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Management of root: knot nematodes (*Meloidogyne* spp.) using different chemicals in papaya nursery

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Abstract
Various methods are used to manage Phytonematodes under field conditions. Among the various methods, application of chemicals is very popular. While scanning literature, few chemicals are found effective to control Phytonematodes. Therefore to assess the efficacy of new chemicals *i.e.* fluopyram, Fluensulfone, fluazaindolizine, Chlorantraniliprole, Carbosulfan, Carbofuran and Cartap hydrochloride each @ 3 kg a.i./ha against *Meloidogyne* spp. were tested in papaya nursery having initial nematode population 310 J_2/200 cm^3 soil. The result found as an application of fluazaindolizine 500 SC @ 3 kg a.i./ha followed by fluopyram 400 SC @ 3 kg a.i./ha found effective to reduce root-knot nematode population *viz.,* number of females, number of egg mass/3 g roots and number of eggs/egg mass and increase transplantable seedlings of papaya.

Keywords: Papaya, root-knot nematode, fluopyram, fluensulfone, fluazaindolizine, chlorantraniliprole

Introduction
Fruits and vegetables constitute an important part of our dietary, providing minerals and vitamins for necessary growth and development of the body. Papaya (*Carica papaya* Linn.) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. Sudhakar (2014) [13] opined that *C. papaya* is commonly called as paw-paw and it belongs to the family *Caricaceae*. Papaya cultivation had its origin in South Mexico and Costa Rica. It possesses excellent medicinal properties for treatment of different ailments. Growth, development and yield of papaya are highly influenced by various biotic stresses such as bacteria, fungi, viruses, insects and nematodes (Anon., 2014) [5]. Papaya is reported to be a good host of *Meloidogyne* spp. in many tropical and sub-tropical regions. It causes leaf yellowing and low leaf production as well as premature dropping of both leaves and fruits of papaya (Inserra and Cartia, 1977; Roy and Das, 1980 and Khan, 1989) [7, 12, 9]. Root-knot nematodes cause swelling and gall formation in the roots, which prevent water and nutrient uptake. Nematode population may be high in papaya without producing symptoms. Heavy nematode infestations can cause wilting, stunting, decreased plant vigor, reduced yields and shortening of the productive life of a papaya tree (Anon., 2008) [4].

Review of literature
Carbofuran, Aldicarb and Ethoprophos were tested by Nayak (1990) [11] to evaluate their effectiveness on hatching and survival of *M. incognita*. Aldicarb at 20 ppm found to be the most effective followed by Carbofuran and Ethoprophos. In pot culture study, aldicarb at 10 kg/ha found to increase seedling growth of papaya cv. Solo. Carbofuran at 6 kg/ha found most effective in checking development and reproduction of *M. incognita* in the roots of papaya *cv*. Paw Paw seedlings.
Research carried out by Faske and Hurd (2015) [6] showed that fluopyram can be used for effective control against *M. incognita*. Exposure of *M. incognita* to a variety of SDHI (Succinate dehydrogenase inhibitor) fungicides including fluopyram showed that fluopyram provides the highest level of control. There was a reduction in infection of plants inoculated with *M. incognita* which were exposed to fluopyram. Becker *et al.* (2016) [1] reported that Fluensulfone (Nimitz) and fluopyram (Velum) both products reduced root galling of the root-knot nematode susceptible tomato cultivar and significantly Increased yield compared to the non-treated control.

Both products are considered environmentally safer than organophosphate and Carbamate Nematicides.

Cabrera *et al.* (2016) showed that a single application of Velum was significantly reduced the number of root-knot nematodes in grape compared to the untreated control.

Crow (2016) [3] narrated several new Nematicides have been launched. The active ingredients in these new Nematicides include Emamectin, Fluensulfone, and fluopyram. These active ingredients against the three most problematic nematode genera, sting (*Belonolaimus* spp.), root-knot (*Meloidogyne* spp.), and lance (*Hoplolaimus* spp.) nematodes.

