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EFFECT OF CHEMICALS ON CORM AND CORMEL PRODUCTION IN GLADIOLUS (*Gladiolus grandiflorus* L.)

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ABSTRACT

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Effect of chemicals on corm and cormel production in gladiolus cvs. American Beauty and White Prosperity were studied in herbal garden at College of Horticulture, Rajendranagar, Hyderabad. The chemicals, Potassium nitrate (KNO_3) at 0.5, 1.0 and 1.5 per cent, Salicylic acid (SA) at 50, 100 and 150 ppm, Propyl gallate (PG) at 0.5, 1.0 and 1.5 per cent were used on two cultivars. The corms were dipped in the solutions for a period of 10 hours before planting. Cultivar American beauty treated with Potassium nitrate at 1.5 per cent recorded highest number of replacement corms per corm (1.45), however with Salicylic acid at 150 ppm it recorded maximum number of cormels per corm (4.72). Among the chemical treatments, Salicylic acid at 150 ppm recorded maximum corm size (4.41 cm), corm weight (21.56 g), cormel weight per corm (6.59 g) and highest propagation co-efficient (184.72) with cv. White Prosperity followed by cv. American Beauty.

KEYWORDS: American Beauty, White Prosperity, Potassium nitrate (KNO_3), Salicylic acid (SA) and Propyl gallate (PG)

INTRODUCTION

Gladiolus (*Gladiolus grandiflorus* L.) is a bulbous cut flower of beauty and perfection. It is popularly known as 'Queen of the bulbous flowers' because of attractive spikes, having florets of different colours with long keeping quality. Gladiolus is very popular for its wide open, good texture, impressive coloured spikes which are of great demand in both domestic and international market. It is commercially propagated by corms. Poor multiplication rate and presence of corm dormancy for 3 to 4 months restricts their immediate use in the following season, resulting in high cost of corms which is often higher than the sale price of flower spike produced by the corm. The profitability of gladiolus flower spike production and export is closely linked to the cost of corms. Effective chemical treatments are to be standardized for this purpose irrespective of the cultivar, location and environment (Kumar and Raju, 2007). Synthetic growth regulating chemicals were reported to be very effective in manipulating the growth, flowering, corm and cormel production in gladiolus. Favourable effect of chemicals on sprouting, growth, flowering, corm and cormel multiplication in gladiolus has been reported by Roy Choudary *et al.* (1985).

MATERIALS AND METHODS

The present study on the effect of chemicals on corm and cormel production in gladiolus cvs. American Beauty and White Prosperity was studied in herbal garden at College of Horticulture, Rajendranagar, Hyderabad. The chemical treatments, Potassium nitrate (KNO_3) at 0.5, 1.0 and 1.5 per cent, Salicylic acid (SA) at 50, 100 and 150 ppm, Propyl gallate (PG) at 0.5, 1.0 and 1.5 per cent were treated on two cultivars. The corms scales were removed before dipping in the solutions for a period of 10 hours before planting. The treatments were replicated thrice in randomized block design with factorial concept. The data was analyzed using computer software programmed by the method of variance outlined by Panse and Sukhatme (1985). Propagation co-efficient (%) is defined as the ratio of the total weight of corm(s) and cormels produced and the weight of corm planted and multiplied by 100 to express in percentage (Rajivkumar *et al.*, 2002).

RESULTS AND DISCUSSION

Results obtained from the present study indicated that, the two cultivars differed significantly in respect of number, size and weight of corms and cormels produced per corm due to chemical treatments. Cv. American Beauty recorded maximum number of replacement corms

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Table 1. Effect of pre planting chemical treatments of Gladiolus corms on number of replacement corms produced per corm, corm size (cm) and corm weight (g) in cultivars American Beauty and White Prosperity

Treatments	Replacement corms produced per corm			Corm size (cm)			Corm weight (g)		
	A.B	W. P	MEAN	A.B	W. P	MEAN	A.B	W. P	MEAN
Potassium nitrate (0.5%)	1.25	1.03	1.14	3.30	3.32	3.31	17.05	17.52	17.28
Potassium nitrate (1.0%)	1.35	1.13	1.24	3.50	3.52	3.51	18.12	18.53	18.33
Potassium nitrate (1.5%)	1.45	1.20	1.32	4.13	4.21	4.17	19.76	20.50	20.13
Salicylic acid (50 ppm)	1.16	1.10	1.13	3.99	4.07	4.03	19.27	20.11	19.69
Salicylic acid (100 ppm)	1.20	1.18	1.19	4.20	4.23	4.21	20.71	21.10	20.91
Salicylic acid (150 ppm)	1.24	1.22	1.23	4.30	4.41	4.35	21.33	21.56	21.44
Propyl gallate (0.5%)	0.98	0.92	0.95	3.90	3.98	3.94	17.90	18.13	18.01
Propyl gallate (1.0%)	0.91	0.86	0.88	3.41	3.53	3.47	17.20	17.55	17.37
Propyl gallate (1.5%)	0.83	0.80	0.81	3.30	3.45	3.47	16.96	17.21	17.09
Control	0.98	0.94	0.96	3.56	3.67	3.61	17.45	17.85	17.65
Mean	1.13	1.03		3.76	3.83		18.57	19.00	
C.D at 5%									
Cultivars (C)		0.033			0.02			0.22	
Treatments (T)		0.073			0.06			0.49	
Interaction(C × T)		0.104			N.S.			N.S.	

A.B : American Beauty; W.P : White Prosperity

Table 2. Effect of pre planting chemical treatments of Gladiolus corms on number of cormels produced per corm, cormel weight (g) per corm and propagation co-efficient in cultivars American Beauty and White Prosperity

Treatments	Number of cormels produced per corm			Cormel weight (g) per corm			Propagation co-efficient		
	A.B	W.P	Mean	A.B	W.P	Mean	A.B	W.P	Mean
Potassium nitrate (0.5%)	3.57	3.42	3.49	3.25	3.31	3.28	135.48	118.22	126.85
Potassium nitrate (1.0%)	3.72	3.63	3.67	3.60	3.99	3.80	154.31	138.17	146.24
Potassium nitrate (1.5%)	3.85	3.75	3.80	4.42	4.57	4.50	182.92	162.36	172.64
Salicylic acid (50 ppm)	4.12	3.95	4.03	4.02	4.42	4.22	141.06	154.05	147.56
Salicylic acid (100 ppm)	4.38	4.30	4.34	5.31	5.66	5.48	165.15	170.98	168.06
Salicylic acid (150 ppm)	4.72	4.55	4.63	6.27	6.59	6.43	179.72	184.72	182.22
Propyl gallate (0.5%)	3.82	3.74	3.78	3.99	4.33	4.16	113.52	120.93	117.22
Propyl gallate (1.0%)	3.61	3.54	3.57	3.39	3.69	3.54	100.67	107.72	104.20
Propyl gallate (1.5%)	3.44	3.35	3.39	2.86	3.06	2.96	91.74	95.16	93.45
Control	3.52	3.33	3.42	3.69	3.86	3.77	110.55	117.81	114.18
Mean	3.87	3.75		4.08	4.35		137.51	137.01	
C.D at 5%									
Cultivars (C)		0.004			0.22			N.S	
Treatments (T)		0.010			0.49			10.76	
Interaction(C × T)		0.014			N.S.			15.2	

A.B : American Beauty; W.P : White Prosperity

(1.13) and number of cormels per corm (3.87) compared to cv. White Prosperity (Table 1 and 2). The variation in production of number of replacement corms and cormels per corm might be due to variation in number of buds sprouted per corm, which might have been governed by the presence of number of active buds in the corms. Variation in cultivars on individual gladiolus corm characteristics was earlier reported by several workers (Prasad *et al.*, 2002; Uma devi, 2002 and Kumar *et al.*, 2007).

Number of replacement corms and cormels per corm in gladiolus cultivars differed significantly due to chemical treatments. Potassium nitrate in all the concentrations recorded maximum number of replacement corms followed by salicylic acid. The chemical treatment Potassium nitrate at 1.5 per cent recorded highest number of replacement corms (1.32) (Table 1) where as Salicylic acid at 150 ppm recorded maximum number of cormels per corm (4.63) (Table 2). Lowest number of replacement corms per corm (0.81) and cormels per corm (3.39) was recorded with Propyl gallate at 1.5 per cent. Potassium nitrate and salicylic acid increased the number of corms and cormels produced per corm (Table 1 & 2) significantly over control. In gladiolus besides photosynthesizing leaves, the corms used for planting also serve as source of reserve food in the early stages of sprouting and establishment of developing plant. Likewise, it has two competitive sinks, inflorescence or flower spike and developing corm/cormels and application of Potassium nitrate and salicylic acid increased the sink activity of both. Increase in corm and cormel production by Potassium nitrate and Salicylic acid treatments may be attributed to their ability to alter the hormonal balance in the corms and cormels resulting in increased ratio of promoters versus inhibitors. This alteration in hormonal balance maintains sink activity of corms and cormels which resulted in production of more number of replacement corms and cormels per corm. Similar results were also reported by Kumar (2005) in gladiolus cvs. Jyotsna and Shabnum.

Cultivar White Prosperity recorded significantly maximum corm diameter and weight over cv. American Beauty. The replacement corm size (3.83 cm), weight (19.00 g) and cormels weight per corm (4.35 g) was significantly high with the cultivar White Prosperity over cv. American beauty (Table 1 and 2).

The chemical treatments were also effective in improving the individual corm characteristics. Salicylic acid

at 150 ppm recorded maximum replacement corm size (4.35 cm), weight (21.44 g) and weight of cormels per corm (6.43 g). Lowest replacement corm size (3.31 cm) was observed with Potassium nitrate at 0.5 per cent, however Propyl gallate at 1.5 % recorded lowest replacement corm weight (17.09 g) and cormels weight per corm (2.96 g). Potassium nitrate and Salicylic acid at higher concentrations recorded maximum vegetative growth over the lower concentrations studied. Whereas Propyl gallate at lower concentrations recorded maximum vegetative growth over higher concentrations studied. Potassium nitrate and Salicylic acid stimulates alternate oxidase and in turn promotes alternate respiration (Chen and Klersig, 1991) thereby they improved the vegetative growth. These treatments were consistent and equally effective in increasing the leaf area almost during the entire crop growth period. The increase in leaf area and increased assimilate synthesis, might have contributed to increased number, size and weight of replacement corms and cormels by these treatments. Propyl gallate, an inhibitor of alternate respiration and ethylene biosynthesis (Krishnamoorthy, 1993) recorded in maximum number of days for sprouting of corms and lowest sprouting percentage resulted in low vegetative growth. Due to inhibitory action of Propyl gallate, higher concentrations might have suppressed plant growth and effects number, size and weight of replacement corms and cormels. Similar results were also reported by Kumar (2005) in gladiolus cvs. Jyotsna and Shabnum.

There was no significant difference between the cultivars on propagation co-efficient. Salicylic acid at 150 ppm recorded maximum propagation co-efficient (182.22) whereas Propyl gallate at 1.5 per cent recorded minimum propagation co-efficient (93.45).

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ESTIMATION OF DAMAGE CAUSED BY ROOT GRUB *Holotrichia reynaudi* Blanchard IN GROUNDNUT IN DIFFERENT DATES OF SOWING

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ABSTRACT

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Holotrichia reynaudi Blanchard is one of the predominant species of root grub in groundnut ecosystem of Rayalaseema region, Andhra Pradesh. Two field experiments were conducted at the research farm of Agricultural Research Station, Utukur, Kadapa during *khari*f, 2014 and 2015 to estimate the damage caused by root grub, *H. reynaudi* in groundnut under three different dates of sowing. The studies revealed that, in June IInd FN sown crop, the average per cent plant mortality per m², number of grubs per m² in unprotected and protected plots were 23.36 per cent, 2.23 grubs m⁻² and 6.20 per cent, 0.39 grubs m⁻² respectively. In July Ist FN sown crop, they were 21.20 per cent, 2.08 grubs m⁻² and 5.41 per cent, 0.37 grubs m⁻² and in July IInd FN sown crop they were 20.46 per cent, 1.95 grubs m⁻² and 5.14 per cent, 0.34 grubs m⁻² respectively. The pod yield in June IInd FN sown unprotected and protected plot were 1063.50 kg ha⁻¹ and 1680.50 kg ha⁻¹, in July Ist FN sown it was 1148.50 kg ha⁻¹ and 1745 kg ha⁻¹ and in July IInd FN sown it was 1175 kg ha⁻¹ and 1771 kg ha⁻¹. In June IInd FN sown crop the per cent loss in yield was higher (36.74%) followed by July Ist FN sown plot (34.19%) and July IInd FN sown plot (33.65%).

KEYWORDS: *Holotrichia reynaudi*, plant mortality, assessment of loss, damage, groundnut.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a principal oilseed crop of India. In Andhra Pradesh, it is cultivated in an area of 8.72 lakh ha, out of which 95 per cent of area belongs to Rayalaseema region (adpdes.ap.gov.in). Groundnut crop is known to be infested by more than 360 species of insect pests in different parts of the world (Wightman and Amin, 1988). The insects that live in the soil of groundnut fields are responsible for higher levels of yield loss than foliage feeders. Soil insects are difficult to manage because farmers usually do not know that they are present until plants die (or) until the crop is harvested. One of the most important soil pests affecting groundnut is root grub. The root grubs or white grubs belonging to the family Scarabaeidae are some of the diverse and devastating pests of several crops and assumed national importance due to high per cent yield losses (Sreedevi and Tyagi, 2015). Root grubs are universally known as May beetles, June beetles or cockchafers because adults become active during the month of May/June with the onset of monsoon, once active, adults fly to trees at dusk for feeding and mating, female subsequently lay eggs in the soil. Groundnut planting in Rayalaseema region mostly coincides with the onset of monsoon. The root grubs cause damage by

feeding on the roots and underground parts of the plant from one to several inches below the soil surface. The plant turns yellow and wilts resulting in patchy growth in fields. Affected plants when pulled shows feeding symptoms i.e., cut ends of the roots.

The root grub causes damage to other agricultural crops such as sugarcane, pearl millet, sorghum, maize, pea, potato etc. (Vasanth *et al.*, 2014). In endemic areas, the damage to groundnut ranges from 20-100 per cent. The presence of one grub/m² can cause 80-100 per cent mortality (Yadava and Sharma, 1995), damage upto 39.40 per cent (Umeh *et al.*, 1999) and 12-60 per cent (Pokhrel, 2004). About 80,000 ha of groundnut has been reported to be affected by white grubs in Andhra Pradesh (Wightman, 1995). Though a lot of work has been done on biology, ecobiology and management of white grubs in groundnut ecosystem, not much attention is paid on the estimation of damage caused by root grubs in groundnut ecosystem of Andhra Pradesh. Hence an attempt was made to know the extent of damage caused by root grub, *H. reynaudi* in groundnut.

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Table 1. Pooled data of plant mortality in groundnut caused by root grub, *Holotrichia reynaudi* in different dates of sowing in *kharif*, 2014 and 2015

Dates of sowing	Particulars	Unprotected plot					Protected plot					Per cent protection over untreated plot (%)
		30 DAS	50 DAS	70 DAS	90 DAS	Average	30 DAS	50 DAS	70 DAS	90 DAS	Average	
D1 (II FN of June)	Per cent plant mortality m ⁻²	16.92	22.80	26.57	27.14	23.36	2.03	5.13	8.39	9.33	6.20	72.88
	Number of grubs m ⁻²	1.85	2.15	2.45	2.45	2.23	0.15	0.30	0.50	0.60	0.39	-
D2 (I FN of July)	Per cent plant mortality m ⁻²	20.92	23.45	21.25	19.17	21.20	3.05	5.64	7.26	5.70	5.41	74.48
	Number of grubs m ⁻²	2.15	2.30	2.10	1.75	2.08	0.20	0.35	0.50	0.40	0.37	-
D3 (II FN of July)	Per cent plant mortality m ⁻²	22.84	25.13	20.83	13.02	20.46	4.08	6.66	5.67	4.15	5.14	74.87
	Number of grubs m ⁻²	2.30	2.35	1.90	1.25	1.95	0.30	0.50	0.35	0.20	0.34	-

Table 2. Pooled data of pod damage and yield loss in groundnut caused by root grub, *Holotrichia reynaudi* in different dates of sowing in *kharif* 2014 and 2015

Dates of sowing	Unprotected plot	Protected plot	Per cent loss in yield
	Pod yield (kg ha ⁻¹)	Pod yield (kg ha ⁻¹)	
D1 (II FN of June)	1063.50	1680.50	36.74
D2 (I FN of July)	1148.50	1745.00	34.19
D3 (II FN of July)	1175.00	1771.00	33.65

MATERIAL AND METHODS

The crop (variety Dharani) was sown on three dates *i.e.*, June IInd FN, July Ist and IInd FN during *kharif*, 2014 and 2015 with two treatments protected and unprotected. In protected plot, seeds were treated with chlorpyrifos 20 EC @ 6 ml/kg seed 12 hours before sowing. No seed treatment was done in unprotected plot. Data was recorded on per cent plant mortality, larval incidence per m² on 10 randomly selected spots at 30, 50, 70 and 90 days after sowing. Pod yield in each plot was recorded after harvest. Per cent yield loss was calculated with the pod yield parameters of protected and unprotected treatments. Per cent plant mortality and per cent yield loss was calculated as under

Per cent plant mortality =

$$\frac{\text{Number of dead plants due to white grubs / m}^2}{\text{Total number of plants / m}^2} \times 100$$

Per cent yield loss =

$$\frac{\text{Pod yield in unprotected plot}}{\text{Pod yield in protected plot}} \times 100$$

RESULTS AND DISCUSSION

In June IInd FN sown crop, per cent plant mortality increased from 30 to 90 DAS, while in July Ist and IInd FN sown per cent plant mortality increased from 30 to 50 DAS and decreased from 50 to 90 DAS. In June IInd FN sown crop the pooled average per cent plant mortality m⁻², number of grubs m⁻² in unprotected and protected plots were 23.36 per cent, 2.23 grubs m⁻² and 6.20 per cent, 0.39 grubs m⁻². Whereas in July Ist FN sown crop, they were 21.20 per cent, 2.08 grubs m⁻² and 5.41 per cent,

0.37 grubs m⁻² and in July IInd FN sown crop they were 20.46 per cent, 1.95 grubs m⁻² and 5.14 per cent, 0.34 grubs m⁻². Pooled highest per cent plant mortality m⁻² due to root grub was observed in unprotected plots of June IInd FN sown crop (23.36%) followed by July Ist FN sown crop (21.20%) and July IInd FN sown crop (20.46%). Highest protection over unprotected plot (74.87%) was observed in July IInd FN sown crop followed by July Ist FN sown crop (74.48%) and June IInd FN sown crop (72.88%).

The pooled pod yield in June IInd FN sown unprotected and protected plot was 1063.50 kg ha⁻¹ and 1680.50 kg ha⁻¹, in July Ist FN sown it was 1148.50 kg ha⁻¹ and 1745 kg ha⁻¹ and in July IInd FN sown it was 1175 kg ha⁻¹ and 1771 kg ha⁻¹. Highest pod yield in protected plots was recorded in July IInd FN sown crop (1771 kg ha⁻¹) followed by July Ist FN sown crop (1745 kg ha⁻¹) and June IInd FN sown crop (1680.50 kg ha⁻¹). In June IInd FN sown crop highest pooled per cent plant mortality was observed hence the pod yield might have decreased in unprotected plot (Table 2).

In June IInd FN sown crop the per cent loss in yield was 36.74 per cent followed by July Ist FN sown plot (34.19%) and July IInd FN sown plot (33.65%). The present results are in close agreement with those of Umesh *et al.* (1999) who reported that white grub cause damage in groundnut upto 39.40 per cent. Hussain (1974) also reported that the grubs of *Holotrichia reynaudi* feed on roots of groundnut and cause damage upto 70 per cent. Adsule and Patil (1990) reported the losses caused by white grub to the extent of 25 to 100 per cent in sugarcane, paddy, maize, groundnut, potato, vegetables and other crops.

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INTEGRATED MANAGEMENT OF COLLAR ROT OF BETELVINE CAUSED BY *Sclerotium rolfsii* Sacc.

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ABSTRACT

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The studies were carried out on collar rot caused by *Sclerotium rolfsii* Sacc. on betelvine (*Piper betle* L.) during 2015 at department of plant pathology, College of Agriculture Badnapur, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani. The *in-vitro* evaluation revealed highest average mycelial growth inhibition with systemic fungicides, carboxin and hexaconazole (100% in both), cymoxanil+ Mancozeb (92.26 %), carbendazim (90.64%) and least inhibition rate was recorded in thiophanate methyl (70.69%). While mancozeb recorded maximum growth inhibition (100%) that differed significantly with other non-systemic fungicides. *Trichoderma viridae* among the bio agents and *Allium sativum* among the botanicals significantly inhibited the mycelial growth of the pathogen to the tune of 82.47 per cent and 100 per cent respectively. In the integrated management of disease study, significantly highest percentage of successful cuttings were recorded with treatment carbendazim + mancozeb + garlic extract + *T. harzianum* (80.17%) as compared to rest of treatments.

KEYWORDS: *Sclerotium rolfsii*, fungicides, plant extracts, bio-agents, betelvine.

Betelvine (*Piper betle* L.) is the Neglected Green Gold of India. It belongs to the family Piperaceae. It is perennial dioecious creeper. It is usually grown under shade by farmers. The plant is a climber having heart shaped deep green leaves and in India it is locally called as “Paan” in Hindi and “Nagveliche pan” in Marathi. The leaves of betelvine are regarded as excellent mouth freshener and routinely served on the social, cultural and religious occasions such as marriages, puja, sradha, ceremony etc.,. The leaves also helps to improve the digestive capacity when used with lime besides acting as blood purifier. The leaves of betelvine contains vitamins, enzymes thiamin, riboflavin, tannin, iodine, iron, calcium, minerals, proteins, essential oils and medicine for liver, brain, and heart diseases (Khanna, 1997).

Betelvine subjected to a number of diseases viz., root rot, foot rot, collar rot, leaf spot, powdery mildew, anthracnose, bacterial stem canker and root knot nematode. Among these diseases collar rot caused by *Sclerotium rolfsii* Sacc. is consider as serious disease responsible for causing huge loss of 25-40 per cent in west Bengal (Maiti and Sen, 1982). The disease caused by this pathogen on different crops are difficult to control because of the production of sclerotia by pathogen. These sclerotia are considered to be extremely hard structures and relatively resistant survival structures.

The pathogen *Sclerotium rolfsii* Sacc. infests the stem and produce symptoms of darkening of the stem at the collar region of the plant near ground level, above or occasionally higher up in different vines. The leaves soon turn yellow and become flaccid and drop off, eventually whole vine wilts and dries up. The darkened portion of stem tends to shrink and becomes soft and slimy and the bark peels off easily. The colour of the darkened portion ultimately becomes black. White, ropy, fan- shaped mycelial strands creeps over stem portion, developing small light brown to dark brown sclerotia on the infected portion. The sclerotial initials are white at first, later turn brown.

Keeping in view economic importance, and yield losses caused by *Sclerotium rolfsii* in betelvine the present investigations were undertaken.

MATERIALS AND METHODS

In-vitro evaluation of fungicides

Eleven different fungicides (seven systemic and four non systemic) viz., carboxin (Vitavax 75% WP), tridemefon (Bayleton 25% EC), carbendazim (Bavistin 50% WP), hexaconazole (Contaf 5% EC), thiophanate methyl (Topsin M 70% WP), cymoxynil+ mancozeb (Curzet 70% WP), metalaxyl (Ridomyl 75% WP), captan (Captan 50% WP), copper-oxy-chloride (Blitox 50 % WP)

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, bordeaux mixture (1% bordeaux mixture) and mancozeb (Dithane M -45 50WP) were tested each at a concentration of 500, 1000ppm (systemic) 2000 and 2500 ppm (non-systemic) against *Sclerotium rolfsii* by poisoned food technique (Nene and Thapliyal, 1993). Potato dextrose agar (PDA) medium amended with test concentration of fungicide was poured in Petri plates and inoculated at the centre with mycelial disc (5mm) from actively growing 5 days old culture of *Sclerotium rolfsii*. Un amended PDA medium served as control and each treatment was replicated thrice. The inoculated Petri plates were incubated at $27\pm 1^\circ\text{C}$. Observations on radial mycelial growth/ colony diameters were recorded at an interval of 24 h and continued till untreated control plates were fully covered with growth of test pathogen. The per cent mycelial growth inhibition of test pathogen with test fungicides over untreated control was calculated by applying the formula given by Vincent (1927).

$$\text{Per cent inhibition (I)} = \frac{C - T}{C} \times 100$$

where,

C = Growth (mm) of test fungus in control plate.

T = Growth (mm) of test fungus in treatment plate

In vitro efficacy of bio-agents:

Six fungal antagonists viz., *Trichoderma viride*, *T. harzianum*, *T. koningii*, *T. virens*, *T. hamatum*, *T. lignorum* and two bacterial antagonist *Pseudomonas fluorescens* and *Bacillus subtilis* were evaluated *in-vitro* against *Sclerotium rolfsii*, by dual culture technique (Dennis and Webster, 1971). Seven days old cultures of the bio-agents and test fungus (*Sclerotium rolfsii*) grown on agar media were used for evaluation. Discs (5 mm) of PDA along with culture growth of the test fungus and bio-agents were taken with sterilized cork borer. The two culture discs, one of the test fungus and the other of the bioagent were placed at equidistance and exactly opposite with each other on solidified PDA medium in Petri plates under aseptic conditions and plates were incubated at $27\pm 1^\circ\text{C}$. Plates inoculated with culture disc of test fungus were maintained as untreated control. Observations on linear mycelial growth of test fungus and bio-agents were recorded at an interval of 24 hours and continued till untreated control plate was fully covered with mycelial growth of the test fungus. Per cent inhibition of the test

fungus over untreated control was calculated by applying the formula given by Arora and Upadhyay (1978) as follows.

Per cent growth inhibition=

$$\frac{\text{Colony growth in control plate} - \text{Colony growth in intersecting plate}}{\text{Colony growth in control plate}} \times 100$$

In- vitro evaluation of botanicals / plant extracts:

Plant extracts of eight botanicals viz. onion (*Allium cepa*), garlic (*Allium sativum*), neem (*Azadirachta indica*), tulsi (*Ocimum sanctum*), periwinkle (*Catharanthus roseus*), bougainvillea (*Bougainvillea spectabilis*), giripushpa (*Gliricidia maculata*), and nilgiri (*Eucalyptus* spp.) were evaluated *in-vitro* against *S. rolfsii*. Leaf extracts were prepared by grinding with mixer-cum grinder, the 100 g washed leaves, ginger rhizomes and garlic bulbs of each plant species in 100 ml distilled water and filtered through double layered muslin cloth. The filtrates obtained were further filtered through Whatman No. I filter paper using funnel and volumetric flasks (100 ml capacity). The final clear extracts filtrates obtained formed the standard plant extracts of 100 per cent concentration, which were evaluated @10 per cent and 20 per cent *in- vitro* against *S. rolfsii* applying poisoned food technique (Nene and Thapliyal, 1993) using potato dextrose agar as basal culture medium.

Observations on radial mycelial growth/colony diameter of the test pathogen were recorded treatment wise at 24 hours interval and continued till mycelial growth of the test fungus was fully covered in the untreated control plates. Per cent inhibition of mycelial growth over untreated control was calculated by applying the formula given by Vincent (1927) as follows

$$\text{Per cent inhibition (I)} = \frac{C - T}{C} \times 100$$

where,

C = Growth (mm) of test fungus in control plate.

T = Growth (mm) of test fungus in treatment plate.

Integrated evaluation of fungicides, botanicals, bio-agents and organic amendments

The identified effective fungicides, botanicals, bio-agents and amendments against *S. rolfsii* during *in-vitro* studies were selected for integrated management of collar rot (*S. rolfsii*) of betelvine in pot culture under screen house conditions. The earthen pots (30cm dia.) disinfected with 5 per cent solution of copper sulphate were filled with autoclaved potting mixture of soil, sand and FYM (2:1:1) The Mass multiplied (sand maize medium) inoculums of *S. rolfsii* was inoculated @ 50g/kg potting mixture, to the potting mixture in pots, mixed thoroughly watered adequately and incubate for two weeks in the screen house to proliferate the pathogen and make the soil/ potting mixture sick. The experiment comprised nine treatments (Table 5). All the treatments were replicated thrice. The most effective test fungicides and talc based formulations of bio-agents were applied (alone and in combinations) as pre- planting treatment (preventative)

to healthy betelvine cuttings and were planted (10 cuttings/ pot) in the earthen pots containing *S. rolfsii* sick soil/ potting mixture.

