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Evaluation of tillage practices on the productivity and profitability of sugarcane in calcareous soil of Bihar

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ABSTRACT

A field experiment was conducted at Pusa (Bihar) during spring seasons of 2006 – 07 and 2007 – 08 to evaluate various tillage practices (conventional tillage, two harrowing, rotavator twice, rotavator once and no tillage) on growth, yield and economics of sugarcane (*Saccharum* hybrid complex). Results revealed that conventional tillage gave significantly higher number of shoots (1,20600 and 1,17200/ha), plant height (237 and 232 cm), millable canes (1,02200 and 1,00200/ha) and single cane weight (860 and 850 g) than that of other tillage practices during 2006-07 and 2007-08, respectively. Conventional filled sugarcane significantly out yielded other tillage practices in respect of cane and sugar yield also. The magnitude of increase in cane yield by conventional tillage, rotavator twice, rotavator once and two harrowing over no tillage practice was 49.9, 29.6, 26.1 and 17.9 % in 2006-07 and 48.1, 27.7, 27.0 and 15.5 % in 2007-08, respectively. Similarly, conventional tillage produced significantly higher net returns (47,928 and 46,723) and benefit: cost ratio (1.92 and 1.89) respectively over others, during first and second years of experimentation.

Key words: Economic returns, Production Potential, Sugarcane, Tillage practices

Sugarcane is an important industrial crop of India grown primarily for sugar. Recently, efforts on reduced tillage system in sugarcane too is gaining ground because of saving in time and economic inputs. Therefore, it becomes imperative to sustain the productivity of sugarcane based production system through reduced tillage system. It permits management of water and soil for agricultural production without excessive disturbance to soil. Zero or no tillage is emerging a way of transition to sustainability of intensive production system, besides, generating net social gains to society (Bhale and Wanjari, 2009). Tillage is a critical practice in crop production as it provides favourable soil conditions for crop growth and development. Conventional tillage method is observed to be costlier inputs which needs refinement for higher monetary returns. Thus, minimum tillage practices are gaining popularity in recent years and challenging the need of pre-planting conventional tillage operation in sugarcane cultivation. Therfore, the study was undertaken to assess the performance of different tillage practices on yield, quality and economics of sugarcane.

MATERIALS AND METHODS

A field experiments was conducted during spring seasons of 2006-07 and 2007-08 at Sugarcane Research Institute, Pusa (Bihar). The soil was sandy loam, having 8.3 pH, 0.46 % organic carbon, 25.8 % free $CaCO_3$, available N, P and K levels of 225, 10.8 and 89 kg/ha, respectively. Five tillage practices *viz.,* T_1 : Conventional tillage; T_2 : Two harrowing; T_3 : Rotavator twice; T_4 : Rotavator once and T_5: No tillage, were tried in a randomized block design with four replications. Conventional tillage consists of disc ploughing once + cultivator twice + leveler, whereas, no tillage included planting directly by opening furrows and leveling. Fertilizers were applied uniformly in all the plots through urea, diammonium phosphate and muriate of potash @ 150 kg N, 85 kg P_2O_5 and 60 kg K_2O/ha in both the years. Half the nitrogen and full quantity of phosphate and potash were given as basal dressing and the remaining nitrogen was top dressed in two equal splits just after the first irrigation in and before onset of mantion. Sugarcane was planted in third week of February and harvested in first week of January during both the years. Normal seed rate of 60 q/ha was used in all the treatments. The mean rainfall received during both the cropping seasons was 1275.7 mm. Other operations were performed as per normal package of practices. Observations on germination and shoots were recorded at 45 and 125 days after planting, respectively. At the time of harvesting observations on cane length, girth, weight, millable canes, juice quality and cane yield were recorded. The sugar yield was obtained by multiplying the CCS % with cane yield. For economic evaluation, prevailing market prices of both the seasons were taken into account to work out economics of different treatments.

