month intervals to avoid residual toxicity due to continuous inscecticidal sprays. Also seaweed extract is known to activate plant's immune response (Bolles and Chatfield 2009; Macho and Zipfel 2014). Specific recognition of these elicitors and their subsequent transduction may trigger defense responses leading to downstream effects such as; thickening of plant cell walls, increased activity of defense enzymes and the production of phytoalexin like defense compounds *etc.*, (Keen and Yoshikawa 1983 and Bonhoff and Grisebach 1988). More recently, the red seaweed *Schyzimenia binderi* derived oligo sulphated galactan, poly-Ga, has been shown to induce long term protection against TMV in tobacco plants (Vera *et al.*, 2012). During the process of cellular damage or infection induced necrosis, plant cells are known to produce few molecules that potentially activate plant's immune response termed as DAMPs (Damage Associated Molecular Patterns) immunity (Tang *et al.*, 2012; Choi *et al.*, 2016). It is pertinent to note here that oligogalacturonides (OGs), the fragments of pectic polysaccharide, are well known DAMPs elicitors. The oligogalacturonide, a linear polymer of 1, 4-linked α-D galacturonic acid, was shown to bind to leucine rich repeat containing TLR (TLR2 and TLR4) receptors to induce immune responses such as MAPK activation, callose deposition, production of reactive oxygen species (ROS), elevated cytosolic Ca^{2+} and defense gene activation (Chandra and Low, 1997; Denoux *et al.*, 2008; Brutus *et al.*, 2010). It is possible that the sulphated oligosugars or any unknown chemical compounds in *K. alvarezii* extract may mimic as DAMPs elicitors leading to activation of plant's immune response.

The third best treatment is T_3 which contains eight sprays of only seaweed extract along with micronutrients. Seaweeds have been reported to produce diverse secondary metabolites including antimicrobial, antifungal and antiviral compounds (Madhusudhan *et al.*, 2011; Abu-Ghannam and Rajauria 2013) due to which, T_3 was free from PRSV incidence up to 150 DAT.

It may be also noted that complete dependence on the bio rationals is not advisable as the treatment T_2 (eight spray of bio oils with micronutrients) recorded higher disease incidence. However these bio rationals in combination with insecticide (T_4) performed better having less disease incidence. The bio rationals can be incorporated in between the insecticidal sprays to reduce the toxicity. Chemicals and bio rationals significantly delayed the incidence of PRSV infection. This finding was encouraging, as escape from early infection is reported to avoid severe reduction in yield (Gonsalves, 1998). However, different combination of insecticides and oils differed in their effectiveness in delaying PRSV infection. A combination of neem oil 1 % + dimethoate 1.05 % recorded the least disease incidence of 6.66 per cent and 41.66 per cent respectively at 60 and 150 DAP (Singh *et al.,* 2008). Similarly, combination of reflective row cover, mineral oil and imidacloprid spray was the most effective treatment in delaying the PRSV incidence (83.33% at 18 month after planting) while only mineral oil or neem oil application did not protect the crop.

CONCLUSION

The studies on the management of PRSV under field condition during 2019-20 using insecticides and bio rationales revealed that treatment T_1 (8 sprays at 30 days intervals, 1st Tolfenpyrad 15% EC @ 1 ml/lt, 2nd Imidacloprid 17.8%SL @ 0.2 ml/lt, 3rd Thiacloprid 21.7 SC @ 1 ml/lt, 4th Dinotefuran 20 % SG @ 0.5g/lt, 5th Tolfenpyrad 15% EC @ 1 ml/lt, 6th Imidacloprid 17.8% SL @ 0.2 ml/lt, 7th Thiacloprid 21.7 SC @ 1 ml/lt, 8th Dinotefuran 20 % SG @ 0.5g/lt and followed with micronutrients) proved as the best treatment in managing PRSV under field conditions. It recorded least diseases incidence *i.e.*, 2.78 % at 240 DAT and took 360 DAT to reach 100 % Treatment, T_5 (8 sprays at 30 days intervals having combination of four different insecticide and seaweed extract, Tolfenpyrad 15% EC @ 1 ml/lt, Seaweed extract @ 4ml/lt, Imidacloprid 17.8% SL @ 0.2 ml/lt, Seaweed extract @ 4ml/lt, Thiacloprid 21.7 SC @ 1 ml/lt, Seaweed extract @ 4ml/lt, Dinotefuran 20 % SG @ 0.5g/lt, Seaweed extract @ 4ml/lt and followed with micronutrients) was next best treatment and least was recorded in control treatment T_9.

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