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BIO-EFFICACY OF INSECTICIDES AGAINST SAFFLOWER LEAF EATING CATERPILLAR *Perigea capensis* Guenée UNDER FIELD CONDITION

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ABSTRACT

Studies on the field efficacy of different new insecticide molecules and botanicals against safflower leaf eating caterpillar *Perigea capensis* Guenée under field condition was conducted during 2014. All the treatments rendered significant suppression of leaf eating caterpillar compared to untreated control. Among the chemical treatments, least larval population was recorded in chlorantraniliprole 18.5 SC which was significantly superior in recording the lowest population and was on par with emamectin benzoate 5 SG, flubendiamide 480 SC and spinosad 45 SC. Among botanicals significantly lowest larval population was recorded in the treatment with garlic chilli kerosene extract @ 2 per cent which was significantly superior in recording the lowest population and was on par with NSKE @ 5 per cent and chilli garlic aqueous extract @ 3 per cent. Among chemical treatments highest grain yield and BC ratio was realised in chlorantraniliprole 18.5 SC and emamectin benzoate 5 SG followed by flubendiamide 480 SC and spinosad 45 SC.

KEYWORDS: Safflower, *Perigea capensis,* New molecules and Botanicals

INTRODUCTION

Safflower (*Carthamus tinctorius* Linn.) is one of the important *rabi* oilseed crops cultivated in India. In India, safflower is mainly grown in the drought prone areas of Maharashtra, Karnataka and Andhra Pradesh either as a strip crop, mixed crop, border crop or as a sole crop. In India, Maharashtra is the leading producer (63%) of safflower from the largest growing area of 67 per cent followed by Karnataka (32% in production and 27% in area) (Jadhav *et al.,* 2012).

Among the several factors that are responsible for safflower yield loss, insect pests contribute a major share. A total of 101 insect pests have been recorded on safflower throughout the world (Vijay Singh *et al*., 1996). In Karnataka, 20 insect pests have been recorded on safflower along with nine species of natural enemies (Mallapur *et al*., 1997).

Safflower aphid, *Uroleucon compositae* Theobold, capsule borer, *Helicoverpa armigera* (Hub.) and leaf eating caterpillar, *Perigea capensis* Guenée are considered as major pests which cause severe damage to safflower causing high to very high levels of infestation. During the recent years, the incidence of safflower leaf eating caterpillar is increasing in Karnataka (Balikai, 2000). Since, not much work has been carried out on the incidence and management of *Perigea capensis*, the research for evaluation of newer insecticides was the need of the hour in effective management of the pest.

MATERIAL AND METHODS

The experiment was conducted at Regional Agricultural Research Station (RARS), Vijayapur during *rabi* 2014-15. The experiment was laid out in randomized block design in three replications with sixteen treatments. The size of each plot was 17.64 m^2 (4.2 m × 4.2 m). The crop was raised using A-1 variety of safflower with a spacing of 60 cm × 30 cm by adopting recommended agronomical practices. Totally there were 16 treatments including control. Treatments were imposed twice at an interval of 20 days when leaf eating caterpillar population exceeded economic threshold level.

Observations were recorded on number of safflower leaf eating caterpillars from five randomly selected plants from each treatment a day before and three, seven, nine and fifteen days after each spray. The larval population count was recorded and later data was transformed to $\sqrt{X + 0.5}$ before analysis. Per cent larval reduction was subjected to arc sine transformation before analysis. Grain yield from each plot with respect to the treatments was

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recorded after harvest and was expressed as q ha^{-1}. Later data was analyzed using ANOVA technique and subjected to DMRT (Duncan's Multiple Range Test).

RESULTS AND DISCUSSION

A day before spray, there was no statistical significant difference among the treatments with respect to mean number of larvae per plant. The larval population in different treatment was uniform and ranged from 3.47 to 4.20 per plant (Table 1).

In first spray, at three day after spray, there was a significance difference among the treatments where the population of leaf eating caterpillar ranged between 1.20 to 4.37 larvae per plant. The plots sprayed with chlorantraniliprole 18.5 SC @ 0.15 ml/l recorded least number of larvae per plant (1.20 larvae/plant) which was on par with emamectin benzoate 5SG @ 0.2gm/l (1.30 larvae /plant), flubendiamide 480 SC @ 0.1ml/l (1.47 larvae/plant), spinosad 45 SC @ 0.15ml/l (1.60 larvae/ plant) and indoxacarb 15 EC @ 0.3ml/l (1.73 larvae/ plant). Among the botanicals, garlic chilli kerosene extract @ 2 per cent recorded less number of larvae per plant (2.47 larvae/plant) which was statistically on par with NSKE @ 5 per cent (2.60 larvae /plant), chilli garlic aqueous extract 3 per cent (2.73 larvae/plant) and nimbecidine 1500ppm @ 5 ml/l (3.03 larvae/plant). The highest number of larvae (4.37 larvae/plant) were observed in control followed by treatments with neem oil 10 ml/l (3.23 larvae/plant) and *Vinca rosea* @ 2 per cent (3.17 larvae/plant) which were statistically inferior to other treatments. With respect to the per cent larval reduction, the highest reduction of larval population (72.22%) was observed in the plots treated with chlorantraniliprole 18.5 SC @ 0.15 ml/l followed by emamectin benzoate 5SG @ 0.2gm/l (58.82%), flubendiamide 480 SC @ 0.1ml/l (61.11%) and spinosad 45 SC @ 0.15ml/l (50.00%). The least reduction (8.57 %) of population was in neem oil @ 10ml/l and *Vinca rosea* @ 2 per cent (15.79%) (Table 1).

At seven day after spray, the larval population ranged between 0.07 to 4.93 larvae per plant. The least number of larvae per plant (0.07) were recorded in chlorantraniliprole 18.5 SC, which was on par with emamectin benzoate 5SG (0.13), flubendiamide 480 SC (0.27), spinosad 45 SC (0.30 larvae /plant) and indoxacarb 15 EC (0.87 larvae/plant each). Similarly, the highest larval reduction (97.22%) was recorded in the plots sprayed with chlorantraniliprole 18.5 SC, followed by emamectin benzoate 5SG (94.44%), flubendiamide 480 SC (94.12%), spinosad 45 SC (70.04%) and indoxacarb 15 EC (83.33%). The least per cent reduction (28.57%) of population was recorded in neem oil @ 10ml/l and *Vinca rosea* 2% (35.47 %) (Table 1).

In second spray, at three day after spray, the treatments with chlorantraniliprole 18.5 SC recorded least number of larvae per plant (0.40 larvae/plant) which was on par with emamectin benzoate 5SG (0.47 larvae/plant), flubendiamide 480 SC (0.57 larvae/plant), spinosad 45 SC (0.60 larvae/plant) and indoxacarb 15 EC (1.00 larvae/ plant). The data on per cent reduction revealed that, chlorantraniliprole 18.5 SC recorded highest per cent reduction (68.19%) of larvae followed by emamectin benzoate 5SG (65.16%), flubendiamide 480 SC (55.70%) and spinosad 45 SC (55.08%) (Table 2).

The mean population of *Perigea capensis* was between 0.07 to 5.57 larvae/plant at seven days after spray. Among the treatments, least number of larvae per plant (0.07) were recorded in chlorantraniliprole 18.5 SC, which was on par with emamectin benzoate 5SG (0.10), flubendiamide 480 SC (0.13), spinosad 45 SC (0.13 larvae/plant) and indoxacarb 15 EC (0.37 larvae/plant). The highest larval reduction (93.45%) was also recorded in the plot sprayed with chlorantraniliprole 18.5 SC, followed by emamectin benzoate 5SG (92.62%), flubendiamide 480 SC (90.01%), spinosad 45 SC (79.82%) and indoxacarb 15 EC (65.18%) (Table 2). Similar trend was noticed at nine and fifteen days after both first and second spray.

In general, chlorantraniliprole 18.5 SC, emamectin benzoate 5 SG, flubendiamide 480 SC and spinosad 45 SC shown more efficacy only up to nine days after spraying. Later, the larval population was increased due to reduced efficacy of insecticides.

Chlorantraniliprole belongs to a new class of selective insecticides (anthranilic diamides) featuring a novel mode of action. By activating the insect ryanodine receptors (RyRs) it stimulates the release and depletion of intracellular calcium ions from the sarcoplasmic reticulum of muscle cells, causing impaired muscle regulation, paralysis and ultimately death of sensitive species. It has very low toxicity for mammals (both acute and chronic), high intrinsic activity on target pests, strong ovi-larvicidal and larvicidal properties, long lasting crop protection and no cross-resistance to any existing insecticide.

Table 1. Effect of insecticides and botanicals on safflower leaf eating caterpillar, *Perigea capensis* (1st spray)

Sl. No.	Treatments	Dosage ml/gm/l	Number of larvae/plant					Per cent reduction			
			1 DBS	3 DAS	7 DAS	9 DAS	15 DAS	3 DAS	7 DAS	9 DAS	15 DAS
1	Chlorantraniliprole 18.5 SC	0.15	3.47 (1.99)	1.20 (1.30)^{a}	0.07 (0.75)^{a}	0.03 (0.73)^{a}	0.13 (0.80)^{a}	72.22 (53.92)	97.22 (83.48)	99.02 (86.67)	97.22 (78.80)
2	Emamectin benzoate 5 SG	0.2	3.33 (1.96)	1.30 (1.34)^{a}	0.13 (0.79)^{a}	0.10 (0.77)^{a}	0.20 (0.84)^{a}	58.82 (51.35)	94.12 (80.46)	97.00 (79.99)	94.12 (75.79)
3	Flubendiamide 480 SC	0.1	3.50 (2.00)	1.47 (1.40)^{ab}	0.27 (0.87)^{ab}	0.23 (0.86)^{ab}	0.33 (0.91)^{a}	61.11 (49.63)	94.44 (74.13)	93.33 (75.07)	91.67 (72.02)
4	Indoxacarb 15 EC	0.3	3.40 (1.97)	1.73 (1.49)^{abc}	0.87 (1.15)^{cd}	0.73 (1.11)^{b}	0.83 (1.15)^{ab}	55.56 (44.29)	77.22 (63.13)	78.44 (62.31)	80.56 (60.24)
5	Spinosad 45 SC	0.15	3.67 (2.04)	1.60 (1.45)^{ab}	0.30 (0.89)^{ab}	0.47 (0.98)^{ab}	0.57 (1.03)^{a}	50.00 (48.63)	83.33 (70.04)	87.18 (69.21)	86.11 (66.84)
6	Indoxacarb 15 EC	0.15	3.43 (1.98)	2.20 (1.64)^{cde}	1.53 (1.43)^{cde}	1.67 (1.47)^{bc}	1.93 (1.56)^{cd}	40.44 (36.63)	55.56 (46.86)	51.32 (45.74)	50.00 (41.26)
7	Profenophos 50 EC	2	3.77 (2.07)	2.67 (1.78)^{de}	1.47 (1.40)^{cd}	1.53 (1.41)^{c}	1.70 (1.47)^{cd}	28.58 (32.38)	60.53 (51.54)	58.94 (50.46)	73.68 (47.48)
8	Malathion dust 5D	20 kg/ha	3.87 (2.09)	3.30 (1.95)^{e}	2.57 (1.75)^{e}	2.70 (1.79)^{e}	3.07 (1.88)^{d}	10.00 (22.41)	35.00 (35.35)	30.19 (33.31)	20.00 (26.55)
9	Fenvalerate dust 0.4 DP	25 kg/ha	3.83 (2.08)	3.13 (1.91)^{e}	2.40 (1.67)^{de}	2.57 (1.75)^{e}	2.93 (1.84)^{d}	21.62 (25.29)	38.92 (37.68)	32.98 (34.98)	31.95 (29.09)
10	NSKE 5%	50	3.60 (2.02)	2.60 (1.76)^{de}	1.43 (1.31)^{def}	2.13 (1.60)^{def}	2.27 (1.65)^{cd}	22.22 (31.64)	60.00 (41.01)	40.29 (36.73)	24.89 (28.87)
11	*Vinca rosea* 2%	20	3.70 (2.04)	3.17 (1.90)^{ef}	2.30 (1.67)^{de}	2.37 (1.68)^{def}	2.63 (1.77)^{d}	15.79 (22.42)	35.47 (35.80)	36.88 (37.24)	18.13 (22.20)
12	Garlic Chilli Kerosene Extract 2%	20	3.53 (2.01)	2.47 (1.72)^{de}	1.40 (1.39)^{cd}	1.87 (1.54)^{def}	2.07 (1.60)^{cd}	25.71 (33.12)	54.29 (44.46)	47.01 (43.26)	37.14 (32.54)
13	Chilli Garlic Aqueous Extract 3%	30	3.73 (2.06)	2.73 (1.79)^{de}	2.20 (1.64)^{de}	2.33 (1.67)^{def}	2.50 (1.68)^{d}	20.00 (31.19)	50.00 (39.25)	37.76 (37.31)	34.55 (30.40)
14	Neem oil	10	3.57 (2.02)	3.23 (1.92)^{e}	2.50 (1.73)^{e}	2.63 (1.77)^{e}	2.87 (1.83)^{d}	8.57 (17.44)	28.57 (33.10)	25.93 (30.44)	12.12 (23.38)
15	Nimbecidine 1500 ppm	5	3.80 (2.07)	3.03 (1.86)^{de}	2.33 (1.68)^{e}	2.47 (1.72)^{ef}	2.57 (1.75)^{d}	25.00 (26.52)	42.50 (38.34)	35.15 (36.30)	25.00 (31.64)
16	Untreated check	-	4.20 (2.17)	4.37 (2.21)^{f}	4.93 (2.33)^{f}	5.63 (2.48)^{f}	6.27 (2.60)^{e}	-	-	-	-
	S.Em ±		0.04	0.08	0.11	0.08	0.10	1.71	2.34	4.51	1.72
	CD at 5 %		0.18	0.24	0.33	0.25	0.30	5.13	7.02	13.52	5.14
	CV (%)		3.49	8.09	13.69	9.8	11.80	9.00	8.37	16.50	7.12

Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values DBS – Day Before Spray DAS – Days After Spray.

Table 2. Effect of insecticides and botanicals on safflower leaf eating caterpillar, *Perigea capensis* (2nd spray)

S. No.	Treatments	Dosage ml/gm/l	No. of larvae per plant					Per cent reduction			
			1 DBS	3 DAS	7 DAS	9 DAS	15 DAS	3 DAS	7 DAS	9 DAS	15 DAS
1	Chlorantraniliprole 18.5 SC	0.15	1.33 (1.35)	0.40 (0.95)^{a}	0.07 (0.75)^{a}	0.03 (0.73)^{a}	0.13 (0.80)^{a}	68.19 (71.41)	93.45 (77.90)	97.62 (84.80)	89.75 (71.41)
2	Emamectin benzoate 5 SG	0.2	1.37 (1.37)	0.47 (0.98)^{a}	0.10 (0.77)^{a}	0.07 (0.75)^{a}	0.17 (0.81)^{a}	65.16 (70.36)	92.62 (79.39)	94.84 (79.21)	88.17 (70.36)
3	Flubendiamide 480 SC	0.1	1.50 (1.39)	0.57 (1.03)^{a}	0.13 (0.80)^{a}	0.10 (0.77)^{a}	0.23 (0.86)^{a}	55.70 (62.00)	90.01 (73.35)	87.91 (73.83)	77.92 (62.00)
4	Indoxacarb 15 EC	0.3	2.10 (1.57)	1.00 (1.20)^{a}	0.37 (0.93)^{ab}	0.43 (0.96)^{b}	0.57 (1.03)^{ab}	55.04 (50.14)	65.18 (53.03)	68.90 (56.09)	58.93 (50.14)
5	Spinosad 45 SC	0.15	1.47 (1.37)	0.60 (1.05)^{a}	0.13 (0.80)^{a}	0.20 (0.84)^{b}	0.27 (0.88)^{a}	55.08 (57.89)	79.82 (68.54)	86.57 (63.54)	68.56 (54.67)
6	Indoxacarb 15 EC	0.15	2.93 (1.81)	2.10 (1.61)^{bc}	1.17 (1.25)^{cd}	1.23 (1.31)^{de}	1.70 (1.48)^{bc}	28.32 (34.41)	47.38 (42.14)	44.31 (41.71)	31.98 (34.41)
7	Profenophos 50 EC	2	2.63 (1.70)	1.70 (1.48)^{c}	0.90 (1.17)^{de}	0.97 (1.19)^{ef}	1.47 (1.30)^{bc}	35.06 (40.71)	47.16 (43.53)	45.64 (42.48)	42.58 (40.71)
8	Malathion dust 5 D	20 kg/ha	3.53 (2.01)	2.90 (1.84)^{c}	2.17 (1.63)^{f}	2.27 (1.65)^{ef}	2.87 (1.83)^{d}	18.79 (25.27)	39.18 (38.73)	34.31 (35.83)	18.26 (25.27)
9	Fenvalerate dust 0.4 DP	25 kg/ha	3.43 (1.98)	2.93 (1.85)^{c}	2.07 (1.60)^{f}	2.20 (1.64)^{ef}	2.80 (1.82)^{d}	14.03 (25.32)	39.61 (38.97)	35.15 (36.33)	18.34 (25.32)
10	NSKE 5%	50	3.07 (1.87)	2.50 (1.73)^{bc}	1.73 (1.49)^{bc}	1.67 (1.46)^{de}	2.30 (1.67)^{cd}	16.24 (26.67)	35.07 (39.30)	27.89 (34.20)	20.17 (27.34)
11	*Vinca rosea* 2%	20	3.17 (1.88)	2.80 (1.82)^{c}	2.10 (1.61)^{b}	2.23 (1.64)^{ef}	2.60 (1.74)^{d}	6.48 (19.61)	23.56 (32.00)	23.56 (28.99)	11.33 (19.61)
12	Garlic chilli kerosene extract 2%	20	2.97 (1.86)	2.33 (1.68)^{bc}	1.53 (1.42)^{cde}	1.60 (1.44)^{ef}	2.13 (1.62)^{cd}	18.57 (30.64)	47.67 (43.64)	36.45 (37.12)	26.01 (30.64)
13	Garlic chilli aqueous extract 3%	30	3.13 (1.91)	2.60 (1.76)^{c}	1.80 (1.51)^{de}	2.10 (1.61)^{ef}	2.50 (1.73)^{d}	16.37 (26.60)	42.93 (37.58)	32.22 (32.22)	20.20 (25.93)
14	Neem oil	10	3.53 (1.89)	2.97 (1.86)^{c}	2.10 (1.60)^{e}	2.63 (1.77)^{e}	3.03 (1.87)^{d}	13.72 (17.83)	45.07 (28.78)	18.29 (25.26)	9.40 (17.83)
15	Nimbecidine 1500ppm	5	3.17 (1.90)	2.60 (1.76)^{c}	1.87 (1.53)^{de}	2.03 (1.59)^{ef}	2.40 (1.70)^{d}	16.16 (23.29)	34.26 (35.95)	29.42 (32.66)	16.37 (23.29)
16	Untreated check	-	5.43 (2.42)	5.33 (2.41)^{d}	5.57 (2.46)^{g}	5.87 (2.52)^{g}	7.07 (2.75)^{e}	-	-	-	-
	S.Em ±		0.23	0.11	0.09	0.08	0.12	1.84	2.48	3.34	1.77
	CD at 5 %		1.06	0.31	0.28	0.25	0.36	5.52	7.43	10.01	5.29
	CV (%)		22.33	11.07	11.93	10.42	13.80	8.76	9.34	13.04	8.45

Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values DBS – Day Before Spray DAS – Days After Spray.

Table 3: Seed yield and economics of safflower crop as influenced by different insecticides and botanicals

S. No.	Treatments	Dosage ml/g/ha	Yield (q ha^{-1})	Gross income (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net income (₹ ha^{-1})	B C ratio
1	Chlorantraniliprole 18.5 SC	75 ml	12.34	44421.77	16645.66	27776.11	2.67
2	Emamectin benzoate 5 SG	100 gm	11.39	41020.41	15495.66	25524.75	2.65
3	Flubendiamide 480 SC	50 ml	11.04	39727.89	15495.66	24232.23	2.56
4	Indoxacarb 15 EC	150 ml	10.07	36258.50	15435.66	20822.84	2.35
5	Spinosad 45 SC	75 ml	10.77	38775.51	15320.66	23454.85	2.53
6	Indoxacarb 15 EC	75 ml	8.60	30952.38	15115.66	15836.72	2.05
7	Profenophos 50 EC	1000	8.54	30748.30	15335.66	15412.64	2.01
8	Malathion dust 5 D	20 kg	7.88	28367.35	15395.66	12971.69	1.84
9	Fenvalerate dust 0.4 D P	25 kg	8.28	29795.92	15795.66	14000.26	1.89
10	NSKE 5%	-	8.45	30408.16	15095.66	15312.50	2.01
11	*Vinca rosea* 2%	-	5.97	18231.29	15045.66	3185.63	1.21
12	Garlic chilli kerosene extract 2%	-	8.20	29523.81	15295.66	14228.15	1.93
13	Garlic chilli aqueous extract 3%	-	7.73	25714.29	15195.66	10518.63	1.69
14	Neem oil	-	5.06	21496.60	15395.66	6100.94	1.40
15	Nimbecidine 1500ppm	-	7.14	27823.13	15520.66	12302.47	1.79
16	Untreated check		3.08	11088.44	14795.66	-3707.22	0.75
	S.Em ±		0.17	-	-	-	-
	CD@ 5%		0.51	-	-	-	-
	CV (%)		20.06	-	-	-	-

Emamectin benzoate is a novel semi-synthetic derivative of the natural product in the avermectin family of 16-membered macrocylic lactones derived from the fermentation of the soil actinomycete *Streptomyces avermitilis*. The mode of action is similar to abamectin (GABA and glutamate-gated chloride channel agonist) (Jansson *et al.,* 1996). Flubendiamide a novel class of insecticide having a unique chemical structure used against broad spectrum of lepidopterous insect pests including resistance strains. It has a unique mode of action i.e. acts on ryanodine receptor modulator (Tohnishi *et al.,* 2005). Spinosad is the active ingredient proposed for a new class of insect control products like naturalytes. Spinosad is derived from the metabolites of the naturally occurring actinomycetes, *Saccharopolyspora spinosa.* It is neuro toxin and acts on nicotinic acetylcholine receptors.

The present results clearly indicated the superiority of these four newer insecticides in controlling safflower leaf eating caterpillar. There is no published literature to compare present findings as the present investigation is first of its kind to evaluate newer insecticides and botanicals against *P. capensis* in safflower crop ecosystem. The efficacy of new insecticides molecules against lepodopteran insect pests is well documented in various crops. Spinosad 45 SC and indoxacarb14.5 SC were found more effective against greengram leaf eating caterpillar, *Agrius convolvuli* (Jayaram, 2006). Similarly, emamectin benzoate 5 SG was found most effective against *Spodoptera litura* in soybean (Harish *et al.,* 2009), *Helicoverpa armigera* in groundnut (Gadhiya *et al.,* 2014) and chickpea (Kambrekar *et al.,* 2012). These findings confirm the efficacy of new molecules used in the present investigation.

The moderate efficacy of GCK (Garlic Chilli Kerosene extract) and NSKE in the present study is inconformity with the results of Hegde and Nandihalli (2009), who found that GCKE recorded least number of eggs of bhendi fruit borer (1.40 eggs/plant) followed by NSKE (5%).

The data pertaining to seed yield and cost economics of different treatments is presented in Table 3. The seed yield obtained from different insecticides and botanicals was significantly higher compared to untreated control. Among the different treatments, chlorantraniliprole 18.5 SC @ 0.15 ml/lit registered higher seed yield (12.34 q/ha) followed by emamectin benzoate 5 SG @ 0.2 g/lit (11.39 q/ha), flubendiamide 480 SC @ 0.10ml/lit (11.04 q/ha) and spinosad 45 SC @ 0.15 ml/lit (10.77 q/ha). Whereas, GCK extract @ 2 per cent recorded seed yield to the extent of 8.45 q/ha followed by NSKE @ 5 per cent (8.20 q/ha) and chilli garlic aqueous extract @ 1 per cent (7.73 q/ha). The lowest seed yield was recorded in neem oil @ 10 ml/lit (5.06 q/ha) followed by *Vinca rosea* @ 2 per cent (5.97 q/ha).

The cost economics of different treatment revealed that, among different chemicals highest net return was realized in the treatment with chlorantraniliprole 18.5 SC @ 0.15 ml/lit (₹ 27776 ha^{-1}) followed by emamectin benzoate 5 SG @ 0.2 g/lit (₹ 25524 ha^{-1}), flubendiamide 480 SC @ 0.10 ml/lit (₹ 24232 ha^{-1}) and spinosad 45 SC @ 0.15 ml/lit (₹ 23454 ha^{-1}). Whereas, among the botanicals, the higher net returns (₹ 15312) per hectare was realized in NSKE @ 5 per cent followed by GCK extract @ 2 per cent (₹ 14228 ha^{-1}) and nembecidine 1500 ppm @ 5 ml/lit (₹ 12302 ha^{-1}). The results on the benefit cost ratio revealed that, among the chemical treatments, highest benefit cost ratio was obtained in chlorantraniliprole 18.5 SC @ 0.15 ml/lit and emamectin benzoate 5 SG @ 0.2 g/lit (2.65) followed by flubendiamide 480 SC @ 0.10 ml/lit (2.56) and spinosad 45 SC @ 0.15 ml/lit (2.53) (Table 3).

In the present investigation, all the chemical treatments recorded significantly superior seed yield and benefit cost ratio over botanicals. The new insecticide molecules used in the present study have shown greater efficacy against safflower leaf eating caterpillar because they have already been found most effective against different lepidopteran pests in various crops. Since, these are having unique mode action and highly toxic to the lepidopteran insect's pests, they have successfully controlled the pest and that has reflected on higher yield and benefit cost ratio. Gadhiya *et al*. (2014) reported that, highest benefit cost ratio 3.3 was observed in chlorantraniliprole (0.006%) treatment in groundnut for the management of both *H. armigera* and *S. litura*. Sreekanth *et al*. (2014) also reported highest benefit cost ratio of 4.64 in chlorantraniliprole 18.5 SC (0.43) treatment in pigeonpea for the management of gram pod borer *H. armigera*. These studies strongly support the results of the present investigation.

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FATTY ACIDS, HYDROCARBON TOLERANCE AND HEAVY METAL TOLERANCE PROPERTIES OF HALOALKALIPHILIC *Bacillus* sp.

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ABSTRACT

Microorganisms live almost everywhere including the harsh habitats on earth. In order to survive in these environments the microbes produce a variety of metabolite productcs and polymeric compounds which confer the ability to survive and thrive in such habitats. The haloalkaliphilic environments are harsher as they have a combination of saturating salinity and precipitating alkalinity, the bacteria like haloalkaliphilic *Bacillus sp.,* are specialized to thrive in these habitats. This is achieved through the production of different compounds including special fatty acids, which confer different properties to the bacteria. In this article the different ectoines produced was assayed by FAME (Fatty Acid Methyl Esters) analysis using GC-MS (Gas Chromatography-Mass Spectroscopy) and ability to tolerate hydrocarbons and heavy metals in the surroundings is measured for three haloalkaliphilic Bacillus sp., isolated from solar salterns. The FAME GC-MS assay revealed the ectoines based fatty acids are different in the three isolates and their quantity also varied among the isolates even the source of isolation was same. The results conclude the more the ectoines produced the more tolerance they showed to hydrocarbons (petrol, diesel, xylene, toluene, and kerosene) and heavy metals (mercury, lead, cadmium, chromium, aluminum, zinc, copper, and nickel). This is the imperative to understand, and even manipulate different bacteria to accumulate/and immobilize heavy metals and decrease the toxicity of hydrocarbons which are the major environmental pollutants.

KEYWORDS: Haloalkaliphilic Bacillus sp.; Fatty Acid Methyl Esters (FAME); Gas Chromatography-Mass Spectroscopy (GC-MS); Hydrocarbons; Heavy metals.

INTRODUCTION

Microorganisms are omnicompetent in survivability, and occupy and thrive in even the harshest of environments comprising the coldest, hottest, saltiest, the most acidic, and alkaline, which are supposed to be inhabitable based on human habitability criteria (Purohit *et al.,* 2014). In some instances the habitats have more than one restraining factor to survive with, such as halophilic milieu has acidity or alkalinity as a second limiting factor, in order to cope with these harsh and limiting environments microorganisms have evolved many distinct and diverse mechanisms making them unique from the rest of the organisms. One such group is haloalkaliphilic species which has the ability to cope with saturating salinity and acidity or alkalinity via., production of certain metabolites and proteins which reduce the stress on cytoplasm and more importantly the fatty acids produced are very effective in protecting the internal cation concentration thus giving rise to "keeping the salt out" strategy (Garabito *et al.,* 1998).

Along with the extracellular proton gradient based pumps to keep the internal ionic proportion the long chain fatty acids like Hentriacontane, Dodecane,1-Fluoro-, 2-T-Butyl-5-Choloromethyl-3-Methyl-4-Oxoimidazolidine-1-Carboxylic Acid, T-Butyl Ester, 1.4-Epoxynaphthalene-(2h)-Methanol, 4, 5, 7-Tris (1, 1-Dimethylethyl)-3, 4-Dihydro, etc, have been shown to play a prominent role in protecting the cell wall from degrading agents like salinity, alkalis, acids and even temperature driven stress also (Kampfer, 1994). There are many species which have these adaptations developed in both facultative and obligatory modes, the later ones are restricted to hyper saline environments only but, the former are widespread and can be termed as haloalkaliphilic in nature if they are able to survive the salinity and alkalinity and comprise of *Halomonas*, *Halobacterium, Halovibrio, Bacillus* etc (Arahal and Ventosa, 2002). But *Bacillus* sp, which have adapted to thrive in halophilic environments have much wider applications owing to the wide range of distribution ecologically and their ability to further tolerate /and thrive in multiple restricting factors make them potential organisms to the current study.