RESULTS AND DISCUSSION

Growth and yield attributes

Germination % of cane buds did not differ significantly under different tillage practices treatments (Table 1). Singh *et al.* (2008) found similar results of tillage practices on germination % of cane. However, number of shoots, plant height as well as millable cane and single cane weight of sugarcane exhibited significant differences under various tillage methods (Table 1). The highest number of shoots (1,20600 and 1,17200/ha) were recorded under planting with conventional tillage, which was significantly superior to rest of the tillage practices treatments during first and second years, respectively. Though, two harrowing, rotavator twice and rotavator once were at par with each other, and all of them were significantly superior to no tillage during both the years. Fine tilth and better aeration under conventional tillage less apparantly impedance to sugarcane roots was responsible for better root development, thereby producing higher number of tillers. Similarly, significantly higher cane height was recorded due to conventional tillage (237 and 232 cm) during 2006-07 and 2007-08, respectively. Though, it was statistically on par with rotavator twice during second year of investigation. Such beneficial effect of conventional tillage might be due to increased availability of soil moisture which prevented runoff, and therefore, more water was absorbed in the soil profile resulted in higher cane height under these treatments. Significantly higher number of millable cane (1,02200 and 1,00200/ha) were recorded under conventional tillage practices, and it was significantly superior to rest of the tillage practices. Number of millable canes under two harrowing (85100 and 83,900/ha), rotavator twice (90,800 and 89,800/ha) and rotavator once (89,100 and 89,000/ha) were at par with each other, and all of them were significantly superior to no tillage (73,800 and 73,300) during 2006-07 and 2007-08, respectively. Higher number of millable canes under conventional tillage due to various favourable factors like minimum crop- weed competition, proper placement of sets in the more pulverized soil created by conventional tillage and availability of sufficient moisture content, helped the crop toattain more vigour of cane plants than that of other fillage practices. These results are close conformity with the findings of Sinare and Sonawane (2011). Conventional tillage recorded significantly higher cane weight (860 and 850 g) followed by rotavator twice (844 and 840 g) and rotavator once (838 and 822 g) and minimum cane weight was recorded under no tillage practice (800 and 795 g) during first and second years, respectively. The thicker canes under conventional tillage method may be ascribed to higher dry matter production and translocation and conversion of photosynthates into reproductive parts.

Yield and quality

The cane yield was significantly affected by various tillage practices (Table 2). The yield recorded under conventional tillage practice was out-yielded (86.8 and 86.2 t/ha) over rest of the tillage practices, however, two harrowing, rotavator twice and rotavator once were at par among

Table 1. Effect of tillage practices on growth and yield attributes of sugarcane

Treatment	Germination %		Shoots (000/ha)		Millable canes (000/ha)		Plant height (cm)		Single cane weight (g)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Conventional tillage	36.5	32.9	120.6	117.2	237	232	102.2	100.2	860	850
Two harrowing	34.1	31.0	102.7	101.2	210	203	85.1	83.9	819	801
Rotavator twice	36.2	33.1	109.1	108.1	219	222	90.8	89.8	844	840
Rotavator once	35.6	32.3	103.2	102.3	220	212	89.1	89.0	838	822
No tillage	32.4	29.4	93.6	92.7	201	199	73.8	73.3	800	795
SEm (±)	1.37	1.25	2.63	2.81	4.93	4.39	2.26	2.55	8.38	5.82
CD (P=0.05)	NS	NS	7.8	8.5	15	13	7.3	7.9	25	18

Table 2. Yield and quality of sugarcane as influenced by various tillage practices

Treatment	Cane yield (t/ha)			Pol % juice			Sugar yield (t/ha)		
	2006-07	2007-08	Mean	2006-07	2007-08	Mean	2006-07	2007-08	Mean
Conventional tillage	86.8	86.2	86.5	17.44	17.23	17.34	9.45	9.40	9.43
Two harrowing	69.7	67.2	68.5	17.47	16.72	17.10	7.40	7.33	7.37
Rotavator twice	76.6	73.9	75.3	17.41	17.25	17.33	8.70	8.46	8.58
Rotavator once	74.5	74.3	74.4	17.37	17.21	17.29	8.55	8.61	8.58
No tillage	59.1	58.2	58.7	16.96	17.22	17.09	6.86	6.79	6.83
SEm (±)	3.27	3.43	-	0.190	0.180	-	0.381	0.450	-
CD (P=0.05)	9.9	10.2	-	NS	NS	-	1.09	1.26	-

Table 3. Influence of various tillage practices on cost of production, gross return, net return and benefit -cost ratio of sugarcane

