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K Sunil Kumar
Scientist (Ento), Agricultural Research Station, Utukur, Kadapa, Andhra Pradesh, India

T Murali Krishna
Programme Coordinator, KVK, Kalyandurgam, Ananthapuramu, Andhra Pradesh, India

K Sreedevi
Senior Scientist (Agril. Ento), NBAIR, Banglore, Karnataka, India

G Karuna Sagar
Professor and Head, Department of Agronomy, S.V. Ag. College, Tirupati, Andhra Pradesh, India

K Manjula
Principal Scientist, Department of Entomology, IFT, RARS, Tirupati, Andhra Pradesh, India

R Sarada Jayalakshmi Devi
Professor and Head, Department of Plant Pathology, S.V. Ag. College, Tirupati, Andhra Pradesh, India

B Ravindra Reddy
Associate Professor, Department of Statistics, S.V. Ag. College, Tirupati, Andhra Pradesh, India

Corresponding Author:
K Sunil Kumar
Scientist (Ento), Agricultural Research Station, Utukur, Kadapa, Andhra Pradesh, India

Management of root grub, *Holotrichia reynaudi* with different insecticides as seed treatment and soil application in groundnut

K Sunil Kumar, T Murali Krishna, K Sreedevi, G Karuna Sagar, K Manjula, R Sarada Jayalakshmi Devi and B Ravindra Reddy

Abstract
Field experiments on evaluation of different insecticides as seed treatment and soil application against root grub in groundnut was conducted in the microplots specially designed for the management of root grubs at Agricultural Research Station, Utukur, Kadapa during *kharif*, 2014 and 2015. *Holotrichia reynaudi* was the test insect, as it was the predominant species in groundnut of Rayalaseema region, Andhra Pradesh. The results revealed that all the insecticides were statistically superior over untreated check (36.31% cumulative plant mortality and 65 kg ha^{-1} pod yield). Imidacloprid 600 FS @ 2 ml + 2 ml water per kg seed was found to be best treatment with lowest cumulative per cent plant mortality per plot of 3.26%, highest per cent protection over control 91.03%, with highest cost-benefit ratio of 1:1.61 and highest pod yield of 1613 kg ha^{-1}.

Keywords: Management, groundnut, *Holotrichia reynaudi*, imidacloprid 600 FS, root grub

Introduction
Groundnut (*Arachis hypogaea* L.) belongs to the Fabaceae family and is a principal oilseed crop of India. It is cultivated in 4.68 million hectares with the production of 6.56 million tons and productivity of 1400 kgha^{-1} was recorded in 2014-15 (www.agricoop.nic.in, 2016) [1]. In Andhra Pradesh, it is grown in 8.74 lakh hectares of area, 4.93 lakh tons of production with a productivity of 564 kg ha^{-1} (www.apdes.ap.gov.in, 2014-15) [2]. Out of which an area of 8.32 lakh hectares is cultivated in Rayalaseema region only. The low productivity is due to biotic and abiotic stresses during crop growth period. Pests and diseases are the major biotic constraints for low groundnut production. The insects that live in the soil of groundnut fields are responsible for higher levels of yield loss than foliage feeders. Soil insects are difficult to manage because farmers usually do not know that they are present until plants die (or) until the crop is harvested. One of the most important soil pests affecting groundnut is root grub.
Root grub is a national pest and it has worldwide distribution. In endemic areas the damage to groundnut ranges from 20-100%. The presence of one grub/m^2 may cause 80-100% mortality (Yadava and Sharma, 1995) [3], causing damage upto 39.40% (Umeh *et al*., 1999) [4], 12-60% (Pokhrel, 2004) [5]. About 80,000 ha of groundnut has been reported to be affected by white grubs in Andhra Pradesh (Wightman *et al*., 1990) [6]. Management of root grubs by seed treatment with chlorpyriphos 20 EC @5g *a.i.*/kg (Yadava and Sharma, 1995) [3], chlorpyriphos @ 0.6-1.2*a.i.*/kg andimidacloprid @ 3.5 *a.i.*/kg (Anitha *et al*., 2005, Gangwar *et al*., 2015) [7, 8] were found to be effective against root grub in groundnut. Soil drenchingwith imidacloprid 40% + fipronil 40% 80 WG at 187 g/ha (Patel *et al*., 2010) [9], imidacloprid 17.8 SL at 333 ml/ha (Bhatnagar *et al*., 2012) [10], imidacloprid 40% + fipronil 40%80 WG at 300 g/ha and clothianidin 50 WDG at 250 g/ha (Mane and Mohite, 2015) [11] were found to be effective in management of rootgrubs in groundnut at different states of the country.In view of increasing problem of development of resistance to different group of recommended insecticides and interspecific variation in the susceptibility to insecticides among *Holotrichia* species, attempts need to be made to explore novel group of insecticides against predominant root grub species associated with groundnut in Andhra Pradesh.