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The haloalkaliphilic *Bacillus* sp., also have multiple applications including, enzyme production, waste degradation (both organic like agricultural and house hold and inorganic from industries like dyes, effluents, etc), metal bioremediation (*via* biosorption), and agricultural applications including plant protection and growth promotion and are easily grown on a variety of substrates with relative ease (Syed, 2016).

The ability of these fascinating organisms has driven many researchers to pursue them in order to gain insight into the molecular basis of their unique properties and ultimately employ those for human purposes like salt water agriculture, desalination of salt water, treatment of acidic or alkaline effluents from industries (leather units, paper mills, textiles, etc), reforestation of contaminated lands to prevent desertification (Ghozlan *et al.,* 2006; Syed, 2016).

The current study employs three isolates of haloalkaliphilic *Bacillus* sp. which showed considerable tolerance to temperature (45°C for optimal growth) and alkalinity (pH 12 for optimal growth) along with moderate salinity (15% salinity threshhold) namely *B. licheniformis NSPA5, B. subtilis NSPA8* and *B. cereus NSPA13* isolated from solar salterns of Nellore district (Syed and Paramageetham, 2015).

MATERIALS AND METHODS

Fatty acid methyl ester (FAME) analysis

The fatty acid methyl ester analysis was carried out by initial growth on standard media; Trypticase soy broth agar medium (TSBA), extraction of cellular fatty acids as their methyl esters followed by GC-MS analysis and finally comparing the GC-MS data with instant libraries The extraction processes involved as follows.

Approximately 20 mg (wet weight) of cells were harvested from the streaked plates and transferred into culture tubes for whole cell fatty acid extraction. The cells were saponified with saponification reagent (The saponification reagent consists of 45 gm of sodium hydroxide in 150 ml of methanol and 150 ml of distilled water). Then culture tubes were capped, vortexed for 10 sec, incubated at 100°C for 5 min and vortexed and again incubated for 25 min and cooled to room temperature. The saponification step lyses the cells and converts the released fatty acids into their sodium salts. These fatty acids were methylated with 2.0 ml of methylation reagent (The methylation reagent consists of 325 ml of 6.0 N HCl and 275 ml methyl alcohol). The tubes were vortexed for 5 sec and placed in water bath at 80° C for 10 min and cooled to room temperature immediately to minimise degradation of fatty acid methyl esters. Then the poorly soluble FAMEs were extracted using 1.25 ml of 1:1 (v/v) solution of hexane and methyl-tert-butyl ether. After capping, the culture tubes were mixed end-over-end continuously for 10 min on a laboratory mixer and the aqueous (lower) phase was extracted using a sterile glass Pasteur pipette. For sample clean up, 3.0 ml of sample clean up reagent was used (The sample clean up reagent consists of 0.27 N NaOH in distilled water). A 3.0 ml of clean up reagent was added to the tubes, rotated again continuously for 5 min. Two thirds of the organic (upper) phase was transferred with glass Pasteur pipette into a glass gas chromatography vial, which was sealed with Teflon-lined caps (Sasser, 1990).

FAMEs were quantified using a Perkin Elmer Clarus 680 Gas Chromatography-Clarus 600 Mass Spectrometer equipped with flame ionization detector and ultra 2-Capillary column. The stationary phase of this column was cross linked to the silica tube which provides low noise and drifting during temperature programmed runs. The temperature program was from 170° C to 270°C for 2 min to clean the column off extraneous material and decrease the possibility of carry over. The inlet temperature was 250° C and it was kept constant at a pressure of 9.0 psi. This gave an initial hydrogen carrier flow of approximately 0.4 ml per minute. The flame ionisation detector temperature was 280° C. The makeup gas was ultra high purity nitrogen set at a constant flow rate of 30 ml per minute. Ultra high purity hydrogen and air to the detector were 40 and 350 ml per minute respectively.

The individual FAMEs were identified by comparisons made by using the National Institute of Standards and Technology (NIST) mass spectral El library (NIST 2014/EPA/NIH) with the obtained Electrical Ionisation peaks of the respective fatty acids from the three isolates.

Hydrocarbon tolerance of the Haloalkaliphilic Bacillus sp.

The hydrocarbon tolerance was measured by adding the particular hydrocarbon in to the liquid medium (Nutrient broth) at 5, 10 and 15 per cent followed by inoculating the same with the isolates NSPA5, NSPA8, and NSA13 individually and measuring the optical density

Table 1. Fatty Acid Methyl Esters analysis of *B. licheniformis* NSPA5

S. No	RT	Name of the Compound	Abundance %	Formula	M.W	CAS NO
1	2.533	Heptane, 1, 1'-Oxybis-[2]	3.314	C14H30O	214	629-64-1
2	2.608	1-Phenyl-5-Methylheptane	4.444	C14H22	190	103240-92-2
3	2.879	Propionic Acid, 2, 2-Dimethyl-, 2-Ethylhexyl Ester	4.230	C13H26O2	214	16387-18-1
4	3.694	O-Oxylene [2]	2.178	C8H10	106	95-47-6
5	4.604	1, 2, 4, 5-Tetrazine, 1, 4-Diethylhexahydro-	1.368	C6H16N4	144	35035-69-9
6	5.795	Dodecane, 1-Fluoro-[6]	7.404	C12H25F	188	334-68-9
7	8.586	Benzene, 1, 1'-(1, 1, 2, 2-Tetramethyl-1, 2-Ethanediyl) Bis-	7.151	C18H22	238	1889-67-4
8	8.966	Hentriacontane [6]	12.714	C31H64	436	630-04-6
9	17.159	1, 2-Benzenedicarboxylic Acid, Bis (2-Methylpropyl) Ester	2.338	C16H22O4	278	84-69-5
10	17.645	7, 9-Di-Tert-Butyl-1-Oxaspiro (4, 5) Deca-6, 9-Diene-2, 8-Dione	3.828	C17H24O3	276	82304-66-3
11	17.790	Tetradecanoic Acid, 10, 13-Dimethyl-, Methyl Ester	4.164	C17H34O2	270	267650-23-7
12	18.130	Dibutyl Phthalate	2.550	C16H24O4	278	84-74-2
13	23.132	1, 2-Benzenedicarboxylic Acid, Mono (2-Ethylhexyl) Ester	4.750	C16H22O4	278	4376-20-9
14	25.203	2, 6, 10, 14, 18, 22-Tetracoashexaene, 2, 6, 10, 15, 19, 23-Hexamethyl-, (All-E)-[2]	4.626	C30H50	410	111-02-4

after a incubation period of 72 hrs and at constant stirring at 37°C. A separate series with only pure hydrocarbon was maintained to assay the hydrocarbon degradation potential of the isolates with similar treatment (Margesin and Schinner, 2001).

Heavy metal tolerance of the haloalkaliphilic Bacillus sp.

The heavy metal tolerance was assayed by using diffusion method on nutrient agar medium (NAM); the solid media was inoculated with the isolates via spread plate technique and the metal solutions prepared as their solutions with 1000 ppm final concentration were placed onto 3 mm discs and a volume of 50 µl was added sequentially to make up to 200 µl and incubated for 24 hrs at 37°C, and the zone of inhibition around each disc was measured in mm (Hassen *et al.,* 1998).

RESULTS AND DISCUSSION

Fatty acid methyl ester (FAME) analysis

The fatty acid composition varied greatly among the three isolates *B. licheniformis NSPA5, B. subtilis NSPA8* and *B.cereus NSPA13.* Different fatty acid variations in their proportions gave rise difference in their response to the assays further carried out. Primarily, the fatty acid composition was assayed using GC-MS assisted FAME analysis of the three isolates *B. licheniformis NSPA5, B. subtilis NSPA8* and *B. cereus NSPA13* and the obtained chromatograms are given in Fig. 1, 2, and 3. The chromatogram clearly indicates the variations as well as the change in the intensity of the peaks also, which might lead to the variations of further analysis. The identified peaks from the NIST library are provided in table-1, 2, and 3. The fatty acids like Heptane, 1, 1'-Oxybis-, Dodecane, 1-Fluoro-, Benzene, 1, 1'-(1, 1, 2, 2-

Table 2. Fatty Acid Methyl Esters analysis of *B.subtilis* NSPA8

S. No.	RT	Name of the Compound	Abundance %	Formula	M.W	CAS-NO
1	2.538	Heptane, 1, 1'-Oxybis	2.678	C14H30O	214	629-64-1
2	2.608	1-Phenyl-5-Methylheptane	3.801	C14H22	190	103240-92-2
3	3.819	O-Xylene	1.883	C8H10	106	95-47-6
4	4.314	Thiazole	1.478	C3H3NS	85	288-47-1
5	4.599	1, 24, 5-Tetrazine, 1, 4-Diethylhexahydro-	1.964	C6H16N4	144	35035-69-9
6	8.576	Benzene, 1, 1'-(1, 1, 2, 2-Tetramethyl-1, 2-Ethanediyl) Bis-	5.768	C18H22	238	1889-67-4
7	8.956	Hentriacontane [7]	23.947	C31H64	436	630-04-6
8	10.407	Dodecane, 1-Fluoro- [2]	3.270	C12H25F	188	334-68-9
9	17.144	1, 2-Benzenedicarboxylic Acid, Bis (2-Methylpropyl) Ester	2.151	C16H22O4	278	84-69-5
10	17.619	7, 9-Di-Ert-Butyl-1-Oxaspiro (4, 5) Deca-6, 9-Diene-2, 8-Dione	3.325	C17H24O3	276	82304-66-3
11	17.764	Tetradecanoic Acid, 10, 13-Ddimethyl-, Methyl Ester	3.120	C17H34O2	270	267650-23-7
12	18.105	Dibutyl Phthalate	2.023	C16H22O4	278	84-74-2
13	23.112	1, 2-Benzenedicarboxylic Acid, Mono (2-Ethylhexyl) Ester	3.899	C16H22O4	278	4376-20-9
14	24.012	1.4-Epoxynaphthalene-(2h)-Methanol, 4, 5, 7-Tris(1, 1-Dimethylethyl)-3, 4-Dihydro	31.079	C23H36O2	344	56771-86-9
15	30.374	2-T-Butyl-5-Cholоromethyl-3-Methyl-4-Oxoimidazolidine-1-Carboxylic Acid, T-Butyl Ester	16.252	C14H25O3N2CL	304	900192-88-5

Tetramethyl-1, 2-Ethanediyl) Bis-, Hentriacontane, 1, 2-Benzenedicarboxylic Acid, Bis (2-Methylpropyl) Ester, 7, 9-Di-Tert-Butyl-1-Oxaspiro (4, 5) Deca-6, 9-Diene-2, 8-Dione, Tetradecanoic Acid, 10, 13-Ddimethyl-Methyl Ester, 1, 2-Benzenedicarboxylic Acid, Mono (2-Ethylhexyl) Ester were present in all the isolates, whereas N-(4-Methylbenzenesulfonyl)-2-Methylazetidin-3-One, Propionic Acid, 2, 2-Dimethyl-, 2-Ethylhexyl Ester, Melonic Acid, Decyl Isobutyl Ester, Phenol, 3, 5-Bis(1, 1-Dimethylethyl)-, were present in only isolate *B. cereus NSPA13,* and *B. licheniformis NSPA5, B. subtilis NSPA8* showed over all similar fatty acid composition as evident from table-4 (Toshi, 1968; Welch, 1991).

Hydrocarbon tolerance of the Haloalkaliphilic Bacillus sp.

The hydrocarbon tolerance assay showed all the three isolates *B. licheniformis NSPA5, B. subtilis NSPA8* and *B. cereus NSPA13* were unable to degrade all the tested hydrocarbons (petrol, diesel, xylene, toluene, and kerosene) but showed tolerance to their presence in the medium up to 15 per cent in case of petrol, diesel and kerosene, and the same was limited to 10 per cent in case of xylene and toluene. Among the *B. licheniformis NSPA5, B. subtilis NSPA8* and *B. cereus NSPA13* isolates *B. cereus NSPA13* showed maximum tolerance of hydrocarbons.

Heavy metal tolerance of the haloalkaliphilic Bacillus sp.

The metal tolerance was also diverse in the three isolates *B. licheniformis NSPA5, B. subtilis NSPA8* and *B. cereus NSPA13.* The isolate *B. subtilis NSPA8* is the least tolerant among the three assayed, showing the sensitivity towards six of the metals tested followed by *B.cereus NSPA13* with sensitivity towards five metals. The most tolerant to the tested metals was isolate *B. licheniformis NSPA5* with sensitivity to only three metals. But, as common trait all were sensitive to mercury, lead,

Table 3. Fatty Acid Methyl Esters analysis of *B. cereus* NSPA13

S. No	RT	Name of the Compound	Abundance %	Formula	M.W	CAS-NO
1	2.538	Heptane, 1, 1'-Oxybis-	1.931	C14H30O	214	629-64-1
2	2.608	N-(4-Methylbenzenesulfonyl)-2-Methylazetidin-3-One	2.360	C11H13O3NS	239	76543-28-7
3	2.879	Dodecane, 1-Fluoro- [4]	8.928	C12H25F	188	334-68-9
4	8.576	Benzene, 1, 1'-(1, 1, 2, 2-Tetramethyl-1, 2-Ethanediyl) Bis-	4.386	C18H22	238	1889-67-4
5	8.961	Melonic Acid, Decyl Isobutyl Ester	2.555	C17H32O4	300	900349-10-6
6	11.772	Hentriacontane [8]	9.80	C31H64	436	630-04-6
7	12.753	Trans-2-Methyl-4-N-Pentylthiane, S, S-Dioxide	5.628	C11H22O2S	218	900215-75-3
8	15.169	Chloroacetic Acid, Tetradecylester	3.280	C16H31O2CL	290	18277-86-6
9	17.144	1, 2-Benzenedicarboxylic Acid, Bis (2-Methylpropyl) Ester	1.687	C16H22O4	278	84-69-5
10	17.620	7, 9-Di-Tert-Butyl-1-Oxaspiro(4, 5) Deca-6, 9-Diene-2, 8-Dione	2.692	C17H24O3	276	82304-66-3
11	17.765	Tetradecanoic Acid, 10, 13-Ddimethyl-, Methyl Ester	3.043	C17H34O2	270	267650-23-7
12	23.102	1, 2-Benzenedicarboxylic Acid, Mono (2-Ethylhexyl) Ester	3.437	C16H22O4	278	4376-20-9
13	23.987	Phenol, 3, 5-Bis (1, 1-Dimethylethyl)-	23.412	C14H22O	206	1138-52-9
14	30.350	2-T-Butyl-5-Cholоromethyl-3-Methyl-4-Oxoimidazolidine-1-Carboxylic Acid, T-Butyl Ester	16.435	C14H25O3N2CL	304	900192-88-5

and cadmium. The metal tolerance patterns of the isolates were different from hydrocarbon tolerance, clearly an indication of the dependence of the cellular fatty acid composition on the stress tolerance of the haloalkaliphilic *Bacillus* sp (Nieto *et al.,* 1989; Margesin and Schinner, 2001).

CONCLUSION

The fatty acid composition and variance in the overall fatty acid composition both in type and content showed great difference in the stress resistance towards the limiting factors - different hydrocarbons and heavy metals. The results revealed the cell wall fatty acids play a crucial role in the microorganisms living in harsh and extreme conditions. Metals like copper, chromium received variable response from the isolates, might be indicative of variance in the interaction of cell wall molecules and the metal ions. In order to understand the molecular basis of this kind of variance and the ability to resist the harsh conditions, further studies are required with comparative emphasis on extreme environments.

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Fig. 1. Gas Chromatography-Mass Spectroscopy Spectrum of Fatty Acid Methyl Esters of *B. lichineformis* NSPA5

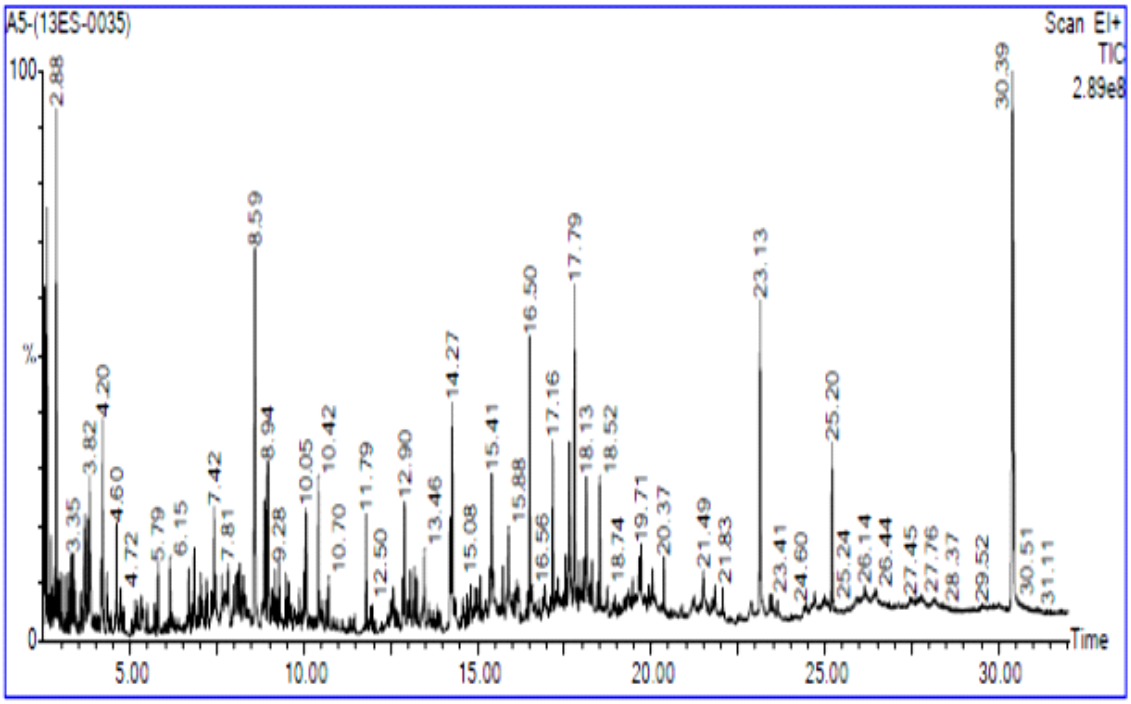


Fig. 2. Gas Chromatography-Mass Spectroscopy Spectrum of Fatty Acid Methyl Esters of *B. subtilus* NSPA8

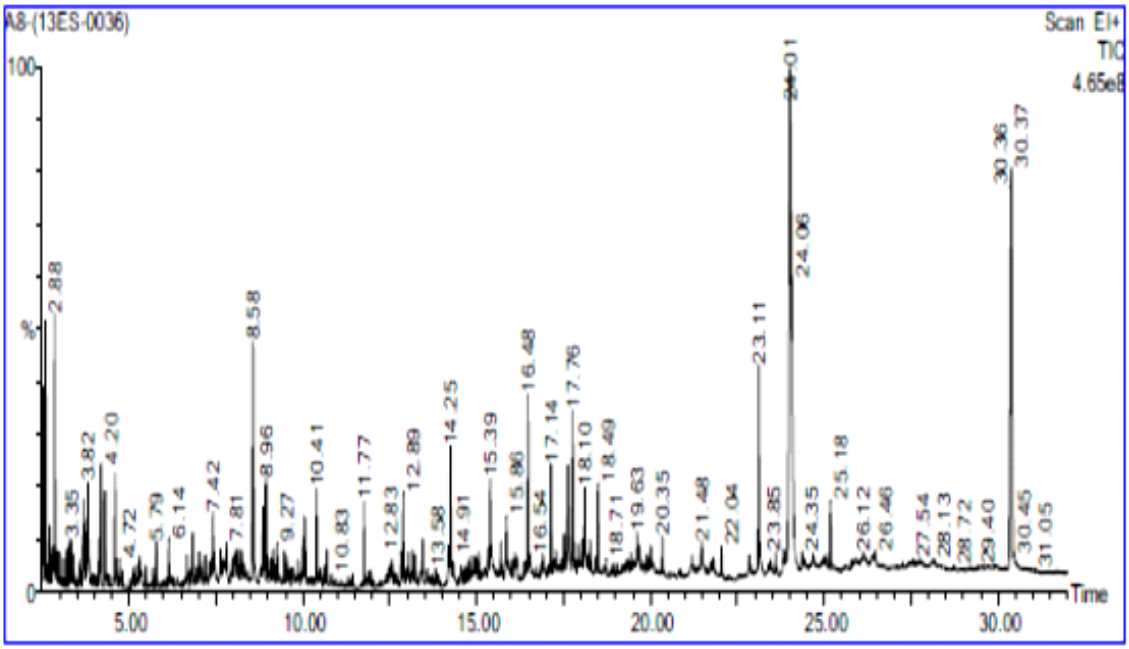
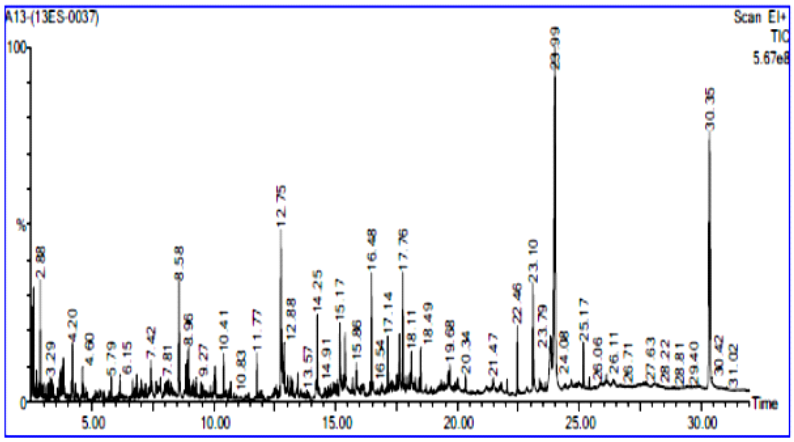


Table 4. Fatty Acid Methyl Ester profiles of the *B. licheniformis* NSPA5 *B. subtilis* NSPA8 and *B. cereus* NSPA13

S. No	RT	Name of the Compound	Abundance %		
			NSPA5	NSPA8	NSPA13
1	2.533	Heptane, 1, 1'-Oxybis-	3.314	2.678	1.931
2	2.608	1-Phenyl-5-Methylheptane	4.444	3.801	-
3	2.608	N-(4-Methylbenzenesulfonyl)-2-Methylazetidin-3-One	-	-	2.360
4	2.879	Propionic Acid, 2, 2-Dimethyl-, 2-Ethylhexyl Ester	-	-	2.360
5	2.879	Dodecane, 1-Fluoro-	7.404	3.270	8.928
6	3.694	O-Oxylene	2.178	1.883	-
7	4.314	Thiazole	1.478	-	-
8	4.599	1, 2, 4, 5-Tetrazine, 1, 4-Diethylhexahydro-	1.368	1.368	-
9	8.576	Benzene, 1, 1'-(1, 1, 2, 2-Tetramethyl-1, 2-Ethanediyl)Bis-	7.151	5.768	4.386
10	8.961	Melonic Acid, Decyl Isobutyl Ester	-	-	2.555
11	8.956	Hentriacontane	12.714	23.947	9.80
12	12.753	Trans-2-Methyl-4-N-Pentylthiane, S, S-Dioxide	-	-	5.628
13	15.169	Chloroacetic Acid, Tetradecylester	-	-	3.280
14	17.144	1, 2-Benzenedicarboxylic Acid, Bis(2-Methylpropyl)Ester	2.338	2.151	1.687
15	17.620	7, 9-Di-Tert-Butyl-1-Oxaspiro (4, 5)Deca-6, 9-Diene-2, 8-Dione	3.828	3.325	2.692
16	17.765	Tetradecanoic Acid, 10, 13-Ddimethyl-, Methyl Ester	4.164	3.120	3.043
17	18.105	Dibutyl Phthalate	2.550	2.023	-
18	23.112	1, 2-Benzenedicarboxylic Acid, Mono(2-Ethylhexyl)Ester	4.750	3.899	3.437
19	23.987	Phenol, 3, 5-Bis(1, 1-Dimethylethyl)-	-	-	23.412
20	24.012	1.4-Epoxynaphthalene-(2h)-Methanol, 4, 5, 7-Tris(1,1-Dimethylethyl)-3, 4-Dihydro	-	31.079	-
21	25.203	2, 6, 10, 14, 18, 22-Tetracoashexaene, 2, 6, 10, 15, 19, 23-Hexamethyl-, (All-E)-[2]	4.626	-	-
22	30.374	2-T-Butyl-5-Cholоromethyl-3-Methyl-4-Oxoimidazolidine-1-Carboxylic Acid, T-Butyl Ester		16.252	16.435

Fig. 3. Gas Chromatography-Mass Spectroscopy Spectrum of Fatty Acid Methyl Esters of *B.cereus* NSPA13



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RESPONSE OF MAIZE (*Zea mays*) TO GRADED LEVELS OF NITROGEN AND PHOSPHORUS DURING *RABI*

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ABSTRACT

A field experiment was conducted for three consecutive years (2010-11, 2011-12 and 2012-13) on sandy clay loam soils at RARS farm, Tirupati during *rabi* season to study the response of maize to the graded levels of nitrogen and phosphorus. The experiment consisted of twelve treatments with four nitrogen levels i.e. 100, 150, 200 and 250 kg N ha^{-1} and three levels of phosphorus i.e. 30, 60 and 90 kg P_2O_5 ha^{-1}. The experiment was laid out in randomized block design with factorial concept and replicated thrice. Application of nitrogen @ 250 kg ha^{-1} had recorded the highest grain yield which was significantly superior over N_{100} and N_{150} kg ha^{-1} however it is on a par with N_{200} kg ha^{-1}. The grain yield of maize did not influenced significantly by different levels of phosphorus. However, application of nitrogen @ 200 kg ha^{-1} in combination with 30 kg P_2O_5 ha^{-1} recorded statistically non measurable grain yield. The other parameters such as plant height and yield attributes such as cob length and test weight followed the same trend. Nitrogen requirement for *rabi* maize was found to be 200 kg ha^{-1} with application of phosphorus @ 30 kg ha^{-1} that would be optimum for realizing optimum yield.

KEYWORDS: Maize, nitrogen and phosphorus levels, yield attributes and kernel yield.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal food crop of the world with the highest production and productivity as compared to rice and wheat. It is the third most important cereal after rice and wheat as human food, contributing to 9 per cent of India's food basket and 5 per cent to World's dietary energy supply (Saikumar *et al.*, 2012). Maize production has increased more than 12 times from a mere 1.73 million tons in 1950-51 to 21.57 million tons in 2011-12 and currently maize is grown on 9.3 million hectares with production of 24.2 million tons and with a productivity of 2602 kg ha^{-1} in India (FAO STAT, 2014). In Andhra Pradesh (13 districts), it is cultivated in an area of 1.2 lakh hectares with a production of 6.65 lakh tons and productivity of 5546 kg ha^{-1}.

Demand of maize grain for poultry, livestock, fish and wet and dry milling industries is expected to increase from current level of 21.57 million tonnes to 45 million tonnes by 2030 (DMR, 2011).To meet the growing demand, enhancement of maize yield in coming years across all the growing locations in India is the big challenge. There is little scope for horizontal expansion of this crop. The challenge of achieving higher productivity of maize can be realized only through nutrient management. Hence, an attempt was made to study the response of maize to graded levels of N and P during *rabi*.