Jones *et al.* (2017) [8] reported that new nematicides, Fluensulfone (Nimitz 480 EC @ 1.64 L a.i./ha) and fluopyram (Luna Privilege SC @ 0.22 L a.i./ha) significantly reduced root-knot nematode population and had greater yield of lima beans in the microplot study.

Lahm *et al*. (2017) [10] demonstrated efficacy of fluazaindolizine and found excellent control of plant parasitic nematodes, resulting in higher quality crops and increased potential in crop yields.

Material and Method

Seeds of papaya *cv*. Madhubindu were sown at 15 x 10 cm spacing of 1.2 x 1.2 m beds. Granular formulations of the chemicals were applied before sowing in furrows and covered with soil. Liquid formulations of the chemicals were applied after seeding as drenching. Beds without any chemical application were kept as untreated check.

After 60 days of sowing, the experiment was discontinued by removing the seedlings from the nursery and roots were washed gently under running tap water and observations on fresh seedling weight and root-knot index were recorded. Roots were cut in to 2-3 cm length mixed thoroughly and three gram roots were stained in 0.05 per cent acid fuchsin in lactophenol. Then roots were washed with tap water to remove excess stain and kept overnight in lactophenol, Then the roots were examined for nematode population.

Table 1: List of chemicals tested

Treatments code	Treatments
T_1	Fluopyram 400 SC @ 3 kg a.i./ha
T_2	Fluensulfone 2 GR @ 3 kg a.i./ha
T_3	Fluazaindolizine 500 SC @ 3 kg a.i./ha
T_4	Chlorantraniliprole 0.4 GR @ 3 kg a.i./ha
T_5	Carbosulfan 25 EC @ 3 kg a.i./ha
T_6	Carbofuran 3 G @ 3 kg a.i./ha
T_7	Cartap hydrochloride 4 G @ 3 kg a.i./ha
T_8	Control (Untreated check)

Table 2: Root-knot Index Scale

Rating scale (0-5), per cent root infection and reaction pertaining to root-knot nematodes		
Root Knot Index (RKI)	**Per cent root infection**	**Reaction**
0	No galling	Highly resistant
0.01-1.0	Up to 20% root galling	Resistant
1.01-2.0	Up to 40% root galling	Moderately resistant
2.01-3.0	Up to 60% root galling	Moderately susceptible
3.01-4.0	Up to 80% root galling	Susceptible
4.01-5.0	More than 80% root galling	Highly susceptible

Result

Germination count/1.44 m^2

Data on seed germination presented in Table 3 showed non-significant differences among all the treatments including control. It indicates that there was no any adverse effect of tested chemicals on seed germination.

Fresh seedling weight (g)

Seedlings raised in the beds treated with fluazaindolizine @ 3 kg a.i./ha (T_3) had maximum fresh seedling weight (866.67 g) which significantly differed with rest of the treatments. Next effective treatment was fluopyram @ 3 kg a.i. /ha (T_1) which remained at par with Fluensulfone (T_2). Fresh seedling weight was lowest in the control (T_8). However, it was statistically at par with Carbosulfan (T_5), Carbofuran (T_6) and Cartap hydrochloride (T_7) (Table 3).

Transplantable seedlings (per 1.44 m^2)

Significantly highest number of transplantable seedlings (85) was recorded in fluazaindolizine (T_3) treatment followed by fluopyram (T_1) which did not differ significantly from rest of the treatments except carbofuran (T_6), cartap hydrochloride (T_7) and control (T_8). Lowest number of transplantable seedlings was noticed in the control (Table 3).

Non-transplantable seedlings (per 1.44 m^2)

Significantly highest number of non-transplantable seedlings *i.e.* 10 was observed in control (T_8) treatment which was significantly differed with rest of the treatments. Minimum number of non-transplantable seedlings was found in the treatment of fluazaindolizine (T_3) and Chlorantraniliprole (T_4) (Table 3).