Materials and Method
Two field experiments were conducted in the microplots specially designed for the management

of root grubs with different insecticides as seed treatment and soil application at ARS, Utukur, Kadapa during *kharif*, 2014 and 2015. *H. reynaudi* was the test insect, as it was the predominant species in groundnut of Rayalaseema region, Andhra Pradesh.

Mass culturing of *H. reynaudi* in the laboratory

Adult beetles of *H. reynaudi* were collected from the light traps of ARS, Utukur and were transferred to aluminium rearing cages of 75cm ×45cm × 45 cm with rearing troughs containing 75 percent of moist sand and leafy neem twigs were provided as food (Plate.1). Beetles were allowed to lay eggs in the soil. Eggs were transferred to pneumatic troughs with moistened sand. Grubs after hatching from eggs were allowed to grow in the troughs. Pearl millet seeds were sown in trough to provide root material as food material for the grubs. After first moult, second instars were transferred to small pneumatic troughs of 10cm diameter filled with moist soil and organic matter in 1:1 ratio and covered with muslin cloth (Plate. 2). Pearl millet seeds were sown in these dishes to provide root material for the grubs to feed on each dish that contained five second instars, which were observed in alternate days for moulting. Care was taken to maintain the moisture in troughs. After second moult, third instar grubs were used as the test insect in the experiment.

Microplots

Microplots or bays were enclosures, built of paving kadapa slabs in a hole dug in the ground. The bays were 50cm deep and measured as 1.2m × 1.2m (Plate.3). Experiment was conducted in microplots to avoid the migration of grubs from one plot to another and count on larval mortality was recorded easily for all treatments after destructive sampling**.** In the *kharif*, 2014 and 2015 field trials were conducted in microplots for chemical control of root grubs. The experiments were laid out in RBD with 12 treatments replicated four times. Microplots were filled with sandy clay loam, which was favourable for the growth of root grubs (Plate. 4).

Seed treatment

Seed treatment with different insecticides was done by adding the required quantity of the insecticide to the seed in a small polythene sheet of 20cm × 10cm. After the addition of the insecticide, the cover was gently shaken for a few minutes for proper mixing of the chemical with seed. Care was taken to see that the testa was not damaged during treatment. The seed treatment was done 12 hours before sowing and the seed was shade dried.

Soil application of insecticides

Soil application with different insecticides was done by weighing required quantity of the granules and mixed with equal quantity of sand for uniform distribution of the insecticides in the microplots. Insecticides mixed with sand were applied to the plots immediately after sowing of groundnut. Details of the test insecticides are given in table .1

Table 1: Details of test insecticides in management of root grub, *Holotrichia reynaudi* in groundnut during *kharif*, 2014 and 2015

S. No.	Treatment	Dose	Method of application
1	T_1 : Imidacloprid 600FS	2ml +2ml water/ kg seed	Seed treatment
2	T_2 : Imidacloprid 600FS	2ml +4ml water/ kg seed	Seed treatment
3	T_3 : Thiamethoxam 35FS	2ml +2ml water/ kg seed	Seed treatment
4	T_4 : Thiamethoxam 35FS	2ml +4ml water/ kg seed	Seed treatment
5	T_5 : Fipronil 5SG	8 kg/acre	Soil application
6	T_6 : Chlorantraniliprole 0.4GR	4 kg/acre	Soil application
7	T_7 : Cartap hydrochloride 4G	8 kg/acre	Soil application
8	T_8 : Carbofuran 3G	10 kg/acre	Soil application
9	T_9 : Phorate 10G	4 kg/acre	Soil application
10	T_{10} : Chlorpyriphos 20EC (check)	6ml/ kg seed	Seed treatment
11	T_{11} : Imidacloprid 17.8SL (check)	2ml/ kg seed	Seed treatment
12	T_{12} : Untreated control	--	--

Table 2: Pooled data of efficacy of different insecticides against root grub, *Holotrichia reynaudi* in groundnut during *kharif*, 2014 and 2015.