MATERIAL AND METHODS

A field experiment was conducted on sandy clay loam soil of Regional Agricultural Research Station, Tirupati consecutively for three years during *rabi* 2010-11, 2011-12 and 2012-13 respectively. The experimental field had a pH of 7.8, EC of 0.15 dSm^{-1}, low available nitrogen (172 kg ha^{-1}) medium available phosphorus (32 P_2O_5 kg ha^{-1}) and available potassium (221 K_2O kg ha^{-1}). A total rainfall of 15.50 mm and 37.20 mm and 296mm was received during 2010-11, 2011-12 and 12-13 respectively. (Table 1). The experiment was laid out in randomized block design with factorial concept and replicated thrice. The twelve treatments consisted of four nitrogen levels i.e. 100, 150, 200 and 250 kg N ha^{-1} and three levels of phosphorus i.e. 30, 60 and 90 kg ha^{-1}. Hybrid from M/s Kaveri Seeds (Kaveri) was used during all the years of study. The field was well prepared with the help of tractor drawn cultivator twice and rotavator once to get fine tilth. Later ridges and furrows were made with ridgemar at a spacing of 60 cm. Seeds were sown at intra row spacing of 20 cm. Nitrogen was applied in four

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Table 1. Weather parameters (means) recorded during *rabi* 2010-11, 2011-12 and 2012-13

Date	Temperature		Relative Humidity		Sunshine hours	Rainfall (mm)	No. of rainy days	Evaporation (mm)
	Max	Min	I	II				
2010-11	32.56	17.98	85.01	43.73	7.95	15.50	2	5.40
2011-12	33.17	19.00	81.85	41.66	7.90	37.20	2	5.08
2012-13	30.60	18.00	88.00	51.20	7.00	296.00	9	3.90

Table 2. Plant and yield attributes of maize as influenced by different levels of nitrogen and phosphorus during rabi 2010-11

Treatment	Plant height (cm)	Cob length (cm)	Cob girth (cm)	100 seed wt. (g)	No. of seeds / cob (g)	Seed yield (kg ha^{-1})
Nitrogen level (kg ha^{-1})						
100	183.6	15.2	13.4	18.0	471	3588
150	220.4	17.0	13.8	18.9	555	4120
200	255.6	17.9	14.5	20.3	582	4565
250	275.4	18.2	14.9	20.5	633	4787
C.D. at 0.05 level	15.8	1.6	0.9	NS	93	343
Phosphorus level (kg ha^{-1})						
30	230.0	16.3	13.6	18.1	534	4104
60	234.6	17.3	14.2	20.0	554	4253
90	236.0	17.7	14.6	20.2	593	4439
C.D. at 0.05 level	NS	NS	NS	NS	NS	NS

Table 3. Plant and yield attributes of maize as influenced by different levels of nitrogen and phosphorus during *rabi* 2011-12

Treatment	Plant height (cm)	Cob length (cm)	Cob girth (cm)	100 seed wt. (g)	No. of seeds / cob (g)	Kernel yield (kg ha^{-1})
Nitrogen level (kg ha^{-1})						
100	204	20.4	14.9	22.8	307	5009
150	214	20.6	15.7	24.6	326	5584
200	222	21.1	16.1	24.8	340	5841
250	223	21.2	16.3	25.7	341	6016
C.D. at 0.05 level	13.1	NS	0.53	NS	15.6	406
Phosphorus level (kg ha^{-1})						
30	211	20.8	15.5	24.2	321	5334
60	218	20.6	15.8	24.8	330	5713
90	220	21.0	16.0	24.5	334	5790
C.D. at 0.05 level	NS	NS	NS	NS	NS	352

equal splits. One fourth dose at the time of sowing, remaining three doses at 25-30, 45-50 and 60-65 days after sowing (DAS) and phosphorus fertilizers were applied basally as per the treatments and a common recommended dose of potassium (60 kg K_2O ha^{-1}) was also applied at the time of sowing uniformly for the entire experimental field. Atrazine @ 2.0 kg ha^{-1} was sprayed immediately after sowing of maize seeds as pre-emergence herbicide in order to control weeds in the initial stages. Prophylactic measures were taken in maize crop as and when required. Initial and final soil samples were taken for analysis of various physico-chemical properties. The data on growth and yield attributes *viz*., cob length, number of kernels per cob, test weight, kernel and stalk yield and uptake of nitrogen and phosphorus were recorded and subjected to statistical analysis as per Panse and Sukhatme (1978).

Methodology adapted:

a) Treatments:

Nitrogen levels (kg ha^{-1})	Phosphorus levels (kg ha^{-1})
N_1: 100	P_1: 30
N_2: 150	P_2: 60
N_3: 200	P_3 : 90
N_4: 250	

A common dose of 60 kg K_2O ha^{-1} was applied uniformly to all treatments.

a) Replications : Three

b) Design : Randomized Block Design with factorial concept

c) Spacing : 60 cm x 20 cm

d) Hybrid : Pinnacle

f) Irrigation : as and when required

g) Plot size : 5.4 m x 5.0 m

f) Duration : Three seasons

RESULTS AND DISCUSSION

All the weather parameters were congenial for realizing higher productivity of maize during the three consecutive years (Table 1). Maximum temperature during these seasons ranged from 30.60°C to 33.17°C.

Table 4. Yield of maize in kg ha^{-1} as influenced by different levels of nitrogen and phosphorus during *rabi* 2011-12

N levels (kg ha^{-1})	P levels (kg ha^{-1})			
	30	**60**	**90**	**Mean**
100	5130	4303	5592	5009
150	5409	5453	5889	5584
200	5258	**6606**	5659	5841
250	5538	6491	6020	6016
Mean	5334	5713	5790	

Sunshine hours ranged from 7 to 7.95 hours. Evaporation ranged from 3.9 to 5.4 mm per day.

During *rabi* 2010-11, plant height of maize was significantly influenced by different levels of nitrogen. The tallest plant height (275.4 cm) was recorded with 250 kg N ha^{-1}. The shortest plants were recorded with lowest level of N (183.6 cm). Phosphorus levels did not show any influence on plant height. There was no interaction effect between N and P levels on plant height. Cob length was significantly influenced by N levels. The largest cobs were recorded with 250 kg N ha^{-1} which was significantly superior over cobs recorded at lowest N level (100 kg ha^{-1}), however it was on a par with 150 and 200 kg N ha^{-1}. Cob girth was also highest with 250 kg N ha^{-1} which was significantly superior over lowest N level (100 and 150 kg ha^{-1}), however it was on a par with 200 kg N ha^{-1}. Neither P levels nor interaction with N levels were found significant on cob girth. Test weight of maize grains were not influenced by N, P levels and their interaction. Among nitrogen levels, the highest seed yield was recorded with application of N @ 250 Kg ha^{-1}. However, it is comparable with application of N @ 200 kg ha^{-1}. Progressive increment in seed yield was recorded with increasing levels of nitrogen from 100 to 250 kg ha^{-1}. The yield differences were not significant with respect to phosphorus application. Enhanced levels of nutrient supply exerted a significant and positive influence on the kernel yield of maize. Graded levels of N have profound influence on the kernel yield of maize. Nitrogen is a critical input in agriculture and is a powerful tool for increasing the grain yield in cereals. Maize has maximum nitrogen use efficiency of about 50 per cent, but under poor management, its efficiency varies from 30 – 40 per cent (Patel *et al.,* 2006). Among the major nutrients, P ranked next to N in its importance because of its vital

Table 5. Plant and yield attributes of maize as influenced by different levels of nitrogen and phosphorus during *rabi* 2012-13

Treatment	Plant height (cm)	Cob length (cm)	Cob girth (cm)	100 seed wt. (g)	No. of seeds/ cob (g)	Seed yield (kg ha^{-1})
Nitrogen level (kg ha^{-1})						
100	210.8	19.4	15.83	27.6	451	5053
150	225.4	20.0	16.03	27.9	509	6007
200	234.6	20.6	16.06	28.0	514	6609
250	235.6	20.8	16.41	29.2	540	6911
C.D. at 0.05 level	12.1	0.69	NS	NS	46.7	594
Phosphorus level (kg ha^{-1})						
30	225.9	20.2	16.09	28.1	513	6155
60	230.6	20.2	16.14	28.5	504	6206
90	223.3	20.1	16.02	28.0	493	6074
C.D. at 0.05 level	NS	NS	NS	NS	NS	NS

Table 6. Yield of maize (kg ha^{-1}) as influenced by nitrogen levels and phosphorus levels (Pooled data of 2010-11, 2011-12 and 2012-13)

Treatment	2010-11	2011-12	2012-13	Pooled
Years				
2010-11	-	-	-	4265
2011-12	-	-	-	5612
2012-13	-	-	-	6145
CD (0.05)				218
Nitrogen level (kg ha^{-1})				
100	3588	5009	5053	4549
150	4120	5584	6007	5237
200	4565	5841	6609	5672
250	4787	6016	6911	5905
CD (0.05)	343	406	594	252
Phosphorus level (kg ha^{-1})				
30	4104	5334	6155	5197
60	4253	5713	6206	5390
90	4439	5790	6074	5434
CD (0.05)	NS	352	NS	NS
N x P	NS	Sig.	NS	NS

role in major life processes and its availability to the growing crop in required levels is of very important. Application of phosphorous in a balanced proportion with other essential nutrients has produced higher yields and ensured more profit to the farmers (Manimaran and Poonkodi, 2009). Similar trend was recorded in all the three consecutive years except during 2011-12 where in interaction of N with P levels was found to be significant. Interaction effects showed that application of N @ 200 kg ha^{-1} along with P_2O_5 @ 60 kg ha^{-1} recorded highest seed yield (6606 kg ha^{-1}).

The pooled data of 2010-11, 2011-12 and 2012-13 also revealed that significant differences in yield were observed among nitrogen levels (Table 6). The response was significant up to 200 kg ha^{-1} which recorded seed yield of 5672 kg ha^{-1}. Highest level of nitrogen i.e. 250 kg N ha^{-1} recorded seed yield of 5905 kg ha^{-1} but was on par with 200 kg N ha^{-1} (5672 kg ha^{-1}). Significant differences were not observed among phosphorus levels tested. Tyagi *et al.* (1998) observed an increase in grain yield of maize from 61 to 137 per cent with increased levels of N application from 75 to 250 kg ha^{-1} over that of no nitrogen on sandy loam soils of Hissar, Haryana. Patel *et al.* (2006) also reported that with increasing levels of N from 75 to175 kg ha^{-1} also improved all the yield attributes and grain yield of maize in alfisols of Anand, Gujarat. Increased dry matter production with increased nitrogen application coupled with P increased biomass as reported by Wadsworth (2002). Thus greater availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased dry weight of grain. Enhanced levels of nitrogen supply exerted a significant and positive influence on the kernel yield of maize.

CONCLUSION

Results revealed that nitrogen requirement for *rabi* maize was found to be 200 kg ha^{-1} with application of phosphorus @ 30 kg ha^{-1} would be optimum for realizing profitable grain yield in maize.

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BIOLOGY AND MORPHOMETRIS OF CIGARETTE BEETLE, *Lasioderma serricorne* (Fab.) ON FENNEL AND CORIANDER

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ABSTRACT

Investigations were carried out on "Biology and morphometrics of *Lasioderma serricorne* Fabricius on fennel and coriander" during 2015-2016 at Department of Entomology, S. V. Agricultural College, Tirupati, at prevailing room temperature of 26 ± 2°C and relative humidity of 60-95 per cent. The durations of 1st, 2nd, 3rd and 4th instars were 8.42, 6.90, 7.60 and 7.73 days when insects were reared on fennel and 6.31, 6.60, 6.90 and 7.93 days when insects were reared on coriander respectively. The total larval duration, pupal duration and adult longevity were shorter (27.83, 12.26 and 12.93) on coriander than that of fennel (28.90, 12.63 and 13.19 days). Morphometric studies revealed that the head capsule width from 1st instar to 4th instar was more when insects were reared on coriander (0.109, 0.153, 0.239 and 0.434 mm) compared to fennel (0.109, 0.157, 0.227 and 0.331 mm). Body length of (1st, 2nd, 3rd, 4th, pupa and adult) were more when insects were reared on coriander (0.592, 0.967, 0.230, 3.430; 1.850 and 1.570 mm) than that of fennel (0.544, 0.934, 2.160, 3.23, 1.820 and 1.510 mm). The oviposition potential of the female insects reared on coriander was 62 eggs and on fennel were 56 eggs per female. Among two food materials tested, coriander provided the higher per cent survival (73.33%) of *L. serricorne,* followed by fennel (66.66%) from first instar to adult. The male to female ratio was worked out to be 1:1.44 on coriander whereas on fennel it was 1:1.33. It can be concluded that coriander was most supportive food material for the growth and development of cigarette beetle with least mean developmental period, higher morphometrics, higher per cent pupal and adult survival as compared to fennel.

KEYWORDS: Biology, coriander, fennel, morphometrics, *Lasioderma serricorne*, Per cent survival.

INTRODUCTION

Lasioderma serricorne (Fabricius) is a small (2-3 mm,) brown beetle of the family Anobiidae, commonly known as the cigarette beetle, cigar beetle, tobacco beetle or herbarium beetle (Jacob, 1998; Lyon, 1991). Its common name refers to the fact that this beetle is the most significant insect pest of all forms of stored tobacco, from cigarette packets to hogs heads and bales. Larvae of the cigarette beetle can feed on dried tobacco (Minor, 1979) either in the stored bundled form or in cigars, cigarettes and chewing tobacco. In addition to tobacco, these beetles also infest a variety of different food products such as ginger, cayenne pepper, dried yeast, chili powder, red pepper, paprika, turmeric, opium and pyrethrum powder (Tenhet and Bare, 1951; Howe, 1957). It also causes damage to a variety of stored products including grain cereal products, ginger, raisins, dates, pepper, dried fish, drugs and seeds. An effort was made in the present investigation to find a suitable host for growth and multiplication of *L. serricorne* along with morphometrics.

MATERIALS AND METHODS

The nucleus culture has been maintained on turmeric in the laboratory, since 2014. Eggs were collected from the nucleus culture with the help of fine camel hair brush and were placed in separate Petri Plates of size (9 cm). Grubs obtained from the eggs collected from nucleus culture were used for further experiments. First instars grubs were transferred to a multi cell well plate with the help of a fine camel brush. The length and breadth of the each plate was 12.5 and 8.5 cm respectively with six cells of 3.3 cm diameter and depth of 2.5 cm. The multi cell well plate had a loose transparent lid helped in taking observations without disturbing the insects. The grubs were provided with broken pieces of fennel and coriander and maintained at room temperatures of 26 ± 2°C and relative humidity of 60-95 per cent.

A total 30 insects were used for rearing on fennel and coriander separately. Each cell well was examined daily until emergence of adults to record the duration of immature life stages viz., eggs, larvae, pupae and adult.

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After every moulting, the larval duration was recorded and the numbers of instars were also recorded. From durations of larval instars, total larval duration was determined. From the total number of pupae formed, per cent pupal recovery was calculated. Pupae differentiated as male and female on the basis of genital papillae (Halstead, 1963) to determine sex ratio and pupal durations were recorded as date of pupation to date of adult emergence.

Freshly emerged one male and one female adult were released in separate plastic jars size of (6 × 4 cm) and observations were recorded adult longevity. The raw data was subjected to statistical analysis in Completely Randomised Design (CRD) with the help of SPSS statistical package (SPSS, 2013).

RESULTS AND DISCUSSION

The details of duration of various stages of cigarette beetle reared on fennel and coriander and their morphometric measurements are presented in table 1, 2 and 3.

First instar grubs were creamy white in colour and possessed few hairs on each segment. They were observed to be extremely active and immediately after hatching, started feeding voraciously. The developmental period of first instar grub was 6.66 ± 0.60 days when reared on fennel and duration of first instars when reared on coriander was 6.30 ± 0.70 days (Table 1). The second instar grub was also creamy white in colour, with a dense covering of hairs which soon after first moult became erect. Among fennel and coriander the duration of second instar grub was 6.90± 0.80 days when reared on fennel and 6.6 0 ± 0.72 days when reared on coriander (Table 1). The third instar grub was stout bodied, slightly yellowish in colour. They possessed long hairs on abdominal segments. The duration was 6.96 ± 0.61 days when grubs were reared on coriander where as on fennel it was 7.60 ± 0.72 days, were significantly different (Table 1). The fourth instar grub was "Scarabaeiform". The head was darkly sclerotized and body was whitish in colour with long hairs all along the body. The late fourth instar had sparse hairs on body. The developmental period was 7.73 ± 0.583 days when the insects were reared on fennel and on coriander it was 7.97 ± 0.49 days (Table 1) and were significantly different each other. When insects were reared on fennel the total grub developmental period was 28.90 ± 1.27 days and on coriander the total development period was 27.83 ± 1.48 days, were significantly different (Table 1). The present results are in conformity with Abraham (1975) who reported that the larval periods of *L. serricorne* was 17 - 28 days, on coriander under Kerala conditions. The larval stage lasted for 32-34 days on stored spice of *Carum copticum* as a new host of *Lasioderma serricorne* (Padmavathamma and Rao, 1989).

Pupae were creamy white in colour with black compound eyes. The pupal duration when reared on fennel was 12.63± 0.92 days and on coriander it was 12.26 ±0.98 days (Table 1). The results are in accordance with Abraham (1975) who reported that the pupal periods of *L. serricorne* were 2 - 12 days on coriander in Kerala conditions.

The adults were observed to be dark brown in colour and oval in shape with the first thoracic segment bent downwards. The head was deflexed and obscured from the above, giving the insect a humped appearance. The antennae were serrate. Body was covered with fine hairs. Females were observed to be usually larger than males. When disturbed they often pull in their legs and head and remain motionless. They were active through the night and were found most active at dusk. Mating took place within a day of adult emergence from the cocoon and lasted for 51 – 68.5 minutes. The adult longevity was 13.17± 1.09 days on fennel and on coriander it was 12.93 ± 0.94 days (Table 1). The male to female ratio observed on coriander was 1:1.44 whereas on fennel it was 1:1.33. The present results are in conformity with Alaa Saleh (2012) who reported the average longevity of female as 19.80 ± 0.66, 15.20 ± 0.37, 14.20 ± 0.37, 13.80 ± 0.37 and 12.80 ± 0.37 days when reared on dried ficus, grains millo, powdered chicken stock (Maggi), yeast and dried tobacco leaves, respectively.

On coriander the total development period was 53.03 ± 1.97 days and it was 54.70 ± 1.80 days on fennel. Total developmental periods differed significantly with each other. On an average, a female laid 56 eggs on fennel and 62 eggs on coriander. The total egg-to-adult development on fennel and coriander was 54 and 53 days. These observations were in close conformity with the findings of Rolania (2009) they reported the total developmental period of beetles varied from 46.3 to 64.2 days on different fennel varieties.

The female beetle deposited the eggs loosely and singly on the surface of the food material. The eggs of cigarette beetle were observed to be pearly white in colour and oval in shape with a slight swelling in the middle and

Table 1. Duration (days) of various life stages of cigarette beetle, *L. serricorne* on fennel and coriander

Treatments	1st instar (Mean ± SD)	2nd instar (Mean ± SD)	3rd instar (Mean ± SD)	4th instar (Mean ± SD)	Total larval duration (Mean ± SD)	Pupal duration (Mean ± SD)	Adult longevity (Mean ± SD)	Total developmental period (Mean ± SD)
Fennel	6.66 ± 0.60	6.9 ± 0.803	7.6 ± 0.724	7.73 ± 0.583	28.90 ± 1.269	12.63 ± 0.92	13.17 ± 1.09	54.7 ± 1.803
Coriander	6.30 ± 0.70	6.60 ± 0.72	6.96 ± 0.61	7.97 ± 0.49	27.83 ± 1.48	12.26 ± 0.98	12.93 ± 0.94	53.03 ± 1.97
Significance of F value at	0.035	0.134	0.001	0.099	0.004	0.142	0.362	0.001

Table 2. Head capsule width (mm) of different instars of cigarette beetle, *L. serricorne* on fennel and coriander

Treatments	1st instar (mm) (Mean ± SD)	2nd instar (mm) (Mean ± SD)	3rd instar (mm) (Mean ± SD)	4th instar (mm) (Mean ± SD)
Fennel	0.109 ± 0.006	0.157 ± 0.010	0.227 ± 0.012	0.331 ± 0.070
Coriander	0.109 ± 0.015	0.153 ± 0.006	0.239 ± 0.013	0.434 ± 0.015
Significance of F value at	1	0.098	0.001	0.01

Table 3. Body length of various life stages of cigarette beetle *L. serricorne* on fennel and coriander

Treatments	Egg length (mm) (Mean ± SD)	Egg width (mm) (Mean ± SD)	1st instar (mm) (Mean ± SD)	2nd instar (mm) (Mean ± SD)	3rd instar(mm) (Mean ± SD)	4th instar(mm) (Mean ± SD)	Pupal (Mean ± SD)	Adult (Mean ± SD)
Fennel	0.344 ± 0.050	0.168 ± 0.021	0.544 ± 0.053	0.934 ± 0.082	2.160 ± 0.152	3.230 ± 0.220	1.82 0 ± 0.02	1.510 ± 0.024
Coriander	0.391 ± 0.034	0.182 ± 0.01	0.592 ± 0.070	0.967 ± 0.071	2.230 ± 0.100	3.430 ± 0.154	1.850 ± 0.024	1.57 0 ± 0.024
Significance of F value at	0.025	0.091	0.004	0.105	0.065	0	0	0

bluntly rounded. There were small papillae like structures projecting at one end from which the grub emerges out. This feature, distinguishes the egg of *L. serricorne* from the egg of other anobiid, *Stegobium paniceum* (Linnaeus, 1758). The eggs when freshly laid were translucent, smooth and shining, which later became pearly white in colour. The length and breadth of eggs obtained from adults of coriander was 0.391± 0.034 mm and 0.182±0.01 mm, while on fennel it was 0.344 ± 0.050 mm and 0.168±0.021 mm respectively. The results were similar to that of Chaitanya *et al*. (2016) they reported the average length and breadth of the egg was 0.36 ± 0.004 mm and 0.18 ± 0.004 mm, respectively.

Morphometric studies revealed that the head capsule width from 1st instar to 4th instar was more in coriander (0.109, 0.153, 0.239 and 0.434 mm) compared to fennel (0.109, 0.157, 0.227 and 0.331mm) (Table 2). The head capsule width of 3st instar grubs were significantly different each other. The results were in accordance with the Rao *et al*. (2003) they reported the head capsule width of four instars were 0.10, 0.15, 0.36 and 0.49 mm, respectively.

Body length of (1st, 2nd, 3rd, 4th, pupa and adult) were more in coriander (0.592, 0.967, 2.23, 3.43; 1.85 and 1.57 mm) than that of fennel (0.544, 0.934, 2.16, 3.23, 1.82 and 1.51 mm), respectively (Table 3). The body length of 1st instar grubs were significantly different each other. The results were in accordance with the Rao *et al*. (2003) they reported the body length were 0.55, 0.77, 1.33, 2.62, 1.73 and 2.39 mm for 1st, 2nd, 3rd, 4th, pupa and adult, respectively.

CONCLUSION

It can be concluded, among the two foods tested, coriander was proved to be more congenial for growth and development of cigarette beetle with least mean developmental period, higher morphometrics, higher pupal and adult per cent survival as compared to fennel.

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DOCKING AND MOLECULAR DYNAMICS SIMULATIONS FOR DISCOVERY OF POTENTIAL INHIBITORS OF SOLUBLE ACID INVERTASE IN SUGARCANE

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ABSTRACT

Inversion of sucrose, impairing sugar recovery from harvested sugarcane leads to reduction in sugar production. The inversion or sucrose catabolism in sugarcane stalks mostly is due to the enzymatic activity of soluble acid invertases. With an objective to save sucrose from degradation to glucose and fructose, virtual screening, docking and molecular dynamics simulations were implemented to identify potential soluble acid invertase inhibitors. Soluble acid invertase 3D structure (PM0076107) was prepared in protein preparation wizard of Maestro v9.2. A set of 372 structural analogues of sucrose were obtained from one million compounds of ligand info Meta database. Ligands were prepared using LigPrep to generate fully customized ligand dataset of 2,520 conformations. Using Glide v5.7, the dataset was docked with in the active site of soluble acid invertase. Out of the docked ligands, 64 lead molecules with better XPGscore than sucrose were identified. The 15 leads selected based on clustering were re-docked through quantum polarized ligand docking. Based on results of the both docking protocols, 15 leads were proposed as potential inhibitors of soluble acid invertase. Lead 1, showed the best Gscore (XP: -12.07 kcal/mol; QPLD: -13.07 kcal/mol) and interactions with residues that are important for sucrose binding. Furthermore, Prime/MM-GBSA calculation of soluble acid invertase-lead1 complex obtained after QPLD showed lowest free energy of ligand binding ("G = -166.02 kcal/mol). The conformational and interaction stability of soluble acid invertase – lead1 docking complex was stable during 10ns molecular dynamic simulations. Therefore, lead1 was proposed as potential competitive inhibitor to sucrose.

KEYWORDS: Sugarcane, sucrose, soluble acid invertase inhibitors, virtual screening, molecular dynamics simulations.

INTRODUCTION

Sugarcane (*Saccharum* spp.) is the basic raw material for sugar production contributing 75 per cent to the total sugar pool globally apart from sugar beet and other sources. Sixty to seventy per cent of the cane produced in India is used for sugar production and this is steadily increasing to meet ever increasing demand. The requirement of sugar by 2030 is projected as 36 million tones in India. To achieve this target, sugarcane production should be about 500 million tons from the current 350 million tons. The increased sugar production has to come from higher sugarcane productivity and sugar recovery as increasing the area might not be possible. Increasing productivity from the current 68 t ha^{-1} to 100 t ha^{-1} or beyond is possible with intervention of production technologies in sugarcane growing states of India as we already have an example of the state of Tamilnadu where the productivity is 105 t ha^{-1}. On the other hand, sugar recovery ranged from 9.5 per cent to 10.5 per cent in India over several decades and an increase beyond 10.5 per cent might be a difficult target to achieve.

Several factors that can reduce sucrose content in sugarcane crop such as the nature of cultivars and their inversion behavior, atmospheric conditions, flowering, lodging of the crop, water logging, drought and infestation of microbes (*Leuconostoc spp.*) and pests are categorized as causes for pre-harvest sucrose losses which are managed in various proportions in field conditions. Whereas time lag after harvest and external temperature are the most important factors that are responsible for post-harvest sucrose losses which determine the rate of sucrose loss through inversion, dextran formation and respiration (Solomon, 2000). Post harvest sucrose loss in the field or in the factory has become an alarming issue (Eggleston, 2002; Solomon, 2009). In India, the time lag between harvesting to milling of canes ranges between 3 and 7 days, which entails 10 to 15 per cent loss in recoverable sugar (Solomon *et al*., 2001) translating to a minimum loss of 2 million tons of sugar annually.

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The inversion of sucrose to its monosaccharides, glucose and fructose, is catalyzed by three isoenzymes of invertases (â fructofuranosidase, E.C. 3.2.1.26) which are categorized into 2 groups based on pH optima (Wyse & Dexter, 1971). Soluble acid invertase is high in apoplast and vacuoles of young internodes but virtually absent in mature tissue with pH optimum 4.4 and Km = 1.3 × 10 2 M. Bound acid invertase present in cell wall is bounded in all aged tissues with pH optimum 3.8 and Km = 8 × 10 3 M. Neutral invertase occurs in cytoplasm at low concentrations in young tissue and greater concentrations in mature tissue having pH optimum 7.0 and Km = 3 × 10 4 M (Hawker and Hatchi, 1965; Glasziou and Gayler, 1972). Acid invertases have been hypothesized to be key enzymes for sucrose catabolism in sugarcane stalks (Singh *et al*., 2008). They exhibit greatest activities in the pH range of 3.5 5.5 and occur as soluble enzyme (soluble acid invertase, SAI) in the vacuole or insoluble enzyme (cell wall bound acid invertase, CWI) in the cell wall. A sharp increase in acid invertase leads to increases in reducing sugars and a subsequent drop in commercial cane sugar (CCS) (Solomon *et al*., 1997). It has been proposed that the endogenous invertases are activated due to loss of moisture and lack of any physiological and biochemical control mechanism soon after harvest (Solomon *et al*., 1990).

The soluble acid invertase, occurring in the vacuole and apoplastic space of elongating internodes, disappeared when internode growth ceased by application of growth inhibitor, glyphosate (Su *et al*., 1992) and reappeared when growth increased with application of gibberillic acid (Gayle and Glasziou, 1972). Thus growth promoters have short term effect and can be used to control pre harvest but not post harvest sucrose losses. Some inhibitors of sugarcane invertases have been reported such as iodide, lead, mercury, arsenic, tungsten, (Alexander, 1965), tris (hydroxymethyl) aminomethane (Hatch *et al.,* 1963) and sodium metasilicate (Alexander, 1968a). The latter compound completely inhibited purified invertase at 3 4 mM inhibitor concentration and also lowered the activity of several hydrolytic and oxidative enzymes in sugarcane (Alexander, 1968b). They were found to be effective in preserving sucrose in crude cane juice but not in the standing crop or harvested sugarcane piled in the field or factory. Inhibiting the endogenous invertase, the target protein, appears to be a promising option in arresting to certain extent pre and to greater extent post harvest sucrose losses in sugarcane wherein an inhibitor would act as a competitive binder to sucrose which binds with invertase and arrests the cleavage of sucrose into glucose and fructose akin to the principle of drug designing in medicine. Homology modeling, virtual screening, docking and molecular dynamics simulations were implemented in the present study to identify potential competitive inhibitors of soluble acid invertase of sugarcane.

MATERIAL AND METHODS

Homology modeling

Homology models are useful in structure based drug designing applications, especially when a crystallographic or NMR structure is unavailable (Sivasubramanian *et al*., 2009). In our previous work, a homology model of soluble acid invertase was constructed in complex with sucrose (Hemanthkumar and Umamaheswari, 2012). The model was validated using GA341 score, DOPE score, Procheck, ProSA, ProQ etc. and was deposited in protein model database (PMDB) (Hemanthkumar and Umamaheswari, 2012). The homology model of soluble acid invertase was retrieved from the PMDB (Hemanthkumar and Umamaheswari, 2012; Castrignano *et al.,* 2006).

Geometry based high throughput screening

The Ligand.Info meta-database tool retrieves structural analogues for the queried small molecule by implementing 2D geometry search techniques from eight renowned small molecule databases such as Havard's ChemBank, ChemPDB, KEGG Ligand, Drug likeliness National Cancer Institute (NCI), Anti-HIV NCI, Unannotated NCI, AkoS GmhB, Asinex Ltd. *etc*. Sucrose structure was imported to Ligand.Info meta-database tool and an in-house library of structural analogs was compiled (Grotthuss *et al*., 2003; Umamaheswari *et al*., 2010a; Umamaheswari *et al*., 2010b; Priyadarshini *et al.,* 2011; Sandeep *et al*., 2012).

Virtual screening through molecular docking

Tertiary structure of soluble acid invertase and in-house library of sucrose structural analogs were imported to Maestro v9.4, Schrodinger LLC, 2013, for molecular docking to investigate binding affinity of the ligand dataset towards soluble acid invertase. The soluble acid invertase structure was preprocessed with the protein preparation workflow in Maestro v9.4. All hydrogens were added to soluble acid invertase and energy was minimized using OPLS 2005 force field in impact

molecular mechanics engine setting the maximum root mean square deviation (RMSD) of 0.30 Å (Umamaheswari *et al*., 2010a; Umamaheswari *et al*., 2010b; Priyadarshini *et al*., 2011; Sandeep *et al*., 2012). Minimization was performed constraining the heavy atoms with the hydrogen torsion parameters turned off to allow free rotation of the hydrogen atoms.

