Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(5): 1850-1853
Received: 20-07-2017
Accepted: 21-08-2017

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Effect of Phytotoxicity of pesticides on grain yield of *Rabi* sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
A field experiment was conducted at Regional Agricultural Research Station, Vijayapur, UAS, Dharwad during *rabi*-2015 to assess the phytotoxicity of different pesticides in *rabi* sorghum. Totally 15 pesticides were evaluated consisting of 13 insecticides, 1 acaricide (spiromesifen), and 1 botonical (NSKE) along with control (water spray) at 3 dosages *i.e.,* recommended, two times the recommended and four times the recommended dosage. The pesticides were applied at seedling (20 DAS), vegetative (60 DAS) and reproductive (90 DAS) stages of the crop growth. Observation on different phytotoxic symptoms like chlorosis, white blotches and bronzing type of symptoms were recorded based on percentage leaf damage by visual score (1-10) and later the per cent phytotoxicity was calculated. The highest mean per cent phytotoxicity index was recorded in the profenophos 50 EC @ 1.0, 2.0, 4.0 ml/litre treated plots (20.2, 44.1 and 56.1 PPI) at seedling, vegetative and reproductive stage of crop growth, respectively and was followed by spiromesifen 240 SC treated plots. Other treatments such as malathion 50 EC, methomyl 40 SP, chlorphyriphos 20 EC, cypermethrin 10 EC, alphamethrin 10 EC, imidacloprid 17. 8 SL treated plots produced the phytotoxic symptoms to a various level. Acephate 75 SP, fipronil 5 SC, carbofuron 3G, Phorate 10 G, chlorantraniliprole 18.5 SC, emamectin benzoate 0.5 SG and NSKE were found safe to the sorghum crop at recommended, two times the recommended and four times the recommended dosage of pesticides tested. The grain yield was inversely correlated with the per cent phytotoxicity index.

Keywords: Pesticides, Phytotoxicity, Sorghum

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is one of the important cereal crops of the world. Sorghum ranks fifth among the world cereals in the order of wheat, maize rice and barley. It is the major source of food and fodder for millions of people and animals in tropics and semi-arid tropics (House, 1980) [4]. Karnataka is one of the leading states in sorghum cultivation after Maharashtra with an area of 18.91 lakh hectares and production of 12.38 lakh tonnes of grain (Parthasarathy Rao *et al.,* 2010) [8]. In the Karnataka state, sorghum is grown both in monsoon and post-monsoon seasons. The cultivation of sorghum is concentrated more in northern districts of Karnataka *viz.*, Vijayapur, Bagalkote, Kalaburgi, Dharwad, Gadag, Haveri, Raichur, Koppal and Bellary.

The commonly recommended insecticide in sorghum was endosulfan against major pest *viz.*, shoot fly, shoot bug and aphids. As the endosulfan usage is banned, hence there are no alternative chemical insecticides available in the form of spray formulation against key pests of sorghum. Application of chemical pesticides has adverse effect by producing the various phytotoxic symptoms on sorghum, as the crop is very succulent and possess soft texture and highly sensitive to chemical insecticides (Ningaraj and Shekarappa, 2015) [7]. Thus, before recommending the pesticides based on efficacy there is an urgent need to know their phytotoxicity. Keeping this in view, to find alternate insecticide to endosulfan, the study was undertaken to assess the level of phytotoxicity of different pesticides in sorghum crop.

Material and methods
The experiment was conducted at Regional Agricultural Research Station, Vijayapur, crop was sown during September 2015, in a Randomized Block Design (RCBD) with 46 treatments and two replications, using M 35-1 variety of sorghum in a plot size of 3.15 x 4.0 m (7 rows of 4 m length) for each treatment. The crop was raised with a spacing of 45 x 15 cm by following all recommended package of practices of University of Agricultural Sciences, Dharwad (Anon., 2014) [1] except plant protection measures.

The pesticides were sprayed at an age of 20, 60 and 90 days after sowing by using manually hand operated knapsack sprayer. Sufficient care has been taken to avoid the drift hazard problem to adjacent rows (barrier creation).

Observations on phytotoxic symptoms like chlorosis, white blotches and bronzing are recorded based on percentage leaf damage by visual score using the following scale (0-10) as reported by Rajeswaran *et al.* (2004) [9].