S. No.	Treatment	Plant mortality due to root grub (%)			Protection over control (%)	Pod yield (kg ha^{-1})	Increased yield over control (kg ha^{-1})
		7 DAR	14 DAR	21 DAR			
1	T_1: Imidacloprid 600FS @2ml +2ml water/ kg seed	0.76 (2.89)^a	1.84 (6.33)^a	3.26 (10.28)^a	91.03	1613	955
2	T_2: Imidacloprid 600FS @2ml +4ml water/ kg seed	0.37 (2.02)^a	2.50 (9.04)^a	4.30 (11.97)^a	88.17	1562	904
3	T_3: Thiamethoxam 35FS @2ml +2ml water/ kg seed	7.25 (15.58)^d	14.53 (22.36)^e	21.40 (27.55)^e	41.14	971	313
4	T_4: Thiamethoxam 35FS @2ml +4ml water/ kg seed	11.15 (19.49)^e	17.79 (24.94)^f	25.22 (30.14)^f	30.64	891	233
5	T_5: Fipronil 5SG @ 8 kg/acre	1.41 (6.72)^a	3.53 (10.71)^b	4.98 (12.88)^a	86.30	1508	850
6	T_6: Chlorantraniliprole 0.4GR @ 4 kg/acre	1.43 (6.77)^a	2.89 (9.74)^a	3.94 (11.43)^a	89.16	1567	909
7	T_7: Cartap hydrochloride 4G @8 kg/acre	12.62 (20.80)^f	21.05 (27.30)^g	27.66 (31.73)^g	23.93	851	193
8	T_8: Carbofuran 3G @10 kg/acre	5.01 (12.92)^c	10.12 (18.53)^d	15.07 (22.82)^d	58.55	1151	493
9	T_9: Phorate 10G @5kg/acre	2.55 (9.15)^b	5.11 (13.05)^c	6.21 (14.41)^b	82.92	1429	771
10	T_{10}: Chlorpyriphos 20EC (check) @ 6ml/ kg seed	2.94 (9.84)^b	5.19 (13.11)^c	7.74 (16.12)^c	78.71	1343	685
11	T_{11}: Imidacloprid 17.8SL (check) @	2.52 (9.09)^b	4.38 (12.01)^b	5.73 (13.83)^b	84.24	1459	801

	2ml/ kg seed						
12	T_{12}: Untreated control	14.19 (22.10)^{g}	22.28 (28.16)^{h}	36.36 (37.08)^{h}	-	658	-
	CD @ 5%	1.48	1.56	1.76			
	SEm±	0.50	0.53	0.59			

Figures in parentheses are arc sine transformed values. The values followed by same letters do not differ significantly.

Table 3: Economics of different insecticides evaluated against root grub, *H.reynaudi* in groundnut during *kharif*, 2014 and 2015.