The powdered test organic amendment was pre amended (100 g/kg soil or potting mixture) in the earthen pots containing *S. rolfsii* sick soil mixed thoroughly, watered adequately and maintained in screen house. After 72 h, these pots were planted (10 cuttings of betelvine / pot) with the surface sterilized with Hgcl₂ (0.01%), healthy cuttings of cv. local were planted. After 72 h of planting, crude extracts @ 20 per cent concentration of test botanical was drenched @ 50 ml/kg soil as curative treatment.

Surface sterilized (0.01% Hgcl₂) healthy betelvine cuttings were planted (10 cuttings/pot) in sick soil/potting mixture. All these pots (treated and untreated) were watered regularly and maintained in the screen house for further observation The observations on per cent successful cuttings, mortality percentage at 15, 30 and 45

Table 1. *In vitro* effect of systemic fungicides on mycelial growth and inhibition of *S. rolfsii*

Tr. No.	Fungicides	Mean colony diameter of pathogen *(mm)		Average (mm)	Per cent inhibition		Per cent average inhibition (%)
		500 ppm	1000 ppm		500 ppm	1000 ppm	
T ₁	Carboxin (Vitavax75% WP)	00.00	00.00	00.00	100 (90.00)	100 (90.00)	100
T ₂	Triadimefon (Bayleton 25% EC)	21.21	17.27	19.24	76.42 (49.83)	80.80 (53.90)	78.61
T ₃	Carbendazim (Bavistin 50WP)	8.77	8.07	8.42	90.26 (64.49)	91.02 (65.53)	90.64
T ₄	Hexaconazole (Contaf 5% EC)	00.00	00.00	00.00	100 (90.00)	100 (90.00)	100
T ₅	Thiophanate methyl (Topsin M 70% WP)	28.39	24.36	26.37	68.45 (43.19)	72.93 (46.82)	70.69
T ₆	Cymoxynil (8%) + Mancozeb (64%) (Curzet70% WP)	7.78	6.13	6.95	91.35 (65.98)	93.18 (68.73)	92.26
T ₇	Metalaxyl (Ridomyl 25% WP)	18.24	16.72	17.48	79.73 (52.87)	81.41 (54.49)	80.57
T ₈	Control	90.00	90.00	90.00	00.00 (00.00)	00.00 (00.00)	00.00
	SEm ±	0.34	0.35	-	0.34	0.42	-
	CD (P = 0.05)	1.02	1.06	-	1.02	1.25	-

* : Means of three replications; Figures in parenthesis are arc sine values

days after planting and per cent disease incidence were calculated.

RESULTS AND DISCUSSION

In vitro evaluation of systemic fungicides against *S. rolfsii*

The results indicated that all the systemic fungicides tested at 500 and 1000 ppm concentrations inhibited mycelial growth of *S. rolfsii* significantly over the control and the inhibition increased with increase in concentration of fungicide tested (Table 1).

Radial mycelial growth (diameter mm)

At 500 ppm, radial mycelial growth ranged from 00.00 mm (carboxin and hexaconazole) to 28.39 mm (thiophanate methyl) as against 90.00 mm in untreated control. Highest mycelial growth was recorded with the fungicide thiophanate methyl (24.36 mm) followed by tridimefon (17.27mm) and metalaxyl (18.24 mm). Less mycelial growth was found in carbendazim (08.77 mm) and cymoxanil+ mancozeb (07.78 mm). Whereas, nil mycelial growth was found with carboxin and hexaconazole.

At 1000 ppm systemic trend of mycelial growth was observed and it ranged from 0.00 (carboxin and hexaconazole) to 24.36 mm (thiophanate methyl), as against 90.00 mm in untreated control. Significantly highest mycelial growth was recorded with fungicides thiophanate methyl (24.36 mm) followed by tridimefon (17.27 mm) and metalaxyl (16.72 mm). While nil mycelial growth was recorded with carboxin and hexaconazole (00.00 mm in both), followed by cymoxanil+ mancozeb (06.13 mm) and carbendazim (08.07 mm) (Table 1).

Mycelial inhibition

At 500 ppm, per cent mycelial growth inhibition ranged from 68.45 (thiophanate methyl to 100 per cent (carboxin and hexaconazole). Among the tested fungicides, carboxin and hexaconazole were proved the most effective as it gave completely inhibited colony growth (100%). It was followed by fungicides viz., cymoxanil + Mancozeb (91.35%), carbendazim (90.26%) and metalaxyl (79.73%). Thiophanate methyl proved less effective and inhibited colony growth of 68.45 per cent.

At 1000 ppm, similar trend in mycelial growth inhibition was observed and it ranged from 72.93 per cent in thiophanate methyl to 100 per cent (carboxin and hexaconazole) Amongst the tested systemic fungicides

completely inhibited mycelial growth inhibition were recorded with fungicides carboxin and hexaconazole (100%) followed by other fungicides viz., cymoxanil + mancozeb (93.18%), carbendazim (91.02%), metalaxyl (81.41%) while thiophanate methyl proved less effective among all the fungicides tested in inhibition of mycelial growth of *S. rolfsii* (72.93%) (Table 1).

Non systemic fungicides

All non systemic fungicides tested at both concentrations significantly inhibited mycelial growth of *S. rolfsii* over untreated control and it increased with increase in concentrations (Table 2).

Radial mycelial growth (diameter mm)

At 2000 ppm, radial mycelial growth of the test pathogen ranged from 55.85 (bordeaux mixture) to 00.00 mm (mancozeb) as against 90 mm in untreated control. However, significantly highest mycelial growth was recorded with the fungicide Bordeaux mixture (55.85 mm), followed by copper- oxy-chloride (38.17 mm) and captan (23.09 mm), while no mycelial growth (00.00 mm) was recorded with mancozeb treatment.

At 2500 ppm radial mycelial growth of the test pathogen ranged from 50.57 mm (bordeaux mixture) to 00.00 mm (mancozeb). Significantly highest radial mycelial growth was recorded with bordeaux mixture (50.57), followed by copper- oxy-chloride (30.96 mm) and captan (21.37 mm). While no (00.00 mm) mycelial growth was recorded with (mancozeb) (Table 2).

Mycelial inhibition

The results indicated that all the non-systemic fungicides tested at both the concentrations inhibited mycelial growth of *S. rolfsii* significantly over the control and its mycelial inhibition was increased with increase in concentration of the fungicides tested (Table 2).

At 2000 ppm, percentage mycelial growth inhibition ranged from 37.94 (bordeaux mixture) to 100 per cent (mancozeb). However, significantly highest mycelial growth inhibition was recorded with mancozeb (100 %), followed by, captan (74.34 %), and copper oxy-chloride (57.58%). Whereas, least inhibition was found in bordeaux mixture (37.94%).

At 2500 ppm, similar trend of mycelial growth inhibition with the test fungicides was recorded and it

Table 2. *In vitro* effect of non- systemic fungicides on mycelial growth and inhibition of *S. rolfsii*

Tr. No.	Fungicides	Mean colony diameter of pathogen*(mm)		Average (mm)	Per cent inhibition		Average (mm)
		2000 ppm	2500 ppm		2000 ppm	2500 ppm	
T ₁	Captan (Captan 50% WP)	23.09	21.37	22.23	74.34 (48.02)	76.25 (49.68)	75.30
T ₂	Copper oxychloride (Blitox 50%WP)	38.17	30.96	34.57	57.58 (35.15)	65.60 (40.98)	61.59
T ₃	Bordeaux Mixture (1% Bordeaux mixture)	55.85	50.57	53.21	37.94 (22.29)	43.80 (25.97)	40.87
T ₄	Mancozeb (Diathene M-45)	00.00	00.00	00.00	100 (90.00)	100 (90.00)	100
T ₅	Control	90.00	90.00	90.00	00.00 (00.00)	00.00 (00.00)	0.00
	SEm±	0.55	0.26	-	0.45	0.21	-
	CD (P = 0.01)	1.73	0.84	-	1.43	0.68	-

* : Means of four replications; Figures in parenthesis are arc sine values

ranged from 43.80 (bordeaux mixture) to 100 per cent (mancozeb). However, significantly highest of mycelial growth inhibition was recorded with mancozeb (100%). Followed by captan (76.25 %) and copper oxy-chloride (65.60 %) and bordeaux mixture (43.80%).

Similar fungistatic effects of fungicides (systemic and non systemic) against *S. rolfsii* infecting betelvine along with many other crops have been reported (Bhat and Shrivastav, 2003; Mundhe, 2005; Patil and Raut, 2008; Bindu and Bhattiprolu, 2011; Rather *et al.*, 2012; Mahato *et al.*, 2014 and Suryawanshi *et al.*, 2015).

***In vitro* effect of bio-agents**

All the bio-agents tested exhibited fungistatic activity against *S. rolfsii* and significantly inhibited the mycelial growth of test pathogen over control.

Of all the treatments significantly lowest mycelial growth (15.75 mm) and highest mycelial inhibition (82.47 %) were recorded with *Trichoderma viride* (Table 3). The second and third best treatment found were *T. harzianum* (19.36 mm and 78.48%) and *T. virens* (20.50 mm and 77.22%) with mycelial growth and mycelial growth inhibition per cent. These were followed by the treatments viz., *T. lignorum* (20.90 mm and 76.77 %), *T. koningii* (25.54 mm and 71.62 %), *Pseudomonas fluorescens* (28.78 mm and 68.01 %), *T. hamatam* (33.58 mm and

62.69 %) and *B. subtilis* (59.51 mm and 33.87 %) with mycelial growth and mycelial inhibition, respectively.

Similar antagonist effect of bio-control agents were reported earlier against *S. rolfsii* and other pathogens (Agrawal *et al.*, 1977); Henis *et al.* 1983; Tribhuvanmala *et al.* 1999; Dutta and Das, 2002; Tripathi and Khare, 2005; Banyal *et al.* 2008; Patil and Raut, 2008; Bindu and Bhattiprolu, 2011; Kumar *et al.* 2011; Manu *et al.*, 2012 and Suryawanshi *et al.*, 2015).

***In vitro* effect of plant extract**

Aqueous extract of all the eight botanicals at both the concentrations significantly inhibited mycelial growth of *S. rolfsii* over the control and it was found to increase with increase in concentration of the botanicals tested (Table 4).

Mycelial growth of *S. rolfsii*.

At 10 per cent concentration, radial mycelial growth of *S. rolfsii* ranged from 00.00 (*Allium sativum*) to 72.77 mm (*Gliricidia maculata* L) as against 90 mm in untreated control.

It was significantly maximum with *Gilricidia maculance* (72.77mm), this was followed by the botanicals viz., *Ocimum santum* (68.00 mm), *Bougainvillea spectabilis* (64.89 mm), *Catharanthus roseus* (64.56

Table 3. *In vitro* effect of bio agents against mycelia growth and inhibition of *S. rolfsii*

Treatment	Treatments	Colony diameter of pathogen*(mm)	Per cent inhibition
T₁	<i>Trichoderma harzianum</i>	19.36	78.48 (51.69)
T₂	<i>Trichoderma lignorum</i>	20.90	76.77 (50.16)
T₃	<i>Trichoderma koningi</i>	25.54	71.62 (47.73)
T₄	<i>Trichoderma hamatum</i>	33.58	62.69 (38.82)
T₅	<i>Trichoderma virens</i>	20.50	77.22 (50.54)
T₆	<i>Trichoderma viride</i>	15.75	82.47 (55.53)
T₇	<i>Bacillus subtilis</i>	59.51	33.87 (19.80)
T₈	<i>Pseudomonas fluorescens</i>	28.78	68.01 (42.85)
T₉	Control	90.00	00.00 (00.00)
	SEm±	0.75	0.60
	CD (P = 0.01)	2.24	1.80

* : Means of three replications; Figures in parenthesis are arc sine values

mm) and *Allium cepa* (61.33 mm). Comparatively minimum mycelia growth was recorded with the botanicals viz., *Eucalyptus* spp. (22.63 mm) and *Azadirachta indica* (18.65 mm). While no colony diameter of test pathogen was recorded with *Allium sativum*.

At 20 per cent, radial mycelial growth recorded with test botanicals was ranged from 0 0.00 mm (*Allium sativum*) to 71.37 mm (*Gliricidia maculatum*). However, significantly highest mycelial growth was recorded with *Gliricidia maculatum* (71.37 mm), this was followed by *Catharanthus roseus* (63.24 mm), *Bougainvillea spectabilis* (62.63 mm), *Allium cepa* (58.32 mm) and *Ocimum sanctum*. (56.48 mm). Comparatively minimum mycelial growth was recorded with the botanicals viz., *Eucalyptus* spp. (20.97 mm) and *Azadirachta indica* (16.81 mm). Whereas, nil mycelial growth of test pathogen was found with *Allium sativum*.

Mycelial growth inhibition of *S. rolfsii*.

Results obtained on mycelial growth inhibition of *S. rolfsii* with the aqueous extracts of the test botanicals tested are presented in the (Table 4) revealed that all the botanicals tested (@10 and 20 % each) significantly inhibited mycelial growth of the test pathogen, over untreated control and it was increased with increase in concentration of the botanicals tested.

At 10 per cent, mycelial growth inhibition of *S. rolfsii* ranged from 19.13 (*Gliricidia maculata*) to 100 per cent (*Allium sativum*). However, significantly highest mycelial growth inhibition was found with *A. sativum*(100%). This was followed by the botanicals viz., *Azadirachta indica* (79.13%) and *Catharanthus roseus* (74.85%). While the botanicals viz., *Allium cepa* (31.84 %), *Catharanthus roseus* (28.25%) *Ocimum sanctum*. (24.43 %) and *Gliricidia maculata* (19.13 %) were found comparatively less effective in inhibiting mycelial growth of test pathogen.

Table 4. *In vitro* efficacy of the botanicals aqueous extracts on growth and inhibition of *S. rolfsii*.

Tr. No	Treatments	Colony diameter of pathogen* (mm)		Average colony diameter of pathogen (mm)	Per cent inhibition		Average inhibition per cent
		10%	20 %		10%	20%	
T ₁	<i>Gliricidia maculata</i> L. (Giripushpa)	72.77	71.37	72.07	19.13 (11.03)	20.69 (11.94)	18.38
T ₂	<i>Allium sativum</i> L. (Garlic)	00.00	00.00	00.00	100 (90.00)	100 (90.00)	100
T ₃	<i>Eucalyptus</i> spp. (Nilgiri)	22.63	20.97	21.80	74.85 (48.68)	76.70 (50.08)	73.08
T ₄	<i>Allium cepa</i> L. (Onion)	61.33	58.32	59.82	31.84 (18.56)	35.18 (20.60)	32.72
T ₅	<i>Azardirchta indica</i> L. (Neem)	18.65	16.81	17.73	79.13 (52.30)	81.32 (54.40)	79.42
T ₆	<i>Bougainvillea glaba</i> (Bougainvillea)	64.89	62.63	63.76	27.88 (16.19)	30.40 (17.70)	26.27
T ₇	<i>Catharanthus roseus</i> L. (Periwinkle)	64.56	63.24	63.90	28.25 (16.41)	29.73 (17.29)	27.77
T ₈	<i>Ocimum sanctum</i> L. (Tulsi)	68.00	56.48	62.24	24.43 (14.14)	37.24 (21.86)	30.83
T ₉	Control	90.00	90.00	90	00.00 (00.00)	00.00 (00.00)	00.00
	SEm±	0.77	0.76	-	0.55	0.52	-
	CD (P = 0.01)	2.30	2.25	-	1.64	1.56	-

* : Means of three replications; Figures in parenthesis are arc sine values

At 20 per cent, mycelial growth inhibition of *S. rolfsii* ranged from 20.69 (*Gliricidia maculata*) 100 per cent (*Allium sativum*). However, significantly highest mycelial inhibition was recorded with *A. sativum* (100%). This was followed by the botanicals viz., *Azardirachta indica* (81.32 %) and *Eucalyptus* spp. (76.70 %). While minimum mycelial inhibition was recorded with *Ocimum santum* (37.24 %), *Allium cepa* (35.18 %), *Bougainvillea spectabilis* (30.40 %), *Catharanthus roseus* (29.73 %), and *Gliricidia maculata* (20.69 %).

Aqueous extract of botanical *Allium sativum* was reported earlier as antifungal against *S. rolfsii* and other pathogens (Shivapuri *et al.*, 1997; Suryawanshi *et al.*, 2007; Patil and Raut, 2008 and Sultana *et al.*, 2012).

Integrated Management:

The results revealed that there were significant differences in per cent disease incidence for management of collar rot of betel vine caused by *Sclerotium rolfsii* by utilizing fungal bio-agents, organic amendments, botanicals and fungicides. All the treatments significantly enhanced the percentage of successful cuttings and found effective in reducing mortality or percent disease incidence over untreated control (Table 5)

Significantly highest percentage of successful cuttings was recorded with the treatment carbendazim 12 per cent + mancozeb 63 per cent + Garlic extract+ *T. harzianum* (80.17 %). The Second and third highest percentage of successful cuttings was recorded with the treatments viz., carboxin+ hexaconazole 5 EC + *T. viride* + neem seed cake and carbendazim 12 per cent + Mancozeb 63 per cent (each 75.25% and 70.60% respectively). This was followed by Garlic extract (69.32%), *T. viride* (68.63%),

Table 5. Effect of fungicides, bio-agents and soil amendments in management of collar rot of betelvine caused by *S. rolfsii* by Pot culture

Sr. No.	Treatment	Rate of application		Per cent of successful cuttings	Mortality (%)			Total mortality (%)	Reduction (%) over control
		ST	SA		15 DAS	30 DAS	45 DAS		
1	Carboxin 50 ml 0.1% solution/pot	3 g	-	70.10 (56.85)	2.69	4.66	4.38	11.73	48.29 (44.02)
2	Hexaconazole 5 EC (Contaf) 50 ml 0.1% solution/pot	1 ml	-	67.97 (55.53)	4.35	5.55	5.68	15.58	28.48 (32.25)
3	Carbendazim 12% + Mancozeb 63% (Sixer) 50 ml 0.1% solution/ pot	1.5g + 1.5 g	-	70.60 (57.16)	2.62	4.47	4.3	11.47	49.54 (44.73)
4	Garlic extract (20%) (SD)	-	20 ml	69.32 (56.36)	4.39	5.40	5.65	15.44	28.83 (32.44)
5	Neem seed cake (SA)	-	50g	66.23 (54.47)	3.64	5.44	7.46	16.54	27.58 (31.67)
6	<i>T. viride</i>	10g	-	68.63 (55.93)	3.19	4.28	5.22	12.69	43.01 (40.98)
7	Carbendazim 12% + Mancozeb 63% (Sixer) + Garlic Extract + <i>T. harzianum</i>	1.5 g + 1.5 g + 10 g	20 ml	80.17 (63.55)	2.10	3.47	3.36	08.95	60.44 (51.02)
8	Carboxin (37.5%) + Hexaconazole 5 EC (Contaf) + <i>T. viridae</i> + Neem seed Cake(SA)	1.5 g + 1.5 g + 10 g	50g	75.22 (60.14)	2.40	4.12	4.25	10.77	52.77 (46.58)
9	Control	-	-	57.40 (49.25)	4.62	9.41	9.25	23.58	0.00 (0.00)
SEm ±				0.20	0.12	0.11	0.04	-	6.70
CD(P=0.01)				0.59	0.34	0.32	0.11	-	20.82

*Mean of three replications

Figure in parenthesis are angular transformation values

ST: Set Treatment

SA : Soil Application

SD: Soil Drenching

hexaconazole 5 EC (67.97%) and Neem seed cake (66.23%) which were at par with each other.

The collar rot disease recorded with all the treatments ranged from 8.95-16.54 per cent as against 23.58 per cent in untreated control. However the treatments, viz., carbendazim (12%) + mancozeb (63%) + Garlic extract + *T. harzianum*, carboxin + hexaconazole 5 EC + *T. viride* were found with significantly lowest stem cutting mortality/ per cent disease incidence of 8.95, 10.77 per cent respectively. The treatments viz., garlic extract (15.44%), hexaconazole 5 EC (15.58%) and neem seed cake (16.54%) were found comparatively less effective with highest stem cutting mortality.

The percentage reduction in cutting mortality/ per cent disease incidence recorded with all the treatments and ranged from 27.58 to 60.44 per cent. However, carbendazim (12%) + mancozeb (63%) + Garlic extract + *T. harzianum*, carboxin + hexaconazole 5 EC + *T. viride* + neem seed cake, carbendazim 12 per cent + mancozeb (63%), carboxin and *T. viride* found most effective with significantly highest reduction in cutting mortality/ per cent disease incidence of 60.44, 52.77, 49.54, 48.29 and 43.01 per cent respectively. Garlic extract (28.83%), hexaconazole 5 EC (28.48%) and neem seed cake (27.85%) were found least effective with minimum reduction in cuttings mortality /percent disease incidence over untreated control. The results of present study obtained on the integrated bio efficacy of the fungicides, botanicals, bio agents and organic amendments against collar rot of betelvine and in other crops are in conformity with those reported earlier by several workers. Integration of fungicides, botanicals with *Trichoderma* spp. and organic amendments were effective against *S. rolfsii* as reported earlier by Suryawanshi *et al.*, 2005; Khosla and Gupta, 2005; Khode and Raut, 2010; Rather *et al.*, 2012; and Tripathi, 2015.

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ADOPTION BEHAVIOUR OF PADDY FARMERS IN CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

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Krishi Vigyan Kendra (KVK) is a district level innovative science based institution established by Indian Council of Agricultural Research (ICAR) for assessment and refinement of the technologies released by National Agricultural Research Systems and identifies technologies in terms of location specific sustainable land use systems. To generate the production data and feedback information of the successful technologies, front line demonstrations are conducted by the KVKs. Through multifarious activities, KVK touches almost all the psychological aspects of an individual thereby directly affecting his decision to adopt a new technology. An attempt was made to study the adoption behaviour of respondents from adopted villages of RASS – Acharya Ranga Krishi Vigyan Kendra (RASS - ARKVK) with respect to the recommended Paddy production technologies in Chittoor district of Andhra Pradesh. The research study was conducted in eight adopted villages of ARKVK in Chittoor district covering a sample size of 180 respondents. The adoption behaviour of the farmers was studied in terms of four types of behaviour viz., full adoption, partial adoption, discontinuation and non adoption and presented in the form of frequencies and percentages. Reasons expressed by the farmers for each type of behaviour for each and every technology was also presented and discussed. The results reveal that there was a positive trend in the adoption behaviour of the beneficiaries of RASS - ARKVK, thus strengthening the ideology of establishing the innovative institutions all over the country by ICAR.

KEYWORDS: Krishi Vigyan Kendra, Adoption behaviour; Paddy production technologies; full adoption; partial adoption; discontinuation; non adoption.

INTRODUCTION

The Indian Council of Agricultural Research (ICAR) has created a network of 665 Krishi Vigyan Kendras (KVKs) in the Country (<http://www.icar.org.in/en/krishi-vigyan-kendra.htm>). Ever since their establishment, KVKs have played effective role of technology backstopping to extension personnel and in turn to farmers so as to enable them to augment their productivity and profitability (Kokate, 2010). The KVKs are playing the role of intermediary institutions to fine tune the research conducted, often under controlled conditions, before its adoption in farmer's field.

RASS – Acharya Ranga Krishi Vigyan Kendra (ARKVK) has completed two decades in serving the farmers of Chittoor district, Andhra Pradesh. Paddy, Groundnut and Sugarcane are the major crops cultivated in the district apart from horticultural crops like Tomato and Mango. An attempt was made to study the adoption behaviour of respondents from adopted villages of RASS (Rayalaseema Seva Samithi) – Acharya Ranga Krishi Vigyan Kendra (RASS - ARKVK) with respect to the

recommended Paddy production technologies in Chittoor district of Andhra Pradesh.

Wilkenning (1950) stated that the farmer's decision for adoption of improved farm practices may be considered as a process in which he (a) hears about the practice, (b) discusses its advantages and disadvantages with other farmers or with experts, (c) makes the decision to adopt the practice and obtains the specific information necessary to carry out the practice. This process may occur over a period of time. Degree of adoption of any item of package may be of complete or full, partial, non-adoption and discontinuation. A proper feedback from the farmers will certainly provide an insight to the scientists for further research or modification of the new farm technology. In the present study, adoption behaviour of farmers from adopted villages of ARKVK with respect to recommended production technologies of Paddy crop was examined.

METHODOLOGY

Study area and respondents

RASS-Acharya Ranga Krishi Vigyan Kendra of Chittoor district, Andhra Pradesh was purposively selected

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Adoption behaviour of paddy farmers of Chittoor district

for the study. Out of the 66 mandals of Chittoor district, ARKVK has so far adopted villages of 20 mandals. Of these, five Mandals viz., Yerpedu, Chandragiri, Ramachandrapuram, Narayanavanam and Karvetinagaram were selected randomly for the study. Of the 23 villages adopted by ARKVK in these five mandals, eight villages were selected randomly for the study. About 180 respondents were selected from these five villages proportionately for the study.

Measurement of adoption behaviour

The adoption behaviour of the farmers was studied using an interview schedule with respect to recommended package of practices of Paddy in terms of four types of behaviour viz., full adoption, partial adoption, discontinued and not adopted with the scores 3, 2, 1 and 0 respectively. The reasons associated with each type of behavior were extracted from the respondents and presented in the form of frequencies and percentages.

RESULTS AND DISCUSSION

The adoption behavior of the respondents towards recommended package of practices was given in terms of Percentage in Table 1.

About 34.72 per cent respondents fully adopted recommended improved varieties of Paddy viz., NLR-34449, NDLR-8, NDLR-7, NLR 3041, while 11.39 per cent have partially adopted, 4.73 per cent have discontinued the usage of varieties and 49.17 per cent of the respondents have not at all adopted the recommended improved varieties.

The data presented in the Table 1 shows that farmers, by and large, had adopted recommended land preparation practices. This was reflected by 82.22 per cent full adoption followed by 15 per cent partial adoption, 2.5 per cent non-adoption and 0.28 per cent discontinuation. About 80 per cent of the respondents adopted recommended seed rate, 12.78 per cent have partially adopted, 2.78 per cent discontinued and 4.44 per cent have not adopted recommended seed rate in Paddy cultivation.

It was observed that 69.44 per cent of respondents fully adopted recommended seed treatment practices followed by 18.89 per cent not-adopted, 6.67 per cent partially adopted and 5 per cent discontinued.

The extent of adoption with respect to planting methods viz., direct seeding method using drumseeder,

‘SRI’ method or using transplanter machine for transplanting was 44.44 per cent full adoption, 32.08 per cent non-adoption, 18.33 per cent partial adoption and 5.13 per cent discontinuation. About 44.44 per cent of the respondents fully adopted recommended method of planting, 18.33 per cent partially adopted, 5.13 per cent discontinued and 32.08 per cent have not adopted the recommended planting methods.

With respect to recommended spacing, 61.94 per cent have fully adopted, 16.95 per cent partially adopted, 6.11 per cent discontinued and 15.00 per cent have not adopted the practice.

About 51.67 per cent of respondents fully adopted recommended water management practices, 24.44 per cent partially adopted, 20 per cent not adopted and 3.89 per cent discontinued.

About 55.18 per cent of the respondents fully adopted the recommended weed management practices, 22.04 per cent have partially adopted, 3.89 per cent have discontinued and the rest 21.85 per cent have not all adopted the recommended weed management practices.

Regarding recommended fertilizer management practices in Paddy cultivation, more than half of the respondents i.e., 72.11 per cent adopted fully, followed by 17.67 per cent of partial adoption, 8.56 per cent non-adoption and 1.67 per cent discontinuation.

About 61.78 per cent of the respondents fully adopted the recommended pest management practices, 19.89 per cent have partially adopted, a negligible 2.00 per cent have discontinued and 16.33 per cent of the respondents have not adopted the recommended pest management practices.

Ample proportion of the respondents were found to have full adoption (87.00%) of recommended harvesting practices in Paddy followed by 11.87 per cent partial adoption and 1.13 per cent non-adoption was observed.

Reasons for different adoption behavior as expressed by the respondents

Various reasons expressed for different adoption behavior of the respondents is presented in Table 2.