Table 1: Phytotoxicity scale

Rating	Per cent Phytotoxicity (leaf injury)
0	No phytotoxicity
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-90
10	91-100

The per cent phytotoxicity index (PPI) was computed using the following formula,

$$PPI\ (\%) = \frac{\text{Sum of all numerical ratings}}{\text{Total no. of plants observed x Max. Phytotoxicity rating}} \times 100$$

The observations was recorded at seedling, vegetative and reproductive stages of the crop growth of randomly selected 5 plants per treatment, at one, three, five, seven, nine, eleven and fifteen days after spraying of pesticides and following scale was used for assessing the phytotoxicity level.

Table 2: Level of phytotoxicity.

Sl. No	Per cent phytotoxicity index (PPI)	Level
1	0	Nil (N)
2	1-5	Low (L)
3	5-10	Medium (M)
4	>10	High (H)

Results and discussion

Among the different pesticides tested at recommended dosage, malathion 50 EC (2 ml/litre), profenophos 50 EC (1 ml/litre), chlorpyriphos 20 EC (2.5 ml/litre), alphamethrin 10 EC (0.25 ml/litre), imidacloprid 17.8 SL (0.3 ml/litre) and spiromesifen 240 SC (2ml/litre) produced the per cent phytotoxicity index of 1.88, 20.2, 2.11, 1.61, 0.5 and 10.3, respectively. Other pesticides such as acephate 75 SP (1 g/litre), methomyl 40 SP (0.6 g/litre), cypermethrin 10EC (0.5 ml/litre), fipronil 5 SC (0.5 ml/litre), carbofuron 3G (30 kg/ha), phorate 10G (40 kg/ha), chlorantraniliprole 18.5 SC (0.15 ml/litre), emamectin benzoate 0.5 SG (0.2 g/litre) and NSKE 5% were found safe to the sorghum at recommended dosage (Table III).

At two times the recommended dosage, malathion 50 EC (4 ml/litre), profenophos 50 EC (2 ml/litre), methomyl 40 SP (1.2 g/litre), chlorpyriphos 20EC (5 ml/litre), alphamethrin 10EC (0.5 ml/litre), imidacloprid 17.8 SL (0.6 ml/litre) andspiromesifen 240 SC (4 ml/litre) produces the per cent phytotoxicity index of 3.55, 44.1, 1.58, 8.18, 3.27, 1.62 and 13.5, respectively. Other pesticides such as acephate 75 SP (2 g/litre), cypermethrin 10EC (1 ml/litre), fipronil 5 SC (1 ml/litre), carbofuron 3G (60 kg/ha), phorate 10G (80 kg/ha), chlorantraniliprole 18.5 SC (0.3 ml/litre), emamectin benzoate 0.5 SG (0.4 g/litre) and NSKE 10% were found safe to the sorghum at two times the recommended dosage (Table III).

Four times the recommended dosage, malathion 50 EC (8 ml/litre), profenophos 50 EC (4 ml/litre), methomyl 40 SP (2.4 g/litre),chlorpyriphos 20 EC (10 ml/litre), cypermethrin 10 EC (2 ml/litre), alphamethrin 10 EC (1 ml/litre), imidacloprid 17.8 SL (1.2 ml/litre) and spiromesifen 240 SC (8 ml/litre) produced the per cent phytotoxicity index of 6.35, 56.1, 3.38, 10.2, 3.38, 8.96, 1.14 and 16.7, respectively. Other pesticides such as acephate 75 SP (4 g/lire), fipronil 5 SC (2 ml/litre), carbofuron 3G (120 kg/ha), phorate 10G (160 kg/ha), chlorantraniliprole 18.5 SC (0.6 ml/litre), emamectin benzoate (0.8 g/litre) and NSKE 20 % were found safe to the sorghum at two times the recommended dosage (Table III).

Table 3: Evaluation of pesticides for their phytotoxic studies in sorghum (mean of all 3 sprays).