S. No.	Treatment	Pod yield (kg ha^{-1})	Gross returns* (` ha^{-1})	Coat of cultivation (` ha^{-1})	Cost of treatment including labour charges (` ha^{-1})	Net returns (`ha^{-1})	Cost benefit ratio
1	T_1: Imidacloprid 600 FS @ 2 ml + 2 ml water/ kg seed	1613	80650	30900	900	49750	1:1.61
2	T_2: Imidacloprid 600 FS @ 2 ml + 4 ml water/ kg seed	1562	78110	30900	900	47200	1:1.52
3	T_3: Thiamethoxam 35 FS @ 2 ml +2 ml water/ kg seed	971	48550	31050	1050	17500	1:0.56
4	T_4: Thiamethoxam 35 FS @ 2 ml +4 ml water/ kg seed	891	44550	31050	1050	13500	1:0.43
5	T_5: Fipronil 5 SG @ 8 kg/acre	1508	75400	31350	1350	44050	1:1.40
6	T_6: Chlorantraniliprole 0.4 GR @ 4 kg/acre	1567	78350	31400	1400	46950	1:1.49
7	T_7: Cartap hydrochloride 4 G @ 8 kg/acre	851	42550	31750	1750	10800	1:0.34
8	T_8: Carbofuran 3 G @ 10 kg/acre	1151	57550	32150	2150	25400	1:0.79
9	T_9: Phorate 10 G @ 5 kg/acre	1429	71450	31300	1300	40150	1:1.28
10	T_{10}: Chlorpyriphos 20 EC (check) @ 6 ml / kg seed	1343	67150	30850	850	36300	1:1.17
11	T_{11}: Imidacloprid 17.8 SL (check) @ 2 ml / kg seed	1459	72950	31100	1100	41850	1:1.34
12	T_{12}: Untreated control	658	32900	30000	-	2900	1:0.09

*Market price of groundnut pods was ` 50 per Kg

Sowing of groundnut

Sowing was done on 11-07-2014 during *kharif*, 2014 and 21-07-2015 during *kharif*, 2015 with the Dharani variety with a spacing of 30 × 10 cm. Treated seeds were sown in the microplots allotted for seed treatment and granules along with sand were applied to respective soil application plots as per lay out. The plant stand was maintained with 48 plants per microplot (Plate.4).

Release of root grubs

Five III instar grubs of *H. reynaudi* reared in the laboratory that weighed as 2100 mg on an average were released into each microplot at 15 days after sowing. Care was taken to maintain sufficient moisture in the microplots.

Data collection

Initial plant population per plot and percent plant mortality were recorded at 7, 14 and 21 days after release of grubs in the plots. Destructive sampling was done in three sets of microplots to recover the grubs at 21 days after release(Plate. 5). The plants were uprooted and dug out from the soil to know larval mortality in each plot. Destructive sampling was not done in the fourth set of microplots which were maintained to record the yield data (Plate. 5). Per cent plant mortality was calculated by using the formula given below. Data recorded was analyzed statistically using Microsoft EXCEL.

$$\text{Plant mortality (\%)} = \frac{\text{Number of dead plants due to white grubs/plot}}{\text{Total number of plants/plot}} \times 100$$

Results and Discussion

Perusal of the pooled data of *kharif*, 2014 and 2015 present in Table. 2 showed all the insecticides of seed treatment and soil application were statistically superior over untreated check (36.36% cumulative plant mortality and 658 kg ha^{-1} pod yield). Imidacloprid 600 FS @ 2ml + 2ml water per kg seed is the best treatment achieving significantly lowest cumulative per cent plant mortality per plot of 3.26% with highest per cent protection over control of 91.03% and highest pod yield 1613 kg ha^{-1} with 955 kgha^{-1} increased yield over control. The next best treatments were chlorantraniliprole (3.94 per cent cumulative plant mortality per plot, 89.16 per cent protection over control, 1567 kg ha^{-1} pod yield and 909 kg ha^{-1} increased yield over control respectively), imidacloprid 600 FS 2ml + 4ml water per kg seed (4.30%, 88.17%, 1562 kg ha^{-1}and 904 kg ha^{-1}), fipronil (4.98%, 86.30%, 1508 kg ha^{-1} and 850 kg ha^{-1}), imidacloprid 17.8 SL (5.73%, 84.24%, 1459 kg ha^{-1} and 801 kg ha^{-1}), phorate (6.21%, 82.92%, 1429 kg ha^{-1}and 771 kg ha^{-1}), chlorpyriphos (7.74%, 78.71%, 1343 kg ha^{-1}and 685 kg ha^{-1}), carbofuran 3G (15.07%, 58.55%, 1151 kg ha^{-1}and 493 kg ha^{-1}), thiamethoxam 35 FS @ 2ml + 2ml water per kg (21.40%, 41.14%, 917 kg ha^{-1}and 313 kg ha^{-1}), thiamethoxam 35 FS @ 2ml + 4ml water per kg (25.22%, 30.64%, 891 kg ha^{-1}and 233 kg ha^{-1}) and cartap hydrochloride (27.66%, 23.93%, 851 kg ha^{-1}and 193 kg ha^{-1}) (Table.2).