Recommended varieties of paddy

The reasons expressed by the respondents for full adoption were ‘high yielding nature of the varieties’ followed by ‘suitability of the varieties for both *kharif*

Table 1. Adoption behavior of farmers towards recommended package of practices in paddy

Adoption behavior										N= 180
S. No.	Recommended package of practice	Full adoption		Partial adoption		Discontinued		Non-adoption		
		Frequency (N)	Per cent	Frequency (N)	Per cent	Frequency (N)	Per cent	Frequency (N)	Per cent	
1	Recommended improved varieties	63	34.72	20	11.39	8	4.73	89	49.17	
2	Land preparation practices	148	82.22	27	15.00	1	0.28	4	2.50	
3	Seed rate	144	80.00	23	12.78	5	2.78	8	4.44	
4	Seed treatment	125	69.44	12	6.67	9	5.00	34	18.89	
5	Recommended method of transplanting	80	44.44	33	18.33	10	5.13	57	32.08	
6	Recommended spacing	112	61.94	30	16.95	11	6.11	27	15.00	
7	Water management	93	51.67	44	24.44	7	3.89	36	20.00	
8	Weed management	99	55.18	39	22.04	2	0.93	40	21.85	
9	Fertilizer management	130	72.11	32	17.67	3	1.67	15	8.56	
10	Pest management	111	61.78	36	19.89	4	2.00	29	16.33	
11	Recommended harvesting practices	157	87.00	21	11.87	0	0.00	2	1.13	

and *rabi* seasons', 'resistance to blast disease' and 'non-lodging nature of the variety'. Partial adoption was due to 'transplanting age of the seedlings is not done at right stage as per recommendation'. 'Low market price' and 'cooking quality not so good' were the reasons expressed by respondents for discontinuing the new varieties. The reasons for non-adoption were 'not aware of the variety', 'non-availability of the variety' and 'marketing problem as traders pay less for this variety'. If the average price that farmers receive increases, this may have an effect on their production decisions in two ways (Tara, 2013). The first is a direct increase in supply as a response to an increase in the price received. The second effect of an increase in producer prices could come through the composition of crops that farmers choose to produce, as suggested by Jensen (2007).

Land preparation

It is evident that main reasons for full adoption were 'soil borne pests will be exposed and killed', 'weeds can be uprooted', 'pest incidence can be reduced to some extent' and 'rodent problem reduction due to trimming of bunds'. The reason for partial adoption was 'high cropping intensity and no gap between two crops to take up deep ploughing operation'. 'Lack of sufficient rainfall for deep ploughing' and 'deep ploughing is a costly process' were the reasons given for non-adoption behaviour. 'Trimming & plastering of bunds is not so effective in managing weeds' was the reason given for discontinuation of the land preparation practice.

Recommended seed rate

More seed rate merely increases the cost of cultivation without any additional benefit' was the reason expressed by respondents for full adoption of recommended seed rate. The reason for partial adoption was 'more the seed rate, more will be the yield'. 'Not aware of the recommended seed rate' was the reason given for non-adoption and 'as a safety measure more seed rate is used' was the reason for discontinuation of this recommended practice.

Seed treatment

The main reasons for full adoption of this practice as expressed by respondents were 'protects crop from diseases in early stages', 'saves cost of pesticides for spraying on entire area' and 'optimum plant population is maintained'. Reason for partial adoption was 'Dosage of

chemicals is not as per recommendation'. 'Not aware of the practice' and 'unaware of the chemicals for seed treatment' are the reasons for non-adoption. 'Not so useful' was the reason expressed by respondents for discontinuation of the practice.

Method of planting

The reasons for full adoption of recommended planting methods are 'Cost of cultivation is very much reduced', 'Labour problem is solved', 'Drumseeder is suitable to all especially small and marginal farmers', 'Net returns are more', 'Shallow planting helps in more tillering', 'Crop is matured earlier than that planted traditionally', 'Transplanter is suitable to big farmers who take up rice in large areas' and 'Clipping of leaf tips reduces stem borer incidence in main field'. 'Weedicides are not applied as per recommendation in drumseeder plot', 'Intermittent wetting and drying of field up to panicle initiation is not followed', 'Seed treatment is not done', 'Conoweeder is not run between rows' and 'Shallow planting is not manageable due to manual transplanting' were the reasons given for partial adoption.

'Weed management is difficult in drumseeder sown plots', 'Not suitable for our soils', 'Difficult to operate transplanter in heavy soils', 'Raising of mat type nursery requires more skill and laborious', 'No big difference in cost of traditional planting and transplanter' and 'Cost of manual labour is high and clipping of tips is additional burden' were the reasons expressed for discontinuation of the recommended practice. 'Direct seeding using drumseeder is not suitable for our soils', 'Not aware of Paddy transplanter' and 'Non availability of transplanter at farmer's level' were the reasons for non-adoption of the practice.

Machine transplanting requires skill in rising mat type nursery, riding the machine in the field farmers and its non-feasibility for small farms, most of the farmers have not opted for adopting this method. In case of 'SRI' method of cultivation, farmers felt that they again need as much labour required for traditional transplanting method without much benefit in terms of net returns, many of the farmers are not continuing the practice. Majority of them felt that of all the options available, direct seeding using drumseeder is the best option which is technically and economically feasible even for small and marginal farmers.

Table 2. Reasons expressed by the respondents for different adoption behavior of the technologies

S. No.	Recommended package of practice	Reasons for		
		Full adoption	Partial adoption	Discontinued
1	Recommended improved varieties	• High yielding than farmers variety • Suitable for both Kharif & Rabi seasons • Resistant to Blast disease • Non lodging variety	• Transplanting age of seedlings is not as per the recommendation	• Low market price • Cooking quality is not good • Not aware of the variety • Non availability of seed • Marketing problem as traders offer low price for this variety
2	Land preparation practices	• Soil borne pests will be exposed and killed • Weeds can be uprooted • Pest incidence can be reduced to some extent • Rodent problem is reduced due to trimming of bunds	• High cropping intensity; no gap between two crops to take up deep ploughing	• Trimming and plastering of bunds is not so effective in managing weeds • Lack of sufficient rainfall for deep ploughing • Deep ploughing is a costly process
3	Seed rate	• High yield is possible with this seed rate • More seed rate merely increases the cost of cultivation without any additional benefit	• More the seed rate, more will be the yield	• As a safety measure, more seed rate is used • Not aware of the recommended seed rate
4	Seed treatment	• Protects crop from diseases in early stages • Saves cost of pesticides for spraying on entire area • Optimum plant population is maintained	• Dosage of chemicals is not as per recommendation	• Not aware of the practice • Unaware of the chemicals for seed treatment

Cont...

Table 2. Contd...

S. No.	Recommended package of practice	Reasons for			
		Full adoption	Partial adoption	Discontinued	Non-adoption
5	Recommended method of transplanting	• Cost of cultivation is very much reduced • Labour problem is solved • Drumseeder is suitable to all especially small and marginal farmers • Net returns are more • Shallow planting helps in more tillering • Crop is matured earlier than that planted traditionally. • Transplanter is suitable to big farmers who take up rice in large areas. • Clipping of leaf tips reduces stem borer incidence in main field	• Intermittent wetting and drying of field up to panicle initiation is not followed • Seed treatment is not done • Conoweeder is not run between rows • Shallow planting is not manageable due to manual transplanting	• Weed management is difficult in drumseeder sown plots • Not suitable for our soils • Difficult to operate transplanter in heavy soils • Raising of mat type nursery requires more skill and laborious • No big difference in cost of traditional planting and transplanter • Cost of manual labour is high and clipping of tips is additional burden	• Direct seeding using drumseeder is not suitable for our soils. • Not aware of Paddy transplanter • Non availability of transplanter at farmer's level
6	Recommended spacing	• Recommended number of hills per sq.m increases yield • Alleyways helps in good aeration and sunlight to plants • Application of fertilizers and pesticides is easy • Monitoring of crop is easy	• Unmanageable due to manual transplanting • Heavy rains after sowing with drumseeder disturbs spacing	• I am practicing Drumseeder method and this method already has 20 cms row to row spacing • Labour shortage	• More labour are required and costly process • Not aware of alleyways making
#					Cont...

Table 2. Contd...

S. No.	Recommended package of practice	Reasons for		
		Full adoption	Partial adoption	Discontinued
7	Water management	• Tillering is increased with intermittent wetting of field • Brown Plant Hopper damage is decreased • Stem rot incidence is reduced • High yielding is possible	• Power shortage • Power is supplied in midnight and hence irrigation is uncontrollable.	• Weeds are intensified • Soils are not supporting intermittent wetting • Intermittent wetting develops field cracking • This practice is not practicable in the field • Unaware of the practice • Not aware of weedicides • Weedicides may damage the main crop
8	Weed management	• Pre-emergence weedicide reduces the intensity of weeds and hence saves cost of manual labour • Running conoweeder between rows uproots weeds and increases aeration to roots resulting in heavy tillering • Cost of weeding process is reduced due to weedicide application • Prevention is better than cure is possible through pre-emergence weedicide application	• Weedicide application is not done timely • Dosage of weedicide is not as per the recommendation • Conoweeder is not run four times @ 10 days interval • No requirement of post emergence weedicide at that stage due to less weed intensity • Use weedicides only whenever adequate manual labour are not available for weeding	• Conoweeder operation is drudgery process

Cont...

Table 2. Contd...

S. No.	Recommended package of practice	Reasons for		
		Full adoption	Partial adoption	Discontinued
9	Fertilizer management	Green manuring increases the crop yields	Soil test based fertilizer doses are not sufficient for obtaining high yields	Not aware of recommended dose of fertilizers
		Three split doses of nitrogen fertilizers is essential to get good yields	Top dressing of Urea is done along with Carbofuron / phorate / cartap	Not aware of Urea + neem cake application
		Zinc deficiency management increases the crop yield.	hydrochloride granules	Soil testing results are not delivered timely
		Green manuring reduces the requirement of inorganic fertilizers	Three split doses of Nitrogen is not done as per the recommended doses	Insufficient soil moisture for growing green manure crop
		Blast and BPH are controlled very much by using recommended dose of fertilizers	Good quality neem cake is not available	
10	Pest management	Soil test based fertilization reduces the cost of cultivation		
		Urea is completely used by the crop if used by mixing with neem cake		
		Carbofuron granule application in nursery before transplanting reduces the incidence of insect pests in main field	Tricyclozole is not applied at recommended doses.	Not raising nursery due to adoption of drumseeder method
		Cost of pest management in main field is reduced	Dose of cartap hydrochloride granules is not as per recommendation	False smut is not observed in our field
		Tricyclozole is effective in controlling blast disease when applied timely	Tricyclozole is applied only at severe infestation of blast at higher doses	The variety used by us is resistant to blast disease
		Yield loss can be minimized by timely pest management practices		It is better not to apply any fungicides after panicle initiation
		Preparation of bait for rats is easy and effective		

Table 2. Contd...

S. No.	Recommended package of practice	Reasons for		
		Full adoption	Partial adoption	Discontinued
11	Recommended harvesting practices	• Fodder requirement for cattle • Reduces the incidence of pest on next crop • Field preparation for next crop will be easy	--	• It is difficult to do close harvesting when the crop is lodged • Harvesting is done using combined harvester

Recommended spacing

Reasons for full adoption included 'Recommended number of hills per sq.m increases yield', 'Alleyways help in good aeration and sunlight to plants', 'Application of fertilizers and pesticides is easy' and 'Monitoring of crop is easy'. 'Unmanageable due to manual transplanting' and 'Heavy rains after drumseeder sowing disturbs spacing' were the reasons for partial adoption. 'I am practicing Drumseeder method and this method already has 20 cms row to row spacing' and 'labour shortage' were the reasons for discontinuation of this practice. The reasons for non-adoption were 'More labour are required and costly process' and 'Not aware of alleyways making'.

Recommended water management practices

Respondents articulated that 'Tillering is increased with intermittent wetting of field', 'Brown Plant Hopper damage is decreased', 'Stem rot incidence is reduced' and 'High yielding is possible' as the reasons for full adoption of recommended water management practices. 'Power shortage' and 'Power is supplied in midnight and hence irrigation is uncontrollable' were the reasons for partial adoption. Reasons for discontinuation were 'Weeds are intensified' and 'Soils are not supporting intermittent wetting'. 'Paddy crop requires continuous water standing', 'Intermittent wetting develops field cracking', 'This practice is not practicable in the field' and 'Unaware of the practice' were the reasons for non-adoption of water management practices.

Recommended weed management practices

'Pre-emergence weedicide reduces the intensity of weeds and hence saves cost of manual labour', 'Running conoweeder between rows uproots weeds and increases aeration to roots resulting in heavy tillering', 'Cost of weeding process is reduced due to weedicide application' and 'Prevention is better than cure is possible through pre-emergence weedicide application' were the reasons given for full adoption. The reasons for partial adoption were 'Weedicide application is not done timely', 'Dosage of weedicide is not as per the recommendation', 'Conoweeder is not run four times @ 10 days interval', 'No requirement of post emergence weedicide at that stage due to less weed intensity' and 'Use weedicides only whenever adequate manual labour are not available for weeding'. 'Conoweeder operation is a drudgery process' was the reason behind discontinuation of the practice. 'Not

aware of weedicides' and 'Weedicides may damage the main crop' were the reasons for non-adoption.

Recommended fertilizer management practices

'Green manuring increases the crop yields', 'Three split doses of nitrogen fertilizers is essential to get good yields', 'Zinc deficiency management increases the crop yield', 'Green manuring reduces the requirement of inorganic fertilizers', 'Blast and BPH are controlled very much by using recommended dose of fertilizers', 'Soil test based fertilization reduces the cost of cultivation' 'Urea is completely used by the crop if used by mixing with neem cake' and 'Soil test based fertilization reduces environmental hazards' were the reasons for full adoption of recommended fertilizer management practices. The reasons for partial adoption were 'Soil test based fertilizer doses are not sufficient for obtaining high yields', 'Top dressing of Urea is done along with Carbofuron / phorate / cartap hydrochloride granules', 'Three split doses of Nitrogen is not done as per the recommended doses' and 'Good quality neem cake is not available'. 'Cost of neem cake is high' was the reason behind discontinuation of the practice. The reasons for non-adoption were 'Not aware of recommended dose of fertilizers', 'Not aware of Urea + neem cake application', 'Soil testing results are not delivered timely' and 'Insufficient soil moisture for growing green manure crop' were the reasons expressed by the respondents for non-adoption.

Recommended pest management practices

The reasons for full adoption of pest management practices given are 'Carbofuron granule application in nursery before transplanting reduces the incidence of insect pests in main field', 'Cost of pest management in main field is reduced', 'Tricyclozole is effective in controlling blast disease when applied timely', 'Yield loss can be minimized by timely pest management practices' and 'Preparation of bait for rats is easy and effective'. 'Tricyclozole is not applied at recommended doses', 'Dose of cartap hydrochloride granules is not as per recommendation' and 'Tricyclozole is applied only at severe infestation of blast at higher doses' were the reasons for partial adoption. 'Rodent problem is unmanageable even after practicing control measures' was the reason for discontinuation behaviour. 'Not raising nursery due to adoption of drumseeder method', 'False smut is not observed in our field', 'The variety used by us is resistant to blast disease' and 'It is better not to apply

any fungicides after panicle initiation' were the reasons for non-adoption of recommended pest management practices.

Recommended harvesting practices

The main reasons expressed by respondents for full adoption were 'Fodder requirement for cattle', 'Reduces the incidence of pests on next crop' and 'Field preparation for next crop will be easy'. 'Harvesting is done using combined harvester' was the reason for partial adoption. The reason for discontinuation was 'Shortage of labour' and 'It is difficult to do close harvesting when the crop is lodged' was the reason for non-adoption.

CONCLUSION AND RECOMMENDATIONS

According to Rogers (1962) adoption process is the mental process through which an individual passes from first hearing about an innovation to final adoption. It has been observed in the study that numerous technology transfer programmes of KVK helped in reducing the wide gap between the scientific know-how and field level do-how, however there lies still a gap in adoption of the recommended technologies by the farmers. The non adoption of the technology by the farmers is either because the technology itself is not known to the farmers i.e., lack of communication, or the technology is not appropriate and farmer is not fully convinced by the technology. Sometimes if the known technology is appropriate but the farmers do not have enough resources to adopt it. Technology gap is the gap between the level of recommendation and the extent of adoption (against recommendations) (Venkatasubramanian *et al.*, 2010).

Technology frequently responds differently to environment. Most small-scale limited resource farmers, however, are not able to apply inputs required to achieve maximum rice production similar to those in Research Centres. Generation and adoption of appropriate technology depends on an interdisciplinary team and approach organized into an interacting and cohesive group involving researchers, extension staff, farmers and other complementary services that affect the technology adoption (Orodho, 1990). The farming situation of the adopted villages of ARKVK varies and hence all the technologies may not fit well for all the farmers. Moreover, the adoption of technologies also varies due to technical and economic feasibility of the recommended technologies and specially the affordability of the farmers. For instance, the recommended latest high yielding varieties may not

be adopted by all the farmers due to non-availability of the seed to all the farmers, un affordability of the farmers to purchase high expensive inputs like seed etc. High cost of fertilizers hinders the full adoption of the application of recommended dose of fertilization. Sometimes even though the farmers are well aware of the recommended technologies and have financial ability, other factors may hamper the scope of full adoption viz., Paddy combine harvester is not suitable for Paddy fields with many small plots as it is difficult to operate the machine in small plots.

Innovative activities are, as expected, positively related to labour resources (which is highly correlated to farm size), market position (indicating whether a farm produces for a market that permits product differentiation), and a farmer's access to information (where an indicator of the extent of his network is used as a proxy). Adoption behaviour shows some persistence in time: being an innovator (or a late adopter) in the past increases the probability of being an innovator (a late adopter) in the current period (Paul Diederer *et al.*, 2002).

The role of a KVK ends up in evaluation of technologies and recommending the successful ones to extension agencies in the distribution to widely disseminating the technologies to the farming community. Hence the concerned line departments should follow the techniques suggested by Van den Ban and Hawkins (1988) for motivating / influencing the farmers behaviour in a social system. Exerting power and forcing the farmers to do something (Compulsion), exchanging goods or services between the two individuals / parties / Organizations (Exchange), advice given to choose solution to a problem (Advice), Openly influencing a farmer's knowledge and attitude when farmers cannot solve their problems, influencing the farmers' knowledge level and attitude without their being aware of it (Manipulation) are some of the techniques that may be used by the extension functionaries to improve the adoption levels of technologies by the farmers.

Extension workers working at the grass root level are required to be motivated through training, orientation and refresher courses, and by providing incentives like awards, appreciation letters, additional increments for their best performance, etc. A proper media-mix along with a sound information system like internet, fax, e-mail, computerized crop doctor expert system, audio and video conferencing etc (wherever possible) at the grass root level should also be provisioned (Chand *et al.*, 2011). The

extension agencies should be geared up to organize multiple extension activities with the technical support of KVKs to develop confidence among the farmers to further improve the adoption status of the farmers. The network of extension agencies for example the Agricultural department has one Mandal Agrl. Officer, one Agrl. Extension Officer and 40-50 Adarsha rythus (model farmers). These Adarsha rythus facilitate at the village level for generating more awareness among the farmers on advanced crop planning, production, horticultural crops, micro-irrigation practices marketing issues, credit related issues etc. Since the KVKs after assessment of the technologies for their suitability, the successful ones should be popularized among the target people with the support of line department's human resources for wider adoption. Need based capacity building programmes and location specific technologies which are technically and economically feasible enhance the adoption levels of the farmers.

The concerned stakeholders should pay relatively higher emphasis and care on those crucial factors, thus identified by this study through strenuous efforts while formulating different development strategies and programmes for farmers.

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INFLUENCE OF VARIETIES AND PLANT DENSITIES ON GROWTH AND YIELD OF GROUNDNUT (*Arachis hypogaea* L.) UNDER IRRIGATED CONDITIONS

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ABSTRACT

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A field experiment was conducted at college farm, Agricultural College, Mahanandi, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India during *rabi* 2012-13 to evaluate the influence of varieties and different plant densities on the growth and yield of groundnut. The treatments consisted of three groundnut varieties viz, Kadiri 6, TAG 24 and TCGS 29 and four plant spacings viz., 30×10 , 22.5×10 , 30×5 and 22.5×5 cm. The experiment was laid out in a randomized block design with factorial concept replicated thrice. The experiment revealed that TCGS-29 (Narayani) significantly produced tallest plants over Kadiri 6 and TAG 24. At 30 DAS higher leaf area index and dry matter production (g m^{-2}), was produced by TCGS 29 (Narayani) and it was comparable with Kadiri 6. At 60 DAS Kadiri 6 was produced higher leaf area index and dry matter (g m^{-2}) and at 90 DAS, TAG-24 had produced higher leaf area index and dry matter production (g m^{-2}) which was comparable with Kadiri-6 and TCGS-29 (Narayani) and at harvest higher leaf area index was produced by TCGS-29 (Narayani) and it was comparable with TAG-24. TAG-24 produced highest pod yield (2732 kg ha^{-1}) however which was comparable with Kadiri 6 (2630 kg ha^{-1}) and TCGS-29 (Narayani) (2688 kg ha^{-1}). TCGS-29 produced highest hulm yield (4833 kg ha^{-1}) which was significantly superior over TAG-24 (4441 kg ha^{-1}). Taller plants (48 cm) were produced with a spacing of 22.5×10 cm. The spacing of 22.5×5 cm was found significantly superior over rest of the treatments in increasing leaf area index (LAI) and dry matter production (g m^{-2}). Significantly highest pod yield was recorded at a spacing of 22.5×10 cm and at a spacing of 30×5 cm was found to be significantly superior in producing highest hulm yield.

KEYWORDS:

INTRODUCTION

Groundnut is an important food legume and an oil seed in the world and presently grown in about 90 countries over an area of 25 million hectares under different agro climatic regions. India is the second largest producer of groundnut accounting for 38 per cent of the total area (7.7 million ha) and 31 per cent production (6.7 million t) of the world (Throat, 2004). The average productivity in India is 977 kg ha^{-1} (Alam, 2002). Groundnut is known for its rich source of vegetable fats, protein and also for its use as cattle feed, fodder and concentrated organic manure. Groundnut kernels contain 42 to 50 per cent oil, 26 per cent protein, 18 per cent carbohydrates and also rich source of riboflavin, thiamine, nicotinic acid and vitamin E. With regard to the consumption pattern, about 10 per cent is used for food purpose, 15 per cent for seed purpose and 75 per cent for oil extraction. Even though groundnut is primarily used for oil extraction; it is also consumed directly because of its high food value (Rajagopal *et al.*, 2000). It is commonly called as poor man's nut. Groundnuts for edible purpose require considerable processing and sorting to ensure high quality.

Choice of the variety plays a significant role in groundnut production. Some of the groundnut varieties have shown that low source and sink relationship resulted in the formation of more unfilled pods and lesser seed yield. Plant density is highly associated with yield potential and optimum plant density per unit area is an important non monetary input to decide the maximum groundnut productivity. Yield is a function of inter and intra plant competition and there is a considerable scope for increasing the in yield by adjusting plant population to an optimum level (Hameed Ansari *et al.*, 1993). The optimum plant density and planting pattern at one site may not apply at other locations because regional variations in weather and soil. Further, traits are needed for each site to validate general recommendations (Azam Ali *et al.*, 1993). Considering all these facts, the present study was undertaken to find out the influence of plant spacing on the growth and yield of different groundnut varieties.

MATERIALS AND METHODS

A field experiment was conducted during *rabi*, 2012 at college farm, Agricultural College, Mahanandi. The soil

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Effect of planting densities on growth and yield of groundnut

of the experimental site was sandy loam and it was slightly alkaline in reaction with a pH of 7.98, EC of 0.06 dSm⁻¹ and low in organic carbon (0.46%) and available nitrogen (266 kg ha⁻¹), medium in available phosphorous (96.6 kg ha⁻¹) and high in available potassium (674.3 kg ha⁻¹). The experiment was laid out in randomized block design with factorial concept and replicated thrice. The treatment consisted of three varieties viz., V₁: Kadiri-6, V₂: TAG-24 and V₃: TCGS-29 and four plant densities viz., D₁: 30 × 10 cm, D₂: 22.5 × 10 cm, D₃: 30 × 5 cm and D₄: 22.5 × 5 cm. Nitrogen, phosphorous and potassium were applied in the form of urea, single super phosphate and muriate of potash. Entire dose of nitrogen (20 kg ha⁻¹) phosphorous (40 kg ha⁻¹) and potassium (50 kg ha⁻¹) were applied as basal at the time of sowing. One inter cultivation followed by two hand weeding in rows was taken at 30 and 45 DAS. All the plots were irrigated uniformly as and when required based on soil moisture content and phenological stages of crop growth. Plant height (cm) was measured from the base of the plant to the tip of the top most leaf at 30, 60, 90 DAS and at harvest. Data on yield attributes, pod and hulk yield were recorded at harvest. Economics was calculated based on present market price of yield and inputs.

RESULTS AND DISCUSSION

Growth parameters

Plant height

Plant height was significantly influenced by the varieties. TCGS-29 (Narayani) significantly recorded tallest plants over Kadiri-6 and TAG-24. Taller plants (48 cm) were produced by a spacing of 22.5 × 10 cm, which was statistically at par with rest of the treatments tried.

Leaf area index and dry matter production

Varietal performance was inconsistent with leaf area index and dry matter production. At harvest higher leaf area index was produced by TCGS-2 and it was comparable with TAG-24. Total dry matter produced in Kadiri-6 was higher at all crop growth stages except at 90 DAS and this was on par with TCGS-29 and significantly higher over TAG-24. At 90 DAS TAG-24 recorded significantly highest dry matter production over rest of the varieties and this was due to high LAI and more no. of branches compared to TCGS-29 and Kadiri 6.

The spacing of 22.5 × 5 cm was found significantly superior over rest of the treatments in increasing leaf area index (LAI). The increase in LAI with increase in plant population was due to more number of plants per unit area. At harvest, leaf area index was decreased due to decrease in number of green leaves per plant due to senescence. Plant spacing of 22.5 × 5 cm was found to be significantly superior in producing maximum dry matter (g m⁻²) at all the stages of crop growth.

Number of pods per plant

Among the different varieties tested significantly highest number of pods per plant were obtained with TAG-24 (15.5) followed by Kadiri-6 (12.08) and TCGS-29 (9.33). Higher number of pods in TAG-24 was due to production of more branches per plant which in turn produced more number of flowers and pegs and finally resulted in more number of pods per plant.

The highest number of pods per plant was recorded with a plant density of 4.44 (13.88) lakhs ha⁻¹ over the other plant densities 3.33 (13.33) and 6.66 (12.77) lakhs ha⁻¹ which were at par with each other.

Number of kernels per pod

The effect of varieties, plant densities and interaction between varieties and plant densities on number of kernels per pod was found to be non significant and this indicates that number of seeds per pod was more of genetically controlled factor and is less influenced by varieties and plant densities. (Konlan *et al.*, 2013, Santo and Gyasi., 2011 and Akpalu *et al.*, 2010).

Hundred kernel weight (g)

The effect of varieties, plant densities and interaction between varieties and plant densities on 100 kernel weight of groundnut was found to be non significant and this indicates that 100 kernel weight was more of genetically controlled factor and is less influenced by varieties and plant densities (Kaushik and Chaubey, 2000).

Shelling percentage (%)

Shelling percentage recorded with TAG 24 (73.67) was significantly higher compared to other varieties. Higher shelling percentage recorded by TAG 24 might be due to its varietal character with thin shell development, which might be due to channelization of more photosynthates from pod wall to kernel.