Table 3: Effect of different chemicals on plant growth characters of papaya

Treatments	Germination count/1.44 m^2	Fresh seedling weight, g	Transplantable seedlings/1.44 m^2	Non-Transplantable seedlings/1.44 m^2
T_1 (Fluopyram)	83	827.33	81	2
T_2 (Fluensulfone)	81	820.67	79	2
T_3 (Fluazaindolizine)	86	866.67	85	1
T_4 (Chlorantraniliprole)	81	811.00	80	1
T_5 (Carbosulfan)	81	787.33	79	2
T_6 (Carbofuran)	81	769.33	75	6
T_7 (Cartap hydrochloride)	82	779.00	78	4
T_8 (CON)	84	756.67	74	10
SEm$\pm$	1.77	9.46	2.02	0.39
CD at 5 %	NS	28.70	6.14	1.17
CV %	3.71	2.04	4.44	19.32

NS = Non-significant

Root- knot index (RKI)

Data on root-knot index presented in table 4 indicated that papaya seedlings raised in the beds treated with fluazaindolizine (T_3) had significantly least (1.19) root-knot index however, it remained at par with the treatment of fluopyram (T_1). Soil application of fluensulfone (T_2) stood third in rank. Maximum RKI was recorded in control and it did not differ significantly with cartap hydrochloride (T_7). Treatment, Chlorantraniliprole (T_4), Carbosulfan (T_5) and carbofuran (T_6) exhibited mediocre effect on RKI.

Final nematode population

Data (Table 4) recorded on number of females from 3 g root indicated that treatment fluazaindolizine (T_3) had significantly least (48) nematode population as compared to other treatments. Treatment fluensulfone (T_2) found next best treatment. However, it remained at par with fluazaindolizine (T_3). Control had maximum (4314) population. Similar trend was observed for number of egg mass/root and number of eggs/egg mass.

Significantly least (585) nematode population from soil was recorded in the treatment of fluazaindolizine (T_3) followed by fluopyram (T_1), fluensulfone (T_2) and chlorantraniliprole (T_4). All these treatments differed significantly from each other. Control had maximum nematode population and it was at par with cartap hydrochloride (T_7) (Table 4).

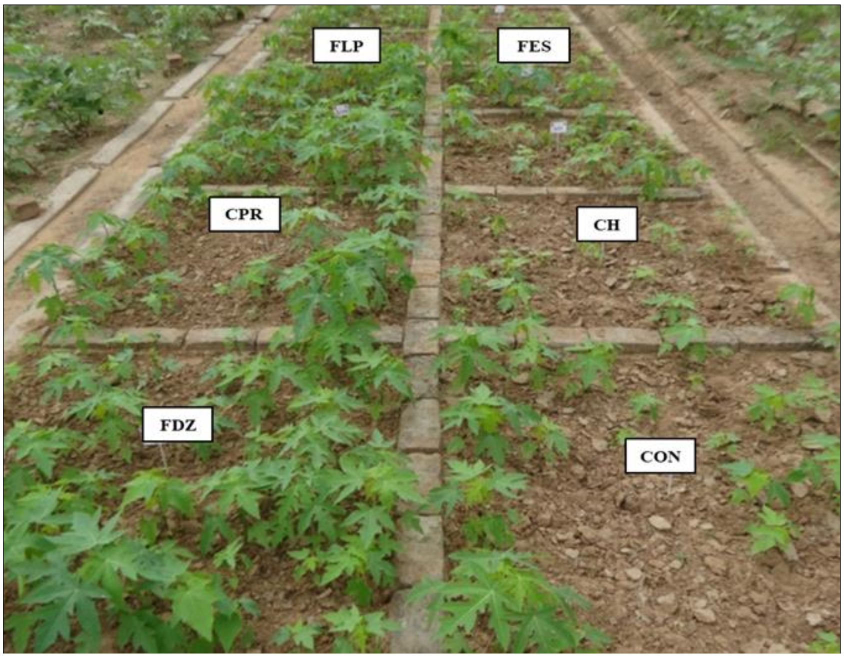
Total nematode population

In case of total nematode population, it was significantly least (911) in the treatment of fluazaindolizine (T_3) which significantly differed significantly from rest of the treatments. Treatment of fluopyram (T_1) proved second best treatment followed by fluensulfone (T_2) and Chlorantraniliprole (T_4) (Table 4).