LigPrep (Brooks *et al*., 2008) is an application tool in Schrödinger software suite that combines tools for generating 3D structures from 1D (SMILES) and 2D (SDF) representation, ionization states using Epik (Shelley *et al*., 2007) and searching for tautomers and steric isomers from a single input structure. The sucrose structural analog library ligands were prepared to expand protonation and tautomeric states at 7.0±2.0 pH units using LigPrep with Epik. Post LigPrep evaluations discarded high-energy ionization / tautomer states.

The grid for molecular docking of soluble acid invertase and ligand dataset was generated centered on active site residues after ensuring that the protein and ligands were in the accurate form for docking. The grid box size was set to 20 Å × 20 Å ×20 Å. Van der Waal radii of receptor atoms were scaled to 1.00 Å with a partial atomic charge of 0.25 to soften the potential for non-polar parts of the receptor. Glide extra precision (XP) docking method was applied to rank the ligands based on their binding affinities towards soluble acid invertase and to study interaction of the best lead (Priyadarshini *et al.*, 2011; Sandeep *et al*., 2012; Friesner *et al*., 2004; Friesner *et al*., 2006; Navya *et al*., 2012). The XP docking method generates 10000 poses for each ligand during docking and reports the best pose based on the energy term Emodel. The XP docking method being highly accurate, the best poses of each ligand were ranked based on XP Gscore. The cutoff XP Gscore parameter for XP docking was set at 0.0 kcal/mol and a constraint was set to discard ligands with positive XP Gscore from the final docking output.

Quantum polarized ligand docking

The 64 leads obtained through XP docking were clustered using Canvas v1.5. Fifteen leads selected based on clustering along with sucrose were re-docked to soluble acid invertase using quantum polarized ligand docking (QPLD) (Du *et al*., 2011).

Molecular dynamics simulations

The simulations of soluble acid invertase – lead1 docking complex was carried out for 10 ns using Desmond v3.0 (Shan *et al*., 2011; Santiago *et al*., 2011; Jatana *et al*., 2011; Priyadarshini *et al*., 2013; Pradhan *et al*., 2014). The system for MD simulation was built by embedding SPC (single point charge) model to describe the water molecules around the docking complex. MD simulation methodology was applied to soluble acid invertase-sucrose complex for comparative analysis with soluble acid invertase-lead1 complex.

RESULTS AND DISCUSSION

Homology modeling

Computational methodologies have become a crucial component of drug discovery programmes, from target identification to lead optimization and beyond. Virtual screening method predicts binding affinities between drug target and ligands through molecular docking and ranks them in decreasing order. Along with binding affinity it also predicts accurate binding modes and molecular interactions between protein and ligand, hence, became immensely important to carry out initial steps of drug discovery prior to experimental validation.

Tertiary structure of the protein is initial requirement for structure based inhibitor design. In the absence of an experimentally determined structure, homology modeling is an efficient method for structure prediction and to obtain quick experimental design. In our previous studies, we have modeled 3D structure of soluble acid invertase, and deposited at the protein model database (PMDB ID: PM0076107) (Hemanthkumar and Umamaheswari, 2012). The model validation report (Table 1) showed that soluble acid 3D structure was reliable for lead discovery based on computational docking (Hemanthkumar and Umamaheswari, 2012). The amino acids *viz*., Asn32, Gln49, Trp57, Ile61, Trp93, Thr94, Gln118, Arg154, Arg157, Asp158 Glu217 and Tyr300 were determined as active site residues (Hemanthkumar and Umamaheswari, 2012). The active site residues were validated through sucrose incorporation into the homology model from the structural template, 2ADD, during homology modeling. Additionally sequence alignment of target and template showed that the active site residues were 100% conserved (Hemanthkumar and Umamaheswari, 2012). Therefore, discovery of lead molecules that would block these residues by interacting with better binding affinity

Table 1. Comparison of target and template structures

Validation method	Target	Template
GA341	1.0	1.0
DOPE Score	-58380.85 kcal/mol	-65962.19 kcal/mol
ProQ	4.026	5.892
PROCHECK		
Most favorable region	85%	84.4%
Additionally allowed region	12.5%	14.9%
Generously allowed region	1.8%	0.4%
Disallowed region	0.6%	0.2%
RMSD		
C-alpha	0.27 Å	---
Overall	0.62 Å	---

Table 2. Proposed leads for soluble acid invertase

Lead No.	Gscore (kcal/mol)		ΔG (kcal/mol)	
	XP	QPLD	XP	QPLD
1	-12.07	-13.77	-74.05	-166.02
2	-12.03	-12.24	-98.11	-152.83
3	-12.01	-11.91	-85.89	-147.49
4	-11.71	-11.75	-72.61	-130.16
5	-11.59	-10.85	-47.21	-137.61
6	-11.54	-11.62	-109.68	-129.29
7	-8.11	-11.11	-87.12	-129.25
8	-11.54	-10.87	-73.48	-128.39
9	-11.47	-11.90	-76.29	-122.09
10	-11.4	-12.42	-69.31	-115.98
11	-11.39	-12.66	-71.92	-114.69
12	-9.46	-10.72	-83.43	-116.99
13	-8.84	-11.71	-59.89	-112.49
14	-11.66	-11.89	-52.35	-105.44
15	-10.31	-10.97	-69.40	-101.95
Sucrose	-9.06	-10.71	-43.37	-111.64

compared to sucrose would be ideal step forward towards inhibitor designing against soluble acid invertase.

Molecular docking

Accurate binding affinity prediction between protein and ligand through molecular docking requires careful optimization of their 3D structures. Therefore, the protein was optimized in protein preparation wizard applying OPLS-2005 force field. The structure was optimized to add hydrogen atoms, remove water molecules and remove steric classes in 3D structure. Further, energy was minimized applying OPLS 2005 force field to obtain a structure with lower energetic conformation. Structural analog search for sucrose led to compile an in-house library of 374 ligands. 2560 conformations were generated during ligand preparation. The ligand preparation in LigPrep ensured all ligands at their lower energetic conformation.

The 2560 conformations of 374 ligands were docked into the active site of soluble acid invertase. 366 unique ligand conformations were docked with soluble acid invertase. The docked compounds were ranked based on XP Gscore. The lowest XP Gscore of a compound represents comparatively higher binding affinity of the particular ligand towards protein. Sixty four ligands were observed to have lowest XP Gscore compared to sucrose. Hierarchical clustering of 64 leads led to identify 15 representing lead molecules which could act as potent competitive inhibitors to sucrose. The 15 leads also docked well in QPLD method (Table 2). The result

showed significant improvement of binding affinity of lead1 towards soluble acid invertase after accurate charge calculation for the ligand through quantum mechanics method.

Lead1 showed the lowest Gscore (XP: -12.066 kcal/mol; QPLD: -13.77 kcal/mol), lowest free energy of ligand binding ("G = -166.02 kcal/mol) compared to other proposed leads and sucrose (Table 2), hence, represents the highest binding affinity towards soluble acid invertase. The docking interaction showed a strong intermolecular hydrogen bond network with 11 hydrogen bonds (Fig. 1). The intermolecular hydrogen bonds (Fig. 1) are comparable to intermolecular hydrogen bonds between soluble acid invertase and sucrose reported earlier (Hemanthkumar & Umamaheswari, 2012). The molecular interactions of docking complex of soluble acid invertase - lead1 showed that the residues such as Asn32, Gln49, Arg154, Asp155, Arg157, Asp180, Met215, Glu217 (2 hydrogen bonds) and Asp261 (2 hydrogen bonds) were involved in intermolecular hydrogen bonding. The residues; Trp30, Asn32, Gln49, Ile56, Trp57, Ile61, Trp93, Thr94, Gln118, Arg154, Asp155, Arg157, Asp158, Asp180, Glu182, Gly214, Met215, Glu217, Asp261, Lys298, Tyr300, Trp318, Gly320, Glu321, Ala334 and Asp328 showed good van der Waal interaction with lead1 (Fig. 1). The result revealed that lead1 would be a potent competitive inhibitor of soluble acid invertase of sugarcane.

MD simulation studies

The binding orientations of lead molecules obtained after simulations showed better correlation to their biologically active states as MD simulations are carried out closer to the physiological environment condition with the system embedded with water molecules, temperature and pressure. The energy of the system was stable throughout the simulations period. The analysis of the RMSD plot for soluble acid invertase and lead1 showed that after a small rearrangement from the initial conformation, the complex was stable during entire MD simulation period. The RMSD of protein and ligand remained below 4Å in all 2084 trajectories. The root mean square fluctuations (RMSF) of a given residue in the MD trajectories were calculated by averaging over all the atoms of the given residue. RSMF of backbone and side chain residues were within the limit of 3Å. Very few fluctuations exceeded the 3Å limit. The lower atomic fluctuations indicated smaller conformational changes. The energy plot, RMSD plot and RMSF plot showed that the docking complex was conformationally stable and well in line with energy plot, RMSD plot and RMSF plots of soluble acid invertase – sucrose MD simulation complex.

The hydrogen bonds observed in the docking complex were monitored in all trajectories. Similar binding interactions were noticed during MD simulation as observed in docking complex. The amino acid residues

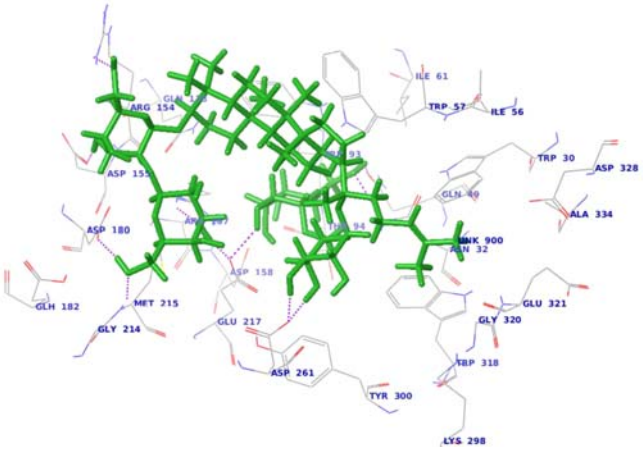

Fig. 1. Docking interaction of lead1 in soluble acid invertase active site

such as Asn32, Gln49, Arg154, Asp155, Arg157, Asp180, Met215, Glu217 (2 hydrogen bonds) and Asp261 (2 hydrogen bonds) were involved in eleven intermolecular hydrogen bonds in the docking complex. These hydrogen bonds were monitored in all 2084 trajectories recorded during 10ns MD simulations. The result revealed that Asn32, Gln49, Arg154, Arg157, Asp180, Met215, Glu217 and Asp261 were involved in intermolecular hydrogen bond formation during MD simulations (Fig.2). Moreover, water mediated hydrogen bonds were also observed in all 2084 trajectories. This analysis revealed that the interaction predicted between soluble acid invertase and lead1 were stable. Further, similar interactions were also revealed in soluble acid invertase-sucrose complex during 10 ns MD simulations (Fig. 3). Therefore, lead1 could be proposed as a potential soluble acid invertase inhibitor.

CONCLUSION

The knowledge of tertiary structure of soluble acid invertase would be useful in designing structure based virtual screening protocols for rational inhibitor design. Competitive inhibitor was predicted through structure

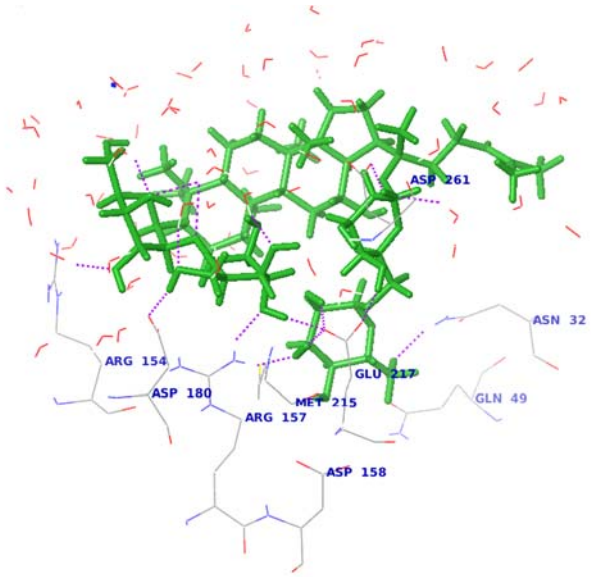

Fig. 2. Interactions of lead1 and soluble acid invertase after 10 ns MD simulations

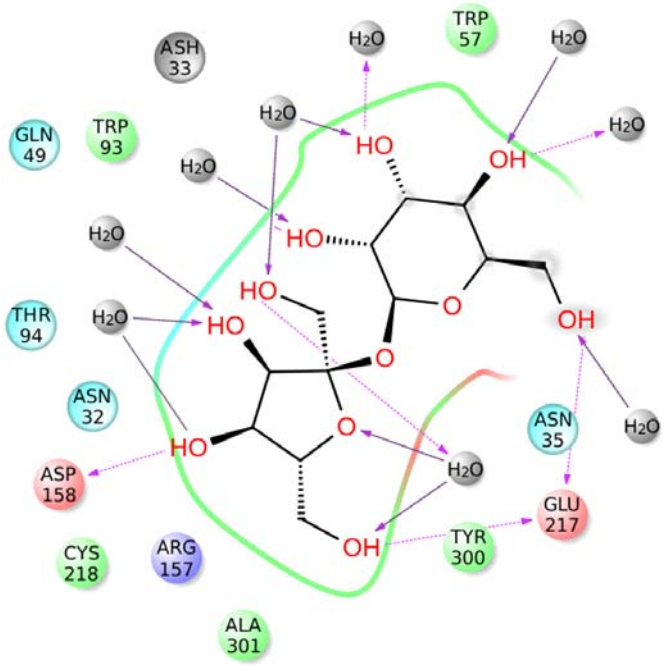

Fig. 3. Interactions of soluble acid invertase – sucrose complex during 10 ns MD simulations

based virtual screening approach by exploring the proposed homology model of soluble acid invertase. The results revealed that the binding interactions between lead1 and the active site residues of soluble acid invertase were stronger when compared with that of sucrose. Molecular dynamics simulations of soluble acid invertase and lead1 complex also revealed that the interactions predicted during docking analysis were stable. Thus, lead1 was proposed as competitive inhibitor binding with soluble acid invertase thereby preventing the binding of sucrose with the enzyme. Along with lead 1, the 14 other potential leads obtained in the study could further be analyzed for potential binding affinity with active site residues of soluble acid invertase through experimental verification *in vitro* and *in vivo*.

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CONVERGENCE LED LIVELIHOOD SECURITY: A CASE STUDY IN CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Millets are small seeded grasses that are hardy and grow well in dry areas as rain-fed crops, under marginal conditions of soil fertility and moisture. Millets have certain intrinsic qualities suited for product development. A study was undertaken on value addition and market linkage to the various products of millets which have a commercial feasibility to enhance the income of the rural women. With this intention, the rural women of Kalikiri and Piler mandal, were extensively trained on processing, preparation of value added products, packing, branding and various possible avenues for market linkages. After acquainting with these aspects, rural women Mrs. M. Faridha, S. Thajwarsulthana and Najimunnisha with technical guidance of Krishi Vigyan Kendra (KVK), Kalikiri established two small scale processing and value addition units. Registration was done for marketing of millet value added products under Food Safety and Standards Authority of India – 2006. Presently these people are involved in preparation and marketing of value added millet products viz., millet biscuits, laddu, muruku, and mixtures under a brand name of "AROGYA MILLET FOODS & STAR HEALTHY SNACKS". The products are being marketed in Chittoor and Kurnool district of Andhra Pradesh.

KEYWORDS: Entrepreneurship, Processing, Value addition, Packing, Branding and Labeling

INTRODUCTION

Most of the operational area of Krishi Vigyan Kendra, Kalikiri is rainfed and the farming community depends mainly on rainfed agriculture for their livelihood. Due to uneven distribution of rain fall and occurrence of frequent drought conditions the farm families are unable to get minimum returns from agriculture. During the off-season, most of the women of this region are free from farm works. KVK, Kalikiri have made some interventions to engage these women in productive works and involve them in income generating activities that may help farm families to get sustainable income throughout the year.

The empowerment of women through self-help groups (SHGs), a non formal Cooperative organization would benefit not only the individual women but also the family and community as a whole through collective action for development (Holvoet, 2005; Tesoriero, 2006).

Millets are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purpose. Millets are one of the most important drought-resistant crops and the sixth cereal crop in terms of world agriculture production. These crops also have inherent resistance to pests and diseases, short crop growth period and are suitable under drought conditions compared to major cereals (Devi *et al*., 2014). In addition, millets also have high nutritive value comparable to that of major cereals such as wheat and rice (Parameswaran and Sadasivam, 1994). Millets could also be accepted as functional food and nutraceuticals as they provide dietary fibers, proteins, energy, minerals, vitamins, and antioxidants required for human health. Millets also have several potential health benefits such as prevention of cancer and cardiovascular diseases, reduction of tumor incidence, lowering of blood pressure, risk of heart disease, cholesterol, rate of fat absorption and supply of gastrointestinal bulk (Truswell, 2002; Gupta *et al*., 2012). It has also been reported that millet proteins are good sources of essential amino acids except lysine and threonine but are relatively high in methionine. Millets are also rich sources of phytochemicals and micronutrients (Mal *et al*., 2010; Singh *et al*., 2012). Compared to rice especially polished rice, millets release lesser percentage of glucose over a longer period of time. This lowers the risk of diabetes.

Millets can be processed and value added into various products such as millet flours, multigrain atta, rawa, millet biscuits, ragi malt, millet based snacks etc,.

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It creates income generating opportunity to the rural women and increase the economic and social strength of women. Linking of farmers to the markets through efficient value chains would reduce the use of intermediaries in the chain and strengthen the value-adding activities by better technology and inputs, upgraded infrastructure and processing and exports. This process can raise the income of farmers and will provide incentive for improving their management practices towards higher farm productivity. The income of the farmers can be enhanced by increasing production, value addition, and better marketing options. The present paper describes the efforts made by Krishi Vigyan Kendra, Kalikiri to establish village level enterprise on processing and value addition to millets with an objective of self employment and income generation to the rural women.

MATERIAL AND METHODS

KrishiVigyan Kendra, Kalikiri, Chittoor district of Andhra Pradesh has conducted three skill development training programs to rural women, each of five days duration on Processing and value addition to millets at Kalikiri and Piler of Chittoor district during the year 2015-16. About 75 Self Help Group women mobilized by District Rural Development Agency (DRDA) participated in these three training programs from different villages of Kalikiri and Piler mandals of Chittoor District.

Trainings and Demonstrations

Interactive lectures coupled with hands on experience on preparation of millet biscuits, savouries, muruku and laddu etc., were given to the selected trainees and also were sensitized on nutrition value of millets, importance of value addition in food products, handling of processing and value addition unit, maintenance of hygiene while handling food products, labeling, packing, licensing and financial management.

Processing and value addition

The aim of processing and value addition of millets was to convert the grains into convenient food and to make the product nutritionally superior, to market easily and to have a shelf life of minimum one month. Accordingly four products viz., biscuits, savouries, muruku and laddu with finger millet, sorghum, bajra and korra (foxtail millet) were selected for preparation and marketing. The flow chart of the same has been given in chart 1, chart 2, chart 3 and chart 4. The selected products

Chat – 1

Bajra Biscuits

Bajra flour (25%), wheat flour (25%), sugar power (25%) and butter (25%)

▼

Sieving of all flours

▼

Sugar power and butter were creamed together

▼

Add remaining flours and prepare soft dough

▼

Dough spread in to a sheet and into suitable shapes and sizes

▼

Cut pieces were gently placed on baking tray

▼

Tray was placed on oven for approx. 15 minutes at 170°C

▼

Baked biscuits remove from oven and cooled

▼

Weighing

▼

Packing and labelling

#

Chat – 2

Finger millet muruku

Fingner millet flour (60%), black gramdal flour (20%), Bengal gram dal flour (20%)

▼

Sieve all flours

▼

Add sesame and cumin seeds, salt and heated oil

▼

Add water and prepare dough

▼

Dough put into muruku presser and press muruku

▼

Fry in oil

▼

Finger millet muruku

▼

Weighing

▼

Packing and labelling

Chat – 3

Sorghum mixture

Sorghum flour (50%), Bengal gram flour (50%)

▼

Sieve flours

▼

Add salt red chilli powder and water

▼

Prepare dough and press jowar sev with muruku presser

▼

Fry in oil

▼

Roasted Bengal gram dal, groundnut and rice flakes fry in oil

▼

Fried ingredients mixed to jowarsev

▼

Jowar mixture

▼

Weighing

▼

Packing and labelling

were assessed for nutrient composition by computation method using 'Nutritive Value of Indian Foods' (Gopalan *et al*., 2004).

Establishment of processing unit

To bring systemization and regular production, there was a need for establishment of t own processing unit for preparation of millet based products. Hence a plan was developed for establishment of processing unit with minimum necessary machineries

Chat – 4

Foxtail millet laddu

Foxtail millet flour (53%) roasted Bengal gram flour (10.5%)

▼

Roast with ghee (10.5%)

▼

Cool it

▼

Add sugar powder (26%) and cardamom

▼

Mill it well

▼

Press laddu

▼

Foxtail millet laddu

▼

Weighing

▼

Packing and labelling

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farm women
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le 1. The age

profile indicated that majority of farm women belonged to the age group of 26-35 years (52%) followed by 21-25 years (32%). With respect to literacy, 57.3 per cent of women were educated up to high school level followed by primary education level (32 %) and only 10.7 per cent were illiterates. The occupation pattern indicated that majority (65.3%) of them were farm labor followed by housewives (34.7%). Majority of these women were having two children (53.3%) and the family size was 2-4 members (62.7%). The results also showed that 76 per cent of families were nuclear.

Nutrient composition of value added products

The nutrient composition of millets value added products viz., bajra biscuits, finger millet muruku, sorghum mixture and foxtail millet laddu was calculated and given in table 2. The nutrient content of the products which were promoted through these interventions ranged from 60.1- 67.08g of carbohydrates, 5.52-15.6g of protein, 2.18-21.6g of fat, 19.25-248.4 mg calcium and 1.85-5.65 mg iron. Nutritional values are on par with the study conducted by Yenagi *et al*. (2010) on nutrient composition of ethnic and novel foods from minor millets.

Establishment of processing and value addition unit:

After acquainting with processing, preparation of value added products and packing, two trainees Mrs. Thajwarsulthana and Najimunnisha from Piler mandal and one trainee Mrs. M. Frida from Kalikiri mandal came forward to take up processing and value addition of millets as an entrepreneurial activity. Under technical guidance of KVK, Kalikiri and with the financial support of Development Of Women And Children In Rural Areas (DWCRA), they have established two small scale processing and value addition units in their locality. Rooms were rented for establishment of the units necessary equipment's viz., bakery oven, weighing scale and sealing machine were purchased. KVK, Kalikiri have assisted them in procuring of equipments, installation and handling. Scientists from KVK, Kalikiri have regularly supervised and monitored the quality of the end products ensuring use of good quality raw material, oils etc. KVK, Kalikiri also have assisted the entrepreneurs for registration of their unit with Food Safety and Standards Authority of India 2006. The units were registered with brand names "AROGYA MILLET FOODS" (FSSAI Reg. No. 20116020000285) and "STAR HEALTHY SNACKS" by the three entrepreneurs.

Marketing of the value added products:

Initially the products produced by these women were sold under the brand name of KVK, Kalikiri during agricultural exhibitions organized by Acharya N.G. Ranga Agricultural University, Guntur and the department of agriculture, Andhra Pradesh in different locations. After creating a platform for these products, the products were placed in the local stores in Kalikiri, Piler, Super markets in Tirupati and wholesale shops in Nandyal of Kurnool district. An exclusive outlet for sale of these products was also opened in the vicinity of KVK, Kalikiru for

Table 1. Socio-demographic profile of farm women

Variables	Category	N=75	
		Number	Percentage
Age	21-25 Years	24	32
	26-35 Years	39	52
	36-40 Years	12	16
Education	Illiterates	08	10.7
	Primary	24	32
	High school/above	43	57.3
Occupation	Housewife	26	34.7
	Labour	49	65.3
Type of Family	Nuclear	57	76
	Joint	18	24
Family size	2-4 members	47	62.7
	5-7 members	28	37.3
Number of Children	One	07	9.3
	Two	40	53.3
	Three and above	28	37.4

meeting the local demand. In addition to the regular market avenues, the value added products were also being supplied to KVK, Kalikiri and Regional Agricultural Research Station (RARS), Tirupati and other institutions for distributing the same as snacks to the participants during various training programs and other official meetings. On an average, about 350 kg of various millet based products were being produced and sold per month with a net profit of ₹ 40,000-45,000/-.

Economics of value addition to millets:

On the basis of one year data, the economic analysis of the four products viz., bajra biscuits, finger millet muruku, sorghum mixture and foxtail millet laddu are presented in the Table-3. The monthly sales were around 95-100kg bajra biscuits, 115-120kg finger millet muruku (Chakli), 110-115kg sorghum mixture and 90-95kg foxtail millet laddu earning monthly net profit of ₹ 10,545-11,100 from bajra biscuits; ₹ 11,845-12,360 from finger millet muruku (Chakli); ₹ 10,670-11,155 from sorghum mixture and ₹ 11,970-12,635from foxtail millet laddu.

Thus, a small intervention made by KVK, Kalikiri in convergence with DRDA resulted in a sustainable income generation for poor rural women and enhanced their livelihood standards. Incidentally, the annual consumption of raw material by these value added units annually was around 1000 kg of finger millet, 800 kg of foxtail millet, 900 kg of jowar and 400 kg of bajra thereby creating market for rainfed farmers of the region. This process can raise the income of farmers and could provide incentive for improving their management practices towards higher farm productivity. The income of the farmers can be enhanced by increasing production, value addition and better marketing options. An efficient value chain by linking small and marginal farmers to these value added units will enhance the net returns for both the parties mutually.

CONCLUSION

The interventions of KrishiVigyan Kendra played a strategic role in increasing self-confidence among farm women in undertaking small scale food processing and value addition units at their village level and to reach the market in urban area. The consolidated initiation of farm women on processing and preparation of value addition to millets is a new way of self-reliance practice. The entrepreneurship activity focusing the millet products has not only generated the additional employment and enhanced income of the families but also saved the farm families from hunting of work to earn livelihood. Further availability of millet products will help in enhancing its consumption which in turn improve the nutritional intake of the consumers.

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Table 2. Nutrient composition of value added millet products

Products	Protein (g)	Carbohydrates (g)	Fat (g)	Calcium(mg)	Iron (mg)
Bajra biscuits	5.52	60.1	21.6	19.25	2.7
Finger millet muruku	13.34	67.08	2.18	248.4	4.16
sorghum mixture	15.6	66.2	3.75	40.5	4.7
Foxtail millet laddu	8.32	65.4	13.1	25.5	2.54

Table 3. Income generated from production and marketing of value added finger millet products

Products	Production cost (₹ kg^{-1})	Selling price (₹ kg^{-1})	Net profit (₹ kg^{-1})	Sales/ month (kg)	Profit/month (₹)
Bajra biscuits	89	200	111	95 – 100 kg	10,545 – 11,100
Finger millet muruku (Chakli)	97	200	103	115 – 120 kg	11,845 – 12,360
Sorghum mixture	103	200	97	110 – 115 kg	10,670 – 11,155
Foxtail millet laddu	107	240	133	90 – 95 kg	11,970 – 12,635
				Total Earnings / month (₹)	**45,030 – 47,250**

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FIELD EVALUATION OF CARBOSULFAN 25 EC (NS) AGAINST RICE GREEN LEAFHOPPERS (*Nephotettix virescens* Distant. and *Nephotettix nigropictus* Stal.)

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ABSTRACT

Supervised field experiments were conducted in rice for two seasons to evaluate the bioefficacy of carbosulfan 25 EC (New Source) as foliar spray against green leafhoppers (GLH) (*Nephotettix virescens* Distant. and *Nephotettix nigropictus* Stal.) in rice ecosystem. Application of carbosulfan 25 EC (NS) at 300, 250, 200 and 150 g a.i. ha^{-1} recorded 83.90, 79.49, 62.94, 55.43 and 80.95, 76.49, 54.44, 41.97 per cent reduction of GLH population during first and second season, whereas carbosulfan 25 EC (Existing Source) 250 g a.i. ha^{-1} recorded 77.60 and 75.37 per cent reduction of GLH population during first and second season, respectively. The standard check chlorpyrifos 20 EC at 375 g a.i. ha^{-1} and at 250 g a.i. ha^{-1} recorded 61.29, 53,54 and 51.69, 40.38 per cent reduction of GLH population during first and second season, respectively. Carbosulfan 25 EC (NS) recorded a significant reduction in the GLH population and the effect was remarkable in both the seasons. Carbosulfan 25 EC (NS) at 300 g a.i. ha^{-1} was more effective in reducing GLH population than the lower doses 150, 200 and 250 g a.i. ha^{-1}. Based on the per cent reduction in mean GLH population over untreated check after two sprays in both seasons, the order of efficacy of different treatments is as follows: carbosulfan 25 EC (NS) 300 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 250 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 200 g a.i. ha^{-1}, chlorpyrifos 20 EC 375 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 150 g a.i. ha^{-1} and chlorpyrifos 20 EC 250 g a.i. ha^{-1}.