Pesticides	Per cent phytotoxicity index (PPI)														
	Dosage (g/ml/litre/ha)			Seedling stage			Vegetative stage			Reproductive stage			Mean of all stages		
	X	2X	4X	X	2X	4X	X	2X	4X	X	2X	4X	X	2X	4X
Acephate 75 SP	1.0	2.0	4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Malathion 50 EC	2.0	4.0	8.0	3.66	5.66	10.3	2.00	5.00	6.00	0.00	0.00	2.75	1.88	3.55	6.35
Profenophos 50 EC	1.0	2.0	4.0	8.76	14.8	35.0	9.66	52.0	64.8	42.3	65.6	68.6	20.2	44.1	56.1
Methomyl 40 SP	0.6	1.2	2.4	0.00	3.00	5.90	0.00	1.75	2.75	0.00	0.00	1.50	0.00	1.58	3.38
Chlorpyriphos 20EC	2.5	5.0	10.0	3.00	12.8	18.6	2.33	10.0	10.0	1.00	1.75	2.25	2.11	8.18	10.2
Cypermethrin 10EC	0.5	1.0	2.0	0.00	0.00	4.83	0.00	0.00	3.33	0.00	0.00	2.00	0.00	0.00	3.38
Alphamethrin 10EC	0.25	0.5	1.0	2.33	4.58	13.0	1.50	4.00	9.30	1.00	1.25	4.60	1.61	3.27	8.96
Fipronil 5 SC	0.5	1.0	2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbofuron 3G	30	60	120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phorate 10G	40	80	160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imidacloprid 17.8 SL	0.3	0.6	1.2	1.50	2.33	3.40	0.00	1.50	3.33	0.00	1.00	2.40	0.50	1.62	1.14
Chlorantrailiprole18.5SC	0.15	0.3	0.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E.benzoate 0.5 SG	0.2	0.4	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spiromesifen 240 SC	2.0	4.0	8.0	21.6	29.2	36.0	9.33	11.5	14.1	0.00	0.00	0.00	10.3	13.5	16.7
NSKE (%)	5.0	10.0	20.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Control (water spray)	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

X= recommended dose, 2X= two times the recommended, 4X= four times the recommended dose

Different pesticides tested at recommended dosage the highest yield was recorded in the treatment fipronil 5 SC (0.5 ml/litre) treated plot (29.2 q/ha), followed by NSKE 5 per cent (29.13 q/ha), other chemicals *viz.*, imidacloprid 17.8 SL (0.3 ml/litre), carbofuron 3G (30 kg/ha) and phorate 10 G (40 kg/ha) were found to be on par with each other (27, 26.4 and 26.2 q/ha, respectively). And the lowest yield was recorded in the treatment control plot (20.72 q/ha) followed by spiromesifen 240 SC (2 ml/litre) and profenophos 50 EC (1 ml/litre) (21 and 21.4 q/ha), respectively (Table IV).

Among the different pesticides tested at two times the recommended dosage, the highest yield was recorded in the treatment fipronil 5 SC (1 ml/litre) treated plot and NSKE 10 per cent (29.5 q/ha), followed by other chemicals *viz.*, acephate 75 SP (2 g/litre), carbofuron 3G (60 kg/ha), phorate 10 G (80 kg/ha) and chlorantraniliprole 18.5 SC (0.3 ml/litre) were found to be on par with each other (27.8, 27, 26.4 and 26.1 q/ha, respectively) and the lowest yield was recorded in the treatment spiromesifen 240 SC (4 ml/litre) (19.6 q/ha) followed by profenophos 50 EC (2 ml/litre) (21.0 q/ha), other treatments *viz.*, control, cypermethrin 10 EC (1 ml/litre) and alphamethrin 10 EC (0.5 ml/litre) were found to be on par with each other (20.72, 21.9, and 23.7 q/ha), respectively (Table IV).

At four times the recommended dosage of pesticides tested the highest yield was recorded in the treatment fipronil 5 SC (2 ml/litre) treated plot (29.8 q/ha) followed by NSKE 20 per cent (29.08 q/ha), followed by other chemicals *viz.*, acephate 75 SP (4 g/litre), chlorantraniliprole 18.5 SC (0.6 ml/litre), carbofuron 3G (120 kg/ha), and phorate 10 G (160 kg/ha) were found to be on par with each other (27.8, 27.7, 27.2 and 26.9 q/ha), respectively, and the lowest yield was recorded in the treatment spiromesifen 240 SC (8 ml/litre) (17.86 q/ha) followed by profenophos 50 EC (4 ml/litre) (18.1 q/ha), other treatments viz., malathion 50 EC (8 ml/litre) and control plots are on par with each other (20.6 and 20.72 q/ha, respectively) (Table IV).