Table 1. Influence of varieties and plant densities on growth parameters of groundnut

Treatment	Plant height (cm)	Leaf area index	Dry matter production (g m ⁻²)		
	At harvest	At harvest	30 DAS	60 DAS	90 DAS
Varieties (V)					
Kadiri-6	45	1.47	107	860	1440
TAG-24	36	1.85	86	623	1884
TCGS-29 (Narayani)	53	1.89	110	801	1422
SEm ±	4.0	0.33	11.9	121.1	268.4
C.D (P = 0.05)	6	0.51	18	178	394
Plant densities (D)					
30 cm × 10 cm	43	1.62	62	462	905
22.5 cm × 10 cm	48	1.30	77	679	1234
30 cm × 5 cm	44	1.94	124	726	1617
22.5 cm × 5 cm	42	2.10	140	1178	2571
SEm ±	4.7	0.39	13.8	139.0	309.9
C.D (P = 0.05)	7	0.59	20	205	455
V × D					
SEm ±	8.07	0.69	23.88	242.14	536.74
C.D (P = 0.05)	NS	NS	NS	NS	NS

Table 2. Influence of varieties and plant densities on pod yield and haulm yield (kg ha⁻¹) of groundnut

Treatment	Number of pods plant ⁻¹	Number of kernels pod ⁻¹	100 kernel weight (g)	Shelling percentage (%)	Pod yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
Varieties(V)						
Kadiri-6	12.08	1.87	38.20	71.73	2630	4558
TAG-24	15.50	1.81	37.39	73.67	2732	4441
TCGS-29 (Narayani)	9.33	1.78	37.98	72.08	2688	4833
SEm ±	0.63	0.02	0.24	0.22	196.98	125.23
C.D (P = 0.05)	1.87	NS	NS	0.67	NS	NS
Plant densities(D)						
30 × 10 cm	13.33	1.79	38.00	72.13	2218	4533
22.5 × 10 cm	13.88	1.81	37.86	73.27	3043	4411
30 × 5 cm	12.77	1.85	37.61	72.27	2445	4988
22.5 × 5 cm	11.22	1.83	37.95	72.29	3027	4511
SEm ±	0.73	0.03	0.27	0.26	227.46	144.61
C.D (P = 0.05)	2.16	NS	NS	0.77	667	424
V × D						
SEm ±	1.27	0.06	0.48	0.45	557.07	250.47
C.D (P = 0.05)	NS	NS	NS	NS	NS	NS

Effect of planting densities on growth and yield of groundnut

Shelling percentage obtained with a plant density of 4.44 (73.27) lakhs ha⁻¹ was significantly higher over the other plant densities 8.88 (72.29), 6.66 (72.27) and 3.33 (72.13) lakhs ha⁻¹, which were at par with each other. Similar findings were reported by Hirwe *et al.* (2005)

Pod yield and hulm yield

TAG-24 produced highest pod yield (2732 kg ha⁻¹), which was comparable with kadiri-6 (2630 kg ha⁻¹) and TCGS-29 (Narayani) (2688 kg ha⁻¹). TCGS-29 produced highest hulm yield (4833 kg ha⁻¹), which was significantly superior over TAG-24 (4441 kg ha⁻¹). The highest pod yield was recorded at a spacing of 22.5 × 10 cm, which was significantly superior over 30 × 10 cm and 30 × 5 cm and comparable with 22.5 × 5 cm. plant spacing of 30 × 5 cm was found to be significantly superior in producing highest hulm yield. These findings are in agreement with the results reported by Ramesh and Reddy (2007) and Chainyara *et al.* (2001).

CONCLUSION

The results from the above investigations lead to the conclusion that sowing of TAG-24 at a spacing of 22.5 × 10 cm in *rabi* was more beneficial to get higher yields.

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EFFECT OF MICRONUTRIENTS (Zn, B and Fe) ON GROWTH, FLOWERING AND VASELIFE OF GLADIOLUS (*Gladiolus grandiflorus*) cv. ARKA AMAR

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ABSTRACT

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Gladiolus (*Gladiolus grandiflorus* L.) is one of the most widely cultivated, economically important and common flowering plants worldwide including India. However, the flower yield is quite low when grown under agro-climatic conditions of Rayalaseema zone of Andhra Pradesh. A field experiment was conducted at Horticulture Research Station, Anantharajupeta, Railway Kodur, Kadapa district Andhra Pradesh, India during 2016-2017 to investigate the effect of micronutrients (Zn, B and Fe) on growth, flower yield and quality of gladiolus cv. Arka Amar. Eight treatments comprised of either each micronutrient alone or a combination of Zn, B and Fe were applied. Corms were planted within the first week of November 2016, Row to row and plant to plant spacing was maintained 30 x 20 cm, respectively. Fifteen corms were planted in each treatment with three replicates. The first spray was applied at 3-leaf while the second at 6-leaf stage. Application of the micronutrients significantly increased plant height, number of leaves per plant, spike length, spike girth, rachies length, florets per spike, number of cormels per plant and flower vase-life. Among the micronutrient treatments, the treatment containing $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (0.2%), H_3BO_3 (0.2%) and $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (0.5%) performed the best for all the parameters except for number of corms per plant and diameter of floret which was not affected significantly by the foliar application of the micronutrients.

KEYWORDS:

INTRODUCTION

Flowers symbolize purity, peace, beauty, love and passion. For Indians, especially, those who are religious minded flowers have a great significance. In our society, none of the social functions will be completed without the use of flowers. Regarding flowers, gladiolus (*Gladiolus grandiflorus* L.) is one of the most cultivated, economically important and common flowering plants world-wide including India and is among the elite cut flowers due to different shapes, hues and prolonged vase life (Bose *et al.*, 2003). Gladiolus, a member of family Iridaceae and sub-family Ixideaceae, originated from South Africa and is a prominent bulbous cut flower plant. The genus *Gladiolus* contains 180 species with more than 10,000 cultivars (Sinha and Roy, 2002). It is of great economic value as a cut flower and flower for decoration. It ranks second after tulip among the bulbous flowers in India and has occupied fourth position in the international trade of cut flowers. The fascinating spike bears a large number of florets with varying sizes and forms with smooth ruffle of deeply crinkled sepals.

The commercial growers are growing gladiolus in different zones of the country especially in Uttar Pradesh, West Bengal, Odisha, Haryana, Maharastra, Karnataka and Andhra Pradesh to fulfill the local consumption demand; however the production and flower quality are still too low to meet the international standards. Its cultivation is gaining popularity among the farmers in different areas of south India specially in Andhra Pradesh and has recently been seen as a lucrative enterprise due to increased awareness and recognition of the high return on its investments. The suitable agro-climatic conditions of the country clearly indicate that a wide range of ornamental crops can be grown, which can improve the economic status of the growers. However, quality production is in dire need of standard agricultural practices, including nutrient management. Chemical fertilizers play a vital role in growth, quality of flowers, corm and cormel production. Gladiolus requires adequate amounts of chemical fertilizers in their balanced proportions for ensuring maximum flower production. Being involved in the physiology of plants, micronutrients well contribute to the growth and yield of the plants. Within different areas,

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productivity of crops is being adversely affected by micronutrient deficiencies, the deficiency having been markedly increased due to intensive cropping, loss of top soil by erosion, loss by leaching, liming of soil and as well, a decreased in the availability and use of farmyard manure (Fageria *et al.*, 2002).

The micronutrients play crucial and vital role in gladiolus production as well as major nutrients in growth and development. The effective study on micronutrients under this aspect zinc, iron is necessary in every stage of plant growth particularly in gladiolus as like in other plants. To determine the commercial value on corm production parameters, the micronutrients contributes most important role on various metabolism and synthesis process in plants. Information regarding nutritional requirements and appropriate soil management practices are lacking for gladiolus cultivation in India. So the growers lack enough information on these elements and are not familiar with their prominent role in increasing yield and producing high quality cut flowers, causing soils deprived of micronutrients which in turn can hamper plants to produce their optimum size of spike, corms and cormels for flower cultivation. There are evidences that iron deficiency impairs many plant physiological processes because it is involved in chlorophyll and protein synthesis and in root tip meristem growth. Tagliavini and Rombola (2001) illustrated that iron deficiency (chlorosis) is a common disorder which affects plants grown on soils of high pHs. This may lead to serious yield and quality losses, demanding the implementation of suitable plant iron-deficiency correction strategies. Iron application through foliar spray is a common practice to cure iron-deficiency (Mortvedt, 1991). Boron plays a vital role as stabilizer of cell wall pectic network (Dordas & Brown, 2005). It promotes the stability and rigidity of cell wall structure and therefore, supports the shape and strength of the plant cell (Brown *et al.*, 2002). Furthermore, boron is possibly involved in the integrity of the plasma membrane (Brown *et al.*, 2002; Cara *et al.*, 2002; Dordas & Brown, 2005). Zinc is an essential micronutrient necessary for sugar regulation and assorted enzymatic activity associated with plant growth (Khosa *et al.*, 2011). The plants treated with Zn shows increase plant height in gladiolus due to its role in synthesis of tryptophan, which is a precursor of auxin (IAA) and is essential in nitrogen metabolism, which stimulates growth. (Rahul and Ashok, 2014) Zinc plays an important role in protein and starch syntheses, and therefore, a low zinc concentration induces accumulation of amino acids and

reducing sugars in plant tissue (Graham and McDonald, 2001). Amir *et al.* (2008) observed that rose cultivars' flower vase life had been extended when plants treated with Zn. Foliar applications of micronutrients are most completely available to the plant, because they are not either fixed or diluted in some large volumes of soil (Baloch *et al.*, 2008). Mukesh *et al.* (2001) investigated the effect of foliar application of Zn, Cu, and Fe at 0, 250, 500 and 1,000 ppm on the yield and quality of gladiolus. Plants treated with micronutrients exhibited better results as compared with the control. However, foliar application of Fe, Cu, and Zn at 1,000 ppm showed best results with respect to growth, flowering and other yield parameters. In gladiolus, spike length, number of florets, weight of spike and size of florets were significantly increased with 0.2% $\text{FeSO}_4 + 0.2\% \text{ZnSO}_4$ application (Kumar and Arora, 2000).

At present, there is an urgent need to standardize agro techniques which are most suitable for local climatic and edaphic conditions. But the paramount problem, the farmers are facing is judicious use of chemical fertilizers. Keeping in view the significance of gladiolus in global cut flower trade, a field experiment was executed to find out the response of *Gladiolus grandifloras* cultivars to foliar application of various micronutrients for enhancing yield and improving quality and corm indices. The objective of the present study was to investigate the effect of micronutrients (Zn, B and Fe) on growth, flowering and vase life of an gladiolus cultivar 'Arka Amar' under agro-climatic conditions of Rayalaseema Zone.

MATERIALS AND METHODS

The experiment on "Effect of Zn, B and Fe on growth, flowering and vase life of gladiolus was conducted at Horticultural Research Station, Anantharajupet, Railway kodur, Kadapa district of Andhra Pradesh, India.. The corms of 'Arka Amar' variety of gladiolus was procured from Indian Institute of Horticultural Research, Bangalore. The experimental field had loamy soil. Manure and fertilizers were given according to recommendation. The experiment was laid out in Randomized Block Design with three replications and 8 treatments. The treatments were randomized for getting equal chance in respect of fertility. Row to row and plant to plant spacing was maintained 30 x 20 cm, respectively. Irrigation, weeding, hoeing, earthing up and staking operations were completed according to needs. The treatments contained 0.5% solution of zinc (Zn), 0.2% solution of each of iron (Fe), boron (B) salts

applied in various combinations. Fe was applied as ferrous sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$), B as boric acid (H_3BO_3) and Zn as zinc sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$). Control plants were sprayed with plain water. The micronutrients were sprayed on the plants. A detail of the treatments is presented in Table 1.

Table -1. Details of the treatment

T1: Zn :0.5%
T2: Boran : 0.2%
T3: Fe :0.2%
T4: Zn : 0.5% + Boran : 0.2%
T5: Zn : 0.5% + Fe : 0.2%
T6: Boran : 0.2% + Fe : 0.2%
T7: Zn : 0.5% + Boran : 0.2% + Fe: 0.2%
T8: Control
Design: RBD
Replications: 3
Time of application: At 3 rd and 6 th Leaf stage.#

The first spray was applied at 3-leaf while the second at 6-leaf stage. The ground of each bed was covered with polythene sheet. For an estimation of the vase life, flower stalks were harvested when most of the lower florets had started showing color. Two lowest leaves were left intact with the plant for better development of corms. Spikes were immediately kept in buckets containing distilled water and brought to the laboratory. The leaves of the stem were removed and the stems kept individually in glass vases containing 200 ml of distilled water. Every two days, vase water was replaced with fresh distilled water and a lower 2.5 cm of stem was also cut for better water uptake. Five spikes per treatment in each of the replications were taken for vase life evaluation. Spikes were considered dead when more than 50 per cent of the florets wilted, dried or faded away. The number of corms and cormels were recorded at the time of lifting the corm.

RESULTS AND DISCUSSION

Plant height

Statistical analysis of the data on plant height revealed significant differences among the micronutrients treatments. The plants sprayed with all the three micronutrients (T7) resulted in maximum plant height (59.33 cm) followed by T5 i.e Zn and Fe (55.33 cm). These findings indicated that all the three micronutrients (Zn, B and Fe) applied as foliar spray were needed for

the plant's growth and contributed towards better growth of gladiolus in terms of plant height. Kumar and Arora (2000) have already reported increased plant height with foliar application of 0.2% FeSO_4 , when gladiolus cv. White prosperity plants were sprayed at 3- and 6-leaf stages with FeSO_4 , MnSO_4 and ZnSO_4 at 0.2 and 0.4% levels of each. Similarly, increased vegetative growth has also been reported in gladiolus grown on partially reclaimed sodic soils by foliar application of Zn+Cu, each at 0.2% applied twice (Katiyar *et al.*, 2005). Lahijie (2012) too, found that an application of FeSO_4 (0.5 or 1%) and ZnSO_4 (0.5 or 1%) either singly or in combination, applied at 2- and 6-leaf stages, significantly increased height of gladiolus cv. Oscar plants.

Number of leaves per plant

Regarding the number of leaves, significant variations were observed. More number of leaves (9.20) was observed with T7 i.e when all the three micronutrients were applied together. T7 is statistically at par with T4, T5, T6 i.e when the micronutrients applied in combinations of two. Leaf number is considered as an important factor in growth, responsible for photosynthesis and ultimately affecting the flower yield and quality. These results are in support of Kumar and Arora (2000) and Halder, *et al.* (2007a) findings, who observed increase in number of leaves as a result of foliar application of different micronutrients on gladiolus. Kumar and Arora (2000) sprayed gladiolus cv. White prosperity with FeSO_4 , MnSO_4 and ZnSO_4 at 0.2 and 0.4% levels of each. The results revealed the number of leaves increased when 0.2% FeSO_4 was applied at 3- and 6-leaf stages. Foliar application of FeSO_4 (0.5 or 1%) and ZnSO_4 (0.5 or 1%) alone or in combination and at 2- and 6-leaf stages, significantly increased number of leaves per plants in gladiolus (Lahijie, 2012).

Spike length, spike girth and rachis length

Spike length, spike girth, Rachis length were significantly influenced by the micronutrients' treatments. Combined application of all the three micronutrients (T7) significantly improved spike length (106.17 cm), spike girth (3.91 cm) and Rachis length (51.83 cm). Length of spike is an important determining factor counted on for good economic return. Kumar and Arora (2000) stated that spike length, number of florets, weight of spike and size of florets significantly increased with 0.2% FeSO_4 +0.2% ZnSO_4 foliar application. Similarly, Lahijie (2012) also reported significant increase in length of spikes of gladiolus

Table 2. Mean values of plant and floral characters of gladiolus cv. Arka Amar

Treatments	Plant height (cm)	Number of leaves plant ⁻¹	Spike length (cm)	Spike girth (cm)	Rachis length (cm)	Number of florets spike ⁻¹	Diameter of floret (cm)	Number of corms plant ⁻¹	Number of cormels plant ⁻¹	Vase life (in days)
T1 : Zn :0.5%	49.43	8.22	91.13	3.47	38.33	13.63	6.53	1.39	15.00	6.53
T2 : Boran : 0.2%	52.92	8.19	94.23	3.52	40.57	14.17	7.19	1.33	15.55	6.75
T3 : Fe :0.2%	51.05	8.42	97.13	3.58	42.83	14.40	6.63	1.28	16.33	6.63
T4 : Zn : 0.5%+ Boran : 0.2%	52.03	8.53	97.37	3.80	44.10	13.87	6.63	1.44	16.88	7.10
T5 : Zn : 0.5% + Fe : 0.2%	55.33	8.73	103.37	3.67	46.87	14.40	6.87	1.50	17.66	6.53
T6 : Boran : 0.2% + Fe : 0.2%	49.93	8.60	101.37	3.67	46.03	15.07	7.07	1.55	17.55	7.40
T7 : Zn : 0.5% + Boran : 0.2% + Fe: 0.2%	59.33	9.20	106.17	3.91	51.83	16.17	7.30	1.66	19.44	8.66
T8 : Control	47.00	7.99	89.53	3.40	35.47	12.07	5.73	1.22	16.44	5.73
S.E.m.±	1.755	0.232	2.835	0.073	1.957	0.358	0.299	0.144	0.445	0.369
C.D. @ 5 %	5.324	0.704	8.601	0.223	5.936	1.087	NS	NS	1.352	1.121

cv. Oscar, when FeSO_4 (0.5 or 1%) and ZnSO_4 (0.5 or 1%) were applied either singly or in combination. Katiyar *et al.* (2005) found that foliar spray of Zn (0.2%) and Cu (0.2%) applied twice increased the length of spikes in gladiolus grown in partially reclaimed sodic soils.

Number of florets per spike

Maximum number of florets per spike (16.17) was noted when all the three micronutrients were applied in combination (T7) and this number was significantly higher than that for all the other micronutrients treatments. It was shown in the present study that with an increase in the spike length, the number of florets per spike was also increased. These results also confirmed the findings of Kumar and Arora (2000), who observed that foliar application of different micronutrients significantly influenced the number of florets per spike. The number of florets per spike was also significantly increased in gladiolus (as a result of the application of FeSO_4 and ZnSO_4) either singly or in combination (Lahijie, 2012). Katiyar *et al.* (2005) also found that foliar application of Zn (0.2%) and Cu (0.2%) to gladiolus plants, grown in partially reclaimed sodic soils, enhanced such floral characteristics as the number of florets per spike.

Diameter of floret

Analysis of variance of the data on diameter of floret depicted non-significant differences for treatments, indicating that the parameter was not affected by the micronutrients treatments applied.

Number of corms per plant

Analysis of variance of the data on number of corms produced per plant depicted non-significant differences for treatments, indicating that the parameter was not affected by the micronutrients treatments applied. In the present study, the number of corms produced per plant varied from 1.22 to 1.66; hence neither a single foliar application of micronutrients nor in combination have any influence on corm number per plant.

Number of cormels per plant

The foliar application of Zn, B and Fe significantly increased the number of cormels per plant (Table 2). Highest number of cormels per plant (19.44) was observed in T7. These findings are in supports of and Chen *et al.* (1982) and Haldar *et al.* (2007 b) in gladiolus.

Vase-life of spikes

Significant differences among treatments was observed regarding vase-life of spikes. Foliar application of all the three micronutrients (T7) resulted in longest vase life of spikes (8.66 days) followed by the combined application of $\text{FeSO}_4 + \text{ZnSO}_4$ (T5). The shortest vase life was observed for the spikes harvested from plants not treated with any micronutrients (T0) and significantly differing from all the other treatments. All the other treatments stood in the middle. Pratap *et al.* (2008) studied the effect of pre-harvest micro-nutrient foliar sprays on post-harvest vase life of gladiolus cv. Traderhorn using post-harvest vase chemicals. Pre-harvest foliar application of FeSO_4 0.75 or 1% along with ZnSO_4 0.5% significantly extended the vase life of the flowers. The results of the present study also confirmed the findings of Amir *et al.* (2008) who observed that application of Zn to rose cultivars resulted in extended vase life of the flowers.

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NUTRITIONAL STATUS VIS-À-VIS SOIL PHYSICO-CHEMICAL PROPERTIES OF SWEET ORANGE GROWING ORCHARDS OF YSR DISTRICT IN ANDHRA PRADESH

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ABSTRACT

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The pH of the soil samples in the study area varied widely, with a mean value of 7.95 and 8.44 at surface and sub-surface soils, respectively. The soils were low in organic carbon at surface and sub-surface and decreased with increasing depth. The electrical conductivity of the soil samples varied from 0.14 to 1.18 dSm⁻¹ with mean value of 0.35 dSm⁻¹ at 0-30 cm and at 30 to 60 cm depth it ranged from 0.12 to 0.85 dSm⁻¹ with a mean value of 0.32 dSm⁻¹. Surface soils recorded high cation exchange capacity (CEC) values than the sub-surface soils. The soils were low in organic carbon and deficit in available nutrients such as Zn, Fe, N, P and Mn. Soil N and Fe had a significant positive correlation with organic carbon (OC). Similarly, Soil K and Ca with CEC, Soil Mg with CaCO₃ and Soil sulphur with soil pH had recorded significant positive correlation.

KEYWORDS: Sweet orange, physico-chemical properties, macro and micro nutrients, YSR district

Sweet orange (*Citrus sinensis* (L.) Osbeck) is one of the most important commercial citrus cultivars of India having significant nutritional source (Breeling, 1971) for human health and most of the fruits are consumed as fresh while some portion is used in the form of squashes, juices and drinks. Sweet orange fruits form an essential commercial commodity for several agro-based industries and possess immense economic value. In India, sweet oranges are grown mainly in the states of Maharashtra, Andhra Pradesh, Punjab, Karnataka and parts of North – East region with an area of 2.78 lakh hectares and 45.26 lakh tones (Horticultural Statistics at a Glance, 2015). In Andhra Pradesh, the chief sweet orange production areas are Prakasam, YSR, Ananthapur and SPSR Nellore districts with an area of nearly 0.94 lakh ha and production of 13.16 lakh tonnes during 2014–15 (Horticultural Statistics at a Glance, 2015). In YSR district, area under sweet orange is 0.11 lakh ha with a production of 1.54 lakh Mt (CPO, YSR district, 2015). In YSR district sweet orange is cultivating in a variety of soils ranging from red loamy sands/sandy loams to black clay loams / sandy clay loams. However, the information regarding to their nutrient status in relation to physico-chemical properties is meager, hence the present investigation was taken up.

MATERIALS AND METHODS

To study the nutrient status of the sweet orange grown soils in the YSR district, 50 sweet orange orchards 12 to

13 years old were selected (Fig. 1) in different Mandals during 2014. In each orchard, two separate pits were dug for collecting random and composite soil samples collected at two different depths viz., 0 – 30 and 30 – 60 cm with geo reference by considering the location co-ordinates. Collected samples were processed for laboratory analysis.

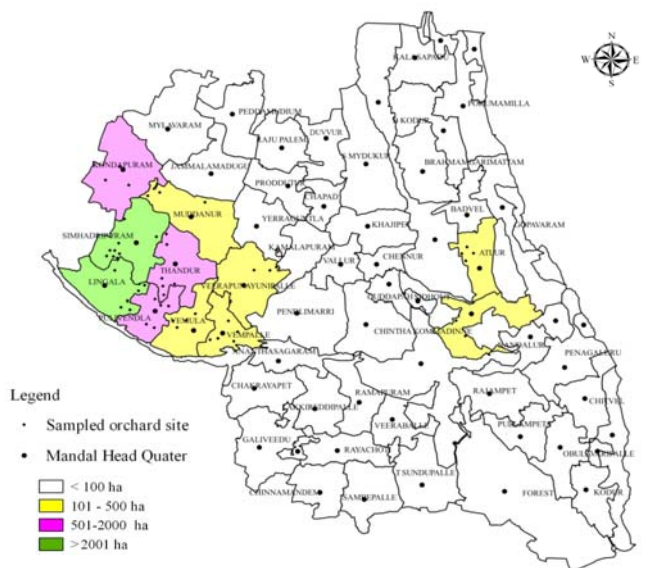


Fig. 1. Map showing area wise distribution of sweet orange and sampled sites in different Mandals of YSR District

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Soil pH was determined in 1:2.5 soil water suspension using digital pH meter (Jackson, 1973). EC was determined in supernatant solution of soil: water suspension (1:2.5) using digital direct read conductivity meter and expressed in dSm^{-1} (Jackson, 1973). CEC was determined by the ammonium acetate displacement method (Bower *et al.*, 1952). The free calcium carbonate content of the soil was determined by treating the soil with a known volume of standard HCl and back titrating the unused acid with standard alkali using bromothymol blue as an indicator (Piper, 1968). Organic carbon was determined according to Walkley and Black wet oxidation (1934).

Available nitrogen in soil was determined by alkaline permanganate method as described by Subbiah and Asija, (1956). Available phosphorus was extracted from soil with 0.5 M sodium bi-carbonate (Olsen *et al.*, 1954) and determined by using double beam US-VIS spectrophotometer. The available K was extracted with the neutral normal ammonium acetate and determined by using flame photometer (Jackson, 1973). Calcium and magnesium were determined by versenate titration method (Vogel, 1978), available S was estimated by extracting the soil sample with 0.15 per cent calcium chloride (Williams and Steinbergs, 1959) and S content in the extract was determined by turbidimetric method (Chesnin and Yien, 1951) and available micronutrients viz., iron, manganese, zinc and copper in soil were extracted with 0.005 M DTPA extractant (1 : 2 ratio) developed by Lindsay and Norvell (1978) and contents were estimated by using Atomic Absorption spectrophotometer (Agilent, 200 Series AA).

Results were analyzed in SPSS 20.0 using Pearson correlation coefficient matrix to know the significant variations among the soil physico-chemical properties with mineral nutrients. Range, mean and standard deviation were calculated using Microsoft Excel (Microsoft, WA, USA) spread sheet.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

Soil pH

The pH of the soils samples ranged from 7.53 to 8.62 and 7.62 to 9.20, with average values of 7.95 and 8.44 at 0-30 cm and 30-60 cm depth, respectively (Table -1). The soils of sweet orange orchards in the study area

indicated that pH of the surface soil (0-30 cm) was low as compared to that of sub-surface soils (30-60 cm). Similar results were reported by Chetna and Prasad (2011), Yasmin *et al.* (2015) and Surwase *et al.* (2016). The lower pH of surface soil might be due to the presence of more amount of organic matter, and release of organic acids during its decomposition (Reddy and Rao, 1990).

Electrical conductivity (EC)

The electrical conductivity of the soil samples varied from 0.14 to 1.18 dSm^{-1} , with mean value of 0.35 dSm^{-1} at 0-30 cm and at 30 to 60 cm depth and ranged from 0.12 to 0.85 dSm^{-1} respectively. Slightly higher EC levels were observed at surface soils than sub-surface soils, which might be due to irrigating the soil with water having high EC. However, all the orchard soils were non-saline in nature as the mean EC was less than 1.0 dSm^{-1} . The growth of citrus could be adversely affected when EC exceeds 0.5 dSm^{-1} as reported by Kanwar and Randhawa (1961)

Organic carbon (OC)

The organic carbon content of the sweet orange growing soils of the study area ranged from 0.07 to 0.50 per cent in surface (0-30 cm) soils and 0.01 to 0.39 per cent in sub-surface (30-60 cm) soils with average values of 0.34 per cent and 0.21 per cent at surface and sub-surface, respectively (Table-1).

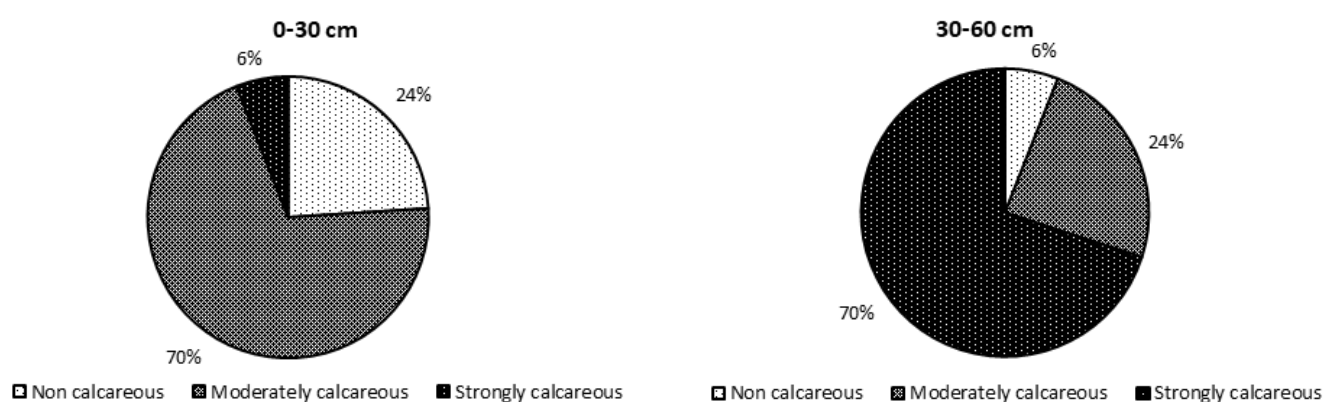
Surface and sub-surface soils in the study area recorded low organic carbon content. Organic carbon content was high in soil samples at 0-30 cm depth than the samples of 30-60 cm depth indicating the organic carbon content decreased with increasing soil depth, which might be due to the additions of organic matter was confined to surface layer in sweet orange growing soils. Similar results were reported by Reddy *et al.* (2013), Yasmin *et al.* (2015) and Surwase *et al.* (2016).