The present findings revealed that seed treatment with imidacloprid 600 FS @ 2ml + 2ml water per kg seed, soil application of chlorantraniliprole 0.4 GR @ 4 kg ac^{-1}, seed treatment with imidacloprid 600 FS @ 2ml + 4ml water per kg seed, soil application of fipronil, seed treatment with imidacloprid 17.8 SL @ 2 ml kg^{-1} seed, soil application with phorate 10 G @ 5 kg ac^{-1} proved to be highly effective against root grub, *Holotrichia reynaudi* in groundnut. The order of toxicity of different insecticides are presented here under.

T_1> T_6> T_2> T_5> T_{11}> T_9> T_{10}> T_8> T_3> T_4> T_7> T_{12}

Imidacloprid 600 FS @ 2ml + 2ml water per kg seed > chlorantraniliprole > imidacloprid 600 FS @ 2ml + 4ml water per kg seed > fipronil > imidacloprid 17.8 SL > phorate > chlorpyriphos > carbofuran > thiamethoxam 35 FS @ 2ml + 2ml water per kg seed > thiamethoxam 35 FS @ 2ml + 4ml water per kg seed > cartap hydrochloride.

Economics of different insecticides evaluated against root grub in groundnut during *kharif*, 2014 and 2015 revealed highest cost benefit ratio of 1:1.61 was recorded for the treatment imidacloprid 600FS @ 2ml + 2 ml water per kg seed followed by 1:1.52 imidacloprid 600FS @ 2ml + 4 ml water per kg seed, chlorantraniliprole 0.4 GR @ 4kg/ac (1:1.49), fipronil 5 SG @ 8 kg/ac (1:1.40), imidaclopid 17.8 SL @ 2 ml/kg (1:1.34), phorate 10 G @ 5 kg/ac (1:1.28), chlorpyriphos 20 EC @ 6 ml/ kg seed (1:1.17), carbofuran 3 G @ 10 kg/ac (1:0.79), thiamethoxam 35 FS @ 2 ml +2 ml

water per kg seed (1:0.56), thiamethoxam 35 FS @ 2ml +4 ml water per kg seed (1:0.43), cartap hydrochloride 4 G @ 8 kg/ac (1:0.34) (Table .3). The order of cost benefit ratio of different insecticides is presented hereunder.

$T_1 > T_2 > T_6 > T_5 > T_{11} > T_9 > T_{10} > T_8 > T_3 > T_4 > T_7$

The present results are in conformity with Anitha *et al.* (2005)[7] who reported that imidacloprid and chlorpyriphos at 3.5 and 1.2 g ai/kg were effective against *Holotrichia reynaudi* in groundnut in South India. Imidacloprid 600 FS is the effective formulation recommended for seed treatment against sucking pest in groundnut, it also might have shown very low plant mortality with its repellent and anti feedant activity against white grubs, in addition to contact and stomach toxicity. Mc Gill *et al.* (2003) [12] also reported that Imidacloprid had shown low plant mortality with its repellent antifeedant activity against white grubs. Bhatnagar *et al.* (2012) [10] reported that soil application of imidacloprid 17.8 SL at 333 ml / ha and clothianidin 30 WDG in the standing groundnut crop against *Holotrichia consanginea* recorded 7.31% plant mortality and 8.46%plant mortality of with pod yield of 21.13 and 18.61 q ha^{-1}.

Singh *et al.* (2012) [13] reported that seed treatment with neonicotinoid group insecticides like imidacloprid (6.19% plant damage) and clothianidin (5.47% plant damage) were effective against *Holotrichia consanguinea* in groundnut, fipronil 5 SC at 1.25 g ai/kg seed was also effective against root grubwith 11.51 per cent plant mortality.

Patel *et al.* (2010) [9] reported that soil drenching of imidacloprid 40% + fipronil 40% 80 WG at 187 g/ha was most effective on groundnut crop for the control of white grub. Gangawar *et al.* (2015) [8] reported that seed treatment with imidacloprid 17.8SL @ 4 ml/kg seed shown lowest plant mortality of 5.87 per cent and highest pod yield of 26.45 q/ha.