Table 2: Effect of phytotoxicity of different pesticides on grain yield of sorghum.

Sl.no	Pesticides	Grain yield (q/ha)			Mean of all stages (PPI)			Phytotoxicity level		
		X	2X	4X	X	2X	4X	X	2X	4X
1	Acephate 75 SP	25.6^{a-e}	27.8^{ab}	27.8^{ab}	0.00	0.00	0.00	N	N	N
2	Malathion 50 EC	26.2^{a-d}	24.8^{a-e}	20.6^{de}	1.88	3.55	6.35	L	L	M
3	Profenophos 50 EC	21.4^{c-e}	21.0^{ef}	18.1^{e}	20.2	44.1	56.1	H	H	H
4	Methomyl 40 SP	23.4^{b-e}	22.2^{c-f}	20.7^{de}	0.00	1.58	3.38	N	L	L
5	Chlorphyriphos 20EC	24.4^{a-e}	23.6^{b-f}	21.4^{c-e}	2.11	8.18	10.2	L	M	H
6	Cypermethrin 10 EC	25.6^{a-e}	21.9^{d-f}	21.0^{de}	0.00	0.00	3.38	N	N	L
7	Alphamethrin 10 EC	24.0^{a-e}	23.7^{b-f}	22.3^{b-e}	1.61	3.27	8.96	L	L	M
8	Fipronil 5% SC	29.2^{a}	29.5^{a}	29.8^{a}	0.00	0.00	0.00	N	N	N
9	Carbofuron 3G	26.4^{a-c}	27.0^{a-c}	27.2^{ab}	0.00	0.00	0.00	N	N	N
10	Phorate 10G	26.2^{a-d}	26.4^{a-d}	26.9^{a-c}	0.00	0.00	0.00	N	N	N
11	Imidacloprid 17.8 SL	27.0^{ab}	24.1^{b-f}	21.4^{c-e}	0.50	1.62	1.14	L	L	L
12	Chlorantraniliprole18.5 SC	25.9^{a-e}	26.1^{a-d}	27.7^{ab}	0.00	0.00	0.00	N	N	N
13	E. benzoate 0.5 SG	24.05^{a-e}	24.2^{b-f}	24.4^{a-d}	0.00	0.00	0.00	N	N	N
14	Spiromesifen 240 SC	21.00^{de}	19.6^{f}	17.86^{e}	10.3	13.5	16.7	H	H	H
15	NSKE	29.13^{a}	29.5^{a}	29.08^{a}	0.00	0.00	0.00	N	N	N
16	Control	20.72^{e}	20.72^{ef}	20.72^{de}	0.00	0.00	0.00	N	N	N
	SEm±	1.53	1.43	1.70						
	C.D. (P= 0.05)	4.61	4.31	5.11						
	CV (%)	8.65	8.24	10.19						

X= Recomended dose; 2X= 2 times the recommended dose; 4X=4 times the recommended dose
L= Low; M=Medium; H=High; N=Nil

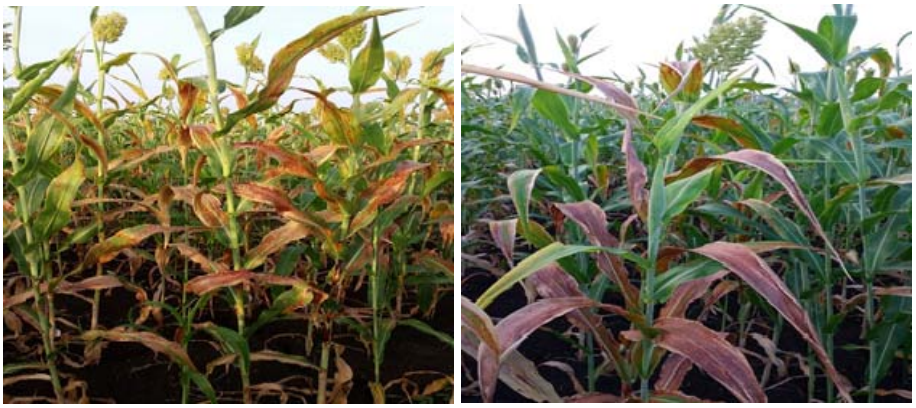
Different pesticides tested for phytotoxicity, malathion 50 EC, profenophos 50 EC, methomyl 40 SP, chlorpyriphos 20 EC, cypermethrin 10 EC, alphamethrin 10 EC, imidacloprid 17.8 SL and spiromesifen 240 SC produces the different phytotoxic symptoms like chlorosis, white blotches, and bronzing to a various extent. The pesticides such as acephate 75 SP, fipronil 5 SC, carbofuron 3 G, phorate 10 G, chlorantraniliprole 18.5 SC, emamectin benzoate 0.5 SG, and NSKE did not exhibit any type of phytotoxic symptoms at recommended, two times the recommended and four times the recommended dosage. Hence these pesticides were used for the management of key pests in sorghum.