Cation exchange capacity and CaCO_3

The cation exchange capacity (CEC) of the surface soils ranged from 24.02 to 64.74 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$, with a mean value of 43.84 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ and the sub-surface soils varied from 8.74 to 57.69 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$, with mean value of 38.59 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ (Table-1). Surface soils reported high CEC values than the sub-surface soils, it is an established fact that the cation exchange capacity of soil depends upon the amount and nature of the clay and organic matter

Table 1. Soil physico-chemical properties of the sweet orange growing orchards of the study area

Parameter	Total samples	0 – 30 cm			30 – 60 cm		
		Range	Mean	SD	Range	Mean	SD
pH	50	7.53 - 8.62	7.95	0.29	7.62 - 9.20	8.44	0.42
EC (dSm ⁻¹)	50	0.14 - 1.18	0.35	0.21	0.12 - 0.85	0.32	0.20
CEC (cmol(p ⁺)kg ⁻¹)	50	24.02 - 64.74	43.84	10.01	8.74 - 57.69	38.59	11.42
CaCO ₃ (per cent)	50	1.00 - 18.50	5.77	2.96	3.00 - 36.50	13.27	6.13
OC (per cent)	50	0.07 - 0.50	0.34	0.097	0.01 - 0.39	0.21	0.09

**Fig. 2. Distribution of CaCO₃ in the sweet orange growing soils of the study area**

content. Owing to the high organic matter and significant amount of clay content in the surface soil, the CEC recorded higher values than the sub-surface. Similar results were reported by Mohekar (1999) and Yadav and Meena (2009).

The calcium carbonate content of soil showed a variation of 1.00 to 18.50 per cent and 3.00 to 36.50 per cent with mean values of 5.77 per cent and 13.27 per cent in surface and sub-surface soils, respectively (Table 1). About 24 per cent of the surface soils were non-calcareous, 70 per cent were moderately calcareous and 6 per cent were strongly calcareous, but in sub-surface, 6 per cent were non-calcareous, 24 per cent were moderately calcareous and 74 per cent were strongly calcareous (Fig. 2). The content of calcium carbonate was low in surface soil (0-30 cm) than in sub-surface soil (30-60 cm). The increase in calcium carbonate with increase in soil depth was also reported by Prasad *et al.* (2001), Yasmin *et al.* (2015) and Surwase *et al.* (2016). The increase of calcium carbonate content in the lower horizon might be due to calcification, leaching of calcium carbonate and inheritance from parent material.

Available soil nutrient status

Major nutrients (N, P and K)

The available N content ranged from 125.26 to 307.33 kg ha⁻¹ at 0-30 cm and at 30 to 60 cm and from 82.72 to 220.69 kg ha⁻¹ (Table 2). Available N content was higher in surface horizons and decreased with depth. This variation in N contents might be due to a number of reasons such as difference in natural fertility, variation in cultural practices and N fertilizers application. Moreover, N contents in surface soil was high as compared to the lower depths of soil profiles, which is due to the presence of more organic matter in surface than sub-surface soil. Similar results with regard to soil N was reported by Ranjha *et al.* (2002).

The available P content of soil showed a variation of 5.26 to 39.54 kg ha⁻¹ and 2.13 to 25.07 kg ha⁻¹ with a mean values of 17.79 kg ha⁻¹ and 11.16 kg ha⁻¹ in surface and sub-surface soils, respectively (Table 2). However, the highest available P content was observed in the surface horizon and decreased with depth. It might be due to the

Table 2. Soil mineral nutrient content of the sweet orange growing soils of YSR district

Parameter	Total samples	0 – 30 cm			30 – 60 cm		
		Range	Mean	SD	Range	Mean	SD
Available N (kg ha ⁻¹)	50	125.26- 307.33	224.31	51.05	82.72 - 220.69	150.79	40.04
Available P (kg ha ⁻¹)	50	5.26 - 39.54	17.79	9.095	2.13 - 25.07	11.16	6.08
Available K (kg ha ⁻¹)	50	116.14 - 955.92	365.00	169.34	69.66 - 554.51	258.54	95.59
Ex. Ca (cmol(p ⁺)kg ⁻¹)	50	8.50 - 45.25	27.13	8.47	6.00 - 46.50	29.52	8.83
Ex. Mg (cmol(p ⁺)kg ⁻¹)	50	2.25 - 41.50	13.48	8.97	2.75 - 22.50	10.51	4.86
Available S (mg kg ⁻¹)	50	14.37 - 73.41	30.12	13.19	8.35 - 29.16	16.58	4.51
DTPA-Fe (mg kg ⁻¹)	50	1.05 - 5.12	2.67	0.92	0.67 - 3.95	1.58	0.72
DTPA-Zn (mg kg ⁻¹)	50	0.08 - 1.23	0.37	0.25	0.01 - 1.19	0.26	0.20
DTPA-Mn (mg kg ⁻¹)	50	0.52 - 9.73	4.05	1.98	0.59 - 9.00	2.93	2.03
DTPA-Cu (mg kg ⁻¹)	50	0.37 - 2.87	1.33	0.53	0.42 - 2.60	0.92	0.41

(Ex. = Exchangeable)

confinement of crop cultivation to the rhizosphere and supplementing the depleted P by external source *i.e.* fertilizers and presence of free iron oxides. The lower available P content in lower horizons compared to upper horizons was due to the fixation (Ranjha *et al.*, 2002).

The available K content of the surface soils was differed from 116.14 to 955.92 kg ha⁻¹, with a mean value of 365.00 kg ha⁻¹. In the sub-surface soils of sweet orange orchards in study area, the available K content was varied from 69.66 to 554.51 kg ha⁻¹, with a mean value of 258.54 kg ha⁻¹ (Table 2). This might be due to more intense weathering, release of liable K from organic residues, and application of K fertilizers.

As per the ratings given by Muhr *et al.* (1965), out of all the soils of sweet orange orchards studied, 82 per cent were deficit in N and 18 per cent were medium in N, 20 per cent were deficient in P, 60 per cent were medium in P and 20 per cent were high in P, but in case of available K, 32 per cent were in medium range and 68 per cent were in high range (Table 3). Similar results with regard to soil N, P and K was reported by Ranjha *et al.* (2002).

All the available N, P and K were higher in surface soils than sub-surface soils. It might be due to addition of organic manures and fertilizers on surface layers. Similar

results were reported by Dhale and Prasad (2009), Allotey *et al.* (2013) and Chaudhari *et al.* (2016).

Secondary nutrients (Ca, Mg and S)

The exchangeable calcium (Ca) content of surface soils was ranged from 8.50 to 45.25 cmol(p⁺)kg⁻¹ with a mean value of 27.13 cmol(p⁺)kg⁻¹ where in sub-surface soils the exchangeable calcium content ranging from 6.00 to 46.50 cmol(p⁺)kg⁻¹ with a mean value of 29.52 cmol(p⁺)kg⁻¹ in sweet orange growing soils of the study area (Table 2). The exchangeable calcium in surface and sub surface soils of all the sweet orange growing soils was higher than the critical limit (<1.50 cmol(p⁺)kg⁻¹) as established by Tandon (1989). The presence of sufficient amounts of the exchangeable calcium in soils of sweet orange growing orchards of study area might be attributed to presence of considerable amount of calcium carbonate in soils. The higher exchangeable calcium in sub-surface layer might be due to the accumulation of more amount of calcium carbonate in sub-surface layer as compared to that of surface layers. Higher exchangeable calcium status was reported by many workers in citrus growing soils of Punjab state (Awasthi *et al.*, 1984, Kanwar *et al.*, 1963 and Mann *et al.*, 1979).

Table 3. Distribution of the mineral nutrients in the sweet orange orchards soils of the study area

Parameter	Total samples	Very low			Low			Medium			High			Very high		
		Number of Samples	per cent	per cent	Number of Samples	per cent	per cent	Number of Samples	per cent	per cent	Number of Samples	per cent	per cent	Number of Samples	per cent	per cent
N (kg ha ⁻¹)	50	–	–	–	41	82.00	9	18.00	–	–	–	–	–	–	–	–
P (kg ha ⁻¹)	50	–	–	–	10	20.00	30	60.00	10	20.00	–	–	–	–	–	–
K (kg ha ⁻¹)	50	–	–	–	–	–	16	32.00	34	68.00	–	–	–	–	–	–
Fe (mg kg ⁻¹)	50	12	24.00	–	34	68.00	4	8.00	–	–	–	–	–	–	–	–
Zn (mg kg ⁻¹)	50	39	78.00	–	9	18.00	2	4.00	–	–	–	–	–	–	–	–
Mn (mg kg ⁻¹)	50	–	–	–	4	8.00	19	38.00	18	36.00	9	18.00	–	–	–	–
Cu (mg kg ⁻¹)	50	–	–	–	–	–	9	18.00	41	82.00	–	–	–	–	–	–

* Soil nutrient indices were referred to the Muhr *et al.* (1965) and Lindsay and Norvell (1978)

Table 4. Pearson correlation coefficient matrix between soil physico-chemical properties

	pH	EC	CaCO ₃	CEC	OC
N	0.023	0.216	-0.124	0.204	0.716**
P	0.09	-0.017	0.093	0.177	0.104
K	0.099	0.086	0.119	0.383**	0.155
Ca	0.121	-0.155	0.054	0.447**	-0.009
Mg	0.119	0.275	0.346*	-0.046	0.122
S	0.314*	-0.018	0.127	-0.05	0.036
Fe	0.147	0.277	-0.104	0.114	0.279*
Zn	0.068	0.185	0.044	0.069	0.224
Mn	-0.277	-0.252	-0.105	0.105	0.091
Cu	-0.166	-0.206	-0.044	0.152	-0.027

* and ** indicate a significant difference at $P < 0.05$ and $P < 0.01$, respectively.

Similarly, the exchangeable magnesium (Mg) status in all the sweet orange grown soils was higher than the critical limit ($<1.0 \text{ cmol(p}^+)\text{kg}^{-1}$) as developed by Tandon (1989). The available Mg content of soil varied from 2.25 to 41.50 $\text{cmol(p}^+)\text{kg}^{-1}$ and 2.75 to 22.50 $\text{cmol(p}^+)\text{kg}^{-1}$ in surface and sub-surface soils, respectively (Table 1 and Fig. 2). Similar results were reported by Patiram *et al.* (2000) in Mandarin orchards soils of Sikkim and Venkata Subbaiah *et al.* (1982) in citrus growing soils of Anantapur district in Andhra Pradesh.

The available sulphur (S) in surface soils was differed from 14.37 to 73.41 mg ha^{-1} and from 8.35 to 29.16 mg ha^{-1} in surface and sub-surface soils, respectively of sweet orange grown soils of study area (Table 2). The high available S in surface soils than sub-surface soils of the study area might be due to the application of organic manures and sulphur containing fertilizers on surface layers. Similar results were reported by Chaudhari *et al.* (2016).

Micronutrients (Fe, Cu, Mn and Zn)

The available Fe, Zn, Mn and Cu content of surface soils was ranged from 1.05 to 5.12, 0.08 to 1.23, 0.52 to 9.73 and 0.37 to 2.87 mg kg^{-1} , with mean values of 2.67, 0.37, 4.05 and 1.33 mg kg^{-1} , respectively in the sweet orange growing orchards of the study area (Table 2). The available Fe, Zn, Mn and Cu content in the sub-surface soils of study area was varied from 0.67 to 3.95, 0.01 to

1.19, 0.59 to 9.00 and 0.42 to 2.60 mg ha^{-1} , respectively (Table 2).

In general, the available micronutrients under study decreased with increase in soil depth. The decrease in the content of Fe in bottom layers might be due to the increase in pH and calcareousness of the soil, and decrease in organic carbon content, similar results were reported by Diwakar and Singh (1995).

The availability of different micronutrients was studied. From the results, it was observed that 24 and 78 per cent soils were deficit for available Fe and Zn, 68, 18 and 8 per cent of soils were found low in available Fe, Zn and Mn, respectively and 8, 4, 38 and 18 per cent soils were medium in available Fe, Zn, Mn and Cu, respectively. The trend of variation in the available micronutrient contents of soils might be due to variations in organic carbon content and micronutrient containing minerals in soil. Similar variations were reported by Subbaiah *et al.* (1982) for Cu, Fe, Mn status of soils of citrus orchards in Anantapur district and many locations of citrus orchards (Khokhar *et al.* (2012), Noor *et al.* (2013) and Surwase *et al.* (2016).

Correlation between soil physico-chemical characteristics and available nutrients

Simple correlations were worked out between soil physico-chemical characteristics and available nutrients

and the correlation coefficients were presented in (Table – 4).

Soil N and Fe had a significant positive correlation with OC ($r = 0.716^{**}$ and $r = 0.279^*$, respectively). Soil K and Ca significantly and positively related with CEC ($r = 0.383^{**}$ and $r = 0.447^{**}$, respectively). Soil Mg had significant positive correlation with CaCO_3 ($r = 0.346^*$). Soil sulphur had a significant positive correlation with soil pH ($r = 0.314^*$).

CONCLUSION

The soil reaction varied widely in the study area and it ranged from mildly alkaline to strongly alkaline, the soils were non-saline in nature as the EC of these soils was far below 4.0 dS m^{-1} . About 24 per cent of the surface soils were non-calcareous, 70 per cent were moderately calcareous and 6 per cent were strongly calcareous. However, in sub-surface soils, 6 per cent were non-calcareous, 24 per cent were moderately calcareous and 74 per cent were strongly calcareous. The soils of the study area were low in organic carbon and deficit in available nutrients such as Zn, Fe, N, P and Mn. Soil N and Fe had a significant positive correlation with OC. Soil K and Ca significantly and positively related with CEC. Soil Mg had significant positive correlation with CaCO_3 . Soil sulphur had a significant positive correlation with soil pH.

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PLANTHOPPER FAUNA ASSOCIATED WITH RICE CROP-ECOSYSTEMS FROM COSTAL ANDHRA PRADESH

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ABSTRACT

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Fourteen planthopper species viz., *Nilaparvata lugens* (Stal); *Sogatella furcifera* (Horvath); *S. kolophon* (Kirkaldy); *S. vibix* (Haupt); *Cemus* sp.; *Coronacella sinhalana* (Kirkaldy); *Euidella* sp.; *Harmalia anacharsis* (Fennah); *Sardia rostrata* (Melichar); *Terthron albobittatum* (Matsumura); *Tagosodes pusanus* (Distant); *Oliarus* sp.; *Nisia nervosa* (Motschulsky); and *Toya propinqua* (Fieber) were collected, identified and described. An illustrated key along with key taxonomic characters were provided for easy identification of the planthoppers associated with rice crop eco-systems from coastal Andhra Pradesh

KEYWORDS: Hemiptera, Delphacidae, planthoppers, rice crop eco-system

INTRODUCTION

Planthoppers belong to the super family Fulgoroidea in Fulgoromorpha of Auchenorrhynchos–Hemiptera comprising 20 families. The economically important planthoppers were included in families viz., Cixiidae, Delphacidae, Derbidae, Dictyophoridae, Eurobrachidae, Flatidae, Fulgoridae, Tettigometridae, and Tropiduchidae (O'Brien and Wilson, 1985). Delphacidae is the largest family of planthoppers belonging to the super family Fulgoroidea of the order Hemiptera. Family Delphacidae comprises of a number of important crop pests. Delphacids are grass feeders and devastating pests on major agricultural crops viz., rice, sugarcane, maize, sorghum and other cereals. Delphacids are the most diverse and economically important family of planthoppers, comprising about 1835 species of which 55 species are known pests on 25 crops (Wilson and O'Brien 1987). Planthoppers damage plants directly by feeding which cause a characteristic yellowing of tissue known as "hopper burn" and in addition planthoppers may also act as vectors for plant viral disease viz., rice grassy stunt virus (*Nilaparvata lugens* (Stal), *N. bakeri* (Muir) and *N. muiri* (China)) (Ou, 1985 and Hibino, 1989), rice ragged stunt virus (*N. lugens*) and *N. bakeri*), rice stripe and black-streaked dwarf virus (*Laodelphax striatellus* (Fallen) and *Terthron albobittatum* (Matsumura)), hoja blanca virus (*Tagosodes oryzae* (Muir) (Nault and Ammar, 1989), sugarcane yellow leaf syndrome (*Saccharosydne saccharivora* (Westwood)), Fiji disease

virus (*Perkinsiella saccharicida* (Kirkaldy), *Perkinsiella sinensis* (Distant) and *P. vastatrix* (Kirkaldy)) (Wilson, 2005), maize rough dwarf virus (*Sogatella vibix* (Haupt)), maize mosaic, maize sterile stunt, maize stripe virus (*Peregrinus maidis* (Ashmead)), finger millet mosaic virus (*P. maidis*), Brazilian wheat spike disease (*Sogatella kolophon* (Kirkaldy)) (Wilson, 2005) etc.,

MATERIALS AND METHODS

Planthopper specimens were collected from different Agro-climatic zones of coastal Andhra Pradesh by sweep netting from rice crop. About 10-15 to and fro net sweepings were taken each time and planthoppers collected were aspirated from the net into a glass tube and killed with a cotton swab wetted with a few drops of ethyl acetate. The killed specimens were transferred to homeopathic vials, labelled, brought to the laboratory and dried in a hot air oven at 45-50°C, for about 5 to 6 hours. For mounting and preparing slides of genitalia the procedure suggested by Knight (1965) was followed. For describing the different body parts the terminology suggested by O'Brien and Wilson (1985) was followed.

RESULTS AND DISCUSSION

In the present studies fourteen planthopper species viz., *Nilaparvata lugens* (Stal); *Sogatella furcifera* (Horvath); *S. kolophon* (Kirkaldy); *S. vibix* (Haupt); *Cemus* sp.; *Coronacella sinhalana* (Kirkaldy); *Euidella* sp.; *Harmalia anacharsis* (Fennah); *Sardia rostrata*

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Planthopper fauna of rice ecosystem from coastal Andhra Pradesh

1. Hind tibia with a movable apical spur (Delphacidae) – 2
 — Hind tibia without a movable apical spur (Cixiidae, Meenoplidae) – 14
2. Presence of one or more lateral spines on the basal segment of hind tarsus; aedeagus slender, broader medially, tapering apically and apex upturned; genital styles flattened; inner margin deeply concave in middle (Fig. 1-2)
 — *Nilaparvata lugens*
 — Hind basal tarsal segment without lateral spines – 3
3. Vertex and mesonotum with a distinct pale yellow or orange or white stripe extending from the head – 4
 — Vertex and mesonotum without a distinct pale yellow or orange white stripe extending from the head – 11
4. Aedeagus twisted, tapering to apex with two rows of small teeth – 5
 — Aedeagus not twisted, tubular without two rows of small teeth – 7
5. Aedeagus twisted, tapering towards apex with two rows of small teeth; tegmina with a pterostigma; clypeus, genae and frons blackish; diaphragm 'U' shaped; genital styles strongly dilated at base, apex relatively small and almost equally bifurcated (Fig. 3-4)
 — *Sogatella furcifera*
 — Tegmina without pterostigma; face with frons, clypeus and genae not entirely blackish; genital styles not as above – 6
6. Face with frons, clypeus, genae entirely pale yellowish in colour; genital styles relatively short, broad, flattened, deeply bifurcated distally and anterior process of the apical bifurcation strongly produced tapering to apex, not distinctly dilated in the middle part, inner process very short; inner edge of the diaphragm rectangular (Fig. 5-6)
 — *Sogatella kolophon*
 — Face with frons and clypeus pale yellowish brown in colour, but genae dark brown in colour; the genital styles have the outer process of apical bifurcation dilating from the base of middle then tapering to apex with dorsal margin forming a blunt angle; diaphragm more or less 'U' shaped (Fig. 7-8) – *Sogatella vibix*
7. Aedeagus tubular with a few small teeth like projections subapically – 8
 — Aedeagus not tubular and not as above – 9
8. Aedeagus tubular and deeply curved; gonopore subapical, more or less rectangular; genital styles densely spinose distally (Fig. 9-10)
 — *Terthron albobittatum*
 — Aedeagus basally wider, gradually narrowed and tubular; two to three spines are there subapically, gonopore apical; genital styles relatively flattened, trapezoidal, distally and shallowly bifurcated (Fig. 11-12)
 — *Tagosodes pusanus*
9. Vertex narrow, elongated between larger compound eyes; tegmina dark brown in colour with pterostigma; aedeagus more or less straight, tubular with subapical serrations; genital styles relatively short, broader medially with a deep sinuation along the inner margin; number of spines are scattered in the middle portion of the style (Fig. 13-14)
 — *Sardia rostrata*
 — Vertex short, not so elongated. Anal tube process present, genital styles without serrated processes – 10

10. Frons with conspicuous raised pits on either side of the median carina; tegmina granulate along the veins and fuscus apically; aedeagus long, slightly decurved with long flagellum arising at apex, dorsal margin with one or two processes; genital styles broader basally, gradually narrowed apically with spines (Fig. 15-16)– ***Cemus* sp.**
 — Frons without conspicuously raised pits on either side of median carina; tegmina not granulate – **11**
11. Vertex and mesonotum dark brown with characteristic cream coloured band on pronotum; anal segment collar like with a pair of slender process; aedeagus is tubular near apex (Fig. 17-18) – ***Coronacella sinhalana***
 — Vertex and mesonotum dark brown without characteristic cream coloured band on pronotum – **12**
12. Aedeagus flattened, curved with a pair of long unequal subapical processes; genital style L- shaped (Fig. 19-22) — ***Euidella* sp.**
 — Aedeagus and genital styles are not as above – **13**
13. Aedeagus tubular with uniform width throughout and without any teeth; genital style bifurcated apically (Fig. 23-24) – ***Harmalia anacharsis***
 — Aedeagus tubular but not with uniform width, serrated subapically, below which slightly sinuated; diaphragm Y- shaped (Fig. 25-26) – ***Toya propinqua***
14. The claval vein of tegmina granulate; median ocellus pearl like; aedeagus very broad basally, gradually narrowed and slightly curved with a pair of transparent wing like structures; genital styles broad basally, elongated with claw like structures in the middle (Fig. 27-28) – ***Nisia nervosa***
 — The claval vein of tegmina not granulate, median ocellus not pearl like. Vertex excavated, reddish brown in colour, mesonotum large with five carinae; aedeagus with processes (Fig. 29-30) — ***Oliarus* sp.**

(Melichar); *Terthron albovittatum* (Matsumura); *Tagosodes pusanus* (Distant); *Toya propinqua* (Fieber) (**Family: Delphacidae**); *Oliarus* sp. (**Family: Cixiidae**); *Nisia nervosa* (Motschulsky) (**Family: Meenoplidae**) were collected, identified and described.

An illustrated key has been prepared to aid rapid and accurate identification of the common species of planthoppers found associated with rice eco-systems of coastal Andhra Pradesh. For those species which were not studied here, literature or a Taxonomist working on the planthoppers may be consulted.

The most brief and important taxonomic and morphological characters of the above keyed species were provided here under for confirmation of identifications.

***Nilaparvata lugens*:** Yellowish brown or dark brown in colour with eyes slightly bluish. Clypeus triangular, with median and lateral carina. Legs slender with tectiform post tibial spur and with teeth on margin. Number of teeth on tibial spur is 15-35. Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. Anal segments were collar like with a pair of moderately long slender spine like processes. Aedeagus slender, broader

medially, tapering apically with teeth on the caudal margin and apex upturned. Genital styles flattened, inner margin deeply concave in the middle.

***Sogatella furcifera*:** Vertex yellowish white, Frons, clypeus and genae black in colour. Pronotum is yellowish. Forewing sub-transparent with black pterostigma. The body is black dorsally, creamy white ventrally with a distinct yellowish white region in the middle of mesothorax in both males and females. Clypeus and genae blackish with whitish yellow carinae. Pronotum yellowish white and laterally darkened. Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. Anal segment collar-like with a pair of stout spine like processes, directed ventrally. Diaphragm broadly U-shaped. Aedeagus is simple, tubular usually sinuate with two rows of teeth, and with apical gonopore. Genital styles broad basally, bifurcated apically.

***Sogatella kolophon*:** Vertex, pronotum and mesonotum yellowish-white to pale stramineous. Lateral mesonotum orange brown. Face with frons, clypeus and genae entirely pale yellowish brown in colour. Clypeus and genae are light brown with yellow carinae. Post tibial spur with 19-

21 teeth. Pygofer more or less round, posterior opening slightly longer dorsoventrally than broad. Anal segment, collar like with a pair of stout spine like processes directed ventrally up to the length of anal tube. Aedeagus twisted, tubular, usually sinuate with two rows of teeth and apical gonopore. Inner edge of diaphragm rectangular. Genital styles relatively short, broad, flattened, deeply bifurcated distally and anterior process of the apical bifurcation strongly produced tapering to apex, not distinctly dilated in the middle part, inner process very short.

***Sogatella vibix*:** Vertex yellowish white and black in colour beyond mid lateral carinae. Forewings without pterostigma and are subtransparent. First segment of hind tarsus distinctly longer than the length of second and third segments put together, with thin and foliaceous tibial spur. Pygofer more or less round, posterior opening slightly longer dorsoventrally than broad. Anal segment moderately short, collar like with a pair of moderately long, slender stout spine like process directed ventrally up to the length of anal tube. Usually sinuate with two rows of teeth. Aedeagus twisted, tubular and gonopore apical. The genital plates have the outer process of the apical bifurcation dilating from base of middle then tapering to apex with dorsal margin forming a blunt angle.

***Cemus sp*:** Vertex, pronotum reddish black with cream coloured carinae. The forewings with blackish dots all along the veins and fuscous maculae apically. Genae reddish black in colour with cream coloured pits. Tegmina with characteristic black dots along veins, fuscous streaks, apically with a distinct pterostigma. Pygofer short dorsally, long and strongly convex ventrally, posterior opening relatively small, longer than broad. Anal segment collar like with a pair of slender processes directed ventrally. Diaphragm long dorsoventrally, with dorsal margin concave, deeply incised medially, medioventral process short, broader than long, quadrate. Aedeagus long, slightly decurved, with a long flagellum arising at apex, dorsal margin with one or two processes

***Coronacella sinhalana*:** Pronotum with cream coloured band. The central carina of the face black; lateral carina of vertex and frons, median line of pronotum and mesonotum white, second segment of antenna and legs yellowish brown, tibial spur with 18 teeth. Pygofer with posterior margin slightly incised near base, latero dorsal angle obtusely rounded, opening wider than long, lateral margins not very distinct; phallus short, tubular with several teeth dorsally near apex; orifice on lower side near apex.

Diaphragm broad, dorsal margin evenly convex medially; anal segment collar like with a pair of slender spinose processes directed ventrally.

***Euidella sp.* :** Eyes reddish brown. Vertex, pronotum and mesonotum tinged with orange to yellowish markings; frons, genae, clypeus, antennae and legs yellowish brown. Pygofer ovoid, medioventral margin with three equally sized and long thin spines; base of paramere with a flattened part extended caudally, mid half concave latero-caudally, twisted apically and diverging, forming tip with series of minute spike-like processes. Aedeagus flattened with long unequal flagellar appendages. Genital styles long and L- shaped.

***Harmalia anacharsis*:** Body is light brown in colour. Vertex very short, broad and excavated, triangular between eyes. Frons dark brown in colour, and carinae lighter in colour. Light brown coloured legs, first tarsal segments longer than the remaining segments, leaf like tibial spur which is broader. Anal segment collar like with a pair of spines directed ventrally. Aedeagus tubular without teeth, uniform width throughout. Genital styles bifurcated apically.

***Sardia rostrata*:** The colouration of vertex, thorax and tegmina is dark brown with black fuscous markings. The clypeus is black in colour and gradually narrows apically. Genae black in colour. Forewings are dark brown with pterostigma and fuscous apically. Pygofer broadly rounded, posterior opening longer dorsoventrally. Aedeagus more or less straight, tubular with subapical serration, gonopore apical. Genital styles relatively short, broader medially with a deep sinuation along the inner margin and number of spines are scattered in the middle portion of the style

***Terthron albovittatum* :** Vertex to apex of mesonotum dark brown with cream colour dorsal median stripe. Genae black in colour, Tibial spur leaf like; first segment of hind tarsus distinctly longer than the length of second and third segments put together. Pygofer dorsoventrally broad, posterior opening slightly longer. Collar like anal segment with a pair of spine like processes directed ventrally. Aedeagus simple, tubular curved deeply, gonopore sub-apical. Genital styles more or less rectangular with densely spinose distally.