Chlorantraniliprole is an anthranilic diamide group of insecticides that binds to a novel target site, the ryanodine receptor, resulting in the uncontrolled release of calcium stores from the sarcoplasmic reticulum (Lahm *et al.*, 2005; Cordova *et al.*, 2006) [14, 15]. In the target organism, this causes impaired regulation of muscle contraction and leads to feeding cessation, lethargy, paralysis and death. Anthranilic diamides have very low vertebral toxicity due to a > 500 fold differential selectivity towards insect over mammalian receptors (Cordova *et al.*, 2006) [15]. Koppen hofer and Fuzy *et al.* (2008) [16] reported that the anthranilic diamide chlorantraniliprole had shown high efficacy against white grubs in turf grass. It can be applied as early as April for preventive white grub control due to its long residual activity.

Plate 1: Rearing cage used for root grub adult beetles rearing, mating and oviposition

Plate 2: Bajra seedling in pneumatic trough used as feed during rearing of grubs

Plate 3: Microplot (1.2 × 1.2 × 0.5 m) built with Kadapa slabs

Plate 4: Microplots constructed for conducting experiment on management of root grubs

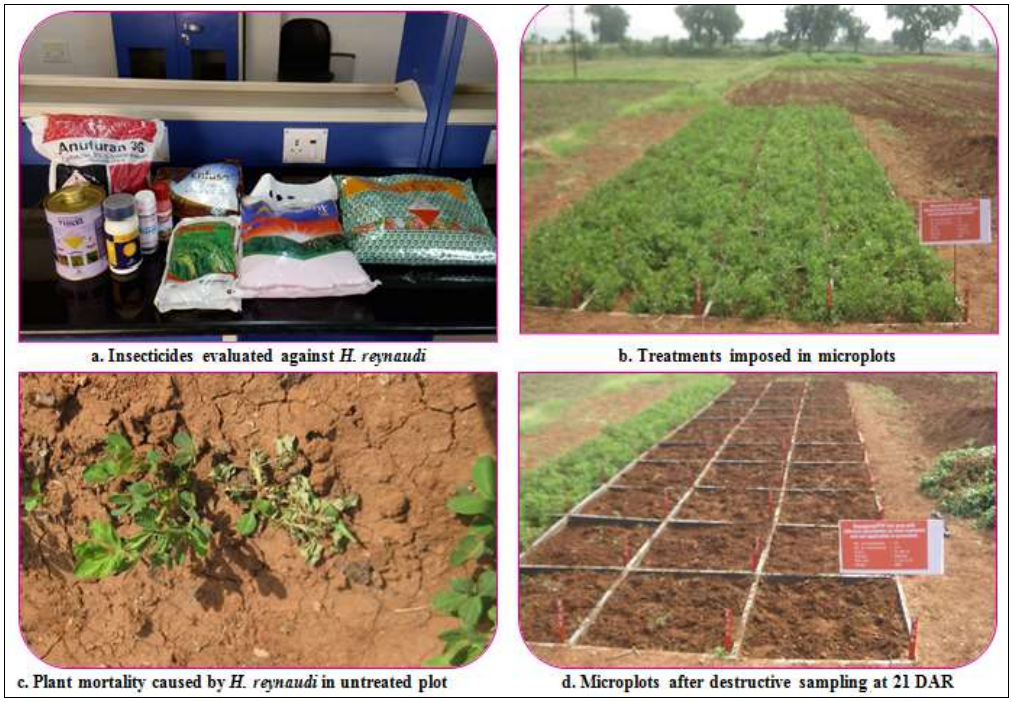

Plate 5: Snapshot view of microplot trial conducted at ARS, Utukur, Kadapa

Conclusion

Among the insecticides evaluated against *H. reynaudi* in groundnut, Imidacloprid 600 FS @ 2 ml + 2 ml water per kg seed, chlorantraniliprole @ 4kg/acre, imidacloprid 600FS @ 2 ml + 4 ml water per kg seed, fipronil @8 kg/acre and imidacloprid 17.8 SL @ 2 ml per kg seed were found to be very effective with low cumulative plant mortality due to root grub, economically viable and high reduction in root grub number over control.

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