Table 4: Effect of different chemicals on multiplication of *Meloidogyne* spp. on papaya

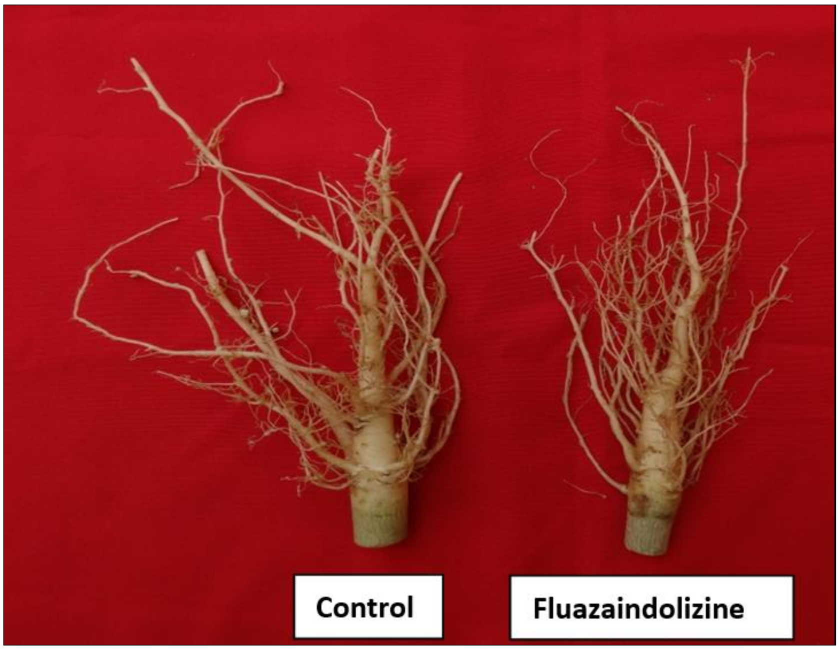
Treatments	RKI (0-5)* (√x+0.5)	Nematode population				
		No. of females/3g root (Log X+1)	No. of egg mass/root (Log X+1)	No. of eggs/egg mass (Log X+1)	No. of juveniles/ 200 cm^3 soil (Log X+1)	Total (Log X+1)
T_1 (Fluopyram)	1.46 (1.63)	1.78 (60)	1.86 (71)	2.40 (250)	2.84 (691)	3.03 (1071)
T_2 (Fluensulfone)	1.50 (1.73)	1.80 (63)	1.91 (80)	2.43 (268)	2.99 (981)	3.14 (1379)
T_3 (Fluazaindolizine)	1.30 (1.19)	1.69 (48)	1.81 (64)	2.33 (213)	2.77 (585)	2.96 (911)
T_4 (Chlorantraniliprole)	1.83 (2.86)	2.13 (135)	1.92 (82)	2.47 (294)	3.11 (1299)	3.26 (1819)
T_5 (Carbosulfan)	1.92 (3.19)	2.27 (186)	1.94 (86)	2.47 (294)	3.41 (2581)	3.50 (3161)
T_6 (Carbofuran)	2.17 (4.20)	2.45 (280)	1.94 (86)	2.57 (371)	3.63 (4265)	3.70 (5011)
T_7 (Cartap hydrochloride)	1.91 (3.15)	2.30 (201)	1.94 (86)	2.47(294)	3.44 (2779)	3.53 (3387)
T_8 (CON)	2.29 (4.75)	2.48 (299)	1.97(92)	2.58(379)	3.63(4314)	3.71(5128)
SEm±	0.06	0.02	0.03	0.03	0.02	0.02
CD at 5 %	0.18	0.07	0.08	0.10	0.05	0.05
CV %	5.78	1.75	2.51	2.40	0.90	0.87

*0 = Free; 5 = Maximum disease intensity.



Figures in parentheses are retransformed values of transmission values

Fig 1: Effect of different chemical effect in papaya nursery



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