KEYWORDS: Carbosulfan 25 EC (NS), Chlorpyrifos, *Nephotettix nigropictus*, *Nephotettix virescens.*

INTRODUCTION

Rice is the staple food for more than 65 per cent Indian population, with largest area of 44.6 m ha under rice cultivation. Rice production in India is limited by severe outbreak of insect pests and diseases. More than 70 insect species are infesting rice in India and among them 20 are of regular occurrence (Pathak, 1975). On an average, farmers lose 37 per cent of their rice yield due to pests and diseases, these losses range between 24 and 41 per cent depending on the production situation (Sparks *et al.,* 2012). Among the biotic stresses, insect pests cause about 10-15 per cent yield losses. Yellow stem borer, brown planthopper and gall midge were the key pests in rice causing 25-30, 10-70 and 15-60 per cent yield losses, respectively. At national level, stem borers accounted for 30 per cent of the loss, while that of planthoppers, gall midge, leaf folder and other pests was 10-25 per cent (Herdt, 1991). Two species of green leafhoppers, *viz.*, *Nephotettix virescens* (Distant.) and *Nephotettix nigropictus* (Stal.) are the most common and act as a vector for Tungro/ yellow dwarf/ Transitory yellowing diseases (Bapreddy, 1968). Rice Tungro Virus (RTV) confined to eastern states till 1981, caused extensive damage in coastal Tamil Nadu and Andhra Pradesh during 1983 and 1984, respectively (Krishnaiah and Varma, 2010).

In order to combat the threat posed by the wide range of insect pest complex and to sustain the production, farmers are using insecticides as first line of defense among the various strategies adopted due to their higher efficacy. In India, about one fifth (17-18%) of the pesticides used in agriculture is on rice (Kapadia and Mohla, 1980).

Carbosulfan 25 EC (Marshal®), carbamate insecticide both contact and systemic in action developed by Farm Machinery and Chemicals (FMC) is recommended for the management of insect pests in agriculture. Carbosulfan both 25 EC and 25 DS formulations have proved effective as foliar spray and seed dresser against many insect pests of okra, chillies, rice, beans, maize, apple, cotton, brinjal, citrus and

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cauliflower as well as found to be a safer molecule (Ali and Chinniah., 1999; Karthikeyan and Purushothaman., 2000; Singh *et al*., 2000; Sontakke and Dash., 2000; Srinivasan and Rabindra., 2001).

Krishnaiah and Kalode (1986) reported that root dip treatment of carbosulfan showed the best control against green leafhopper, *Nephotettix virescens* (Distant). Studies with neem oil, monocrotophos at 0.3l g a.i. ha^{-1} and carbosulfan 0.3l g a.i. ha^{-1} on rice green leafhopper indicated that plots treated with monocrotophos and carbosulfan showed higher yield than control plots. At 32 DAT, monocrotophos treated plots had significantly less green leafhopper population than control and at 36 DAT carbosulfan treated plots had significantly less GLH than control plots. (Jahn, 1992). Efficacy of carbosulfan granules against rice pest complex was observed as similar to carbofuran granules through multilocation trials (DRR, 2001). Carbosulfan (Marshal) was found to be the least toxic to predators in cotton ecosystem. Isofenphos 5 G (2 kg a.i. ha^{-1}), carbosulfan 10 G (4 kg a.i. ha^{-1}), isofenphos 5 G (5 kg a.i. ha^{-1}) and phorate 10 G (4 kg a.i. ha^{-1}) were found to be safer to natural enemies in groundnut (Rajagopal and Gowda, 1992).

In the event of change in source material of carbosulfan 25EC, it is mandatory to generate data on the bioefficacy, phytotoxicity, residues and safety to the natural enemies as per the guidelines of Central Insecticides Board (CIB). To elucidate more information on the impact of carbosulfan 25 EC New Source (NS) in rice ecosystem, the present investigation was under taken.

MATERIALS AND METHODS

Field experiments were conducted at Paddy Breeding Station (PBS), Tamil Nadu Agricultural University, Coimbatore to assess the bioefficacy of carbosulfan 25 EC against rice green leafhoppers, *viz., Nephotettix virescens* (Distant.) and *Nephotettix nigropictus* (Stal.). Two field experiments were laid out using Randomized Block Design (RBD) with the varietal line CB 06 535, one during August – November 2012 and another during December 2012 to March 2013, with three replications, with each plot having size of 40 m^2. Bioefficacy of carbosulfan 25 EC (New Source- NS) and carbosulfan 25 EC (Existing Source- ES) was evaluated against green leafhopper, along with chlorpyrifos 20 EC as standard check. The treatments evaluated were as follows:

Treatment No.	Treatment	Dose (g a.i. ha^{-1})
T_1	Carbosulfan 25 EC (NS)	150
T_2	Carbosulfan 25 EC (NS)	200
T_3	Carbosulfan 25 EC (NS)	250
T_4	Carbosulfan 25 EC (NS)	300
T_5	Carbosulfan 25 EC (ES)	250
T_6	Chlorpyrifos 20 EC	250
T_7	Chlorpyrifos 20 EC	375
T_8	Untreated Control	-

NS – New Source ES – Existing Source

Two rounds of sprayings were given, one at 21 days after transplanting (DAT) and other at 45 DAT with battery operated knapsack sprayer by using 500 litres of spray fluid per hectare.

Assessment of Pest Population

The populations of green leafhoppers (GLH) were recorded on five randomly selected hills from each plot. The observations were recorded one day before spraying and 7, 14 and 21 days after each spraying. Both adults and nymphs were counted on five randomly selected hills from each plot and expressed as number of adults and nymphs per hill. The observations recorded were later averaged to per replication basis.

The data on population number was transformed into $\sqrt{x+0.5}$ before statistical analysis. The data obtained from field experiments were analysed using factorial randomised block design (Gomez and Gomez, 1984) and the mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

RESULTS AND DISCUSSION

The results of the field experiment during first season showed that the population was uniform in the pre treatment count ranging between 5.73 and 6.23 per hill among different experimental plots and was found to be non significant (Table 1). The population observed after first spraying on 7 DAA was the least (1.74 $hill^{-1}$) in carbosulfan 25 EC (NS) 300 g a.i. ha^{-1} treated plots

Table 1. Bioefficacy of carbosulfan 25EC (NS) against rice green leafhoppers after first and second application - Season I

Treatments	Dose (g a.i. ha $^{-1}$)	Number of nymphs and adults per hill*							Mean	Percent reduction over check
		Days after first application				Days after second application				
		PTC	7 DAA	14 DAA	21 DAA	7 DAA	14 DAA	21 DAA		
Carbosulfan 25 EC (NS)	150	6.07 (2.56)	3.97^{c} (2.11)	5.29^{c} (2.41)	5.74^{d} (2.50)	3.27^{bc} (1.94)	5.90^{c} (2.53)	6.14^{c} (2.58)	**5.05**	**55.43**
Carbosulfan 25 EC (NS)	200	5.73 (2.50)	3.26^{bc} (1.94)	4.82^{c} (2.31)	5.04^{cd} (2.35)	2.52^{b} (1.73)	4.68^{b} (2.28)	4.88^{b} (2.32)	**4.20**	**62.94**
Carbosulfan 25 EC (NS)	250	6.13 (2.58)	2.08^{a} (1.60)	3.27^{b} (1.94)	3.42^{b} (1.98)	1.64^{a} (1.46)	1.70^{a} (1.48)	1.84^{a} (1.53)	**2.33**	**79.49**
Carbosulfan 25 EC (NS)	300	6.00 (2.55)	1.74^{a} (1.49)	2.34^{a} (1.69)	2.54^{a} (1.74)	1.17^{a} (1.29)	1.56^{a} (1.44)	1.60^{a} (1.45)	**1.83**	**83.90**
Carbosulfan 25 EC (ES)	250	5.80 (2.51)	2.17^{a} (1.63)	3.57^{b} (2.02)	3.73^{b} (2.06)	1.78^{a} (1.51)	1.81^{a} (1.52)	2.17^{a} (1.63)	**2.54**	**77.60**
Chlorpyrifos 20 EC	250	5.97 (2.54)	4.25^{c} (2.18)	5.35^{c} (2.42)	5.84^{d} (2.52)	3.92^{c} (2.10)	5.94^{c} (2.54)	6.29^{c} (2.10)	**5.27**	**53.54**
Chlorpyrifos 20 EC	375	6.19 (2.59)	3.48^{bc} (1.99)	4.97^{c} (2.34)	5.12^{cd} (2.37)	2.76^{b} (1.80)	4.82^{bc} (2.31)	5.17^{b} (2.38)	**4.39**	**61.29**
Untreated check	-	6.23 (2.59)	8.74^{d} (3.04)	10.40^{e} (3.30)	10.93^{e} (3.38)	11.68^{d} (3.49)	12.80^{d} (3.65)	13.45^{d} (3.73)	**11.33**	**-**
CD at P = 0.05%	-	-	0.23	0.20	0.19	0.25	0.22	0.21	-	-
SEM	-	-	0.07	0.06	0.06	0.08	0.07	0.07	-	-

* Mean of five observations; PTC – Pre treatment count; DAA- Days after application

Figures in parentheses are $\sqrt{x+0.5}$ transformed values of five observations

In a column, means followed by a common letter(s) are not significantly different by DMRT (P=0.05)

Table 2. Bioefficacy of carbosulfan 25 EC (NS) against rice green leafhoppers after first and second application - Season II

Treatments	Dose (g a.i. ha $^{-1}$)	Number of nymphs and adults per hill*							Mean	Percent reduction over check
		Days after first application				Days after second application				
		PTC	7 DAA	14 DAA	21 DAA	7 DAA	14 DAA	21 DAA		
Carbosulfan 25 EC (NS)	150	8.10 (2.93)	5.63^{cd} (2.47)	7.52^{cd} (2.83)	8.16^{c} (2.94)	5.13^{d} (2.37)	7.64^{c} (2.85)	7.89^{c} (2.90)	**7.00**	**41.97**
Carbosulfan 25 EC (NS)	200	7.53 (2.83)	4.16^{bc} (2.16)	6.63^{c} (2.67)	6.90^{b} (2.72)	3.46^{c} (1.99)	5.70^{b} (2.49)	6.10^{b} (2.57)	**5.49**	**54.44**
Carbosulfan 25 EC (NS)	250	7.32 (2.80)	3.67^{b} (2.04)	3.71^{b} (2.05)	4.16^{a} (2.16)	1.64^{b} (1.46)	1.84^{a} (1.53)	1.98^{a} (1.57)	**2.83**	**76.49**
Carbosulfan 25 EC (NS)	300	7.64 (2.85)	2.82^{a} (1.82)	2.90^{a} (1.84)	3.74^{a} (2.06)	0.97^{a} (1.21)	1.62^{a} (1.46)	1.73^{a} (1.49)	**2.30**	**80.95**
Carbosulfan 25 EC (ES)	250	8.00 (2.92)	3.79^{b} (2.07)	3.96^{b} (2.11)	4.30^{a} (2.19)	1.76^{b} (1.50)	1.90^{a} (1.55)	2.10^{a} (1.61)	**2.97**	**75.37**
Chlorpyrifos 20 EC	250	7.94 (2.91)	5.97^{d} (2.54)	7.78^{d} (2.88)	8.35^{c} (2.97)	5.28^{d} (2.40)	7.84^{c} (2.89)	7.90^{c} (2.90)	**7.19**	**40.38**
Chlorpyrifos 20 EC	375	7.87 (2.89)	4.74^{c} (2.29)	6.92^{cd} (2.72)	7.12^{b} (2.76)	3.67^{c} (2.04)	6.00^{b} (2.55)	6.49^{b} (2.64)	**5.82**	**51.69**
Untreated check	-	8.07 (2.93)	9.26^{e} (3.12)	10.38^{e} (3.30)	11.70^{d} (3.49)	12.64^{e} (3.62)	13.48^{d} (3.74)	14.86^{d} (3.92)	**12.05**	-
CD at P = 0.05%	-	-	0.19	0.18	0.17	0.24	0.21	0.20	-	-
SEM	-	-	0.06	0.05	0.05	0.07	0.07	0.06	-	-

* Mean of five observations; PTC – Pre treatment count; DAA- Days after application

Figures in parentheses are $\sqrt{x+0.5}$ transformed values of five observations

In a column, means followed by a common letter(s) are not significantly different by DMRT (P=0.05)

followed by 2.08, 2.17, 3.26, 3.48, 3.97, 4.25 and 8.74 per hill in carbosulfan 25 EC (NS) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 200 g a.i. ha^{-1}, chlorpyrifos 20 EC 375 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 150 g a.i. ha^{-1}, chlorpyrifos 20 EC 250 g a.i. ha^{-1} and untreated check plots, respectively. At 14 and 21 DAA, the green leafhopper population was found significantly minimum in carbosulfan 25 EC (NS) at 300 g a.i. ha^{-1} treated plots with a population of 2.34 and 2.54 per hill respectively compared to all other treatments.

After second application also, the population was observed to be the lowest in plots treated with carbosulfan 25 EC (NS) 300 g a.i. ha^{-1} with pest population of 1.17, 1.56 and 1.60 per hills on 7, 14 and 21 DAA, respectively which were on par with carbosulfan 25 EC (NS) 250 g a.i. ha^{-1}, (1.64, 1.70 and 1.84 hill^{-1}, respectively) and carbosulfan 25 EC (ES) 250 g a.i. ha^{-1} (1.78,1.81 and 2.17 hill^{-1}, respectively) (Table 1).

In second season, at 7 DAA**,** the population per hill observed after first spray was found to be the least (2.82) in carbosulfan 25 EC (NS) 300 g a.i. ha^{-1} treated plots followed by 3.67, 3.79, 4.16, 4.74, 5.63, 5.97 and 9.26 in carbosulfan 25 EC (NS) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 200 g a.i. ha^{-1}, chlorpyrifos 20 EC 375 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 150 g a.i. ha^{-1}, chlorpyrifos 20 EC 250 g a.i. ha^{-1} and untreated check, respectively. On 14 DAA, carbosulfan 25 EC (NS) 300 g a.i. ha^{-1} treated plots recorded significantly the lowest (2.90 hill^{-1}). On 21 DAA, the population was on par in carbosulfan 25 EC (NS) 300 g a.i. ha^{-1}(3.74 hill^{-1}), carbosulfan 25 EC (NS) 250 g a.i. ha^{-1} (4.16 per hill) and carbosulfan 25 EC (ES) 250 g a.i. ha^{-1}(4.30 hill^{-1}) (Table 2). After second application, carbosulfan 25 EC (NS) at 300 g a.i. ha^{-1} treated plot recorded the least population count of 0.97, 1.62 and 1.73 hill^{-1} on 7, 14 and 21 DAA, respectively compared to all other treatments. The order of pest population found in different treatments were similar to that observed in first season. At 21 DAA, carbosulfan 25 EC (NS) 300 g a.i. ha^{-1} (1.73 hill^{-1}), carbosulfan 25 EC (NS) 250 g a.i. ha^{-1} (1.98 hill^{-1}) and carbosulfan 25 EC (ES) 250 g a.i. ha^{-1} (2.10 hill^{-1}) were on par with one another (Table 2).

Based on the per cent reduction in mean GLH population over untreated check after two sprays in both seasons, the order of efficacy of different treatments is as follows: carbosulfan 25 EC (NS) 300 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 250 g a.i. ha^{-1}, carbosulfan 25 EC (ES) 250 g a.i. ha^{-1}, carbosulfan 25 EC (NS) 200 g a.i. ha^{-1}, chlorpyrifos 20 EC 375 g a.i.ha^{-1}, carbosulfan 25 EC (NS) 150 g a.i. ha^{-1} and chlorpyrifos 20 EC 250 g a.i. ha^{-1}. Carbosulfan 25 EC (NS) recorded a significant reduction in the GLH population and the effect was remarkable in both the seasons. Carbosulfan 25 EC (NS) at the test doses *viz*., 150, 200, 250 and 300 g a.i. ha^{-1} registered 55.43 to 83.90 and 41.97 to 80.95 per cent mean reduction in GLH population in season I and season II, respectively. Carbosulfan 25 EC (NS) at 300 g a.i. ha^{-1} was more effective in reducing GLH population than the lower doses 150, 200 and 250 g a.i. ha^{-1} (Fig. 5).

Several workers confirmed the effectiveness of carbosulfan against rice leafhoppers. Reissig *et al.* (1986) reported that monocrotophos and carbosulfan treatments significantly reduced the density of Green leafhopper than the untreated check. Jahn (1992) also reported that even at 36 DAT, carbosulfan treated plots had significantly less GLH population than control plots. Krishnaiah and Kalode (1986) reported that root dip treatment of carbosulfan showed the best control against green leafhopper, *N. virescens*. Superiority of higher doses of carbosulfan 25 EC in these studies were in consonance with the findings of Jasmine (2002) who reported that the highest dose of carbosulfan 25 EC at 300 g a.i. ha^{-1} was superior to the lower dose of 200 g a.i. ha^{-1} in controlling the thrips on cotton.

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SOIL NUTRIENT STATUS AND SPATIAL VARIABILITY ANALYSIS USING RS & GIS: A CASE STUDY OF RAMAKUPPAM MANDAL, ANDHRA PRADESH

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ABSTRACT

Soil nutrients denotes the soil fertility status and play a vital role in crop production for sustainability. Based on geo-statistics and GIS, the spatial variation of pH, EC, available nitrogen, phosphorus, potassium and DTPA extractable micronutrients in the soils of Ramakuppam mandal of Andhra Pradesh was studied. The spatial variation of available nitrogen, phosphorus, potassium and micro nutrients were greatly affected by soil structural factors. The spatial distribution of soil nutrients in Ramakuppam mandal was intuitively characterized by Kriging interpolation. It is very important to understand the spatial distribution of soil nutrients, which will provide guidance for adjusting agricultural management measures in general and fertilizer application in particular.

KEYWORDS: Spatial Analysis, Geo-Statistics, Soil Nutrients, Kriging, Soil Nutrient Maps

INTRODUCTION

The introduction of high yielding varieties and chemical fertilizers during the post independence era in India made a great influence on Indian soils (Bouma and Finke, 1993; Cattle *et al*., 1994; Yao *et al*., 2005) and soil nutrients leading to a high spatial heterogeneity. The spatial heterogeneity is the main factor that influences the yield and quality of crops (Eghball and Schepers, 2003), which also forms an important basis of agricultural management and the foundation of soil resource management. Therefore, it is of greater significance to strengthen the study of spatial heterogeneity of soil nutrients to realize the spatial layout of agricultural production and also to provide the basic information and suggestions for food production and land use planning. In recent years with the advancement of ICTs, the GIS and remote sensing, technologies have been extensively used in the research of soil science, especially in the study of the spatial variability of soil properties (Wang *et al*., 2003**;** Si *et al*., 2009; Liu *et al*., 2010; Qiu *et al*., 2010; Zhang *et al*., 2010), which has provided effective guidance for agricultural production. In this paper, Ramakuppam mandal of Chittoor District of Andhra Pradesh was selected for studying the spatial heterogeneity of soil nutrients quantifiably using Kriging interpolation technique, which would be of great significance for the effective use and management of soil nutrients, and also to provide a reference point for the application of fertilizers.

MATERIALS AND METHODOLOGY

Soil sampling, processing and storage

One thousands and fifty two surface soil samples were collected at the rate of one sample per every 10 hectares of arable land in 39 villages with the help of Global Positioning System (GPS).Samples were then kept in labeled plastic bags and brought to the laboratory for analyses. The soil samples were air-dried and sieved and passed through 2 mm mesh sieve.

The available nitrogen was determined by alkaline permanganate method outlined by Subbaih and Asija (1956) and the results are expressed in kg ha^{-1}.The available phosphorus content was determined by extracting the soil with 0.5M NaHCO3 (Olsen *et al*., 1954) and estimated by developing blue colour using ascorbic acid as reductant on colorimeter (Olsen and Watanabe, 1965). Available potassium in the soils was extracted by neutral normal ammonium acetate and determined by the flame photometer (Jackson, 1973).The available micronutrients *viz*., Zn, Cu, Fe and Mn were determined in the DTPA extract of soil (pH 7.3) using Atomic Absorption Spectrophotometer as outlined by Lindsay and Norwell (1978).

Soil variation is spatial variable and this has been recognized for many years (Burrough, 1993). Quantification of spatial variability of soil fertility parameters is essential

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Table 1. pH, E.C, N, P, K status in the villages of Ramakuppam Mandal

S. No.	Village name	No. of Samples	pH				EC		N kg ha^{-1}			P kg ha^{-1}			K kg ha^{-1}		
			<6.5	6.5-7.5	7.6-8.4	>8.4	<4	>4	L	M	H	L	M	H	L	M	H
1	Mittapalli	12	2	9	1	0	12	0	12	-	-	1	7	4	2	9	1
2	Rajupeta	8	2	6	0	0	8	0	8	-	-	-	1	7	-	6	2
3	Avulakuppam	8	1	4	3	0	8	0	8	-	-	1	2	5	1	7	-
4	Joukupalli	22	2	15	5	0	22	0	22	-	-	-	6	16	7	14	1
5	Govindapalli	25	1	15	9	0	25	0	25	-	-	-	1	24	13	11	1
6	Bhalla	47	1	25	15	6	47	0	47	-	-	10	7	30	36	11	-
7	Peddakurabalapalli	16	1	8	7	0	16	0	16	-	-	-	2	14	11	4	1
8	Peddaganuru	21	6	15	0	0	21	0	21	-	-	-	4	17	17	2	2
9	Unisiganipalli	13	3	6	4	0	13	0	13	-	-	-	2	11	3	9	1
10	Battuvaripalli	4	0	1	3	0	4	0	4	-	-	-	2	2	1	3	-
11	Ankireddipalli	15	3	7	5	0	15	0	14	1	-	4	-	11	13	1	1
12	Kilakupadu	17	0	8	9	0	17	0	17	-	-	-	-	17	12	3	2
13	Kadisinakuppam	14	0	8	6	0	14	0	14	-	-	2	3	9	6	5	3
14	Singasamudram	41	5	33	3	0	41	0	41	-	-	2	3	36	20	21	-
15	Kenchanabhalla	15	0	2	13	0	15	0	15	-	-	1	-	14	3	8	4
16	Patcharumakulapalli	28	1	10	14	3	28	0	28	-	-	-	-	28	4	14	10
17	Reddivanipodu	5	0	1	4	0	5	0	5	-	-	1	1	3	2	3	-
18	Chaldiganipalli	46	4	36	6	0	46	0	46	-	-	6	10	30	12	23	11
19	Muddanapalli	37	5	30	2	0	37	0	37	-	-	4	12	21	13	18	6
20	Giddapalli	4	1	3	0	0	4	0	4	-	-	-	2	2	2	2	-
21	Pamunaboyanapalli	6	0	5	1	0	6	0	6	-	-	1	2	3	3	2	1
22	Konganapalli	30	2	24	4	0	30	0	30	-	-	8	7	15	5	15	10
23	Kallupalli	20	1	13	6	0	20	0	19	1	-	3	5	12	9	11	-
24	Kempasamudram	37	1	29	7	0	37	0	37	-	-	2	13	22	21	13	3
25	Byparedlapalli	41	4	31	6	0	41	0	41	-	-	10	9	22	17	20	4
26	Maneedhram	43	0	26	17	0	43	0	42	1	-	11	7	25	16	14	13
27	Athikuppam	9	0	6	3	0	9	0	9	-	-	-	3	6	3	2	4
28	Bandharlapalli	10	0	6	4	0	10	0	10	-	-	-	2	8	4	6	-
29	Bandharlapalli	30	4	15	11	0	30	0	30	-	-	20	5	5	24	6	-
30	Bandharlapalli	10	4	6	0	0	10	0	10	-	-	4	2	4	7	3	-
31	Bhandarlapalli	10	3	7	0	0	10	0	10	-	-	8	1	1	9	1	-
32	Bandarlapalli	98	1	67	29	1	98	0	98	-	-	35	25	38	68	30	-
33	Ramakuppam	34	1	17	16	0	34	0	33	1	-	4	28	2	22	11	1
34	Pedduru	52	4	28	20	0	52	0	52	-	-	18	10	24	15	28	9
35	Bandalagunta	24	0	11	13	0	24	0	24	-	-	6	2	16	8	13	3
36	Veernamalathanda	73	5	49	19	0	73	0	73	-	-	38	12	23	39	26	8
37	Gurivimakulapalli	66	7	36	23	0	66	0	66	-	-	37	20	9	36	27	3
38	Pandyalamadugu	35	0	17	18	0	35	0	35	-	-	17	12	6	18	13	4
39	Ekambaram	26	0	13	13	0	26	0	26	-	-	13	11	2	16	9	1
	Total No. of samples	1052	75	648	319	10	1052	0	1048	4	0	267	241	544	518	424	110
	Range of nutrients		5.4-<6.5	6.50-7.5	7.6-8.4	>8.4	0.03-1.43	0	70-275	290-375		1-25	26-57.5	60-912.5	1-142.5	145-340	341-1125
	Percentage	100	7.12	61.61	30.32	0.95	100		99.6	0.4	0.0	25.4	22.9	51.7	49.2	40.3	10.5

Table 2. Micronutrient status in the villages of Ramakuppam Mandal

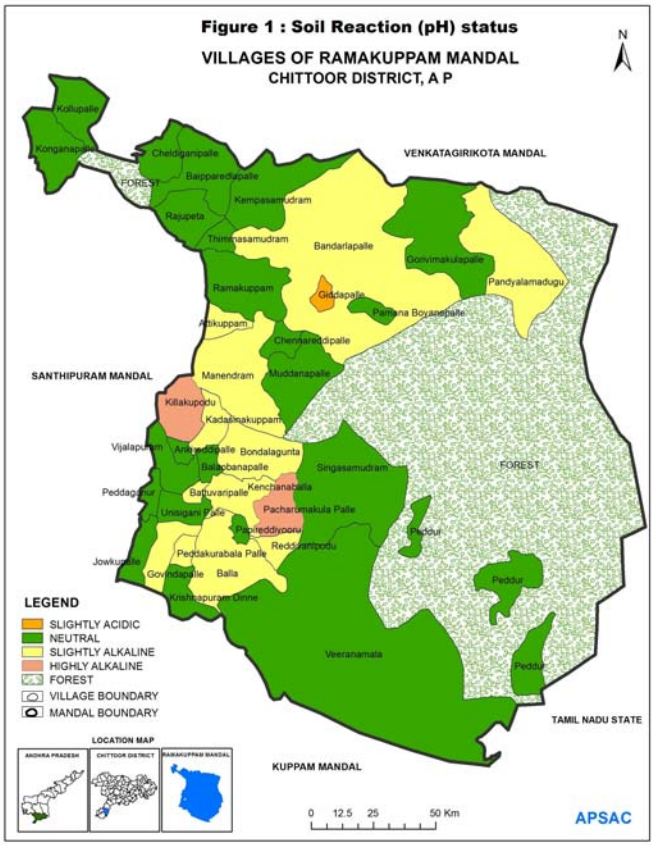
S. No.	Village name	Total	Zn mg kg^{-1}		Fe mg kg^{-1}		Cu mg kg^{-1}		Mn mg kg^{-1}	
			S	D	S	D	S	D	S	D
1	Mittapalli	12	1	11	12	-	12	-	12	-
2	Rajupeta	8	7	1	7	1	7	1	7	1
3	Avulakuppam	8	5	3	4	4	1	7	8	-
4	Joukupalli	22	17	5	11	11	19	3	22	-
5	Govindapalli	25	20	5	13	12	20	5	24	1
6	Bhalla	47	34	13	21	26	45	2	46	1
7	Peddakurabalapalli	16	12	4	7	9	15	1	16	-
8	Peddaganuru	21	19	2	11	10	21	-	21	-
9	Unisiganipalli	13	11	2	6	7	13	-	13	-
10	Battuvaripalli	4	4	-	3	1	4	-	4	-
11	Ankireddipalli	15	13	2	7	8	15	-	15	-
12	Kilakupadu	17	10	7	7	10	17	-	17	-
13	Kadisinakuppam	14	9	5	4	10	12	2	14	-
14	Singasamudram	41	24	17	34	7	41	-	40	1
15	Kenchanabhalla	15	9	6	6	9	14	1	15	-
16	Patcharumakulapalli	28	23	5	12	16	28	-	28	-
17	Reddivanipodu	5	3	2	2	3	5	-	5	-
18	Chaldiganipalli	46	43	3	43	3	46	-	46	-
19	Muddanapalli	37	20	17	20	17	37	-	37	-
20	Giddapalli	4	3	1	2	2	4	-	4	-
21	Pamunaboyanapalli	6	3	3	2	4	6	-	5	1
22	Konganapalli	30	22	8	29	1	30	-	30	-
23	Kallupalli	20	15	5	20	-	20	-	20	-
24	Kempasamudram	37	23	14	37	-	37	-	37	-
25	Byparedlapalli	41	29	12	36	5	41	-	41	-
26	Maneedhram	43	31	12	31	12	43	-	43	-
27	Athikuppam	9	8	1	8	1	9	-	9	-
28	Bandharlapalli	10	7	3	6	4	7	3	10	-
29	Bandharlapalli	30	17	13	11	19	30	-	30	-
30	Bandharlapalli	10	5	5	1	9	10	-	10	-
31	Bhandarlapalli	10	1	9	5	5	10	-	10	-
32	Bandarlapalli	98	70	28	55	43	92	6	98	-
33	Ramakuppam	34	23	11	24	10	34	-	33	1
34	Pedduru	52	46	6	41	11	45	7	52	-
35	Bandalagunta	24	6	18	14	10	22	2	20	4
36	Veernamalathanda	73	32	41	36	37	50	23	73	-
37	Gurivimakulapalli	66	33	33	33	33	59	7	66	-
38	Pandyalamadugu	35	23	12	19	16	30	5	35	-
39	Ekambaram	26	18	8	14	12	25	1	23	3
	Total	1052	699	353	654	398	976	76	1039	13
	Range of nutrients (mg kg^{-1})		0.03-0.65	0.66-6.5	0.1 - 4	4.1 -28.6	0.01 - 0.2	0.21- 13.24	0.8 - 2	2.1- 19.8
	Percentage	100	66.4	33.6	62.2	37.8	92.8	7.2	98.8	1.2

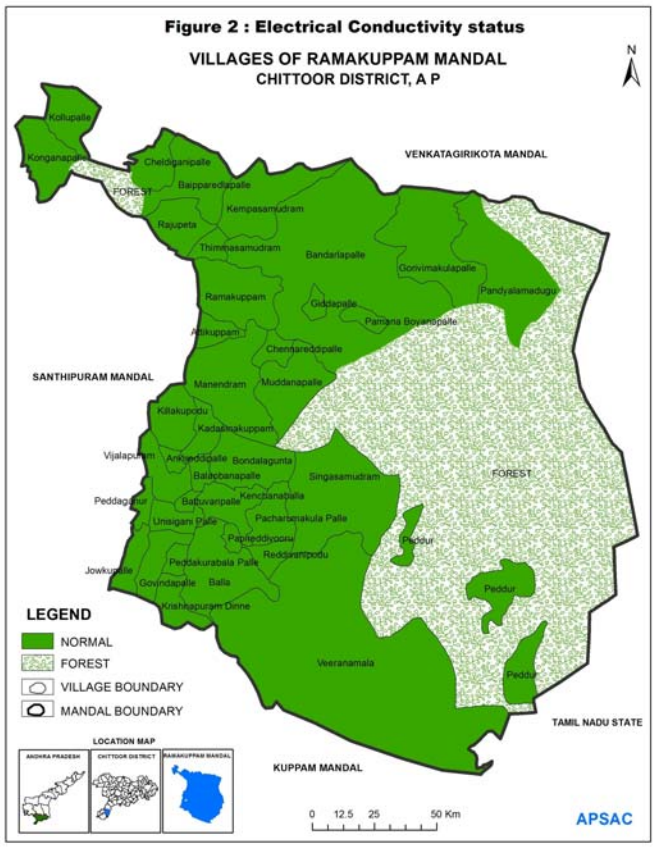
for formulating land management and to increase fertilizer utilization efficiency. Hence, in this study the spatial distribution of soil properties namely pH, EC, available macro and micro nutrients were assessed. Spatial variability maps were prepared through Kriging interpolation technique. Kriging interpolation theory is a method of interpolation which predicts unknown values from data observed at known locations. This method uses variogram to express the spatial variation, and it minimizes the error of predicted values which are estimated by measuring the spatial distribution of the predicted values. In this paper, semivariance analysis of soil nutrients was studied using the ArcGIS10.3 software to do the Kriging interpolation.