***Tagosodes pusanus*:** A white band present along the middle line from the anterior cell of vertex to the caudal tip of the mesonotum. The lateral sides of pro and mesonotum brown or black in colour. Frons and genae

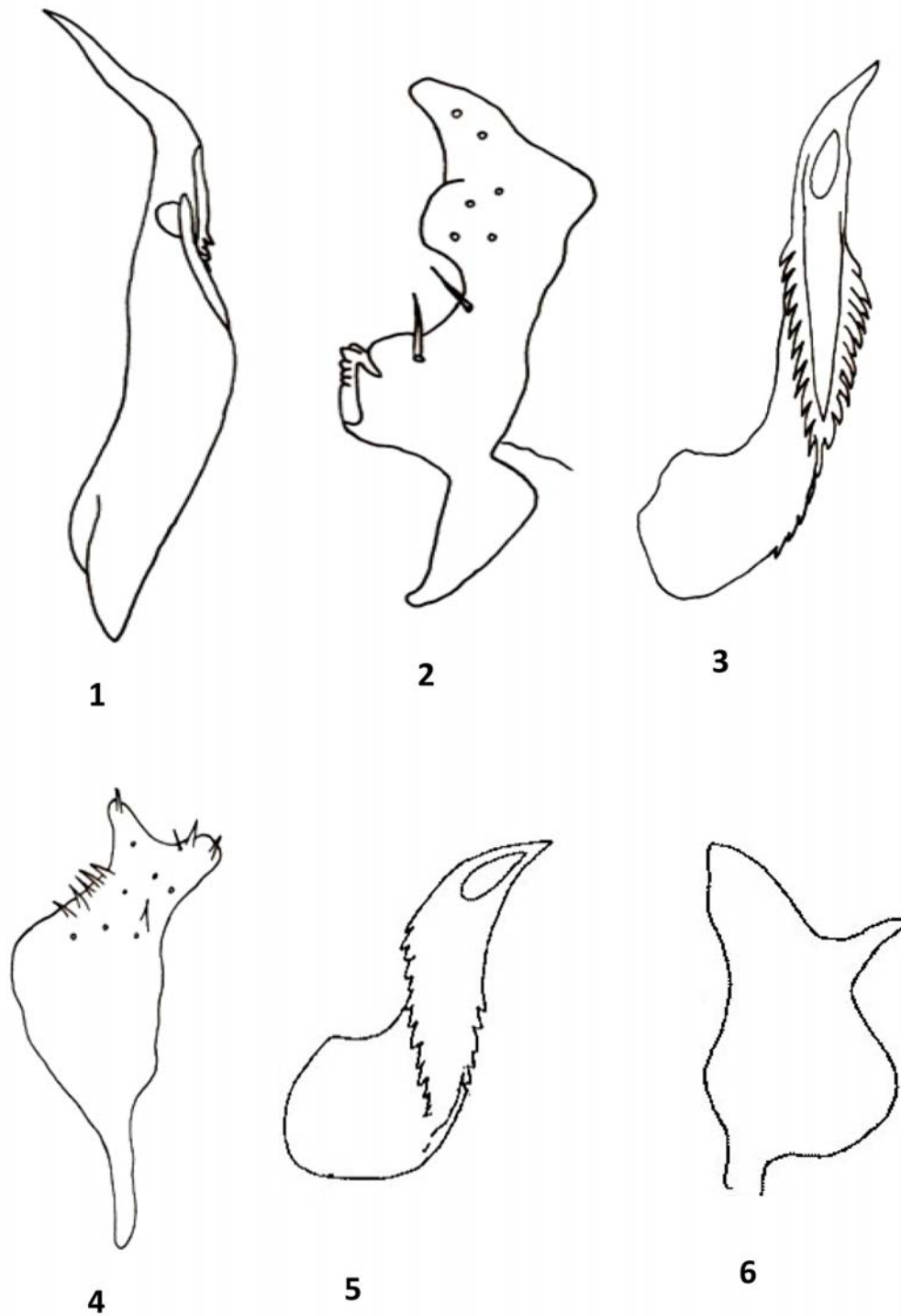


Fig. 1-2; *Nilaparvata lugens*, 1. Aedeagus, lateral view; 2. Style, lateral view; Fig. 3-4; *Sogatella furcifera*, 3. Aedeagus, lateral view; 2. Style, lateral view; Fig. 5-6; *Sogatella kolophon*, 5. Aedeagus, lateral view; 6. Style, lateral view.

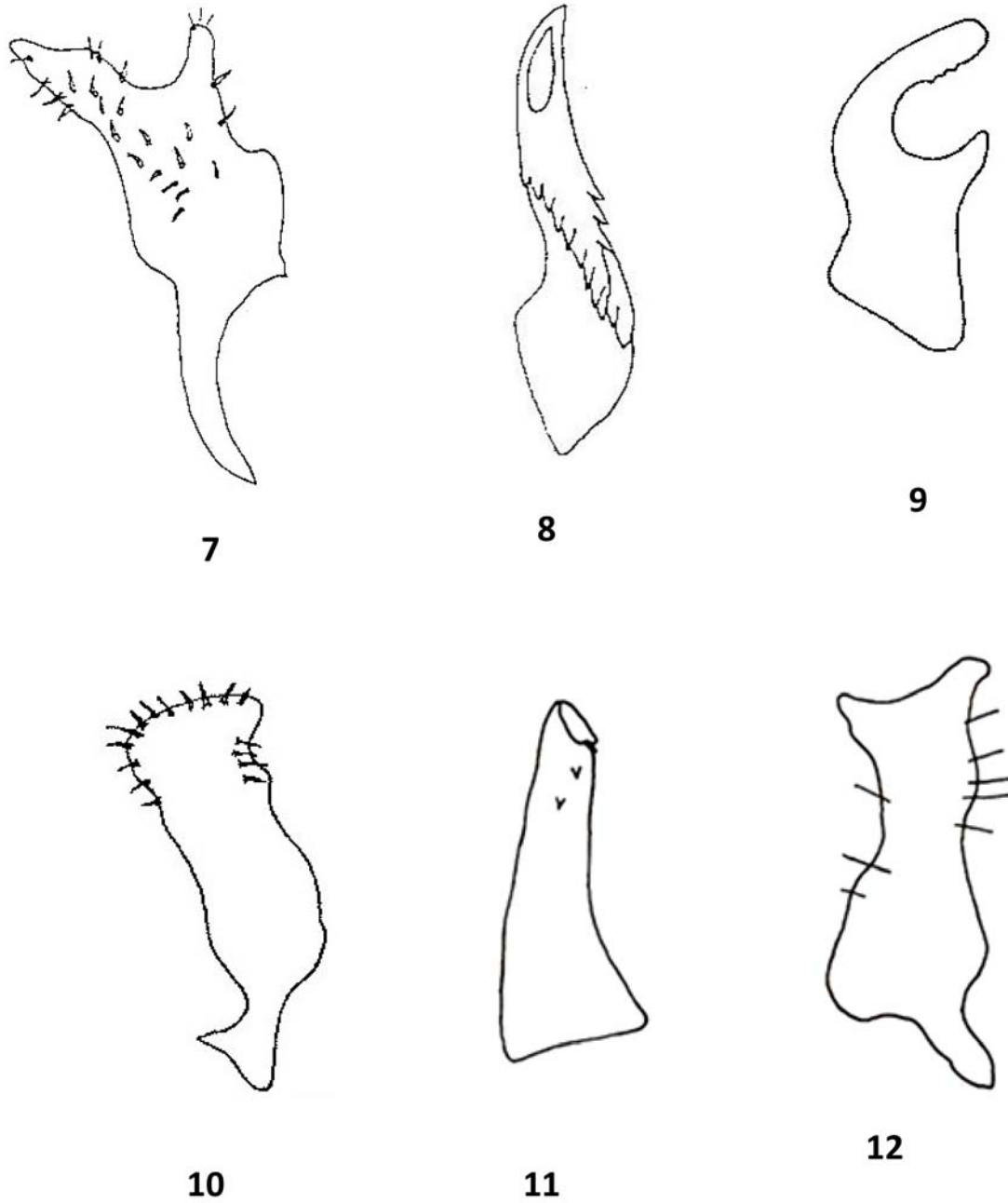


Fig. 7-8; *Sogatella vibix*, 7. Style, lateral view; 8. Aedeagus, lateral view; Fig. 9-10; *Terthron albovittatum*, 9. Aedeagus, lateral view; 10. Style, lateral view; Fig. 11-12; *Tagosodes pusanus*, 11. Aedeagus, lateral view; 12. Style, lateral view.

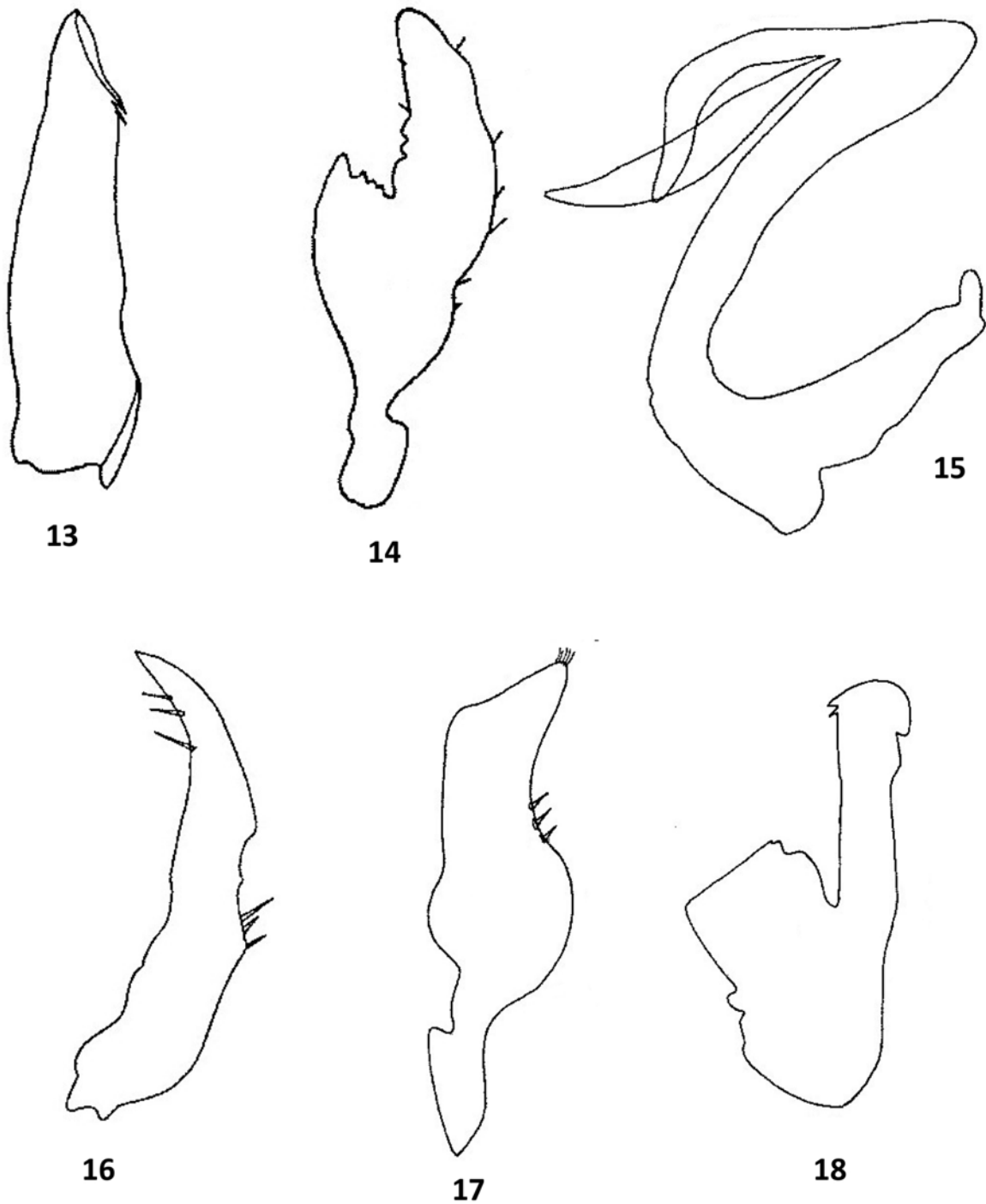


Fig. 13-14; *Sardia rostrata*, 13. Style, lateral view; 14. Aedeagus, lateral view; Fig. 15-16; *Cemus* sp., 15. Aedeagus, lateral view; 16. Style, lateral view; Fig. 17-18; *Coranacella sinhalana*, 17. Style, lateral view; 18. Aedeagus, lateral view

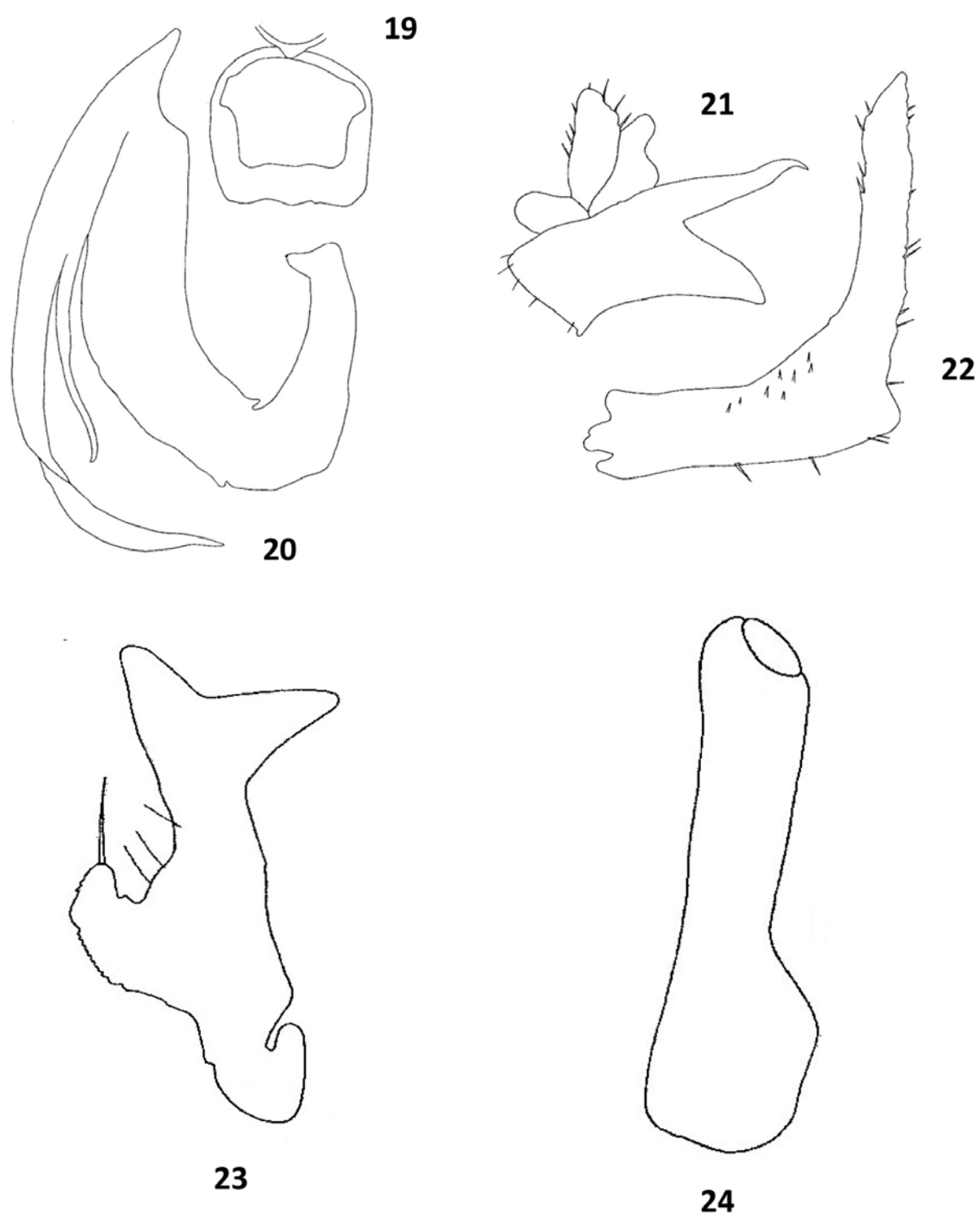


Fig. 19-22; *Euidella* sp., 19. Diaphragm; 20. Style, lateral view; 21. Anal tube; 22. Style, lateral view
Fig. 23-24; *Harmalia anacharsis*, 23. Style, lateral view; 24. Aedeagus, lateral view

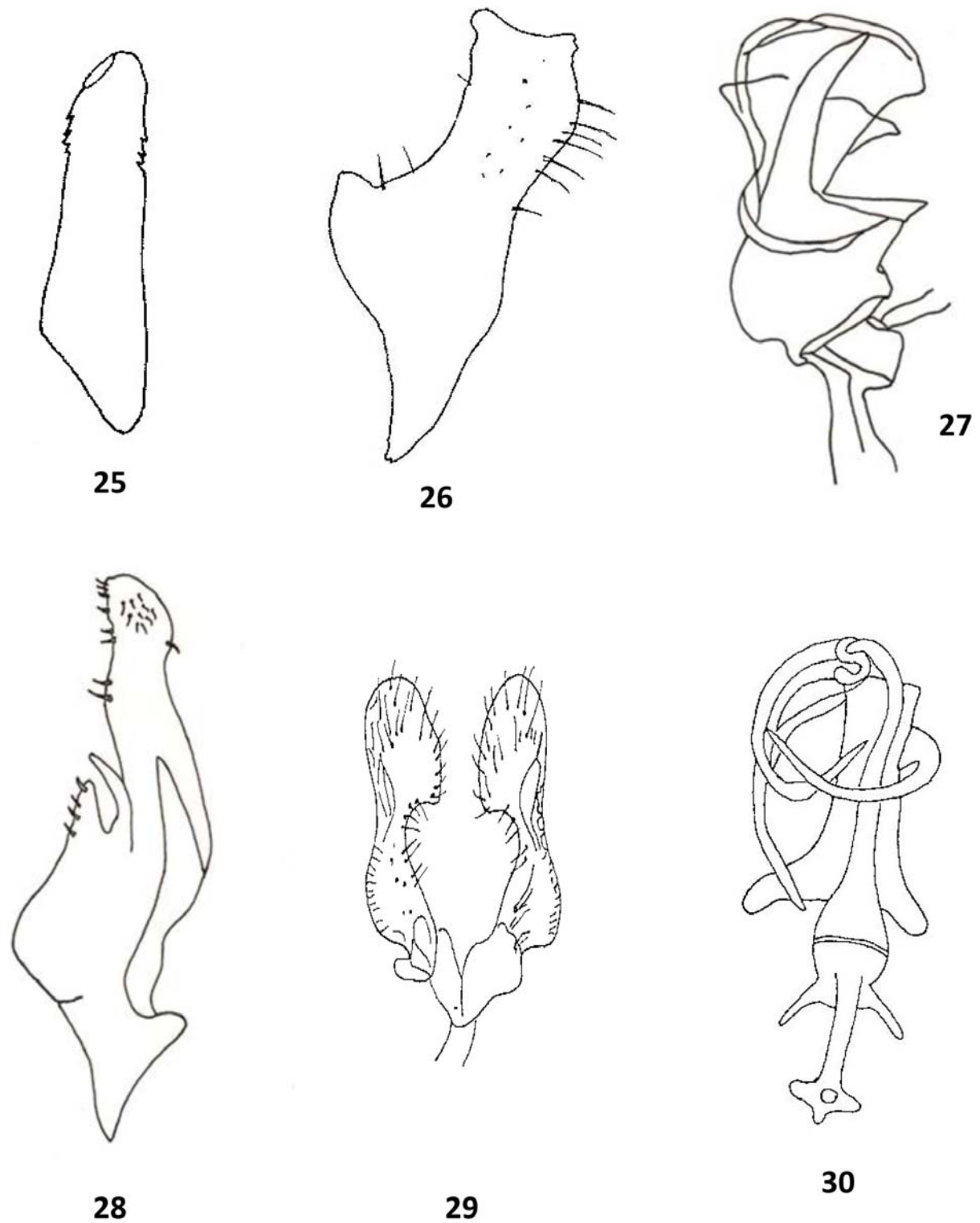


Fig. 25-26; *Toya propinqua*., 25. Aedeagus, lateral view; 26. Style, lateral view, Fig. 27-28; *Nisia nervosa* , 27. Aedeagus, lateral view; 28. Style, lateral view, Fig. 29-30; *Oliarus* , 29. Aedeagus, lateral view; 30. Style, lateral view

are black in colour. Clypeus light brown in colour. Tegmina subtransparent, longer than wide with a pattern of dark markings and pterostigma. Post tibial spur thin, foliaceous and with minute teeth marginally. Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. A pair of short spine like processes directed ventrally on the collar like anal segment. Aedeagus tubular wider basally, gradually narrowed and tubular, 2-3 spines are there sub-apically, gonopore apical. Genital styles relatively flattened, trapezoidal distally and shallowly bifurcated.

Oliarus sp.: Frons with intercarinal areas dark in colour. Tegmina with black dots all along over the veins. Legs yellowish, with 4 tibial spines; two small basal ones, and others longer. Pygofer with medioventral process which are conical and triangular. Lateral lobes well produced, symmetrical, diverging distally in ventral aspect. Aedeagus more or less tubular with curved elongated flagellum like processes. Genital styles broader apically, deeply sinuated along the mesal margin in the middle with spines densely scattered.

Toya propinqua: Stramineous in colour. Vertex very short and shallowly excavated. Tegmina without pterostigma and is light stramineous in colour. Legs normal, tibiae foliaceous. Pygofer dorsoventrally elongated with an elongated ventral opening. A pair of moderately long slender spine like processes on collar like anal segment. Aedeagus tubular, serrated sub-apically below which slightly sinuated, gonopore apical. Genital styles flattened, broader, concave and wider in the middle with number of spines apically.

Nisia nervosa : Stramineous to whitish in colour. Vertex deeply excavated and is not demarcated from the frons. Frons very much elongated, excavated and curved along the eyes. Clypeus shorter and triangular in shape. Tegmina light straw coloured, veins darker, claval vein granulate or tuberculate. Legs slender, mobile spur absent, first two tarsal segments with a row of spines. Pygofer dorsoventrally long, posterior opening slightly longer. Pygofer is shoe shaped laterally. Anal segment without a pair of spines. Aedeagus very broad basally, gradually narrowed and slightly curved with a pair of transparent wing like structures. Genital styles broader basally, elongated and with claw like structures in the middle and broader.

Okada (1977) reported 20 species of delphacid planthoppers as rice pests in Japan, of these only three

species, *Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath) and *Laodelphax striatellus* (Fallen) were considered as major rice pests. Wilson and Claridge (1991) published a comprehensive account of leafhopper and planthoppers found on rice in the major rice growing areas of world. They described 28 species of planthoppers belonging to the families of Delphacidae, Lophopidae, Meenoplidae and Cixiidae of Fulgoroidea on rice. Lakshminarayana *et al.* (2005) reported seven planthoppers species associated with different rice ecosystems of Andhra Pradesh. Rao and Chalam (2007) reported 23 delphacid planthoppers in India from rice and sugarcane ecosystems. Shashank (2009) reported five delphacid planthoppers viz., *Cemus* sp., *Nilaparvata lugens*, *Sogatella furcifera*, *Sardia rostrata*, and *Tagosodes pusanus* found associated with different rice eco-systems from Karnataka. In the present studies fourteen planthopper species belonging to three different families were collected, identified, described and illustrated for easy and quick identification. An attempt has been made in this paper to describe the planthopper fauna associated with rice crop ecosystems of coastal Andhra Pradesh, and an identification key well supported with illustrations was also provided which will be useful aid to identify the planthoppers by research and extension workers. The accurate identification of planthopper fauna associated with a particular agro-ecosystem is very much needed along with their identification key to formulate integrated management strategies whenever they attain pest status.

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OPTIMISATION OF NUTRIENT MANAGEMENT STRATEGY FOR ENHANCING THE GROWTH AND YIELD OF HYBRID MAIZE (*Zea mays* L.)

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ABSTRACT

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A field experiment was conducted during *rabi*, 2015 to optimize the nutrient management strategy for enhancing the growth and yield of hybrid maize. The experiment was laid out in a randomized block design with nine treatments and replicated thrice. The treatments consisted of nine nutrient management practices viz., control; 100 per cent RDF (180-60-50 kg N, P₂O₅ and K₂O ha⁻¹); 125 per cent RDF; 150 per cent RDF; 100 per cent RDF + FYM @ 5 t ha⁻¹; 100 per cent RDF + 25 kg ZnSO₄ ha⁻¹; 100 per cent RDF + ZnSO₄ + FeSO₄ each @ 25 kg ha⁻¹; 100 per cent RDF + sulphur @ 30 kg ha⁻¹ + ZnSO₄ + FeSO₄ each @ 25 kg ha⁻¹; 100 per cent RDF + sulphur @ 30 kg ha⁻¹ + foliar application of ZnSO₄ and FeSO₄ @ 0.5 per cent each at booting and silking. Application of recommended dose of fertilizers (180-60-50 kg N, P₂O₅ and K₂O ha⁻¹) supplemented with 30 kg S ha⁻¹ along with foliar application of ZnSO₄ + FeSO₄ @ 0.5 per cent each at booting and silking recorded the highest stature of growth attributes of maize viz., plant height, leaf area index, dry matter production and yield in maize, which was significantly superior over the rest of the treatments tried. The lowest values of the above said growth parameters and yield were recorded with control.

KEYWORDS: High Maize, nutrient management, growth attributes, yield.

INTRODUCTION

Maize (*Zea mays* L.) is third most important cereal crop after rice and wheat in the world's agricultural economy, both as a food for human and as feed for livestock. It is known as "queen of cereals" because of its maximum yield potential (22 t ha⁻¹) among the cereals and expanded use in different agro industries. In India, it is grown over an area of 9.5 million hectares with a production of 23.3 million tonnes and productivity of 2452 kg ha⁻¹ (DACNET, 2014). Maize is being a C₄ plant has a tremendous yield potential and responds well to growth resources. Despite the impressive strides in acreage and production for last two decades, the productivity of maize in India (2452 kg ha⁻¹) is far below the world average productivity (5490 kg ha⁻¹). Imbalance and inadequate nutrition was the prime reason attributed to low productivity and poor quality of newly evolved high yielding single cross hybrids in India.

Maize is a high nutrient demanding crop, which requires micronutrients along with major nutrients (Verma, 2011). The availability of nutrients such as nitrogen, phosphorus, potassium, sulphur, zinc and iron in balanced proportion in the soil is essential for improving the yield and quality of maize (Randhawa and Arora, 2000). Undoubtedly, the use of high analysis fertilizers must be accompanied by matching doses

of zinc and iron applied at the right time through an appropriate mode (soil or foliar), for sustaining and improving the productivity besides quality in corn (Singh *et al.*, 2000).

MATERIAL AND METHODS

The experiment was conducted during *rabi*, 2015-16 at dryland farm of S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The soil was sandy loam in texture, neutral in soil reaction (pH 6.9), low in organic carbon (0.43%) available nitrogen (125.4 kg ha⁻¹), phosphorus (14.2 kg ha⁻¹), potassium (142.4 kg ha⁻¹), sulphur (12.5 kg ha⁻¹), zinc (1.02 kg ha⁻¹) and iron (2.80 kg ha⁻¹) content. The experiment was laid out in a randomized block design with nine treatments and replicated thrice. The treatments consisted of nine nutrient management practices viz., control; 100 per cent RDF (180-60-50 kg N, P₂O₅ and K₂O ha⁻¹); 125 per cent RDF; 150 per cent RDF; 100 per cent RDF + FYM @ 5 t ha⁻¹; 100 per cent RDF + 25 kg ZnSO₄ ha⁻¹; 100 per cent RDF + ZnSO₄ + FeSO₄ each @ 25 kg ha⁻¹; 100 per cent RDF + sulphur @ 30 kg ha⁻¹ + ZnSO₄ + FeSO₄ each @ 25 kg ha⁻¹; 100 per cent RDF + sulphur @ 30 kg ha⁻¹ + foliar application of ZnSO₄ and FeSO₄ @ 0.5 per cent each at booting and silking. Data

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was recorded on plant height, leaf area index, dry matter production, seed yield, stover yield and harvest index. Leaf area index was calculated by dividing the total leaf area with the corresponding land area as suggested by Watson (1952). The oven dry weight of all the five plants was taken and dry matter production per hectare was worked out and expressed in kg ha⁻¹. Weather conditions indicated that the weather variables were within the cardinal range so as to enable the crop to reasonably express the effect of imposed treatments.