Among the different chemicals tested for phytotoxicity, the spiromesifen 240 SC recorded the highest per cent phytotoxicity index at the seedling stage, it will leads to the reduction in the chlorophyll content of the plant, and hence yield will be reduced. The profenophos 50 EC produced the phytotoxic symptoms (bronzing) at all stages of the crop growth, the chlorophyll content will be reduced and hence the yield will automatically reduced. Hence the phytotoxicity of pesticides is inversly related with grain yield of sorghum.

The present results are agreement with findings of Ningaraj and Shekarappa (2015) [7] reported that six chemical insecticides *viz.*, lambda cyhalothrin 5 EC (0.5 ml/l), alphamethrin 10 EC (0.5 ml/l), fenvalerate 20 EC (0.5 ml/l), quinalphos 25 EC (2 ml/l), dimethoate 30 EC (1.7 ml/l) and malathion 50 EC (2 ml/l) exhibited phyototoxicity symptoms like white blotch and bronzing at various levels in *kharif* sorghum. Similarly Balikai and Lingappa (2003) [2] who reported that application of dimethoate caused phytotoxicity to sorghum leaves.

The perusal of literature revealed that there is scanty work on effect of phytotoxicity of yield of sorghum. However, the present findings can be compared with the reports of Meisch *et al*. (1970**)** [5] who reported that parathion and methyl parathion (0.5 and 1.0 a.i/acre) caused greatest visual leaf damage and resulted in significant yield losses when applied to TE77 variety of sorghum. Methyl parathion (1.0 a.i/acre) also reduced yields of RS 626 variety of sorghum. And Mishra *et al*. (2014) [6] reported that, profenophos 50 EC (curacron) 0.02, 0.05, 0.08, 0.1 and 0.2 per cent, all morphological traits and pigments were significantly reduced

with increase in pesticide concentration in the *Vigna radiata*. Similarly, Freeman (1978) [3] reported that, combination of herbicide eradicance and fonofos insecticide caused 29 per cent malformation of earheads in maize. The injury ranged from slight to severe curvature of the ear together with shortening and twisting of the husk.



Phytotoxic symptoms due to profenophos insecticide on sorghum

Toxicity symptoms due to spiromesifen 240 SC in sorghum

Conclusion

Malathion 50 EC, profenophos 50 EC, methomyl 40 SP, chlorpyriphos 20 EC, cypermethrin 10 EC, alphamethrin 10 EC, imidacloprid 17.8 SL and spiromesifen 240 SC produced different phytotoxic symptoms like chlorosis, white blotches, and bronzing to a various extent. The pesticides such as acephate 75 SP, fipronil 5 SC, carbofuron 3 G, phorate 10 G, chlorantraniliprole 18.5 SC, emamectin benzoate 0.5 SG, and NSKE did not exhibit any type of phytotoxic symptoms at recommended, two times the recommended and four times the recommended dosage and were found to be safe to the sorghum crop. Yield parameters are inversely correlated with the phytotoxicity of pesticides. The lowest yield was recorded in the spiromesifen 240 SC (21.0, 19.6, 17.86 q/ha) at recommended, two and four times the recommended dose treatments, respectively and was followed by profenophos 50 EC. The highest yield was recorded in the fipronil 5 SC (29.2, 29.5, 29.8 q/ha) at recommended, two and four times the recommended dose, respectively and was followed by NSKE treated plots.

Hence for managing the insect pests in sorghum the safer insecticides such as Acephate, Fipronil, imidacloprid and NSKE were found to be effective.

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