RESULTS AND DISCUSSION

Spatial distribution characteristic of soil nutrients

Spatial distribution of different soil parameters like pH, EC, available nitrogen, phosphorus, potassium and DTPA extractable micronutrients were determined by using Kriging interpolation technique in ArcGIS10.3 software. The results were discussed here under

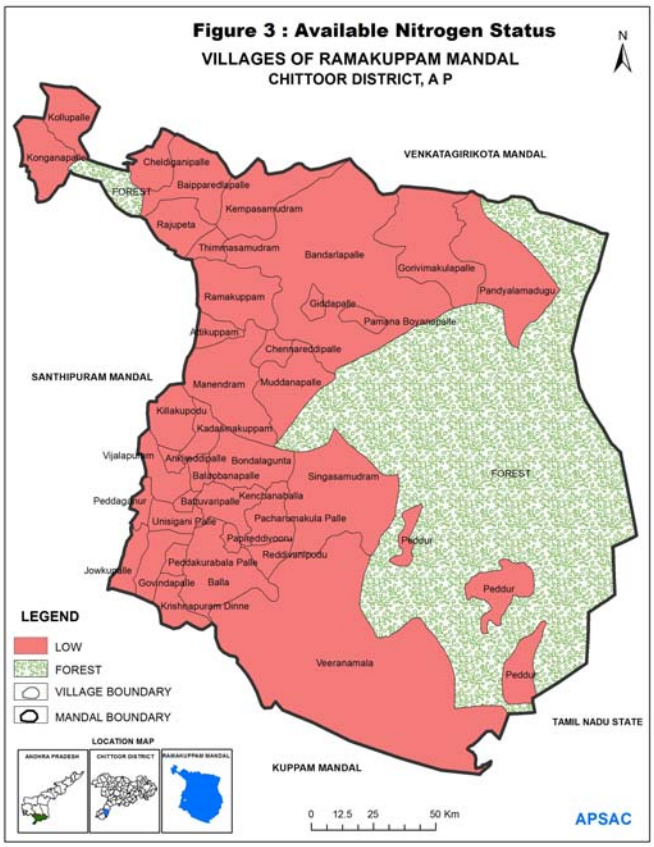




It was observed from Fig. 1 that pH values mainly vary from 5.2 to 9.2 in 39 villages of the mandal showing variation from slightly acidic to highly alkaline soils. Out of the 1052 samples analysed 75 samples were slightly acidic, 648 samples were neutral, 319 were slightly alkaline and the remaining 10 samples were highly alkaline (Table 1). The electrical conductivity of the samples were presented in Table 1 and depicted in Fig. 2 that showed EC range from 0.02 to 1.43 indicating that the entire area was suitable for crop cultivation.

Spatial distribution of available Nitrogen was presented in Table 1 and also depicted in fig.3 that showed that entire area (1048 samples out of 1052) was under low nitrogen status with a range of 70 to 275 kg ha^{-1}. Only 4 samples recorded medium status of available nitrogen (290-375 kg ha^{-1}).

The available phosphorous in the study area was presented in Table 1 that showed that there was a wide variability, with a range from 2.5 to 912.5 kg ha^{-1}. The spatial distribution for phosphorus showed that 267 samples recorded low, 241samples recorded medium and 544 samples recorded high for available phosphorus.



However, when these samples were grouped on village basis they fell in to medium and high range as depicted in fig. 4. The spatial distribution of available potassium was presented in Table 1 that showed that the range was from 1 to 1125 kg/ha. The sample distribution revealed that 518 samples recorded low, 424 samples recorded medium and only 110 samples recorded high for available potassium. On grouping all the villages they fell under low available potassium status and as depicted in fig. 5

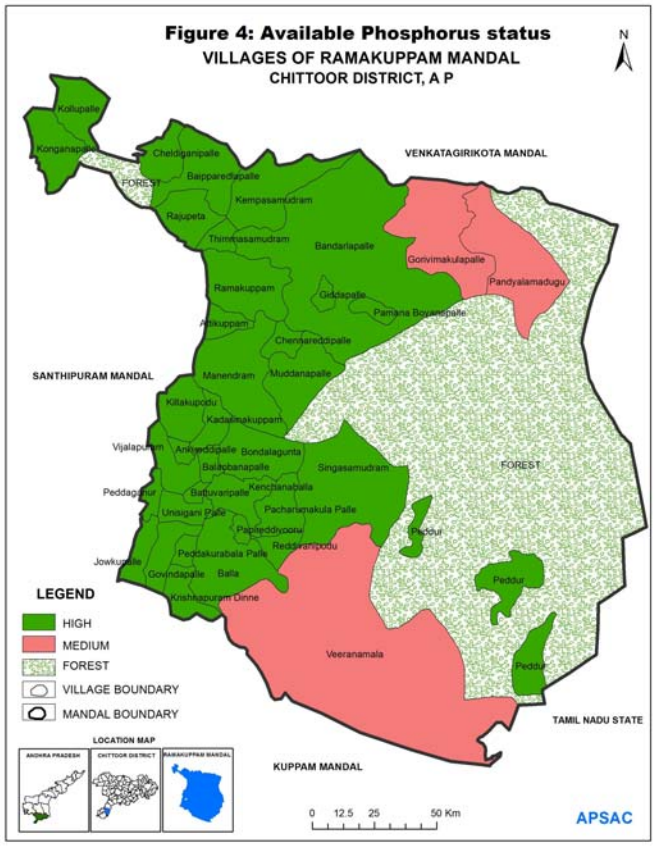
The available zinc status in the study area revealed that a significant number of samples (353 out of 1052) showed low zinc content amounting to 33.6 per cent of the total samples and the remaining 66.4 per cent samples (699) recorded sufficient zinc content. The range of available zinc in the study area was from 0.03- 6.5 mg kg^{-1} soil (Table 2 and Fig. 6). Available iron status of the study area ranged from 0.1 to 28.6 mg kg^{-1} soil and is presented in Table 2. The spatial distribution of available iron depicted in Fig. 7 revealed that 654 (62.2 %) samples recorded more than the critical limit for available iron and the remaining 398 (37.8 %) samples were having the available iron at below the critical limit. The range of available copper was from 0.01 to 13.24 mg kg^{-1} soil in the study area. For available copper, 976 (92.8 %) samples recorded above the critical limit and 76 (7.2%) samples recorded below the critical limit (Table 2). The micronutrient analysis report for available manganese revealed that 1039(98.8%) samples recorded above the critical limit where as only 13(1.2 %) samples recorded below the critical limit with a range from 0.8 to 19.8 mg kg^{-1}soil. The soil samples were grouped according to the availability and depicted in Fig.8 for copper and Fig.9 for manganese.

CONCLUSIONS

This paper studied the spatial variability of soil nutrients in Ramakuppam mandal of Andhra Pradesh by using geo-statistic and geographical information systems. The analysis report of 1052 soil samples collected from Ramakuppam mandal comprising 39 villages revealed that the soil reaction (pH) was slightly acidic to neutral in most of the soils and the electrical conductivity (EC) was normal in the entire study area.

Out of 1052 samples,

1. 99.6 per cent samples were low, 0.4 per cent were medium and 0per cent were high in available Nitrogen.



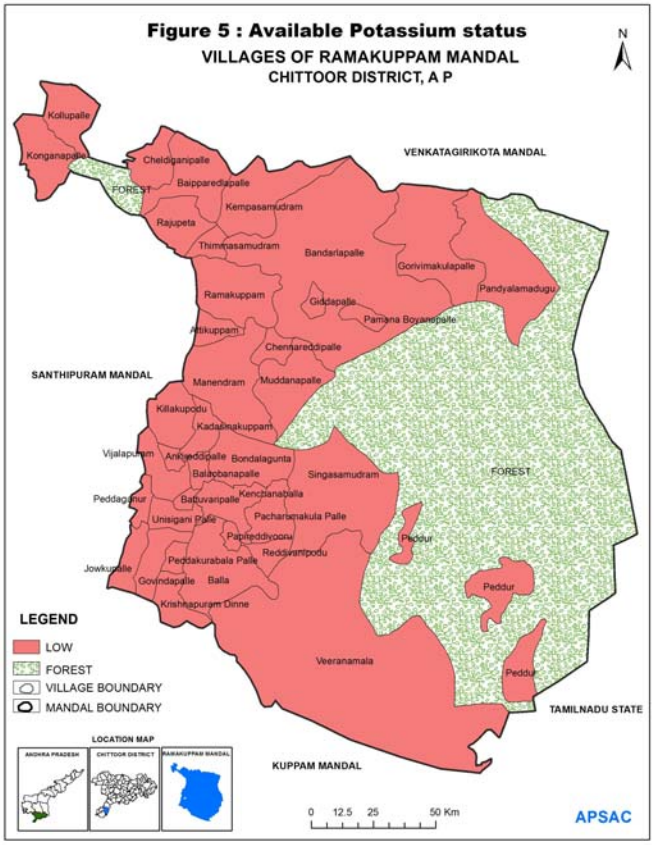


Figure 5 : Available Potassium status
VILLAGES OF RAMAKUPPAM MANDAL
CHITTOOR DISTRICT, A P
N
VENKATAGIRIKOTA MANDAL
SANTHIPURAM MANDAL
KUPPAM MANDAL
TAMILNADU STATE
FOREST
Kollupalle
Konganapalle
Cheldiganipalle
Baipparedipalle
Kempasamudram
Rajupeta
Thimmasamudram
Bandarlapalle
Gorivimakulapalle
Pandyalamadugu
Ramakuppam
Giddapalle
Pamana Boyanapalle
Attikuppam
Chennareddipalle
Manendram
Muddanapalle
Killakupodu
Kadamakuppam
Vijalapuram
Ankireddipalle
Bondalagunta
Balacbanapalle
Singasamudram
Peddagollur
Battuvaripalle
Kenchanaballa
Unisigani Palle
Pacharlamakula Palle
Papireddiyooru
Reddivaripodu
Jowkupalle
Pedakurabala Palle
Govindapalle
Balla
Krishnapuram Dinne
Veeranamala
Peddur
LEGEND
LOW
FOREST
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
ANDHRA PRADESH
CHITTOOR DISTRICT
RAMAKUPPAM MANDAL
0 12.5 25 50 Km
APSAC

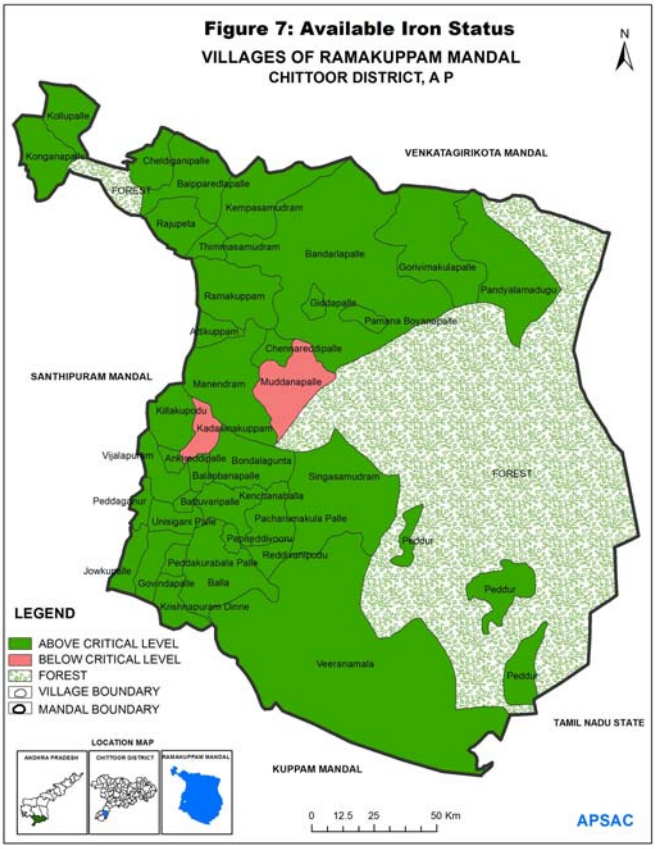


Figure 7: Available Iron Status
VILLAGES OF RAMAKUPPAM MANDAL
CHITTOOR DISTRICT, A P
N
VENKATAGIRIKOTA MANDAL
SANTHIPURAM MANDAL
KUPPAM MANDAL
TAMIL NADU STATE
FOREST
LEGEND
ABOVE CRITICAL LEVEL
BELOW CRITICAL LEVEL
FOREST
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
0 12.5 25 50 Km
APSAC

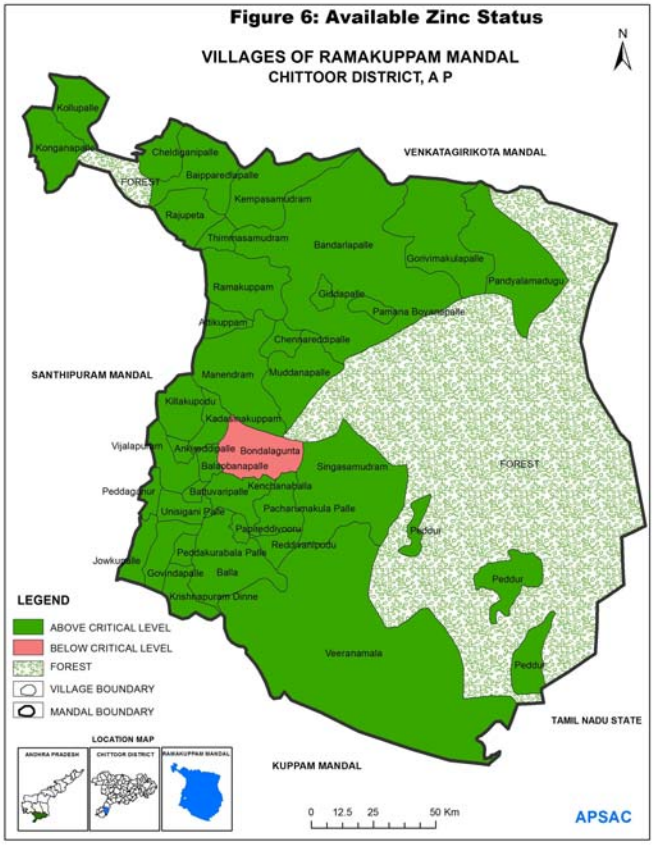


Figure 6: Available Zinc Status
VILLAGES OF RAMAKUPPAM MANDAL
CHITTOOR DISTRICT, A P
N
VENKATAGIRIKOTA MANDAL
SANTHIPURAM MANDAL
KUPPAM MANDAL
TAMIL NADU STATE
FOREST
LEGEND
ABOVE CRITICAL LEVEL
BELOW CRITICAL LEVEL
FOREST
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
0 12.5 25 50 Km
APSAC

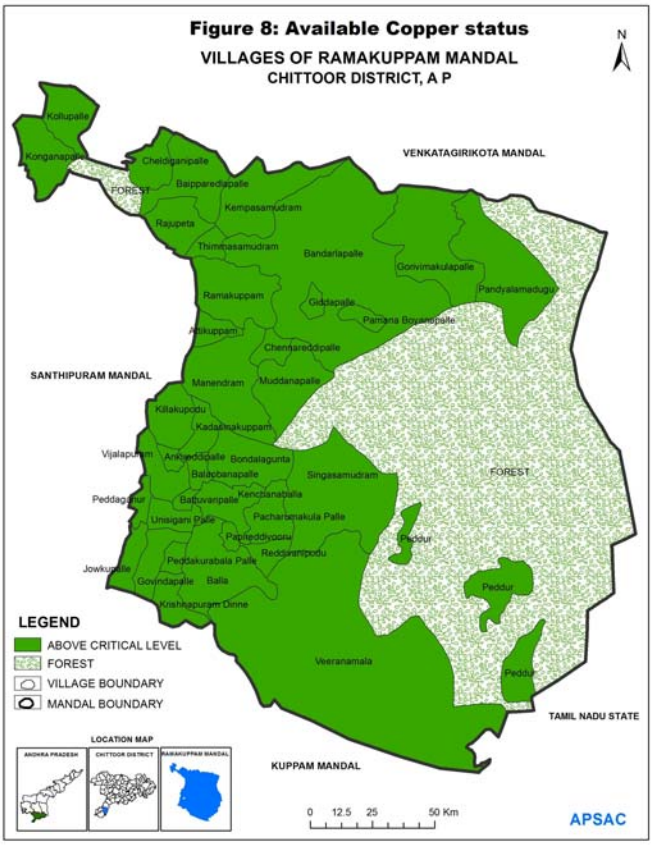
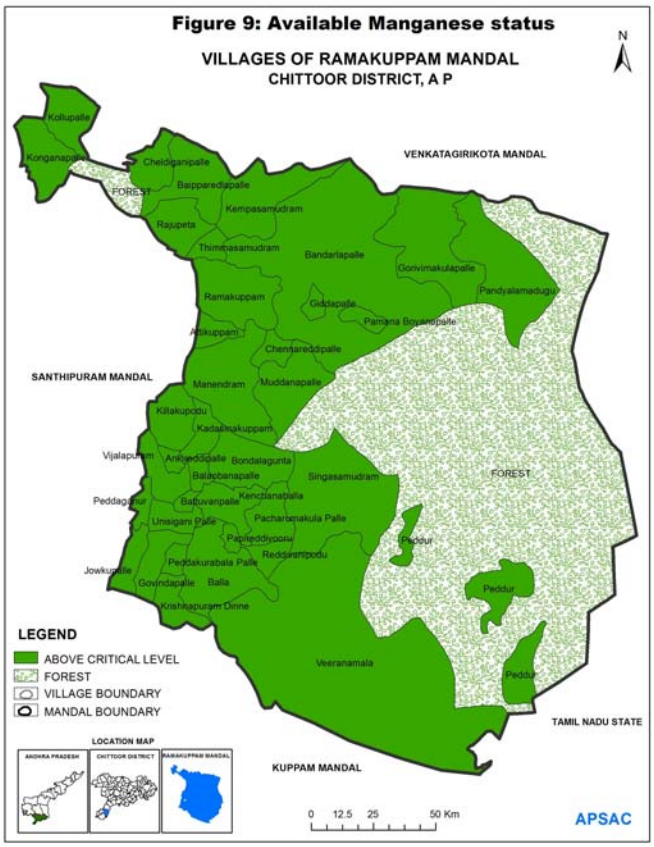


Figure 8: Available Copper status
VILLAGES OF RAMAKUPPAM MANDAL
CHITTOOR DISTRICT, A P
N
VENKATAGIRIKOTA MANDAL
SANTHIPURAM MANDAL
KUPPAM MANDAL
TAMIL NADU STATE
FOREST
LEGEND
ABOVE CRITICAL LEVEL
FOREST
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
0 12.5 25 50 Km
APSAC



2. 25.4 per cent were low, 22.9 5 were medium and 51.7 per cent were high in available Phosphorus.
3. 49.2per cent samples were low, 40.3 per cent were medium and 10.5 per cent samples were high in available Potassium.
4. 66.4per cent sample were sufficient and 33.6 per cent samples were deficient in Zinc.
5. 62.2 per cent samples were sufficient and 37.8per cent were sufficient in Iron.
6. 92.8 per cent sample were sufficient and 7.2 per cent samples were deficient in Copper.
7. 98.8 per cent samples were sufficient and 1.2 per cent samples were deficient in Manganese.

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EFFECT OF DIFFERENT SPACINGS AND NITROGEN RATES ON GROWTH AND YIELD OF WATER MELON GROWN ON POLYETHYLENE MULCH

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ABSTRACT

Worldwide, a significant increase in watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai) growing areas has been registered in the last few years. Though it is a potential vegetable crop, there is not much standardized scientific cultivation technology available for improving the yield. Agro techniques like nutrition and spacing play an important role in commercial production, specially N rates and planting densities vary on a large scale, indicating that there is insufficient knowledge about their effects. Therefore, the objective of this study was to evaluate the effects of N rate and planting density on growth and yield of watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] grown on black polyethylene mulch. The field experiments with 'Aaliya' F1 hybrid (Bayer Crop Science) was planted during January, 2017. The treatments were factorial combinations of three paired row plant spacings (0.45, 0.60, and 0.75 m) and four N rates (75, 100, 125 and 150 kg·ha^{-1}). Part of the N (35 kg·ha^{-1}) was applied preplant and the remainder was fertigated. Vine length increased linearly as N rate increased from 75 to 150 kg·ha^{-1}, and also with plant spacing increased from 0.45 m to 0.75 m. Total yields per ha or per plant and Average fruit weight did not increase with N rates above 100 kg·ha^{-1}. Total yields per acre and number of fruits per plot were linearly decreased with an increase in plant spacing from 0.45 to 0.75 m. With increased plant spacing average fruit weight increased and fruit size distribution shifted to larger categories.

KEYWORDS: Polyetrylene mulch, Watermelon, Nitrogen

INTRODUCTION

The global consumption of watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is greater than that of any other cucurbit (Robinson and Decker-Walters, 1997). It is a popular cash crop grown by farmers during summer due to its high returns in investment, especially in the regions of Ananthapur, Kadapa and Kurnool districts of Andhra Pradesh in an area of 5615 ha. Watermelon contains Vitamin C and A in form of the disease fighting *beta-carotene*. Potassium is also available in it, which is believed to help in the control of blood pressure and possibly prevent stroke .Enhanced earliness and yield in watermelon crop has been achieved through improvement of cultural practices (Lu *et al*., 2003; Soltani *et al*., 1995). Many commercial vegetable producers use mulching and drip irrigation as a common practice. Both technologies have been developed to enhance crop growth and improve water use efficiency (Brinen *et al*., 1979; Elmstrom *et al.,* 1981). Specially mulching was used now a days as mulch as it conserves soil moisture, retains heat as well as it suppresses weed growth. Improved N fertigation efficiency (Hochmuth, 2003) and decreased N leaching have also been noted (Pier and Doerge, 1995a; Romic *et al*., 2003).

Nitrogen has been frequently recognized as a major factor affecting watermelon yield. However, the suggested rates varied considerably. Srinivas *et al.* (1989) found that N up to 120 kg·ha^{-1} increased fruit yield, whereas Hochmuth and Cordasco (1999) who reviewed watermelon response to N, found that in majority of trials optimum yields were achieved with N rates from 134 to 145 kg·ha^{-1}.

Competition for water and nutrients in dense plant stands might be responsible for the decrease in plant growth and yield (Knavel, 1988). Generally, in watermelon the yield and number of fruit per unit area increase with increased crop density, whereas the yield and number of fruits per plant decrease (Brinen *et al.,* 1979; Duthie *et al*., 1999; Motsenbocker and Arancibia, 2002; NeSmith, 1993; Sanders *et al.,* 1999; Srinivas *et al.,* 1989). The increased number of fruit per area is probably the yield component mostly contributing to a

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greater yield under high planting density (Duthie *et al*., 1999; NeSmith, 1993). However, some studies showed that average fruit weight decreases with increasing plant density (Brinen *et al.,* 1979; Motsenbocker and Arancibia, 2002; Sanders *et al.,* 1999).

The impact of both N rate and plant density on watermelon yield has been reported in the literature frequently, yet there is insufficient knowledge about their interaction, especially when N fertigation is used. It is likely that optimal N rate would differ for different watermelon planting densities. Therefore, the objective of this study was to evaluate the effects of N rate and planting density on growth and yield of watermelon.

MATERIALS AND METHODS

The field experiments was conducted at Horticultural Research Station, Anantharajupeta, Kadapa district of Andhra Pradesh, India during summer season…..year?. The F1 hybrid used was "Aaliya " belongs to Bayer crop science which is popularly called as Icebox type "watermelons, with duration 60-65 days. Seeds were sown during January 2017 on black polyethylene mulch (thickness 25 mm; width 100 cm). Drip tape was placed beneath the black PE film, and with emitter spacing at 40 cm (capacity of 4 L h^{-1}) and plants were irrigated as needed. Weeds between rows were removed by hand if necessary, while pests and disease were controlled according to common practices.

The treatments were factorial combinations of three paired row plant spacings (0.45, 0.60, and 0.75 m) and four N rates (75, 100, 125 and 150 kg·ha^{-1}). The rows were 2.0 m apart, and in-row paired plant spacing was 0.45, 0.60, or 0.75 m. Part of the N (35 kg·ha^{-1}) was applied preplant and the remainder was fertigated. Remaining N for the four N treatments was fertigated in the form of ammonium-nitrate (35%N) in four applications. The first application (I) was 7 to 10 days after planting, second (II) at the early runner phase, third (III) when the diameter of fruit was about 50 mm, and fourth (IV) when 10 per cent of fruit reached the full size. To achieve targeted levels of N, the fertigation was scheduled as 1: 3: 1: 1 ratio in the I, II, III and IV stages of the crop respectively. All measurements were taken on a subsample of five plants per plot. Melons were harvested as fruit ripened, and each fruit from all plants was weighed. The total soluble solids content was determined from juice obtained from the fruit heart section using a hand refractometer , one representative melon was measured per plot in the main harvest. The observations on growth, yield and quality parameters were recorded and subjected to statistical analysis of variance.

RESULTS AND DISCUSSION

Paired row plant spacing and N fertigation influenced watermelon vegetative growth, and interactions among variables were not observed (Table 1 to 14). Paired row plant spacing had a significant effect on the main vine length. In general, early watermelon cultivars have a shorter vegetative period and less vegetative growth than late cultivars. In the present study, an early watermelon cultivar was planted. The length of the vine was more (207.67 cm) in spacing 0.75 m as it was less (173.21 cm) in Spacing 0.45 m (Table 1). This might be due to the fact that as the row space was more, plants were able to intercept more solar radiation during the growth stage and this impact on the photosynthesis activity. The fact that during the growth stage the plant did not compete for nutrient, water and light has impacted on the increase in the growth of the vine and this explain the reason why the longest vine was observed on plant under spacing of 0.75 m. The above results were in consonance with Efediyi and Samson (2009) who reported that in-row spacing has positive effect on plant height. The present results were also supported by Ban *et al.* (2011) who found that in-row plant spacing had a significant effect on the growth and yield of watermelon. Sabo *et al.* (2013) also reported an increase in watermelon vine length by increasing in-row plant spacing. Vine length was increased with increasing N fertigation. Vine length was highest (202.67 cm) at N fertigation at the rate of 150 kg ha^{-1}. But regarding the other growth parameters Leaf length, Leaf width, number of branches there was no significant difference observed in different spacings and different N fertigation rates (Table 2, 3, 4).

Yield, yield components and fruit quality

The yields per acre were significantly increased with an increase in N rate from 75 to 100 kg·ha^{-1} whereas the yields were not increased later by increasing N Rates. Highest fruit yield per acre (17.35 t ha^{-1}) was found with N rate 100 kg ha^{-1} (Table 15).