RESULTS AND DISCUSSION

Effect of nutrient management practices on growth attributes of Maize

The results of the present investigation have clearly brought out a noticeable trend of response to nutrient management practices in *rabi* maize (Table 1).

Application of recommended dose of fertilizers (180-60-50 kg NPK ha⁻¹) supplemented with 30 kg S ha⁻¹ along with foliar application of ZnSO₄ + FeSO₄ @ 0.5 per cent each at booting and silking resulted in higher stature of growth attributes of maize viz., plant height, leaf area index, dry matter production, which was significantly superior over the rest of the treatments. The highest plant height might be due to role of nutrients in various physiological and biochemical processes contributing to the growth of the meristematic region (Cakmak *et al.*, 1989). The increase in plant height with application of zinc might be attributed to increase in intermodal distance (Ghaffari *et al.*, 2011). Higher leaf area index recorded was probably due to better absorption and translocation of foliar applied nutrients leading to delayed senescence and abscission. Foliar application of nutrients at the hour of the need enables the plants to maintain higher chlorophyll content, leaf area plant⁻¹, leaf area index which helps in decreasing the rate of senescence (Zayed *et al.*, 2011). As zinc is involved in the synthesis of IAA, which is a component of various enzymes, such as *Carbonic anhydrase* and *Alcoholic dehydrogenase*, which have a suggestive role in chlorophyll formation, photosynthesis and metabolic reactions in plants leading to higher leaf area index. The response to sulphur application might be due to synthesis of more chlorophyll and amino acids resulting in better utilization of carbohydrates from more protoplasm, resulting in increased leaf area (Jeet *et al.*, 2012). Higher dry matter production associated might be due to the significant role of NPK, sulphur, zinc and iron in better root and shoot development and which inturn increased dry matter

production. The foliar application of zinc and iron was found to be more effective due to its higher uptake efficiency compared to soil application as they helps in increased photosynthetic efficiency by delaying leaf senescence. Enhanced growth of maize under balanced supply of nutrients has been undisputed fact and universally acceptable proportion as could be visualized from the research evidence (Kumar *et al.*, 2010).

Effect of nutrient management practices on yield of Maize

Seed Yield

Seed yield of maize was significantly influenced by various nutrient management practices (Table 1). The highest seed yield (5307 kg ha⁻¹) of maize was recorded with foliar application of ZnSO₄ and FeSO₄ @ 0.5 per cent each at booting and silking + 30 kg sulphur ha⁻¹ along with 100 per cent RDF, which was significantly superior over the rest of the nutrient management practices tried, which resulted in 41.7 per cent higher seed yield over 100 per cent RDF. Seed yield of maize is a function of growth and yield attributes, which is significantly higher with these nutrient management practices. Application of 150 per cent RDF, 125 per cent RDF (T₃), FYM @ 5 t ha⁻¹ or ZnSO₄ and FeSO₄ each @ 25 kg ha⁻¹ or ZnSO₄ and FeSO₄ each @ 25 kg + sulphur 30 kg ha⁻¹ along with 100 per cent RDF were the next best treatments, which were comparable among themselves. The comparatively lower yields recorded with soil application of zinc and iron along with RDF and sulphur over the foliar application of zinc and iron along with RDF and sulphur might be due to combination of leaching, fixation and volatalization (Ghaffari *et al.*, 2011). The yield recorded with soil application of 25 kg ZnSO₄ ha⁻¹ along with 100 per cent RDF was comparable with 100 per cent RDF and significantly superior over control. Foliar application of ZnSO₄ and FeSO₄ @ 0.5 per cent each at booting and silking + 30 kg Sulphur ha⁻¹ along with 100 per cent RDF (T₉) resulted in 12.7 per cent higher seed yield over soil application of 25 kg each ZnSO₄ and FeSO₄ + 30 kg S ha⁻¹ along with 100 per cent RDF.

The favourable effect of foliar application of zinc might be attributed to its direct influence on auxin production, which inturn enable the plant to produce more dry matter and consequently enhanced the partitioning of photosynthates towards newly formed sink, which resulted in early bloom, prolonged flowering period, which inturn

Table 1. Growth attributes and yield of maize as influenced by different nutrient management practices

Treatments	Plant height (cm)	Leaf area index	Dry matter production (kg ha ⁻¹)	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index (%)
T ₁ : Control	120.6	1.46	3515	404	1541	20.77
T ₂ : 100 per cent RDF (180-60-50 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	160.0	1.80	8373	3744	4229	46.95
T ₃ : 125 per cent RDF	185.5	2.46	9988	4567	5068	47.40
T ₄ : 150 per cent RDF	190.0	2.62	10340	4880	5550	46.94
T ₅ : 100 per cent RDF + FYM@5 t h ⁻¹	178.7	2.38	9765	4484	4989	47.22
T ₆ : 100 per cent RDF + ZnSO ₄ @ 25 kg ha ⁻¹	164.0	2.02	8950	4027	4528	46.53
T ₇ : 100 per cent RDF + ZnSO ₄ and FeSO ₄ each @ 25 kg ha ⁻¹	181.6	2.37	9856	4535	5049	47.32
T ₈ : 100 per cent RDF + + ZnSO ₄ and FeSO ₄ each @ 25 kg ha ⁻¹ + Sulphur @ 30 kg ha ⁻¹	185.9	2.50	10300	4708	5127	47.86
T ₉ : 100 per cent RDF ++ Sulphur @ 30 kg ha ⁻¹ + Foliar application of ZnSO ₄ and FeSO ₄ @ 0.5 per cent each at booting and silking	205.2	3.10	11298	5307	5555	48.85
SEm±	4.87	0.09	198	138	140	0.28
CD (P=0.05)	14.6	0.27	593	415	420	0.90

resulted in more number of seeds and higher seed weight cob-1, which is a direct function of yield leading to higher seed yield (Mostafavi, 2012). The lowest seed yield (404 kg ha⁻¹) in control without application of fertilizer could be because of the deflated stature of growth parameters and finally lower yields due to the deficiency of N, P, K, Zn, Fe and sulphur as the experimental soil was poor in available nitrogen, phosphorus, potassium, zinc, iron and sulphur.

Stover Yield

Among all the nutrient management practices, the highest stover yield of maize (5568 kg ha⁻¹) was recorded with foliar application of ZnSO₄ and FeSO₄ @ 0.5 per cent each at booting and silking + 30 kg S ha⁻¹ along with 100 per cent RDF, which was however comparable with application of 150% RDF and significantly superior over rest of the nutrient management tried. Stover yield of maize was the interplay effect of plant height and dry matter accumulation and both the parameters were found to be the highest with 150 per cent RDF and foliar spray of ZnSO₄ and FeSO₄ @ 0.5% each at booting and silking along with 30 kg S ha⁻¹ and 100 per cent RDF. This might be due to increased availability of essential plant nutrients from the enhanced level of nutrients applied to the crop in and balanced supply of nutrients. Enhanced stover yield was the outcome of the positive and synergistic interaction between the nutrient supply and growth stature of maize as reflected in enhanced growth parameters with supply of highest dose of NPK or optimum dose of NPK with foliar application zinc and iron along with sulphur (Jyothi *et al.*, 2015). The increase in grain and stover yield was due to role of zinc in metabolism of plants as an activator of several enzymes, which inturn may directly or indirectly affect the synthesis of carbohydrates and protein (Narwal *et al.*, 1993). The lowest stover yield (1541 kg ha⁻¹) was recorded with control due to poor vegetative growth as a result of non supply of nutrients.

Harvest Index

The highest harvest index in maize was recorded with foliar application of ZnSO₄ and FeSO₄ @ 0.5% each at booting and silking + 30 kg S ha⁻¹ along with 100 per cent RDF, which was significantly superior over rest of the nutrient management practices tried (Table 1). This might be due to better absorption and translocation of nutrients (N, P, K and S including zinc and iron) in balanced proportions, where foliar application coincides with the

peak crop demand and thereby maintenance of better source sink relationship owing to higher harvest index. The lowest harvest index was recorded with control might be due to poor source sink relationship owing to inadequate nutrient supply.

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STUDIES ON TOXIC EFFECT OF CHROMIUM AND SILVER HEAVY METALS ON PHOTOSYSTEM II IN CYANOBACTERIA

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ABSTRACT

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In the present study, the chromium and silver ions have been used to identify the alterations in PBPs and analyzed their effect on the energy transfer process of PS II in the above cyanobacterium. By choosing the heavy metals Cr and Ag, attempts were made by incubating the cells and isolated pigment proteins for 24 and 72 h in light with different concentration revealed that the treatment of Cr showed a concentration dependent effect on whole chain electron transport activity and 49 per cent inhibition was noticed with 50 μ M of Cr. Similarly Ag is able to cause 51 per cent inhibition with 10 μ M concentration. Also, the exploitation of cyanobacteria as spectral probes, related to the Hill activity by exposing the cells to different illumination intensity of white light (105 to 300 μ moles) using neutral density filters suggest that the reason for the inhibition of PS II activity at low light intensity (105 μ moles) could be alterations at the light harvesting complex.

KEYWORDS:

INTRODUCTION

The cyanobacteria (Blue-green algae) are the most ancient, filamentous, photosynthetic bacteria that use water as electron donor in photosynthesis giving out oxygen. There are two important species, *Spirulina maxima* and *Spirulina platensis*. These are multicellular organisms, which are multiplied by binary fission. Depending upon the presence of chlorophyll a, botanists included it as micro algae in the class *Cyanophyceae*; but depending on its structural characteristics shown as a prokaryotic bacterium considered by the bacteriologist (Nagendra Babu *et al.*, 2008). *Spirulina platensis* has been commercially used in several countries as health foods, feed, bio-fertilizers and applications in biotechnology because of its valuable constituents such as proteins, vitamins, minerals, carbohydrates, lipids and polyunsaturated fatty acids. They have anti-cancer properties and immune promoting effects. *S. platensis* is an attractive source of various bioactive substances such as sterols function as antimicrobial agents, polysulfated polysaccharides as antiviral agents, phycobilliproteins and carotenoids as antioxidants, mycosporine-like amino acids (MAAs) and scytonemin as photoprotectants, polyunsaturated fatty acid (PUFA) as serum lipids levels reduction and HDL-cholesterol increasing, Gamma-linolenic acid (GLA) as rheumatoid arthritis, eczema,

diabetes, multiple trauma, and premenstrual syndrome. Among the phycobiliproteins derived from *S. platensis*, the most abundant is phycocyanin (PC), a brilliant blue colour pigment have greater importance because of its various biological and pharmacological properties e.g. antioxidant, antiviral, anti-cancer, neuro-protective, hepatoprotective, antitumor, radical scavenging, radioprotection and anti-inflammatory properties (Li *et al.*, 2005; Bhat and Madyastha, 2000; Ivanova *et al.*, 2010 and Roamy *et al.*, 1999). The present study was conducted to investigate to know the deep insights of Electron transport measurements, whole chain electron transport and photosystem II through standard assays.

MATERIAL AND METHODS

Microorganism and culture condition

The experimental organism *S. platensis*, the mother culture was obtained from National Facility for Blue Green Algal collection, New Delhi, India and cultured autotrophically. The cells were transferred from the agar slants to liquid medium i.e. cultivated in Zarrouk's medium (1966). Experiments to evaluate the effect of different stress conditions were carried out in departmental laboratory. Conical flasks of 100 ml capacity were prepared containing 50 ml *S. platensis* culture with initial optical density 0.1 for all treatment groups. The cultures

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placed at west facing window receiving natural day light at temperature $30 \pm 2^\circ\text{C}$ and shaken gently thrice a day to avoid clumping and enhance the growth.

Growth measurements

Measurement of optical density (O.D.) is particularly suitable for determination of growth of *S. platensis*. The basic advantage of turbidity technique in growth rate measurements is the possibility of taking repeated readings on increase in turbidity of the same batch of the suspension of cells.

Extraction and estimation of photosynthetic pigments

Cultures were taken by thoroughly shaking the flask and cells are harvested by centrifuging at 9000 xg for 5 min. The pellets were washed twice with reaction buffer containing (25 mM HEPES-NaOH buffer (pH 7.5) containing 20 mM NaCl) and suspended in the same buffer.

Isolation of PBsomes

The PBsomes were isolated according to the method of Gantt *et al.* (1979) with slight modifications. Cells were grown up to mid-log phase in the medium and harvested by filtration on a whatsmann no.1 filter paper using a Millipore filter assembly. Harvested cells were washed twice and suspended in 0.75 M K-phosphate buffer (pH 7.0) in the cell suspension 1 mM phenylmethylsulphonyl fluoride (PMSF), 2 mM EDTA and 1 mM sodium azide were incubated. The cells were disrupted by ultrasonification at amplitude of 15 microns in MSE ultrasonic disintegrator. The unbroken cells were removed by centrifugation a 6000 xg for 10 min by using Hitachi SCR20BA (Japan). The obtained supernatant was incubated with 1.2 per cent Triton X-100 for 40 min at 20°C . Then the PBsomes were separated from the thylakoids by centrifuging it at 30,000 xg for 30 min at 20°C . The supernatant was then layered on a buffered sucrose density gradients (pH 7.0) containing 1 mM azide. The PB somes were concentrated in the 1.0 M region after spinning the gradients at 1,40,000 xg for 5 hrs at 20°C in a preparative ultracentrifuge (L870M Beckman). The PBsomes were removed from the 1.0 M region as an intense blue band. Sucrose was removed from the isolated PSsomes by using dialysis with 0.75 K-PO₄ (pH 7.0) and PBsomes were used for both spectral and electrophoretic measurements.

Electron transport measurements

Electron transport activities were measured with Clark-type oxygen electrode (Hansatech, UK). The electron assembly consists of a platinum cathode and silver anode, they were saturated with KCL. An electrical measurement of oxygen is directly proportional to the current flow between the cathode and anode. These electron transport measurements were done under saturating light intensity ($4000 \mu \text{mol photons m}^{-2}\text{s}^{-1}$) at 25°C . The assay mixture (25 mM HEPES-NaOH (pH 7.5) 20 mM NaCl an intact cells equivalent to 12 to 15 mg Chl *a*) was continuously stirred during measurement of electron transport activity. For measurement of Electron transport activity at different light intensities, neutral density filters were used.

Whole chain electron transport assay

Whole chain electron transport assay ($\text{H}_2\text{O}^!$ MV) was measured in intact cells in terms of O_2 consumption using MV as electron acceptor (Kok *et al.*, 1965). The reaction mixture contained reaction buffer (25 mM HEPES-NaOH (pH 7.5), 20 mM NaCl, 0.5 mM MV, 1 mM sodium azide and the intact cells equivalent to 12 to 15 μg Chl *a*).

Photosystem II assay

Para benzoquinone (pBQ) was used to measure the PS II catalyzed electron transport ($\text{H}_2\text{O}^!$ pBQ) in the intact cells. Being a lipophilic compound pBQ enters in to the intact cells and accepts electrons at PQ pool in electron transport chain (Warburg and Luthgens, 1944; Trebst, 1974). The reaction mixture contained reaction buffer (same as used in cell harvesting), 0.5 mM freshly prepared pBQ and the intact cells equivalent to 12 to 15 μg Chl *a*.

RESULT AND DISCUSSION

Phycobilisomes are the light harvesting pigment protein complexes of PS II in the cyanobacterium *Spirulina platensis*. Any alterations in the spectral properties lead to the inhibition of PS II catalyzed electron transport activity. Therefore after creating the heavy metal ions, a comparative study has been made among electron transport activities by using various donors, acceptors and inhibitors. The artificial electron acceptor, MV which accepts electrons at the reducing side of PS II has free access to the thylakoid membrane, even in the case of intact cells of *Spirulina platensis* (Robinson *et al.*, 1982).

Table 1. Effect of various concentrations of chromium and silver on whole chain electron transport assay in cyanobacterium *Spirulina platensis*

Concentration (μM)		whole chain electron transport activity (μ moles O_2 consumed $\text{mg ChI}^{-1} \text{h}^{-1}$) $\text{H}_2\text{O} \rightarrow \text{MV}$		Per cent Inhibition	
Chromium	Silver	Chromium	Silver	Chromium	Silver
Control	Control	253 ± 21	251 ± 20	0	0
25	5	211 ± 20	203 ± 17	17	19
50	10	128 ± 10	123 ± 11	49	51
100	15	95 ± 8	85 ± 6	62	66

Table 2. Effect of various concentrations of chromium and silver on photosystem II catalyzed electron transport activity ($\text{H}_2\text{O} \rightarrow \text{MV}$) in cyanobacterium

Concentration (μM)		PS II catalyzed electron transport activity $\text{H}_2\text{O} \rightarrow \text{Pbq}$ (μ moles O_2 consumed $\text{mg ChI}^{-1} \text{h}^{-1}$)		Percentage loss	
Chromium	Silver	Chromium	Silver	Chromium	Silver
Control	Control	369 ± 28	376 ± 29	0	0
25	5	325 ± 26	310 ± 27	12	18
50	10	201 ± 24	191 ± 21	46	49
100	15	143 ± 17	171 ± 18	61	55

Table 3. Effect of chromium and silver on PS II catalyzed electron transport assay ($\text{H}_2\text{O} \rightarrow \text{pBQ}$) in cyanobacterium *Spirulina platensis*

Concentration (μM)		Duration time (h)		PS II catalyzed electron transport activity $\text{H}_2\text{O} \rightarrow \text{pBQ}$ (μ moles O_2 consumed $\text{mg ChI}^{-1} \text{h}^{-1}$)		Per cent inhibition	
Chromium	Silver	Chromium	Silver	Chromium	Silver	Chromium	Silver
Control	Control	0	0	385 ± 30	383 ± 31	0	0
50	10	24	12	301 ± 29	293 ± 28	22	24
		48	24	206 ± 24	201 ± 22	46	48
		72	36	125 ± 15	131 ± 11	67	65

Table 4. Effect of illuminated light intensity on chromium and silver induced inhibition of photosystem II catalyzed electron transport activity ($\text{H}_2\text{O} \rightarrow \text{pBQ}$)

Light intensity (μM)		PS II catalyzed electron transport activity ($\mu\text{ moles O}_2 \text{ consumed mg ChI}^{-1} \text{ h}^{-1}$)				Per cent inhibition	
Chromium	Silver	Chromium		Silver		Chromium	Silver
		Control	Cr treated (50 μM)	Control	Ag treated (50 μM)		
105		43 $\pm$ 4	25 $\pm$ 3	43 $\pm$ 4	24 $\pm$ 2	41	41
1100		106 $\pm$ 11	57 $\pm$ 6	102 $\pm$ 12	56 $\pm$ 6	46	45
2050		185 $\pm$ 21	91 $\pm$ 10	190 $\pm$ 22	95 $\pm$ 9	51	50
3000		370 $\pm$ 35	170 $\pm$ 18	365 $\pm$ 34	172 $\pm$ 18	54	53

Therefore the effect of selected heavy metal ions (Cr, Ag) on the whole chain electron transport activity ($\text{H}_2\text{O} \rightarrow \text{pBQ}$) in the presence and absence of heavy metal ions was studied (Table 1). Control cells showed high rate of oxygen consumption involving whole chain electron transport activity (253 $\mu\text{ mol O}_2 \text{ consumed mg ChI}^{-1} \text{ h}^{-1}$). The treatment of Cr showed a concentration dependent inhibition in whole chain electron transport activity. 25 μM of Cr caused 17 per cent inhibition in whole chain electron transport activity. Further increase in the concentration to 50 μM and 100 μM brought 49 per cent and 62 per cent inhibition respectively. Also, Table 1 shows concentration dependent effect of Ag on whole chain catalyzed electron transport activity. The 51 per cent inhibition was noticed with 10 μM of Ag and further rise in the concentration caused 66 per cent inhibition with 15 μM of Ag. From the data, it is clear that the reason for the inhibition of whole chain electron transport activity could be due to two possibilities, a) either the alteration at the level of PS II catalyzed reaction center or at the level of LHC b) both.

To verify the above proposition the partial electron transport reactions of PS II have measured by using pBQ as Hill acceptor. pBQ is an artificial electron acceptor which accepts electrons from PQ pool (Warburg and Luthgens, 1944; Trebst, 1974). pBQ is a lipophilic acceptor which enters easily into intact cells of *Spirulina* and reaches the PQ pool. Control cells exhibited a high rate of PS II dependent oxygen evolving catalyzed electron transport activity (369 $\mu\text{ mol of O}_2 \text{ evolved mg}^{-1} \text{ ChI h}^{-1}$). The treatment of Cr as expected showed concentration

dependent inhibition in PS II activity was noticed with 50 μM of Cr (Table 2). Further rise in the concentration to 100 μM induced 61 per cent loss in the PS II activity with 10 μM of Ag. Further rise to 15 μM brought 55 per cent loss in PS II activity (Table 2). To compare whether time dependent effect is associated with the above two mentioned heavy metals, a time dependent study was made by choosing the 50 μM of Cr and 10 μM of Ag. To achieve this, the cells were incubated at different intervals from 12 to 72 h and the PS II time dependent effect of Cr on PS II catalyzed electron transport activity. 46 per cent inhibition of PS II activity was noticed with 50 μM of Cr after 48 h of incubation. Further rise in the incubation period could bring 67 per cent inhibition in the Hill activity.

The data in the Table 3 shows the time dependent effect of Ag on pBQ mediated Hill reaction. In this case of Ag, 48 per cent of inhibition was noticed after 24 h of incubation unlike Cr. The loss in the PS II catalyzed electron transport activity under heavy metal stress could be due to three reasons: a) the alteration at the level of WOC b) changes at the PS II reaction center level or LHC or c) modification at the level of reducing side of PS II. Similar reports were made in the photosynthetic electron transport activity of PS II in the same cyanobacterium under heavy metal stress (Murthy, 1991; Ranjani, 2003). From the results it is quite clear that the PS II catalyzed electron transport is main target for heavy metal stress (Cr and Ag) in the cyanobacterium *Spirulina platensis*. Since the main objective of this study is exploitation of the cyanobacteria as spectral probes, PS

II catalyzed electron transport activity at different light intensities was measured. For this study, a variable light intensity from 3000 μ moles to 105 μ moles were used with special filters, neutral density filters. These were helpful in reducing the light intensity as per the convenience. From this study it was clear that the inhibition was more at light saturating conditions than that of light limiting conditions. The difference of inhibition between light saturating and light limiting conditions in case of Cr was 13 per cent. Similar results are also observed in the case of Ag stressed cyanobacterial cells. In the case of Ag the difference of inhibition between light saturating conditions and light limiting conditions was 12 per cent (Table 4). The main reason for the inhibition of PS II activity at light limiting conditions in both the cases was due to alterations in the LHC of PS II. In cyanobacteria, PBsomes can lead to the inhibition of its function i.e. PS II catalyzed electron transport activity.

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EFFECT OF FOLIAR APPLICATION OF FERTILIZERS ON YIELD AND FLOWERING OF MUSKMELON (*Cucumis melo*)

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ABSTRACT

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Foliar fertilizer application efficiently meets the demand of crops during the periods of high nutrient demand particularly when nutrients become fixed in the soil. Hence, a field experiment was conducted at farmer's field in Kadapa district of Andhra Pradesh, to find out the efficacy of foliar application of chemical fertilizers such as borax (1%), KNO₃ (6%) and CaNO₃ (6%) alone or in combination, on flowering and yield of commercially important muskmelon variety Haramadhu. Combined application of nutrients were more effective in promoting early flowering, more number of fruits and higher yields than application of fertilisers independently. The plants treated with combined spraying of borax + CaNO₃ and borax + KNO₃ took less number of days for first staminate and pistillate flower appearance, more number of pistillate flowers/plant (50.0 and 52.50 days respectively) and recorded 57.9 and 31.6 per cent increase in number of fruits and 92.6 and 76.7 per cent higher yields, respectively compared with control (water sprays).

KEYWORDS:

INTRODUCTION

Melon is one of the most important vegetable crops cultivated throughout the world and popular for its taste, flavour and as a source of phytonutrients (Lestes, 2008). The area under muskmelon cultivation is increasing during the past decade owing to its nutritional benefits. Fast growing habit and short lifespan of muskmelon demands balanced fertilizer application in enhancing the yield and quality. Deficiency of major and micro nutrients has been widely reported in cucumbers (Carmona *et al.*, 2015) which hampers the production. Among the macro nutrients, potassium (K) and calcium (Ca) deficiency has been widely reported in cucumbers. Potassium (K) is not a constituent of any functional molecule, but it plays a vital role in plant growth, yield and fruit quality in many plant species. Potassium (K) uptake from soil occurs mainly during vegetative stage and reduces during reproductive development because of reduced root growth (Marschner, 1995). Similarly, when calcium is deficit in soils, new tissues in root tips, young leaves and shoot tips exhibit distorted growth due to improper cell wall formation. Lamikanra and Watson (2004) reported that, calcium regulates senescence and fruit softening in melons.

Among the micronutrients, boron is vital for growth and development and plays a major role in several

physiological processes such as nitrogen metabolism, protein formation, cell division and cell wall formation (Ahmad *et al.*, 2009) and metabolic functions such as translocation of carbohydrates, germination of pollen tube, pollen tube growth, fruit formation (Mengel and Kirkby, 1982), movement of potassium to the guard cells of stomata (Cakmak and Romheld, 1997). The deficiency of boron occurs worldwide and also observed as one of the most common among plant micronutrient deficiencies (Ganie *et al.*, 2013). In India, boron deficiency has been widely reported in tropical and subtropical regions due to high soil pH, low organic matter, high boron adsorption and poor crop management (Singh, 2001).

Melon crop is sensitive to nutrient deficiencies particularly under dry climates due to deficit moisture (Cabello *et al.*, 2009). Soil application of mineral nutrients requires repeated irrigation and causes low fruit quality, since melons are sensitive frequent irrigations that impair fruit quality. Foliar fertilizer application is an efficient way to improve the yield by enhancing the crop nutrient status during the periods of high nutrient demand (Lovatt, 2013) particularly during flowering and fruiting stage. Therefore this study was conducted to elucidate the importance of foliar application of nutrients viz., potassium, calcium and boron for realising the higher yields in a commercially grown muskmelon hybrid Pusa sharbati.

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Table 1. Effect of foliar application of fertilizers on flowering and yield of muskmelon cv. Pusa sharbati

Treatment	Day to 1 st staminate flower appearance	Days to 1 st pistillate flower appearance	Number of staminate flowers/plant	Number of pistillate flowers/plant	Number of fruits/ plant	Average fruit weight (kg)	Yield/ plant (kg)
T ₁	43.17	49.00	116.50	19.50	2.083	0.374	0.776
T ₂	43.67	52.83	121.67	14.33	1.500	0.403	0.607
T ₃	47.17	55.00	121.83	14.17	2.000	0.395	0.791
T ₄	42.17	52.50	120.83	17.67	1.833	0.471	0.864
T ₅	42.50	50.00	119.17	21.50	2.500	0.379	0.942
T ₆	50.50	55.83	126.50	11.50	1.583	0.308	0.489
CD at 5%	1.53	2.57	7.96	1.69	0.513	0.036	0.214

T₁ : Foliar spraying of borox @ 1 per centT₂ : Foliar spraying of potassium nitrate @ 6 per centT₃ : Foliar spraying of calcium nitrate @ 6 per centT₄ : Foliar spraying of borox @ 1 per cent + potassium nitrate @ 6 per centT₅ : Foliar spraying of borox @ 1 per cent + calcium nitrate @ 6 per centT₆ : Water spray

MATERIALS AND METHODS

The study was conducted during the year 2011-12 in farmer's field at Kadapa district of Andhra Pradesh with a commercially important variety Pusa Sharbati in a randomized block design with three replications. Muskmelon was raised as rice fallow crop following standard commercial practices for summer muskmelon production including irrigation, fertilizer management and plant protection. The study was initiated with foliar spraying of analytical grade nutrient fertilizers viz., borax, KNO_3 and CaNO_3 at 30 and 50 days after sowing in six treatment combinations namely, T_1 – Borax @ 1 per cent; T_2 - KNO_3 @ 6 per cent; T_3 - CaNO_3 @ 6 per cent; T_4 - Borax @ 1per cent + KNO_3 @ 6per cent; T_5 - Borax @ 1 per cent + CaNO_3 @ 6 per cent and T_6 - Control. Observations were recorded on days to first staminate flower appearance, days to first pistillate flower appearance, number of staminate flowers per plant, number of pistillate flowers/ plant, sex ratio, number of fruits per plant and yield per plant. Sex ratio was calculated as ratio of female flowers to male flowers. The data were statistically analyzed by WASP and the treatments were compared at 0.05 level of significance.