In contrast to earlier findings (Hochmuth and Cordasco, 1999; Pier and Doerge, 1995b; Srinivas *et al.,* 1989) in our study fruit yield did not increase with N rates above 100 kg·ha^{-1}. We assume that total yields

Table 1. Effect of different spacings and nitrogen levels on vine length (cm) of Water melon

	N1	N2	N3	N4	Mean
S1	157.39	158.89	186.55	190.00	173.21
S2	190.67	207.00	193.00	205.67	199.08
S3	194.67	215.00	208.67	212.33	207.67
Mean	180.91	193.63	196.07	202.67	
	S	19.19		6.54	
	N	NS	S.Em±	7.56	
	S*N	NS		13.09	

Table 2. Effect of different spacings and nitrogen levels on Leaf length (cm) of Water melon

	N1	N2	N3	N4	Mean
S1	15.50	15.95	14.00	15.77	15.30
S2	15.17	16.10	16.73	15.00	15.75
S3	15.13	14.77	16.37	16.20	15.62
Mean	15.27	15.60	15.70	15.66	
	S	NS		0.32	
	N	NS	S.Em±	0.37	
	S*N	NS		0.64	

Table 3. Effect of different spacings and nitrogen levels on Leaf width (cm) of Water melon

	N1	N2	N3	N4	Mean
S1	12.49	12.10	11.39	12.47	12.11
S2	11.60	13.20	15.00	11.67	12.87
S3	12.60	12.33	13.60	12.80	12.83
Mean	12.23	12.54	13.33	12.31	
	S	NS		0.48	
	N	NS	S.Em±	0.55	
	S*N	NS		0.95	

Table 4. Effect of different spacings and nitrogen levels on number of branches of Water melon

	N1	N2	N3	N4	Mean
S1	4.00	4.33	4.22	4.00	4.14
S2	4.00	4.67	4.00	4.00	4.17
S3	4.00	4.67	4.00	4.00	4.17
Mean	4.00	4.55	4.07	4.00	
	S	NS		0.17	
	N	NS	S.Em±	0.19	
	S*N	NS		0.33	

Table 5. Effect of different spacings and nitrogen levels on Average Fruit weight (in g) of Water melon

	N1	N2	N3	N4	Mean
S1	1137.87	1417.94	1564.33	1376.28	1374.11
S2	1581.83	2228.50	2079.08	2109.00	1999.60
S3	1659.83	2334.50	2200.67	2402.17	2149.29
Mean	1459.84	1993.65	1948.03	1962.48	
	S	336.97		114.89	
	N	389.09	S.Em±	132.67	
	S*N	NS		229.78	

Table 6. Effect of different spacings and nitrogen levels on Fruit length (in cm) of Water melon

	N1	N2	N3	N4	Mean
S1	15.69	19.66	19.61	19.05	18.50
S2	17.97	23.03	21.32	22.83	21.29
S3	21.55	22.90	21.80	21.95	22.05
Mean	18.40	21.87	20.91	21.28	
	S	2.13	S.Em±	0.73	
	N	2.46		0.84	
	S*N	NS		1.45	

Table 7. Effect of different spacings and nitrogen levels on Fruit width (in cm) of Water melon

	N1	N2	N3	N4	Mean
S1	10.37	12.99	12.50	10.57	11.61
S2	13.20	13.98	13.70	13.65	13.63
S3	13.47	13.67	15.12	13.63	13.97
Mean	12.34	13.55	13.77	12.62	
	S	1.71		0.58	
	N	NS	S.Em±	0.67	
	S*N	NS		1.17	

Table 8. Effect of different spacings and nitrogen levels on length of Pulp (in cm) of Water melon

	N1	N2	N3	N4	Mean
S1	17.29	17.22	16.79	16.98	17.07
S2	19.53	21.10	18.68	20.22	19.88
S3	19.00	18.90	19.37	19.23	19.13
Mean	18.61	19.07	18.28	18.81	
	S	1.71		0.58	
	N	NS	S.Em±	0.67	
	S*N	NS		1.17	

Table 9. Effect of different spacings and nitrogen levels on Width of pulp (in cm) of Water melon

	N1	N2	N3	N4	Mean
S1	10.20	10.68	9.75	10.56	10.30
S2	10.65	11.73	11.10	10.87	11.09
S3	10.65	10.75	11.00	10.68	10.77
Mean	10.50	11.05	10.62	10.70	
	S	0.58		0.20	
	N	NS	S.Em±	0.23	
	S*N	NS		0.40	

Table 10. Effect of different spacings and nitrogen levels on pulp weight (in gm) of Water melon

	N1	N2	N3	N4	Mean
S1	666.33	888.67	961.22	860.02	844.06
S2	753.08	1071.25	1005.50	1025.75	963.90
S3	827.67	1154.33	1102.00	1165.00	1062.25
Mean	749.03	1038.08	1022.91	1016.92	
	S	153.98		52.50	
	N	177.81	S.Em±	60.62	
	S*N	NS		105.00	

Table 11. Effect of different spacings and nitrogen levels on TSS (^{o}Brix) of Water melon

	N1	N2	N3	N4	Mean
S1	10.39	10.05	9.09	9.91	9.86
S2	10.62	10.40	10.30	10.70	10.50
S3	10.70	9.60	10.53	9.75	10.15
Mean	10.57	10.02	9.97	10.12	
	S	NS		0.22	
	N	NS	S.Em±	0.25	
	S*N	NS		0.44	

Table 12. Effect of different spacings and nitrogen levels on Number of fruits of per vine Water melon

	N1	N2	N3	N4	Mean
S1	1.67	1.33	1.44	2.00	1.61
S2	1.67	2.00	2.00	1.33	1.75
S3	1.33	1.67	1.67	2.33	1.75
Mean	1.56	1.67	1.70	1.56	
	S	NS		0.12	
	N	NS	S.Em±	0.14	
	S*N	NS		0.25	

Table 13. Effect of different spacings and nitrogen levels on Fruit yield per plot (48 sq.m) of Water melon

	N1	N2	N3	N4	Mean
S1	172.60	242.76	228.84	249.79	223.50
S2	157.76	196.59	216.89	190.81	190.51
S3	131.59	185.38	172.95	175.44	166.34
Mean	153.98	208.24	206.23	205.35	
	S	32.16		10.97	
	N	37.14	S.Em±	12.66	
	S*N	NS		21.93	

Table 14. Effect of different spacings and nitrogen levels on Number of fruits per plot (48 sq.m) of Water melon

	N1	N2	N3	N4	Mean
S1	158	151	150	133.5	148.125
S2	111.1	85	108.3	88.88	98.32
S3	56.88	99.54	71.1	99.54	81.765
Mean	108.66	111.8467	109.8	107.3067	
	S	19.73		6.73	
	N	NS	S.Em±	7.77	
	S*N	NS		13.45	

Table 15. Effect of different spacings and nitrogen levels on Fruit yield per Acre (in Tonnes) of Water melon

	N1	N2	N3	N4	Mean
S1	14.38	20.23	19.07	20.82	18.63
S2	13.15	16.38	18.07	15.90	15.88
S3	10.97	15.45	14.41	14.62	13.86
Mean	12.83	17.35	17.19	17.11	
	S	2.68		0.91	
	N	3.10	S.Em±	1.06	
	S*N	NS		1.83	

achieved at the N rate 100 kg·ha^{-1} in the present study were partly the result of splitting N application, which may have enabled better use of the given N rate as it was found on tomato (Locascio *et al.,* 1997) and strawberry (Hochmuth *et al.,* 1996). We suppose that water and N distribution pattern as well as watermelon root development under drippers are factors strongly affecting those findings. As in the case of different parameters, there was no interaction between N and plant spacings on yield and yield components.

Paired row plant spacing had a stronger effect on the total yield. The total yields per acre were linearly decreased with an increase in plant spacing from 0.45 to 0.75 m. The yields per acre was highest (18.63 t/ha) with spacing of 0.45 m (Table 15). On contrary with an increase in plant density the yield and number of fruit per plot linearly increased. Our results confirmed the findings of other studies, which suggest that fruit yield increases with an increase in plant density due to an increase in the number of fruits per plot (Brinen *et al.,* 1979; NeSmith, 1993; Duthie *et al.,* 1999; Sanders *et al.,* 1999; Motsenbocker and Arancibia, 2002; Goreta *et al.,* 2005). The Average size of the fruit was increased with increased plant spacing. Highest size of the fruit (2149.29 g) was observed with S3 spacing (0.75 m) whereas it was lowest (1374.11 g) with S1 spacing (0.45 m). Frequently, the average fruit weight decreases with an increase in the plant density (Brinen *et al.,* 1979; Sanders *et al.,* 1999;

Motsenbocker and Arancibia, 2002; Goreta *et al.,* 2005). Regarding the quality parameters soluble solid content was relatively high and unaffected by the spacing or N rate applied.

The lack of interactions between N and plant spacing is somewhat surprising because we expected such interaction to occur at least under high planting densities. However, the threshold density above which watermelon yield per area starts to decline was not reached in our study. Similarly, Srinivas *et al*. (1989) did not report the significant interaction between plant spacing and N fertilization on watermelon yield.

CONCLUSIONS

Based on our data, it can be concluded that higher yield per acre (18.63 t ha^{-1}) was obtained with plant spacing of 0.45m, whereas average fruit weight (2149.29 g) was higher with spacing of 0.75m. Higher fruit yield per acre (17.35 t ha^{-1}) was obtained with N rate of 100 kg ha^{-1}. So, it is recommended to follow the spacing based on the consumer preference of the fruit size in the area.

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SEASONAL INCIDENCE OF SPOTTED POD BORER, *Maruca vitrata* (Geyer) ON GROUNDNUT (*Arachis hypogaea* L.) DURING *RABI* SEASON

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ABSTRACT

Seasonal incidence (per cent damage) of *Maruca vitrata* in groundnut was studied during *rabi* 2015-16 at dry land farm, S.V. Agricultural College, Tirupati on two groundnut varieties *i.e.,* Dharani and Kadiri-6 (K6) at two different dates of sowing D_1 and D_2. The results indicated that, the incidence (per cent damage) of *M. vitrata* on groundnut on both D_1 and D_2 was observed from 3rd to 12th standard week of 2016. In D_1 and D_2 sown groundnut varieties, damage due to *M. vitrata* was high during 3rd to 9th standard weeks. In D_1 sown crop, weather parameters such as maximum temperature, minimum temperature, sunshine hours and wind speed showed negative association with *M. vitrata* damage whereas morning relative humidity and evening relative humidity showed positive association with *M. vitrata* damage. In D2 sown crop, maximum temperature, minimum temperature, wind speed and evening relative humidity showed a negative correlation whereas sunshine hours and morning relative humidity showed a positive correlation. In D_1 sown crop, six weather parameters *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and wind speed combinedly influenced *M. vitrata* damage to the extent of 74 per cent (R^2= 0.74) and 77 percent (R^2= 0.77) in groundnut cultivars Dharani and K-6. In D_2 sown crop, six weather parameters *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and wind speed combinedly influenced *M. vitrata* damage up to the extent of 76 per cent (R^2=0.76), 77 per cent (R^2=0.77) in Dharani and K-6 respectively.

KEYWORDS: Abiotic factors, *Maruca vitrata*, *Arachis hypogaea*

INTRODUCTION

Groundnut is an important oil seed crop of tropical and subtropical regions of the world. India ranks first in groundnut cultivation with an area of 5.53 m ha and occupies second place in production (9.67 million tons) with productivity of 1750 kg ha^{-1}. In India, groundnut is mostly grown in five states *viz.,* Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra which accounts for 80 per cent of total area and 84 per cent of total production of groundnut. In Andhra Pradesh, groundnut is grown in an area of 13.86 lakh hectares with a total production of 7.48 lakh tonnes and productivity of 644 kg ha^{-1} (Indiastat, 2014).

Several insects damage groundnut crop and cause considerable yield losses. Among these insect pests, white grub cause yield losses up to 100 per cent, tobacco caterpillar causes yield losses up to 15-30 per cent, red hairy caterpillar up to 75 per cent, leaf miner up to 49 per cent, leafhoppers up to 17 per cent and thrips causes yield losses up to 17 per cent (Ghewande and Nandagopal, 1997).

Spotted pod borer *Maruca vitrata* (Geyer), which is a common pest of pulses is extending its incidence on groundnut in southern zone of Andhra Pradesh and has caused damage up to 40 per cent to the terminal growing point at crop maturity during *rabi* season. Not much work was done on seasonal incidence of *M. vitrata* in groundnut. Hence the present studies were conducted at S.V. Agricultural College Farm, Tirupati during *rabi* 2015-16.

MATERIALS AND METHODS

A field trial was laid with two groundnut varieties Kadiri-6 (K-6) and Dharani to study the seasonal incidence (per cent damage) of *M.vitrata* and influence of various weather parameters on incidence of *M. vitrata* during *rabi* 2015-16.The trial was laid in an area of 5 × 5 m^2 with four dates of sowing *i.e*., second fortnight of November (D_1), first fortnight of December (D_2), second fortnight of December (D_3) and first fortnight of January (D_4) by following normal agronomic practices as developed by ANGRAU except for plant protection measures.

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Table.1. Per cent *M. vitrata* damage on groundnut during *rabi* 2015-16

Standard week	Weather parameters						Per cent damage by *Maruca vitrata*							
	Max. temp (°C)	Min. temp (°C)	RH mor. (%)	RH eve. (%)	SSH (hours)	WS (kmph)	D_1 (Nov II FN)		D_2 (Dec I FN)		D_3 (Dec II FN)		D_4 (Jan I FN)	
							Dharani	K6	Dharani	K6	Dharani	K6	Dharani	K6
50 (10-16 Dec)	30.4	20.6	91.9	63.9	6.6	2.2	0	0	0	0	--	--	--	--
51 (17-23 Dec	31.0	19.7	91.0	63.6	8.2	2.0	0	0	0	0	--	--	--	--
52 (24-31 Dec)	29.7	18.1	88.0	60.6	7.7	4.7	0	0	0	0	0	0	--	--
1 (01-07 Jan), 2016	30.0	16.5	90.1	58.0	8.5	3.8	0	0	0	0	0	0	--	--
2 (08-14 Jan)	29.6	14.8	89.1	54.7	8.0	3.4	0	0	0	0	0	0	0	0
3 (15-21 Jan)	30.0	17.9	91.9	60.7	5.6	3.0	13.66	13.78	0	0	0	0	0	0
4 (22-28 Jan)	30.7	20.4	91.7	58.7	6.2	5.1	11.39	10.52	0	0	0	0	0	0
5 (29 Jan – 4 Feb)	33.1	16.9	84.7	33.7	9.0	2.9	12.9	11.97	13.46	11.29	0	0	0	0
6 (05 – 11 Feb)	32.4	18.6	89.6	41.7	7.8	3.5	17.25	11.77	14.79	8.85	0	0	0	0
7 (12 – 18 Feb)	32.5	19.1	88.9	48.0	8.8	4.3	13.96	8.54	8.39	5.49	0	0	0	0
8 (19 – 25 Feb)	34.6	21.1	87.0	39.1	9.6	4.2	8.18	8.14	10.98	5.87	0	0	0	0
9 (26 Feb – 04 Mar)	33.15	21.29	87.13	43.00	7.26	4.39	7.60	7.16	7.82	5.42	0	0	0	0
10 (05 – 11 Mar)	34.54	22.11	86.00	38.14	7.80	3.93	4.90	3.90	2.5	3.34	0	0	0	0
11 (12 – 18 Mar)	36.60	25.53	79.71	41.43	6.24	4.51	3.98	2.98	1.65	2.34	0	0	0	0
12 (19 – 25 Mar)	39.19	24.90	72.14	27.00	7.61	3.96	1.02	0.96	0.89	0.66	0	0	0	0
13 (26 Mar – 01 April)	36.27	23.43	77.67	33.33	8.35	4.07	--	--	0	0	0	0	0	0
14 (02 – 08 April)	36.4	23.7	77.0	34.0	8.3	4.0	--	--	--	--	0	0	0	0
15 (09 - 15 April)	38.3	25.7	76.7	33.7	8.3	4.2	--	--	--	--	0	0	0	0
16 (16 – 22 April)	39.4	26.0	75.9	30.6	8.9	4.6	--	--	--	--	--	--	0	0
17 (23 – 29 April)	39.9	27.0	74.4	33.0	9.9	4.5	--	--	--	--	--	--	0	0

Table 2. Correlation studies of *M. vitrata* damage in relation to weather parameters during *rabi* 2015-16

Weather parameter	D_1		D_2	
	Dharani	K-6	Dharani	K-6
Maximum temperature (X1)	-0.30	-0.32	-0.09	-0.07
Minimum temperature (X2)	-0.38	-0.38	-0.29	-0.28
Morning RH (X3)	0.45*	0.46*	0.23	0.19
Evening RH (X4)	0.06	0.09	-0.24	-0.27
Sunshine hours (X5)	-0.21	-0.26	0.27	0.23
Wind speed (X6)	-0.006	-0.02	-0.07	-0.09

r value at 0.05 is 0.53
* : significant at 5%.
D_1 : Date of sowing: 27-11-2015, D_2 : Date of sowing: 12-12-2015
D_3 : Date of sowing: 27-12-2015, D_4 : Date of sowing: 11-01-2016

The observations were initiated from 30 DAS which coincides with incidence of *M. vitrata*. Data on incidence of *M. vitrata* in terms total number of plants/m^2 and number of plants damaged by *M. vitrata* were recorded at weekly interval for calculating per cent damage. The per cent damage data was correlated with meteorological parameters recorded at meteorological station.

Per cent damage was calculated by using the following formula

$$\text{Per cent damage} = \frac{\text{Number of plants damaged / m}^2}{\text{Total number of plants / m}^2} \times 100$$

RESULTS AND DISCUSSIONS

M. vitrata damage started from 3rd standard week of 2016 to 12th standard week of 2016 in two dates of sowings i.e. D_1 and D_2.

The data indicated that the *M. vitrata* damage was first noticed in 3rd and 5th standard weeks and continued up to 12th standard week of 2016 in D_1 and D_2 sown crops respectively. In D_1 damage was ranged from 1.02 to 17.25 and 0.96 to 13.78 per cent in Dharani and K-6 varieties respectively. In case of D_2 sown crop, the damage ranged from 0.89 to 14.79 per cent in Dharani and 0.66 to 11.29 per cent in K-6. In D1 sown crop (in both Dharani and K6) the damage was high from 3rd SMW to 7th SMW and thereafter started declining and no damage was noticed from 13th SMW. In D2 sown crop (in both Dharani and K6) the damage was high from 5th SMW to 9th SMW and thereafter started declining and no damage was noticed from 13th SMW (Table 1).

The results of present investigation are comparable with that of Annual report of Regional Agricultural Research Station (RARS), 2015 RARS, Tirupati, according to which the damage was high during February to March, 2015 (Anonymous, 2015).

Correlation of *M. vitrata* damage in relation to weather parameters during *rabi,* 2015-2016

Correlation studies between per cent damage and weather parameters such as maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and wind speed indicated that, maximum temperature (-0.30, -0.32), minimum temperature (-0.38, -0.38), sunshine hours (-0.21, -0.26) and wind speed (-0.006, -0.02) showed negative association (non-significant) with *M. vitrata* damage on Dharani and K6. Whereas morning relative humidity (0.45, 0.46) (significant) and evening relative humidity (0.06, 0.09) showed positive association (non-significant) with *M. vitrata* damage on Dharani and K6.

In case of D2 sown crop, maximum temperature (-0.09, -0.07), minimum temperature (-0.29, -0.28), evening RH (-0.24, -0.27) and wind speed (-0.07, -0.09) showed negative correlation (non-significant) and morning relative humidity (0.23, 0.19) and sunshine hours (0.27, 0.23) had a positive correlation (non-significant) with *M. vitrata* damage.

Table 3. Regression analysis for *M. vitrata* damage on groundnut in relation to weather parameters during *rabi*, 2015-16

Regression model	Regression equation *M. vitrata* damage	R^2
Dharani		
D_1 (Full model)	Y = -207.343 + (3.818)Max temp. + (-1.990)Min temp. + (1.826) RH mor. + (-0.300) RH eve. + (-2.750) SSH + (1.497) WS + 3.686	**0.744**
D_1 (Forward selection)	Y = -227.352 + (3.804) Max temp. + (-1.589) Min temp. + (1.619) RH mor. + 4.711	0.486
D_2 (Full model)	Y = -75.158 + (0.287) Max temp. + (-0.250) Min temp. + (1.164) RH mor. + (-0.593) RH eve. + (0.370) SSH + (-0.257) WS + 2.921	**0.768**
D_2 (Forward selection)	Y = -58.068 + (-0.188) Min temp. + (1.108) mor. RH + (-0.638) RH eve. + 2.688	0.759
D_3 (Full model)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	**0.000**
D_3 (Forward selection)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	0.000
D_4 (Full model)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	**0.000**
D_4 (Forward selection)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	0.000
K-6		
D_1 (Full model)	Y = -165.256 + (3.201) Max temp. + (-1.713) Min temp. + (1.466) RH mor. + (-0.237) RH eve. + (-2.591) SSH + (1.121) WS + 3.129	0.77
D_1 (Forward selection)	Y = -175.998 + (2.910) Max temp + (-1.222) Min temp. + (1.269) RH mor. + 4.070	0.448
D_2 (Full model)	Y = -32.730 + (-0.043) Max temp. + (-0.134) Min temp. + (0.714) RH mor. + (-0.446) RH eve. + (0.040) SSH + (-0.392) WS + 1.986	**0.770**
D_2 (Forward selection)	Y = -34.769 + (-0.188) Min temp + (0.716) RH mor. + (-0.437) RHeve. + 1.817	0.763
D_3 (Full model)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	**0.000**
D_3 (Forward selection)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	0.000
D_4 (Full model)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	**0.000**
D_4 (Forward selection)	Y = 0.000 + (0.000) Max temp. + (0.000) Min temp. + (0.000) RH mor. + (0.000) RH eve. + (0.000) SSH + (0.000) WS + 0.000	0.000

The result of present investigations were similar to the findings of Ramesh Babu *et al*. (2006) who reported the minimum temperature had significant negative influence on the larval population of *M. vitrata* on groundnut.

Present investigations are supported by the findings of Umbarkar *et al.* (2010) who reported that among the weather parameters, minimum temperature (r= -0.559) exhibited highly significant negative correlation with the spotted pod borer population on green gram.

Regression model developed for the *M. vitrata* damage in relation to weather parameters during *rabi,* 2015-2016

Regression analysis of *M. vitrata* damage with weather parameters of *rabi* 2015-2016 indicated that, all the six weather parameters *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and wind speed together influenced *M. vitrata* damage to the extent of 74 (R^2= 0.74) and 77 (R^2= 0.77) per cent in groundnut cultivars Dharani and K-6 in D1 sown crop.

In case of D2 sown crop, weather parameters *viz.,* maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and wind speed had influenced *Maruca* damage (Table. 3).

CONCLUSIONS

M. vitrata damage was first noticed in 3rd and 5th standard weeks of 2016 in D_1 and D_2 sown crops respectively. Weather parameters such as maximum temperature, minimum temperature and wind speed showed negative association with *M. vitrata* damage in terms of foliar damage. On the contrary, morning relative humidity showed positive association with *M. vitrata* damage in groundnut and evening relative humidity showed positive association in D_1 and negative association in D_2 sown crop. Sunshine hours showed negative association in D_1 and positive association in D_2 sown crop. Among the six weather parameters, morning relative humidity (r = + 0.45, r = + 0.46) showed significant influence on *M. vitrata* damage in D_1, weather parameters did not show significant influence on the damage of *M. vitrata* while in D_2 and in D_3, D_4 sown crop *M. vitrata* incidence was not observed.

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INFLUENCE OF VARIETIES AND NITROGEN LEVELS ON YIELD AND QUALITY OF FODDER PEARLMILLET (*Pennisetum glaucum* L.)

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ABSTRACT

A field experiment was carried out during *kharif*, 2015 on sandy clay loam soils of dryland farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University. The experiment was laid out in randomized block design with factorial concept and replicated thrice. The treatments consisted of four fodder pearlmillet varieties *viz.,* Gaint bajra, BAIF bajra, Raj bajra chari-2 and APFB-09-1 and four nitrogen levels *viz.,* 75, 100, 125 and 150 kg N ha^{-1}. Among the four varieties evaluated, BAIF bajra recorded higher green forage and dry matter yield, higher crude protein and crude protein yield, but total ash content was found to be non-significant with choice of variety during both the cuts. Whereas the variety Raj bajra chari-2 recorded the higher crude fibre content, while the lowest crude fibre content was recorded with the variety BAIF bajra. Application of 150 kg N ha^{-1} recorded higher green forage and dry matter yield, higher crude protein, crude protein yield but total ash content was significantly influenced by different nitrogen levels of nitrogen during second cut only. Application of 75 kg N ha^{-1} recorded the highest crude fiber content.

KEYWORDS: Crude protein, crude fibre, nitrogen levels, total ash and varieties

INTRODUCTION

Pearlmillet is an important crop grown for food and fodder for human and livestock population respectively. It is an important component of agricultural and animal husbandry dominated rural economy of dryland areas of India. It is a fast growing short duration crop which has high biomass production potential. It is grown in arid and semi arid regions where moisture is the limiting factor for crop growth. It is an ideal crop with high tillering ability, high dry matter production, high protein content (10-12 %) with excellent growth habit, high palatability and better nutritive value. The green fodder of bajra is leafy, palatable and very nutritious feedstock for cattle ensuring good milk yield. It has no HCN content as compared to sorghum and can be fed to cattle at any stage of the crop. Now-a-days many new improved cultivars of fodder pearlmillet are coming up, therefore it is necessary to study the response of these cultivars to fertilizers especially for nitrogen to harvest potential yield. Nitrogen is one of the basic plant nutrients essential for profuse growth. It increases vegetative growth of plant and herbage quality which is highly desirable for the forage yield and dry matter accumulation. Keeping these points in view, the present study is proposed to find out a suitable fodder pearlmillet variety and optimum nitrogen level for higher green fodder yield and quality.

MATERIALS AND METHODS

A field experiment was carried out during *kharif*, 2015 on sandy clay loam soils of dryland farm of S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University. The experiment was laid out in a randomized block design with factorial concept and replicated thrice. The treatments consisted of four fodder pearlmillet varieties *viz.,* Gaint bajra, BAIF bajra, Raj bajra chari-2 and APFB-09-1 and four nitrogen levels *viz.,* 75, 100, 125 and 150 kg N ha^{-1}. Crop was harvested for green fodder purpose at 50% flowering in all the varieties during both the cuts. The analysis of proximate principles in forage was done by the method recommended by Association of Official Analytical Chemists (A.O.A.C., 1990). The data pertaining to growth parameters and yield was recorded at different intervals was statistically analysed following the analysis of variance for randomized block design with factorial concept as suggested by Panse and Sukhatme (1985).

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Table 1. Effect of different varieties and nitrogen levels on yield and quality of fodder pearlmillet

Treatments	Green forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein (%)		Crude protein yield (t ha^{-1})		Crude fibre (%)		Total ash (%)	
	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut	1st Cut	2nd Cut
Varieties												
V_1: Gaint bajra	36.54	16.62	7.31	3.23	6.63	4.23	0.48	0.14	32.70	33.55	14.49	13.35
V_2: BAIF bajra	45.95	23.02	8.27	4.18	8.87	6.22	0.74	0.26	28.34	29.16	14.71	14.62
V_3: Raj bajra chari-2	25.40	12.90	5.59	2.90	6.43	3.88	0.36	0.12	32.94	34.69	13.50	13.03
V_4: APFB-09-1	41.38	17.80	7.86	3.63	6.93	4.31	0.55	0.16	31.31	32.18	14.69	13.99
SEm ±	1.09	0.44	0.14	0.09	0.14	0.16	0.02	0.01	0.56	0.65	0.58	0.48
CD (P=0.05)	3.2	1.3	0.4	0.3	0.3	0.5	0.06	0.03	1.63	1.88	NS	NS
Nitrogen levels (kg ha^{-1})												
N_1: 75	31.41	15.26	6.11	3.21	6.87	4.00	0.42	0.14	32.57	33.68	13.52	12.88
N_2: 100	35.87	16.49	6.99	3.21	7.02	4.48	0.50	0.15	31.48	33.03	14.03	13.39
N_3: 125	39.37	18.37	7.65	3.63	7.38	4.86	0.57	0.18	31.15	31.97	14.53	13.90
N_4: 150	42.62	20.22	8.28	3.99	7.59	5.30	0.64	0.21	30.09	30.90	15.31	14.82
SEm ±	1.09	0.44	0.14	0.09	0.14	0.16	0.02	0.01	0.56	0.65	0.58	0.48
CD (P=0.05)	3.2	1.3	0.4	0.3	0.3	0.5	0.06	0.03	1.6	1.9	NS	1.72
Interaction (V × N)												
SEm ±	2.17	0.88	0.29	0.18	0.29	0.32	0.04	0.02	1.12	1.30	1.20	0.95
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RESULTS AND DISCUSSION

Different fodder pearl millet varieties and nitrogen levels significantly influenced the yield and quality parameters. However interactive effects between varieties and nitrogen levels trials were not significant.At first and second cuts, BAIF bajra recorded the highest green fodder and dry matter yield, while the lowest green forage and dry matter yield (Table-1) was obtained with Raj bajra chari-2.This might be due to the superiority of the genotype to produce more values of growth characteristics like plant height, leaf area index, leaf to stem ratio and number of tillers plant^{-1}. Similar results were also reported by Midha *et al.* (2015) and Damame *et al.* (2013). There was an increase in green forage and dry matter yield with increasing nitrogen levels from 75 to 150 kg N ha^{-1} and the maximum dry matter yield was noticed with the application of 150 kg N ha^{-1} followed by 125 kg N ha^{-1}. The lowest dry matter yield was recorded with application of 75 kg N ha^{-1}. This might be due to the vegetative growth of the crop which was positively correlated for higher green fodder and dry matter yield. Similar results were also obtained by Devi and Padmaja (2007) and Singh *et al.* (2012).

Among the varieties tested, significantly higher crude protein content and crude protein yield (Table-1) were recorded with BAIF bajra and the lowest values were noticed with Raj bajra chari-2.With regard to the nitrogen levels, the highest crude protein content and crude protein yield were obtained with 150 kg N ha^{-1} (N_4), which was however comparable with application of 125 kg N ha^{-1} .The lowest crude protein content and crude protein yield (Table-1) were recorded with 75 kg N ha^{-1} .This might be due to application of nitrogen resulted in increased availability of nitrogen status in the soil, which inturn leads to significant improvement in nitrogen content in fodder and ultimately the crude protein content also increased. Crude protein yield may be due to increased crude protein and dry matter yield. These results were in cognizance with the finding of Damame *et al.* (2013) and Meena and Jain (2013).

The maximum crude fibre content (Table 1) was registered with the variety Raj bajra chari-2, which was significantly superior to the other varieties tried. The lowest crude fibre content was observed with BAIF bajra. Application of 75 kg N ha^{-1} resulted in the highest crude fibre content, while the lowest crude fibre content was noticed with application of 150 kg N ha^{-1}. This may be due to inherent genetic character of the varieties and higher nitrogen content which is the major constituent of amino acids and protein and decreased the pectin, cellulose, hemicellulose and proportion of carbohydrates, hence decreased crude fibre content (Babu *et al.,* 1995).

During both the cuts of fodder pearlmillet, varieties did not exert any significant influence on the total ash content. Nitrogen levels could not influence on the total ash content significantly during the first cut. Whereas, in second cut application of 150 kg N ha^{-1} resulted the highest total ash content, while the lowest total ash content was recorded with the application of 75 kg N ha^{-1}. These findings corroborate with the results of Chaurasia *et al.* (2006).

CONCLUSION

Results of the present experiment revealed that the variety BAIF bajra recorded significantly higher green fodder yield, dry matter yield, crude protein and crude protein yield. However, the variety Raj bajra chari-2 recorded significantly higher crude fibre over the other varieties tested. Application of 150 kg N ha^{-1} has recorded significantly higher green forage yield, dry matter yield, crude protien, crude protein yield and total ash content. Whereas, crude fibre content was significantly reduced with application of 150 kg N ha^{-1}.

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INFLUENCE OF HEAT AND DROUGHT STRESS ON FLORAL ANATOMY AND FLOWERING BEHAVIOR OF RICE (*Oryza sativa* L.) GENOTYPES

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ABSTRACT

Floral anatomy, which determines the yield in rice, is greatly affected by heat and drought stresses during reproductive phenophase. Trials under controlled environmental conditions and field experiments under rain out shelter facility were carried out to elucidate information on floral behavior of rice genotypes to combined heat and drought stresses. Three rice (*Oryza sativa* L.) genotypes namely ADT 43, TKM 9 and N 22 which differed in their tolerance behavior to heat and drought stress but had similar phenology were taken and exposed to combined stresses of heat and drought at panicle initiation (PI) and anthesis stages. Exposure of plants to combined stresses at anthesis resulted in early flowering, reduced anther length, width, pollen viability and stigma receptivity. Stress imposed at anthesis caused greater reduction in anther length compared to stress imposed at panicle initiation. The genotype N 22 was observed to maintain larger anther length and width compared to other genotypes. Pollen viability and stigma receptivity were assessed microscopically and it was found that N 22 registered more number of germinated pollen on stigma while it was less in ADT 43. The genotype N 22 was found to be tolerant with superior floral characters.

KEYWORDS: Anther, Drought, Heat, *Oryza sativa,* Pollen and Stigma

INTRODUCTION

Heat stress combined with drought, is one of the major limitations to food production worldwide. As the world population continues to grow, and water resources for the crop production decline and temperature increases, the development of heat and drought tolerant cultivars is an issue of global concern. Nearly half of the world's population depends on rice and an increase in rice production by 0.6-0.9 per cent annually until 2050 is needed to meet the demand (Carriger and Vallee, 2007). As a result, rice (*Oryza sativa* L.) is increasingly cultivated in more marginal environments that experience warmer temperatures where day/night temperatures average 28/22°C (Prasad *et al.,* 2006). In these environments, day temperatures frequently exceed the critical temperature of 33°C for seed set, resulting in spikelet sterility and reduced yield. Hence, in the future, rice will be grown in much warmer with a greater likelihood of high temperatures coinciding with heat sensitive processes during the reproductive stage.

Although rice has been used as a model plant for many years, the responses of rice genotypes to combined high temperature and drought is still poorly understood. Rice responses to high temperature differ according to the developmental stage, with the highest sensitivity recorded at the reproductive stage. Temperatures more than 35°C at anthesis and lasting for more than 1 hour can lead to high sterility in rice (Jagadish *et al*., 2007). High temperature stress induced increase in spikelet sterility was attributed to abnormal anther dehiscence, impaired pollination and pollen germination (Jagadish *et al.,* 2010). Moreover, high temperature of 39°C given a day before flowering resulted in poor anther dehiscence during subsequent anthesis.

Rice is sensitive to drought stress particularly during flowering stage, resulting in severe yield losses. The physiological processes during the sensitive flowering stage, negatively affect spikelet fertility under water stress. Effect on anther dehiscence and pollen germination were similar to high temperature stress (Jagadish *et al.,* 2010). Additionally, panicle exsertion and peduncle length were partly responsible for increased sterility under water stress.

Impacts of climate change demands adjustments in our rice production methods and development of new rice strains that can withstand higher temperatures, growing multiple stress tolerant varieties that can integrate in future climate change situations. The simultaneous occurrence

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of multiple abiotic stresses rather than one particular stress is commonly noticed under field conditions (Mittler, 2006). The combination of high temperature and water stress represents an excellent example of multiple abiotic stresses occurring concomitantly in the field. But, relatively little information is available with reference to combined high temperature and water stress in general and at the most sensitive flowering stage in particular in rice. Experiments were therefore carried out with the objective to study the flowering behaviour *viz*., anther length, anther width, pollen viability, stigma receptivity of rice genotypes under combined heat and drought stress.

MATERIALS AND METHODS

Three rice (*Oryza sativa* L.) genotypes namely ADT43, TKM9 and Nagina 22 (N22) which are differed in their tolerance behaviour to heat and drought stress but had similar phenology were taken for the study.

Nursery was raised at Paddy breeding station of Tamil Nadu Agricultural University, Coimbatore. Twenty one days old seedlings and one seedling per hill were transplanted with a spacing of 20 ´ 10 cm in the Rain Out Shelter (ROS) facility of the department of Crop Physiology. Stress treatments were imposed in the ROS, while a similar area of control was maintained adjacent to the ROS facility. The dimensions of the Rain Out Shelter and the Control were 21 m long and 6 m wide. Prior to transplanting the land inside ROS and the area which is parallel outside the ROS (Control) were puddled, levelled and incorporated with recommended dosage of basal fertilizer 150:50:50 N, P_2O_5, K_2O kg ha^{-1}. The land was divided into 12 plots with each plot measuring 2 m^2. The experiment was conducted in FRBD comprised of three treatments three varieties and four replications. The treatment details were as follows T_1 - (Control) well-watered throughout the crop growth period T_2 - Drought and natural high temperature stress at Panicle Initiation (PI) stage in which water was withheld for 2 weeks with a moisture stress of -50 to 70 kpa and the temperature ranged from 34.2 to 37.8°C at the time of panicle initiation, T_3 - Drought and natural high temperature stress at anthesis stage in which water was withheld for 2 weeks with soil water tension of -50 to -70 kpa and the temperature ranged from 33.5 to 36.6°C at the time of anthesis.

The time of sowing in the selected genotypes were staggered such that their PI and anthesis stages coincided the natural high temperature around early April for panicle initiation stage stress and May to June for anthesis stage stress. Temperature for the entire experiment period was monitored by installing the log stick data logger (Model. LS350-TH Japan) and an automated weather station inside the ROS and control area. Drought stress treatments were administrated and monitored by measuring the soil water potential using the tensiometers installed at 30 cm depth in each plot. Water was completely withheld for 2 weeks during the stress period. Plants were re-watered when the tensiometers registered soil water tension of -50 to -70 kpa.

Microscopic studies

Anther length and width

Anthers were collected from the spikelets early in the morning before anthesis. These anthers were fixed in a fixative FAA (50% absolute ethanol, 5% acetic acid, 27% formaldehyde, and 18% sterilized water) following the procedure of Jagadish *et al.* (2010). These anthers were observed under a compound microscope. Photographs were taken with SONY 12.1 megapixel camera to measure the anther length and width. The length and width was measured using an image analyser and the measurements were taken using the capture pro software version 4.1. The length of about 3 anthers were measured and their average was taken for analysis.

Pollen viability test

The pollen grains from anthers of randomly selected spikelets were collected and taken on cavity slides and stained with Iodine-potassium iodide solution (0.44 g Iodine + 20.08 g potassium iodide in 500 ml of 70% alcohol). The viable pollen stained immediately dark blue and the non viable ones remained as light yellow. The number of viable and non-viable ones were counted using microscope. The viability percentage was calculated from the mean of three microscopic field counts for each genotype (Jensen, 1962).

$$\text{Viability (\%)} = \frac{\text{Number of viable pollen grains}}{\text{Total number of pollen grains}} \times 100$$

Stigma receptivity

Fifteen to 20 spikelets were randomly sampled between 10.30 hours and 12.00 hours from the treatments. For this, spikelets about to flower on the main tiller were marked using acrylic paint, and, after pollination (around

30 min after the spikelet closed) marked spikelets were collected into vials filled with FAA fixative following the protocol by Jagadish *et al.* (2010). Anthers separated from the fixed spikelets were used to record per cent anther dehiscence. Spikelets were washed in deionized water before dissecting under a stereo-microscope (Olympus SZX7, Olympus Corp., Japan). Isolated stigmas were cleared in 8 N NaOH for 3 -5 hours at room temperature and stained with aniline blue dissolved in 0.1 M K_2HPO_4 for 5-10 minutes and number of germinated pollen on the stigma were recorded.

Factorial Randomized Block Design (FRBD) analysis was carried out on various parameters as per the procedure suggested by Gomez and Gomez (1984). Wherever the treatment differences are found significant, critical differences were worked out at five per cent probability level and the values are furnished.

RESULTS AND DISCUSSION

The reduction in anther length was highly significant among the genotypes with the stress treatments. Lengthier anther were registered in case of N 22 (1.78) followed by ADT 43(1.64) and comparatively shorter anthers in TKM 9 (1.53) in control (Table 1). Heat and drought stress during PI caused reduction in anther length in ADT 43 (1.51 mm) whereas, no much variation was observed in TKM 9 (1.45) and N 22 (1.76). When the stress was imposed at anthesis all the genotypes showed reduction in anther length. The reduction in length was highly significant in ADT 43 (from 1.64 to 1.38) less reduction was observed in N 22 (from 1.78 to 1.74) followed by TKM 9 (from 1.45 to 1.32). Stress imposed at anthesis caused greater reduction in anther width compared to stress at PI in both the trials. There was no significant difference in ADT 43 for anther width (Table 2). Whereas, in control anther width was highest (0.73) in TKM 9 followed by N 22 (0.56) and stress at anthesis caused greater reduction in anther width in ADT 43 (from 0.31 to 0.28). Matsui and Omasa (2002) reported that cultivars with large anthers are tolerant to high temperature at the flowering stage and they further suggested that cultivars with large anthers were tolerant to heat and drought stress because of large number of pollen grains per anther, which compensates for the reduction in the number of pollen grains that germinate under high temperature. Contradictory, to our finding Jagadish *et al.,* (2007) reported that drought and heat stresses did not affect the anther size.

Pollen viability was significantly influenced by stress treatments. Stress at anthesis caused greater reduction in pollen viability. Viability (Table 3) of pollen was higher in control. N 22 recorded highest viability (90.7) followed by TKM 9 (89.8) and ADT 43 (88.6). Stress treatments exhibited significant negative effect on pollen viability. When the stress was imposed at PI maximum pollen viability was observed in N 22 (87.0) followed by TKM 9 (80.6) and least in ADT 43 (75.3). Stress imposed at anthesis caused greater reduction in pollen viability. The genotype N 22 recorded highest pollen viability (83.6) and the least was observed in ADT 43 (69.1). Similar results were also reported by Tao *et al*, (2008). Decreased longevity of pollen under heat and drought could be a result of disruption of carbohydrate accumulation in pollen grains and/or change in the ultra-structure of pollen grain at high temperature (Jain *et al*., 2007). Heat stress reduced carbohydrate accumulation in pollen grains and in the stigmatic tissue by might alter assimilate partitioning and change the balance between symplastic and apoplastic loading of the phloem (Taiz and Zeiger, 2006). In addition, the quick loss of moisture from pollen (Luna *et al*., 2001) due to high temperature and high vapour pressure deûcit could result in quick loss of viability. High temperature during flowering decreased the ability of the pollen grains to swell resulting in poor anther dehiscence. Pollen viability is considered as an important parameter of pollen quality. These studies unequivocally proved that heat and drought stress reduces pollen viability and genotypic variation exists for this trait and hence it is important to identify the genotypes with high pollen viability under combined stresses so as to use them in crop breeding programs as donors.

In the present study, stigma receptivity was assessed microscopically. It was found that N 22 registered more number of germinated pollen on stigma and less number was observed in ADT 43 (Fig 1). Stress imposed at anthesis caused greater reduction in stigma receptivity compared to stress at PI. N 22 showed good anther dehiscence. Under heat and drought stress, the swelling of the pollen grains is inhibited, which leads to indehiscence of the anther. The results are in agreement with Rang *et al*. (2011). Other factors that might influence pollen count on stigma was increased pollen stickiness which prevented pollen shedding even when the anthers were open.

From the controlled environment facility study it was inferred that early flowering genotype recorded higher

Table 1. Anther length (mm) in rice genotypes subjected to combined heat and drought stress under controlled environment facility

Genotypes	Control	Stress	
		Panicle Initiation	Anthesis
ADT 43	1.64 ± 0.012	1.51 ± 0.014	1.38 ± 0.001
TKM 9	1.53 ± 0.013	1.45 ± 0.011	1.32 ± 0.011
N 22	1.78 ± 0.001	1.76 ± 0.012	1.74 ± 0.012
P = CD (0.05) Variety		0.01**	
Treatment		0.01**	
V × T		0.03**	

Table 2. Anther width (mm) in rice genotypes subjected to combined heat and drought stress under controlled environment facility

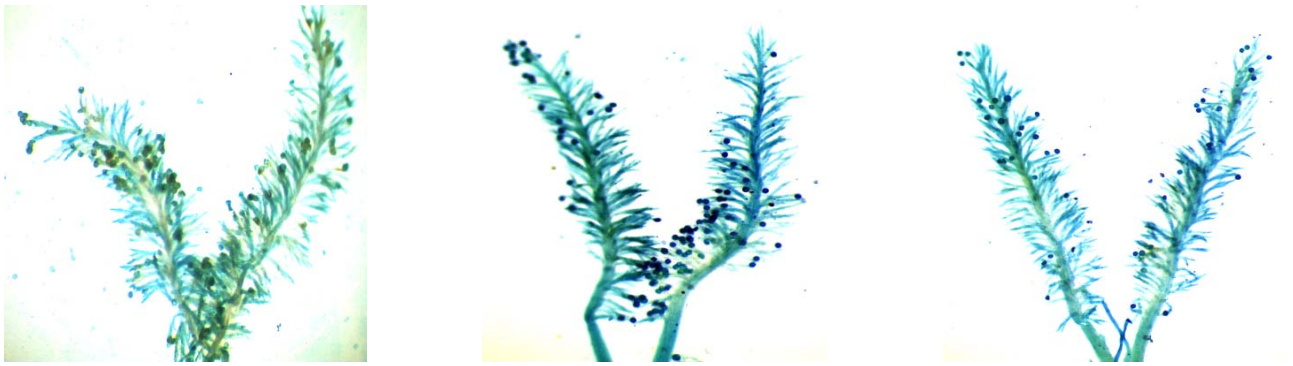
Genotypes	Control	Stress	
		Panicle Initiation	Anthesis
ADT 43	0.31 ± 0.003	0.29 ± 0.011	0.28 ± 0.013
TKM 9	0.73 ± 0.001	0.72 ± 0.011	0.71 ± 0.012
N 22	0.56 ± 0.002	0.56 ± 0.012	0.56 ± 0.001
P=CD(0.05) Variety		0.008**	
Treatment		0.006**	
V × T		0.015**	

Table 3. Pollen viability (%) in rice genotypes subjected to combined heat and drought stress under controlled environment facility

Genotypes	Control	Stress	
		Panicle Initiation	Anthesis
ADT 43	88.6 ± 0.75	75.3 ± 1.25	69.1 ± 0.28
TKM 9	89.8 ± 0.73	80.6 ± 1.16	78.9 ± 1.11
N 22	90.7 ± 0.15	87.0 ± 1.26	83.6 ± 0.47
P = CD (0.05) Variety		1.39**	
Treatment		2.13**	
VXT		2.41**	

i) ADT 43

(a) Control **(b) Stress at PI** **(c) Stress at anthesis**



ii) TKM 9

(a) Control **(b) Stress at PI** **(c) Stress at anthesis**

iii) N 22

(a) Control **(b) Stress at PI** **(c) Stress at anthesis**

Fig 1. Microscopic images of stigma receptivity in rice genotypes exposed to combined heat and drought

pollen viability coupled with better anther length and stigma receptivity. It was obviously observed that the susceptible genotype recorded less pollen viability mainly due to the loss in receptivity of stigma to allow the pollen tube growth and subsequent fertilization. Since N 22 is universal donar, early flowering under high temperature stress condition is an escape mechanism to avoid heat stress and yield normally. Similar to our reported results it was found that an increase in temperature of 4°C during the growing season of rice resulted in earlier maturation of the crop by five to six days for the wet and dry seasons, respectively (Ziska *et al*., 1997).

CONCLUSION

Stress imposed at anthesis caused greater reduction in anther length compared to stress imposed at panicle initiation. From this study, the genotype N 22 was emerged as an ideal donar for the future breeding programme for heat and drought stress.

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SUGGESTIONS GIVEN BY THE RICE FARMERS OF NELLORE DISTRICT TO OVERCOME THE CONSTRAINTS IN RICE PRODUCTION

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ABSTRACT

This paper describes the suggestions given by the rice crop cultivating farmers to overcome the constraints faced by them in SPSR Nellore district of Andhra Pradesh. The data was collected from a sample of 120 rice farmers by following simple random sampling method. The study revealed that among the various suggestions given by the farmers, fetching of better market price/provision of Minimum Support Price (MSP) by the government (91.67%) was ranked first followed by prioritization of agricultural activities in NREGP programme (90.83%), development of pest and disease resistant varieties (89.17%), development of suitable implements and equipment (88.33%), provision of warehousing facilities at Panchayat level (85.00%), availability of combine harvesters at lower rents (79.17%), provision of loans by government agencies at lower interest rates (77.50%), provision of processing, trading and export facilities (70.00%), conducting regular training programmes to the farmers (66.67%), increasing subsidies for rice farming (65.83%), encouraging seed village programme (65.00%), facilitating direct marketing in rice (54.17%), timely supply of high yielding variety (HYV) seed/good quality seed by Department of Agriculture (48.33%), increasing the efficiency of the extension staff (40.00%), adopting group farming approach in rice farming (39.17%), implementation of green manure schemes (34.17%), implementation of crop insurance (31.67%) and recruitment of sufficient extension staff (20.83%).

KEYWORDS: Rice farmers; suggestions and constraints.

INTRODUCTION

Rice cultivation is one of the most important developments in history. Rice has fed more people over a longer period of time than any other crop. Almost one fifth of the world's population, depend on rice cultivation for their livelihoods. Among the prominent rice-producing countries, the seven largest producers were China (197.22 million tonnes), India (120.62 million tonnes), Indonesia (66.41 million tonnes), Bangladesh (49.36 million tonnes), Vietnam (39.99 million tonnes), Myanmar (33.20 million tonnes), and Thailand (31.56 million tonnes); which accounted together for < 80.12 per cent of the 2010 World Production (FAO, 2014). Andhra Pradesh is the Fifth largest state in India accounting for 9 per cent of the country's area. It is the principal food crop cultivated throughout the Andhra Pradesh state providing food for its growing population, fodder to the cattle and employment to the rural masses. Any decline in its area and production will have a perceivable impact on the state economy and food security.

The study area, Nellore district is famous for its paddy fields, thereby deriving its name from "Nell". Nell + Oru (Nel in Tamil indicates Paddy and ooru is town in both Telugu and Tamil languages). The reasons for shrinking of rice cultivating area in SPSR Nellore district are due to numerous constraints in rice production. Some of the farm level rice production constraints include stagnating yield, declining profit, high cost of labour, unavailability of the labour, unavailability of quality seed in time, unavailability of sufficient farmyard manure. Rice farmers are also facing marketing problems which in turn leading to distress sale. Economic factors such as price fluctuation is adversely affecting rice production. Therefore, enhancing adaptability and stability of productivity and providing more profitable livelihood to the rice cultivating farmers is a major challenge to the agricultural research and extension system.

In view of the above scenario, the present study was conducted with the main objective of studying suggestions given by the rice cultivating farmers to overcome the constraints faced by them.

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MATERIAL AND METHODS

The study was conducted in SPSR Nellore district of Andhra Pradesh which is one a major rice growing district in Andhra Pradesh (Visalakshi, 2015). Out of the 46 mandals in Nellore district, four rice growing mandals have been purposively selected and two rice growing villages were selected from each mandal at random, thus making a total of eight villages selected for the study. Among the rice farmers 15 farmers from each village were selected randomly thus making a total of 120 farmer respondents for the study. An interview schedule was developed for the study and pretested in non sample area. The data was collected using standardized interview schedule by personal interview method.

RESULTS AND DISCUSSION

As perceived by the respondents, fetching of better market price/increase in the Minimum Support Price (MSP) by the government (91.67%) (Rank I) was the first suggestion. As most of the respondents were medium farmers, they have depends on to fetch the good market price for final produce. Which in turn they have to spent as the initial investment on rice cultivation and also for family maintenance. Most of the farmers also clearly expressed that when they took the produce to the market, the market prices were made lower by the commission agents, brokers etc. In such cases the market yard people were also not coming to the rescue of the farmers. Hence the rice farmers expressed that government should take stringent action against any defaulter in the market yard and should fix correct and better market price well in advance.

The second suggestion given by the farmers is prioritization of agricultural activities in MGNREGA programme (90.83%) (Rank II). MGNREGA programme should affect the other agricultural operations and engagement of labourers during crop season should be avoided in NREGP so that farmers will be benefited with the shortage of labour and high rate of wages also be avoided. Government should engage and support the local agricultural labourers to avoid the non availability of man power for farm operations, under MGNREGA.

Development of pest and disease resistant varieties (89.17%) (Rank III) was the next suggestion given by the respondents. The pests like Brown Plant Hopper (BPH), leaf folder, stem borer and diseases like blast, sheath blight and Bacterial Leaf Blight (BLB) were frequently occurring on the rice crop incurring huge losses to the farmers.

Development of suitable implements and equipment (88.33%) (Rank VI) was the next suggestion given by the respondents. The rice farmers expressed that there were no suitable implements for the intercultural operations. Some of the activities like transplanting, harvesting etc. The available equipments are not manageable by the farmers due to more cost. The intercultural operations are labour intensive and farmers have to spend a lot of money for paying wages. Therefore, it is required to develop suitable equipment and provide to the for the benefit of farmers to avoid the heavy expenses on labour wages.

The next suggestion indicated by the farmers was provision of storage facilities at Panchayat level (85.00%) (Rank V). Majority of the respondents expressed that they were loosing part of their produce in storage due to damage by different storage grain pests and diseases.

Availability of combine harvesters at affordable rents (79.17%) (Rank VI) was one of the next suggestion given by the respondents as harvesting and threshing were the important activities of the end of the crop season. Hence there is a huge demand for the harvesting and threshing machines which led the farmer to invest more towards the higher rental rates of the machines. So there is every need to provide combined harvesters and threshing machines at local level on affordable rental charges, so that the farmers can come out of the shortage of labour and timely harvest will also be done by the farmers.

Provision of loans by government agencies at lower interest rates (77.50%) (Rank VII) was the next suggestion given by the rice farmers. Every season the farmers had to dependent on the middlemen and brokers for the initial investment who were charging huge interest rates. Hence, farmers suggested for loans by the government agencies at lower rate of interest to protect themselves from the exploitation by the local money lenders at higher interest rates.

The next suggestion given was provision of processing, trading and export facilities (70.00%) (Rank VIII). Rice farmers are always depending on millers for processing of their produce where the milling charges are very high. Hence the farmers were in want of support from the government in processing, trading and export of rice to other states and countries to get the maximum benefit.

Table 1. Suggestions given by the rice farmers to overcome the constraints

S. No.	Suggestions	F	%	Rank
1.	Fetching of better market price / Provision of more Minimum Support Price (MSP) by the Government	110	91.67	I
2.	Allocation of agricultural activities in MGNREGA(Mahatma Gandhi National Rural Employment Guaranty Act) programme to avoid labour shortage	109	90.83	II
3.	Timely and easy availability of pest and disease resistant varieties	107	89.17	III
4.	Easy availability of suitable implements and equipment	106	88.33	IV
5.	Provision of storage facilities at Panchayat level	102	85.00	V
6.	Availability of combine harvesters at lower rents	95	79.17	VI
7.	Provision of loans by government agencies at lower interest rates	93	77.50	VII
8.	Provision of more processing, trading and export facilities	84	70.00	VIII
9.	Conducting regular training programmes to the farmers	80	66.67	IX
10.	Further increase in subsidies for rice farming	79	65.83	X
11.	Encouraging and strengthening of existing seed village programme	78	65.00	XI
12.	Facilitating direct marketing in rice	65	54.17	XII
13.	Timely supply of High Yielding Variety (HYV) seed / Good quality seed by Department of Agriculture	58	48.33	XIII
14.	Frequent visits by the extension staff	48	40.00	XIV
15.	Adopting group farming approach in rice farming	47	39.17	XV
16.	Strengthening of existing green manure schemes	41	34.17	XVI
17.	Further strengthening of crop insurance scheme	38	31.67	XVII
18.	Recruitment of adequate extension staff	25	20.83	XVIII

Conducting regular training programmes for the farmers (66.67%) (Rank XI) was the suggestion given by the respondents. The rice cultivating farmers felt that they were lacking some of the latest technologies about the new varieties, chemicals, methods etc., in rice cultivation.

Increasing subsidies for rice farming (65.83%) (Rank X) was the next suggestion expressed by the respondents. The respondents expressed that even though rice is the most important crop and they felt that there is no subsidy provided for good quality seed and as well as other inputs.

Encourage seed village programme (65.00%) (Rank XI) was the next suggestion as the availability of quality seed is one of the problem faced by most of the farmers at the beginning of the season. Even if the seed is available

it is very costly and the farmers have to transport it from far away places and have to incur additional costs on transport. Hence, it was suggested by the respondents that seed village programme may be taken up in their villages.

Facilitating direct marketing in rice (54.17%) (Rank XII) was the next suggestion given by the respondents. It is known fact that the middlemen, commission agents, brokers etc., were knocking away the profits of the farmers. Hence, farmers suggested that by establishing the farmer's societies, cooperatives or involving government agencies, the produce should be marketed directly to the wholesalers so that farmers will get the maximum benefit. Farmers also expressed that the State Department of Agriculture should ensure timely supply of HYV seed / quality seed (48.33%) (Rank XIII) which was the major problem faced by them.

Increase the extension staff (40.00%) (Rank XIV) is also one of the suggestion given by the rice farmers. Adopting co-operative farming approach in rice farming (39.17%) (Rank XV) is also one of the suggestion expressed by the rice farmers. Some of the farmers felt that to make the rice cultivation more sustainable, the older methods of fragmented cultivation and management is not suitable.

Strengthening of existing green manure schemes (34.17%) (Rank XVI) was the next suggestion given by the respondents. Hence, it is necessary for the government to supply the green manure crop seed in time and in sufficient quantity to promote the farmers to grow these crops by giving some kind of subsidy. These findings are similar to Arathy (2011).

Further strengthening of crop insurance (31.67%) (Rank XVII) was also one of the suggestion expressed by the rice farmers. The respondents stated that implementation of crop insurance is utmost necessary in the event of entire crop failure due to natural calamities such as heavy rains, cyclones and storms.

Recruitment of adequate extension staff (20.83%) (Rank XVIII) was one of the suggestion expressed by the rice farmers. Since, very long, the availability of extension worker per unit farm families was the major question and the respondents also expressed that the extension personnel were not visiting them frequently. Hence they suggested for recruitment of sufficient extension staff to bridge the gap between the farmers and extension workers.

CONCLUSION

It could be suggested that, government must design suitable policies for rice growing farmers. Thorough monitoring of proper supply of inputs with low prices, proper and ease of sanctioning institutional credit, good marketing facilities with remunerative prices to the produce must be improved. There is a necessity to integrate farm production with national and international markets to enable farmers to undertake market driven production plan and adoption of modern marketing practices to get fair price to their produce.

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