RESULTS AND DISCUSSION

The results from Table 1 indicated that , plants sprayed with 1per cent borax + 6 per cent KNO_3 (T_4) took significantly less number of days for appearance of first staminate flower (42.17) and was on par with the treatment T_5 (1 % borax + 6 % CaNO_3) (42.50 days). Similarly plants sprayed with 1 per cent borax + 6 per cent CaNO_3 recorded less number of days for first pistillate flower appearance and higher number of pistillate flowers per plant (21.50) and closely followed by T_4 treatment (1% Borax + 6 % CaNO_3) with 19.50 pistillate flowers/ plant. The control treatment with water sprays (T_6) recorded more number of days for first pistillate flower appearance (55.83) and less number of pistillate flowers/ plant (11.50). Foliar application of borax alone or in combination with KNO_3 and CaNO_3 resulted in early flowering and more number of flower but the effect is more pronounced in treatments where there was combination of fertilizers. The earliness in appearance of both male and female flowers, production of more pistillate flowers in plants treated with borax along with KNO_3 and CaNO_3 might be due to the fact that foliar application efficiently met the high nutrient demands of the crop during the period of experimentation. Rab and Haq (2012) also

reported the superior plant growth in tomato with foliar application of Ca + B as compared to the nutrients applied alone.

Similarly the plants sprayed with borax and CaNO_3 (T_5) recorded more number of fruits/pants (2.50) and higher yield per plant (0.949) followed by 2.08 fruits/plant and yield of 0.864 kg/plant in T_4 treatment (borax and KNO_3) (Table 1). Application of boron alone resulted in less number of fruits per plant (1.83) and lower yield (0.776 kg/plant). Combined spraying of borax + CaNO_3 and borax + KNO_3 recorded 57.9 and 31.6 per cent increase in number of fruits and 92.6 and 76.7 per cent higher yields, respectively when compared to control (water sprays). The application of boron enhances fruit set (Desouky *et al.*, 2009) as it regulates the carbohydrate metabolism and helps in absorption of water. Similarly increase in number of fruits and yield with KNO_3 and CaNO_3 application might be due to the continuous supply of food material which play a vital role in plant growth and development. Jifon and Lester (2011) in cantaloupe reported the enhance yield with foliar application of potassium fertilizer. Similarly, Rab and Haq (2012) reported the higher yield in tomato with the combined application of CaCl_2 and borax.

The results of this research showed that properly timed foliar application of borax in combination with either KNO_3 or CaNO_3 successfully increased the yield of commercially valuable muskmelon.

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EFFECT OF GROWTH REGULATORS ON IMPROVED SEEDLING VIGOUR INDEX OF SUGARCANE BUD CHIPS COLLECTED FROM DIFFERENT PORTIONS OF THE CANE

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ABSTRACT

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2003T121 is a promising pre released cultivar of sugarcane with a problem of sprouting when planted as bud chips as well as 3 budded setts. Bud chips from different portions of the cane (top, middle, bottom) were collected and subjected to pre plant soaking with different growth promoting chemicals viz., hydropriming for 24hours, GA₃@ 100ppm for one hour and BAP@50ppm for one hour. The experiment was conducted in split plot design with four main treatments and three sub treatments. Each treatment was replicated thrice. Bud chips collected from the top and middle portion of the cane treated with BAP @50ppm recorded significantly higher percentage of bud sprouting (48.53,39.45), seedling vigour index (469.04,284.15), shoot length (cm) (11.28,7.87) and also the activity of acid invertase enzyme (1 g invert sugars mg⁻¹ protein) (70.37,76.40). Bud chips collected from the top one third portion of the cane treated with BAP proved to be effective in improving the seedling vigour index.

KEYWORDS: Sugarcane bud chips, germination percentage, seedling vigour index, acid invertase.

INTRODUCTION

Sugarcane is an important commercial cash crop next to cotton grown between 30° N and 30° S. About 75 per cent of the world sugar (sucrose) is produced from sugarcane and the other 25 per cent comes from sugar beet.

Sugarcane is commercially planted using stalk cuttings or setts. In conventional system prevailing in India, about 6-8 tonnes of seed cane per hectare (nearly 10 per cent of produce) is used as planting material. This method of cultivation is gradually becoming uneconomical, as it accounts for over 20 per cent of the total cost of production besides posing a great problem in transport, handling and storage of seed cane which undergoes rapid deterioration and thereby decreasing the viability of buds.

A viable alternative to this method would be the plant excised auxillary buds of cane stalk called bud chips, which are less bulky, more economical and more easily transportable as seed material. Through bud chip method bud chip raised seedlings shall be transplanted instead of the normal sett planting. This component itself has evolved over a period of around 60 years. The noted Sugarcane Physiologist, Van Dillewijn (1952) was first to suggest that a small volume of tissue and a single root primordium adhering to the bud are enough to ensure germination in

sugarcane. However, this technology has not been scaled up at commercial level due to poor survival of bud chips under field conditions. Bud chips consist of lower food reserves (1.2 -1.8g sugar) per bud compared to conventional three budded sett material (6-8 g sugar per bud). The food reserves and moisture content in bud chips depletes faster compared to 2-3 bud setts which reflects in their poor sprouting and early growth.

2003T121 is a popular pre release cultivar of sugarcane for southern agroclimatic zone of Andhra Pradesh with higher yield potential, non flowering habit and good quality jaggery. But it has a specific problem related to field emergence both as setts and bud chips. Germination percentage in this cultivar is very poor (as low as 40 per cent) with a prolonged spread of germination period.

Thus, the present study was conducted to find out the effect of various growth promoting substances on improved sprouting and seedling vigour index of sugarcane bud chips collected from different parts of 2003T121 cane viz., top, middle and bottom.

MATERIAL AND METHODS

The experiment was conducted at department of crop physiology S.V Agricultural college, ANGRAU, Tirupati, situated in the southern agro-climatic zone of Andhra

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Pradesh. A promising pre released cultivar of sugarcane, 2003T121 was selected for this experiment. Experiment was laid out in split plot design. Bud chips collected from different portions of the cane were considered as main treatments and chemical treatments with growth promoting substances as sub treatments.

The treatments imposed in the experiment were shown below.

- M₁T₁. Bud chips of top portion of the cane-untreated
- M₁T₂. Bud chips of top portion of the cane- soaked in water for 24 hours.
- M₁T₃. Bud chips of top portion of the cane-soaked in GA₃ @ 100ppm for 1 hour.
- M₁T₄. Bud chips of top portion of the cane- soaked in BAP @ 50 ppm for 1 hour.
- M₂T₁. Bud chips of middle portion of the cane-untreated
- M₂T₂. Bud chips of middle portion of the cane-soaked in water for 24 hours.
- M₂T₃. Bud chips of middle portion of the cane-soaked in GA₃ @ 100ppm for 1 hour.
- M₂T₄. Bud chips of middle portion of the cane-soaked in BAP @ 50 ppm for 1 hour.
- M₃T₁. Bud chips of bottom portion of the cane-untreated
- M₃T₂. Bud chips of bottom portion of the cane-soaked in water for 24 hours.
- M₃T₃. Bud chips of bottom portion of the cane-soaked in GA₃ @ 100ppm for 1 hour.
- M₃T₄. Bud chips of bottom portion of the cane-soaked in BAP @ 50 ppm for 1 hour.

The experiment was conducted in 36 protrays. Each protrait was considered as one replication for each treatment. Each well of the protrait was filled with moist coco peat. The canes were collected from a healthy seven months old crop. Bud chips were collected from different portions of these canes using bud chipper machine. Each of the bud chip weighing nine grams was placed in the wells of protrait and covered with coco peat.

Observations on germination (bud sprouting) percentage, shoot length (cm) seedling vigour index and acid invertase activity (ig invert sugars mg⁻¹ protein) was recorded with 15 days interval.

Germination percentage

Germination percentage was calculated as follows.

Germination per cent =

$$\frac{\text{Number of bud chips germinated}}{\text{Total number of bud chips kept for germination}} \times 100$$

Shoot length

Shoot length was measured from the base of the plant to tip of the leaf and is expressed in centimetres.

Seedling vigour index

Seedling vigour index was calculated by using the following formula suggested by Abdul-baki and Anderson (1973).

Vigour index = (shoot length + root length) × germination percentage.

Acid invertase (ig invert sugars mg⁻¹ protein):

The activity of invertase was assayed according to the method of Malik and Singh (1980). The reducing sugar formed by the action of invertase was measured by dinitro salicylic acid reagent (Sumner, 1935).

0.3g of the bud tissue and 5ml of chilled tris-maleate buffer (pH 7.0) were homogenized in a blender, strained through two layers of cheese cloth and centrifuged at 17000 rpm for 30 min at 4°C in a refrigerated centrifuge. This supernatant was then used as a source of invertase.

0.4 ml of enzyme extract, 0.4 ml of 0.2M acetate buffer (pH 4.8), 0.2 ml of 0.2 M sucrose and were added in a test tube to give a total volume of 1 ml. In the control test tubes only the sucrose solution was added after the enzyme was inactivated by boiling for about 5 min. The test tubes were incubated at 30°C for 30 min. Then the test tubes were boiled for 10 min and diluted to 5 ml for the degradation of enzyme. Optical density was recorded with spectrophotometer (Model: Genesys 10S UV-VIS) at 560 nm to know the quantity of invert sugars (glucose and fructose).

Table 1. Effect of different growth promoting chemicals on germination percentage of bud chip seedlings

S. No.	Treatment	15 DAP				30 DAP			
		M1	M2	M3	MEAN	M1	M2	M3	MEAN
1.	T ₁ untreated	12.23	12.46	9.32	11.34	22.30	28.13	11.89	20.77
2.	T ₂ (water soaking)	18.17	14.04	11.25	14.49	31.17	25.71	19.72	25.53
3.	T ₃ (GA ₃ @100ppm)	19.37	18.76	13.35	17.16	46.10	40.42	30.49	39.00
4.	T ₄ (BAP @50 ppm)	23.87	25.71	16.04	21.87	48.53	39.45	29.51	39.16
	Mean	18.41	17.74	12.49		37.03	33.43	22.90	
		M	S	M × S		M	S	M × S	
	C.D (P= 0.05)	2.12	1.92	3.33		NS	8.57	NS	
	S.Em.±	0.54	0.62	1.15		3.14	2.88	4.99	

Table 2. Effect of different growth promoting chemicals on shoot length of bud chip seedlings

S. No.	Treatment	15 DAP				30 DAP			
		M1	M2	M3	MEAN	M1	M2	M3	MEAN
1.	T ₁ untreated	67.04	58.32	41.98	55.78	103.91	84.25	49.11	79.09
2.	T ₂ (water soaking)	92.96	103.39	76.01	90.79	123.36	97.73	78.38	99.82
3.	T ₃ (GA ₃ @100ppm)	107.54	99.84	96.50	101.29	292.72	163.01	105.10	186.94
4.	T ₄ (BAP @50 ppm)	123.38	146.49	104.61	124.83	469.04	284.15	113.53	288.91
	MEAN	97.73	102.01	79.78		247.26	157.28	86.53	
		M	S	M × S		M	S	M × S	
	C.D (P= 0.05)	13.43	15.63	NS		32.43	22.65	39.23	
	S.Em.±	3.42	5.26	9.11		8.26	7.62	13.20	

RESULTS AND DISCUSSION

Germination percentage

Germination percentage is more important in vegetatively propagated crops such as sugarcane. Incomplete germination brings wide gaps in the field with resultant low density of crop stand and yield (Subba Rao *et al.*, 1959).

Data on effect of different chemical treatments on survival percentage of bud chips was presented in Table.1.

Germination of bud chips were positively correlated with moisture and glucose content of bud tissue (Babu, 1979). Different chemical treatments showed significant difference in survival percentage. Among all treatments T₄ (BAP @50 ppm for 1 hour) recorded highest germination percentage (39.16,) followed by T₃ (GA₃ @100ppm for 1 hour) (39.00)

There was a significant difference in germination percentage of bud chips with respect to the portion of the cane from which they were collected. Bud chips collected from the top portion of the cane showed highest germination percentage (37.03).

Table 3. Effect of different growth promoting chemicals on seedling vigour index of bud chip seedlings

S. No.	Treatment	15 DAP				30 DAP			
		M1	M2	M3	MEAN	M1	M2	M3	MEAN
1.	T ₁ untreated	4.87	1.91	1.55	2.78	4.87	1.91	1.55	2.78
2.	T ₂ (water soaking)	3.87	1.77	1.31	2.31	3.87	1.77	1.64	2.43
3.	T ₃ (GA ₃ @100ppm)	5.38	2.39	1.80	3.19	7.38	4.39	2.47	4.74
4.	T ₄ (BAP @50 ppm)	8.55	5.37	1.44	5.12	11.22	7.87	4.14	7.74
	MEAN	5.67	2.86	1.53		6.83	3.98	2.45	
		M	S	M × S		M	S	M × S	
	C.D (P= 0.05)	0.47	0.36	0.63		0.64	0.52	0.89	
	S.Em.±	0.12	0.12	0.21		0.16	0.17	0.30	

Table 4. Effect of different growth promoting chemicals on acid invertase of bud chip seedlings

S. No.	Treatment	15 DAP				30 DAP			
		M1	M2	M3	MEAN	M1	M2	M3	MEAN
1.	T ₁ untreated	34.97	32.83	30.00	32.60	30.57	24.17	20.00	24.91
2.	T ₂ (water soaking)	35.70	36.40	32.90	35.00	32.67	26.50	22.90	27.36
3.	T ₃ (GA ₃ @100ppm)	69.33	51.00	46.80	55.71	56.37	42.30	33.47	44.04
4.	T ₄ (BAP @50 ppm)	86.67	84.73	75.63	82.34	70.37	76.40	65.93	70.90
	MEAN	56.67	51.24	46.33		47.49	42.34	35.58	
		M	S	M × S		M	S	M × S	
	C.D (P= 0.05)	4.01	5.13	8.89		5.33	6.97	NS	
	S.Em.±	1.02	1.73	2.99		1.36	2.35	5.06	

Similar results were corroborated with Singh *et al.* (2016). They observed that, in Sugarbeet, BAP (50iM) showed highest germination percentage among the treatments. Among different portions of the cane, bud chips collected from the top and middle portion of the cane showed highest germination percentage (37.03 and 33.43) because percentage of reducing sugars was more in this portion compared to that of bottom portion of the cane. This might be due to more availability of reducing sugars which were essential for germination and further establishment of the crop.

Shoot length (cm)

Data on effect of different chemical treatments on survival percentage of bud chips was presented in Table 2.

Different treatments showed significant difference in the shoot length of the seedlings raised from bud chips. Among the treatments T₄ (BAP @50 ppm for 1 hr) (7.74) followed by T₃ (GA₃ @100ppm for 1 hr) (4.74) recorded higher shoot length. Bud chips collected from different portion of the cane also showed significant difference with respect to shoot length. M₁ (bud chips of top portion of

the cane) showed highest shoot length (6.83) compared to the other two. Interaction of M_1T_4 showed significantly highest shoot length (11.22) followed by M_2T_4 (7.87). M_3T_1 recorded least shoot length (1.55). Jain *et al.* (2011) revealed that BAP (50iM) treated sugarcane bud chip raised seedlings also recorded higher shoot length as they promote cell division, growth, differentiation of cells and synthesis of sucrose in growing meristem of sugarcane. This might be related to the biological function of the kinetin to induce the cell division and cell enlargement.

Seedling vigour index

Data on effect of different chemical treatments on seedling vigour index was presented in table 3.

Significant difference was observed among the treatments with respect to seedling vigour index. Among the mean values of seedling vigour index T_4 (BAP @50 ppm for 1 hour) recorded significantly highest seedling vigour index (288.91) followed by T_3 (GA₃ @100ppm for 1 hour) (186.94). Bud chips collected from the top portion of the cane showed significantly highest seedling vigour index (247.26) compared to that of bud chips collected from other portions of the cane. Interaction of M_1T_4 (bud chips collected from the top portion of the cane treated with BAP @50 ppm for 1 hour) recorded highest seedling vigor index (469.04) followed by M_2T_4 (bud chips collected from the middle portion of the cane treated with BAP @50 ppm for 1 hour) (284.15).

Similar results were corroborated with Singh *et al.* (2016). They revealed that bud chips collected from top portion of the cane showed better results with respect to seedling vigor index compared to bud chips collected from the bottom portion of the cane. According to them, it was due to the conversion of reducing sugars in to non reducing sugars in the bottom portion of the cane.

Acid invertase

Acid invertase is essential for germination of buds in sugarcane. It converts non reducing sugars in to reducing sugars. Results pertaining to this were depicted table. 4.

All the treatments differed significantly with respect to acid invertase activity. Among the treatments T_4 (BAP @50 ppm for 1 hour) recorded highest invertase activity (70.90ig invert sugars mg⁻¹ protein) compared to untreated bud chips (24.91ig invert sugars mg⁻¹ protein). Significant difference was observed in activity of acid invertase

enzyme with different portions of the cane. Top portion of the cane recorded significantly highest enzyme activity (47.49 ig invert sugars mg⁻¹ protein). Very less enzyme activity was observed in the bud chips collected from bottom portion of the cane (35.58ig invert sugars mg⁻¹ protein). The low enzyme activity in the bottom portion of the cane might be the reason for less conversion and more accumulation of non reducing sugars.

In general, acid invertase activity was observed to be more at 15 days after planting compared to that of 30 days after planting in all the treatments.

CONCLUSION

Morpho-physiological and growth attributes were affected by different chemical treatments. Different growth attributes viz., germination percentage, shoot length and seedling vigour index and also the activity of acid invertase enzyme was found to be the highest in bud chips collected from both top and middle portion of the cane and treated with BAP (50ppm). Bud chips collected from the bottom portion of the cane showed less germination percentage. Better germination and further establishment of the crop from the bud chips of top and middle portion of the cane might be due to the faster inversion of the sugars associated with higher activity of acid invertase in those portions of the cane.

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EVALUATION OF CASHEW HYBRIDS FOR COASTAL AREA OF ANDHRA PRADESH

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ABSTRACT

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A field experiment was conducted at AICRP on Cashew, Cashew Research station, Dr. YSR Horticultural University Bapatla, Andhra Pradesh during 2002-15, to evaluate the performance of different new entries of cashew genotypes developed at different centers for their sustainability/adaptability. The experiment was laid out in randomized block design with three replications and ten genotypes and local check (BPP-8). In each treatment, four plants were accommodated with a spacing of 7.5×7.5 m. The results revealed that local check variety BPP-8 performed better over the other genotypes during the period of study. The variety BPP-8 recorded maximum vegetative growth parameters such as canopy height, canopy spread and canopy surface area (4.35 m, 9.19 m and 91.63 m^2). However plant height and trunk girth was found maximum in genotype H-32/4 (4.71 m and 98.53 m^2) followed by BPP-8 (4.50 m and 85.66 m^2). The variety BPP-8 recorded a mean maximum annual nut yield per tree ($8.16 \text{ kg tree}^{-1}$) and maximum mean cumulative nut yield ($54.32 \text{ kg tree}^{-1}$) for eight annual harvests. The variety BPP-8 have been identified as suitable variety for rainfed cultivation in coastal area of Andhra Pradesh.

KEYWORDS: High Yielding Varieties (HYV), Genotypes, F_1 hybrids, Vegetative growth, Nut yield, Cashew kernel.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) belonging to the family Anacardiaceae was introduced from Brazil to India by the Portuguese during 16 century for afforestation as well as soil conservation purposes. Presently, cashew is treated as “wonder nut of the world” having nutrient rich kernel. Cashew kernel is a good source of protein (21%), fat (47%), carbohydrate (22%) and minerals. Cashew nut shell liquid (CSNL), by product of cashew nut is also treated as valuable raw materials for paints and varnish industries. The leading cashew growing state are coastal regions of Maharashtra, Goa, Karnataka, and Kerala in Tamil Nadu, Andhra Pradesh, Odisha and West Bengal in the East. The total production of cashew in India is 7.28 lakh tonnes from an area of 9.82 lakh hectare during 2012-13 (Saroj et al., 2014). Although during last 13 years, there is steady increase in both area and production of cashew in India, but the productivity rate is very low ranging from 600 to 800 kg ha^{-1} with an average of hardly 772 kg ha^{-1} as against potential productivity of 2000 kg ha^{-1} . The primary reasons of low productivity of Indian cashew are due to existence of large areas under old senile plantation. Therefore, this low productivity of cashew can be addressed effectively by developing cashew genotypes with high yielding potential and adoption

of scientific orchard management practices including proper plant protection measures. Keeping this in view, the present investigation was undertaken to evaluate the developed F hybrids for vegetative as well as nut yield under Andhrapradesh condition.

MATERIALS AND METHODS

The 11 genotypes/Verities/Hybrids released from different research centers in Madakathara (H 1597 and K 22-1), RFRS Vengurla (H 662 and H 675) RRS Vridhachalam (H-11 and H-14) NRCC Puttur (H 32/4 and Goa 11/6) CRS Bhubaneswar (BH 85 and BH-6) and Andhra Pradesh (BPP-8) were tested for their performance in comparison with the BPP-8 commercial cultivar.

The field experiment was conducted at AICRP on cashew, Cashew Research Station, Bapatla Dr YSR Horticultural University Andhra Pradesh for the period from 2003 to 2016. To study the performance of different new entries of cashew verities at Bapatla centre. The experiment was laid out in randomized block design with 11 new cashew entries replicated thrice. They were planted at $7.5 \times 7.5 \text{ m}^2$ spacing and accommodated 4 no. of plants per each treatment and adopting recommended package of practices uniformly. The vegetative growth

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Table 1. Mean performance of vegetative growth parameters of 11 genotypes of cashew (Year of planting 2002)

S. No	Variety/Genotype	Mean plant height (m)	Canopy height (m)	Trunk girth (cm)	Mean canopy spread (m)	Canopy surface area (m ²)
1.	Goa 11/6	4.40	3.96	90.0	7.27	60.28
2.	H.662	2.69	2.41	61.6	4.75	25.65
3.	H.32/4	4.71	4.34	98.53	7.60	63.50
4.	K.22/1	4.41	4.15	82.33	7.01	55.03
5.	H.11	4.01	3.62	75.60	6.43	49.57
6.	H.675	3.96	3.65	75.43	6.43	49.57
7.	H.14	3.97	3.40	71.0	6.10	43.99
8.	BPP-8	4.50	4.35	85.66	9.19	91.63
9.	H.1597	4.11	3.78	76.0	6.85	55.97
10.	B.H.6	4.27	3.87	76.0	6.85	55.97
11.	B.H.85	4.30	3.93	78.5	7.09	62.24
	SEM $\pm$	0.255	0.266	5.02	0.597	8.57
	CD@5%	0.757	0.791	14.92	1.774	25.48

Table 2. Mean performance of yield parameters of 11 genotypes of cashew (Year of planting 2002)

S. No.	Verities/ Genotypes	Date of first flowering	Date of last flowering	Duration of flowering (days)	Flowering intensity/Sq.mt	Sex ratio	Mean no of nuts/m ²	Mean no of nuts/panicle
1.	Goa 11/6	26-02-15	15-05-15	79.0	20.50	0.24	19.08	3.33
2.	H.662	10-03-15	09-05-15	61.0	8.20	0.15	13.5	2.5
3.	H.32/4	11-03-15	13-05-15	64.0	8.75	0.20	17.73	3.9
4.	K.22/1	01-03-15	14-05-15	74.0	21.41	0.15	20.8	2.44
5.	H.11	07-03-15	16-05-15	71.0	21.8	0.07	20.06	1.77
6.	H.675	10-03-15	20-05-15	73.0	13.31	0.35	22.96	3.43
7.	H.14	04-03-15	10-05-15	68.0	13.66	0.31	22.4	3.63
8.	BPP-8	20-01-15	10-04-15	80.0	15.3	0.07	18.42	2.50
9.	H.1597	22-02-15	15-05-15	82.0	23.0	0.11	21.3	2.25
10.	B.H.6	25-01-15	01-05-15	96.0	21.29	0.15	25.6	2.38
11.	B.H.85	30-01-15	05-05-15	95.0	21.5	0.14	31.33	2.50
	SEM $\pm$				2.85	0.008	4.11	0.369
	CD@5%				8.48	0.023	12.23	1.097

Table 3. Mean performance of yield parameters of 11 genotypes of cashew (Year of planting 2002)

S. No.	Variety/Genotype	Nut yield/tree (Harvest No. 8) Kg	CNY/tree (2008-2015) (kg)	Nut weight (g)	Apple weight (g)	Shelling (%)
1.	Goa 11/6	6.06	37.65	5.83	57.00	30.59
2.	H.662	4.62	18.5	5.83	57.33	30.03
3.	H.32/4	7.46	44.03	6.75	55.33	32.20
4.	K.22/1	4.08	23.82	5.94	54.0	31.73
5.	H.11	4.66	28.41	4.87	38.42	31.0
6.	H.675	4.23	23.60	3.96	27.66	28.86
7.	H.14	6.11	32.94	4.37	30.33	29.93
8.	BPP-8	8.16	54.32	6.93	55.33	29.27
9.	H.1597	6.70	34.93	5.68	56.0	28.38
10.	B.H.6	3.53	32.19	7.00	73.53	28.37
11.	B.H.85	6.13	28.74	4.62	31.0	29.75
	SEM $\pm$	1.77		0.184	14.70	9.02
	CD@5%	NS		0.547	NS	NS

parameters such as plant height, Trunk girth, Canopy height canopy spread and canopy surface area were recorded. Then the ground coverage by canopy was worked out using following procedure.

Radius of canopy (m), $r = (D1 + D2)/4$

D1: Canopy spread in E-W direction (m)

D2: Canopy diameter in N-S direction (m)

Ground coverage by canopy (m^2), $A = r^2$

% of ground coverage by canopy = Ground coverage by canopy / Actual area on the ground

Similarly, nut yield and yield attributing parameters were recorded from individual plants from each treatment year wise and mean data were considered for statistical analysis. Fresh and dry weights of a sub sample of 50 nuts from each tree was determined. The dry weight was recorded as per sun drying the nuts for at least 5-6 days. The weight per unit including shell was determined at 14% moisture as per the industrial standard (Kuppelweiser, 1989). The yield per tree was calculated as follows.

Nut yield = Mean nut weight $\times$ Total number of nuts per tree.

The statistical analysis was carried out by adopting the procedure suggested by Panse and Sukhatme (1989).

During the initial years of growth, lower branches were removed uniformly for convenience of intercultural operations and also to give a proper canopy shape to the plantation. Pruning was adapted uniformly to all the plants in the experiment as per the requirements.

RESULTS AND DISCUSSION

Among the 11 genotypes evaluated the mean plant height recorded highest in H-32/4 (4.71 m) followed by BPP-8 (4.50 m). The mean canopy height, canopy spread and canopy surface area was recorded maximum in BPP-8 (4.35 m, 9.19 m and 91.63 m^2) (Table 1).

Among the genotypes evaluated the mean plant height and trunk girth was recorded maximum in H-32/4 (4.71 m and 98.53 cm) followed by BPP-8 (4.50 m and 85.66 cm) (Table 1).

The flowering intensity, Number of nuts per panicle and mean number of nuts per square meter was found to be significant among the 11 genotypes. Among the different 11 genotypes the duration of flowering was ranges from 61.0 days to 96.0 days. The flowering intensity per square meter was highest in H-1597 (23.0 days) which was significantly superior followed by H-11 (21.8). The sex ratio was ranged from 0.07 to 0.35 among the different genotypes (Table 2).

The maximum mean annual nut yield per tree during the year was recorded in BPP-8 (8.16 kg tree⁻¹) and cumulative nut yield per tree was also found maximum in BPP-8 (54.32 kg tree⁻¹) for 8 annual harvests. To the mean apple weight was recorded maximum in BH-6 (73.53 g).

CONCLUSION

The commercial var BPP-8, performed very well (interus of annaul net yield per tree), at cashew research station, Bapatla. Compared to an other genotypes, which were released from different agroclimatic zones of India.

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