Treatment	Cost of cultivation (₹/ha)			Gross return (₹/ha)			Net return (₹/ha)			B : C ratio		
	2006-07	2007-08	Mean	2006-07	2007-08	Mean	2006-07	2007-08	Mean	2006-07	2007-08	Mean
Conventional tillage	51892	52292	52092	99820	99015	99418	47928	46723	47326	1.92	1.89	1.91
Two harrowing	49942	50192	50067	80155	77165	78660	30213	26973	28593	1.60	1.54	1.57
Rotavator twice	51692	51692	51692	88090	84985	86538	36398	33293	34846	1.70	1.64	1.67
Rotavator once	50492	50492	50492	85674	85445	85560	35182	34953	35068	1.70	1.69	1.70
No tillage	48692	51505	50099	67965	66930	67447	19273	15429	17351	1.40	1.30	1.35
SEm (±)	-	-	-	3165.6	3143.4	-	2302.7	2169.3	-	0.031	0.059	-
CD (P=0.05)	-	-	-	9500	9422	-	6914	6515	-	0.09	0.18	-

themselves, and all of them were significantly superior to no tillage treatment during 2006-07 and 2007-08, respectively. Pre-planting conventional tillage promoted better root-system as reflected by higher values of growth and yield attributes, which were ultimately responsible for increased cane yield under this treatment. Furthermore, the increase in yield of sugarcane under conventional tillage could be attributed to higher number of millable canes and cane weight. However, pol % juice of sugarcane exhibited non-significant differences under different tillage practices during both the years. Tillage practices had significant impact on sugar yield during both the years (Table 2) and maximum sugar yield (9.45 and 9.40 t/ha) was recorded under conventional tillage. Though, it was statistically similar to rotavator twice (8.70 and 8.46 t/ha) and rotavator once (8.55 and 8.61 t/ha) and all of them were significantly superior to no tillage (6.86 and 6.79 t/ha) during 2006-07 and 2007-08, respectively. The increase in sugar yield was due to higher cane yield under these treatments.

Economics

Economic analysis of tillage practices methods showed significant impact on gross return, net return and benefit : cost ratio (Table 3) during both the years. Maximum gross return (Rs. 99,820 and 99,015) was recorded under conventional tillage, and it was significantly superior to rest of the tillage practices during 2006-07 and 2007-08, respectively. Significantly higher net return was recorded due to the conventional practice of tillage (Rs.47,928 and 46,723) which was significantly higher than rest of the tillage practices during first and second year, respectively. Similarly, higher benefit : cost ratio was recorded under conventional tillage practices (1.92 and 1.89) and minimum being recorded under no tillage method (1.40 and 1.30) during first and second year, respectively.

From the two years study on mean basis, it is concluded that the pre-planting operation under, conventional tillage (Disc ploughing once + twice harrowing + leveler) produced maximum cane yield (86.5 t/ha), sugar yield (9.43 t/ha), and net monetary return (Rs.47,326/ha) and thus proved to be essential for higher productivity and profitability of sugarcane in calciorthents soils of Bihar.

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Studies on the effect of sett size, seed rate and sett treatment on yield and quality of sugarcane

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ABSTRACT

A field experiment was conducted for three consecutive years (2008-09 to 2010-11) to study the effect of size of the sett, seed rate and sett treatment on yield and quality of sugarcane at Regional Agricultural Research Station, Anakapalle (A.P.). The results of the experiment indicated that, planting of sugarcane with 2 bud setts, (86.3 t/ha) or 3 bud setts (84.9 t/ha) proved significantly superior in increasing cane yield as compared to single bud setts (77.9 t/ha) during all the three years of experimentation. The increase in cane yield was 10.8 % and 8.9 % in 3 bud setts and 2 bud setts respectively over single bud setts. Similar increase in cane yield was observed with normal seed rate of 1,20,000 buds /ha (86.2 t/ha) as compared to lower seed rate of 80,000 buds / ha (80.2 t/ha). Significant differences in cane yield were not observed due to sett treatment either with Carbendazim alone @ 0.1% (83.0 t/ha) or Carbendazim @ 0.1% + Gibberellic acid @ 100 ppm for 15 minutes (84.0 t/ha). Sucrose content in juice did not vary with sett size or seed rate or sett treatment. In respect of sugar yield, higher sugar yield was obtained with 2 bud or three bud setts at normal seed rate of 1,20,000 buds/ha.

Key words : Cane yield, Carbendazim, Gibberellic acid, Sett size, Sucrose, Sugarcane

Sugarcane is vegetatively propagated crop through stem cuttings (setts) for the establishment of commercial fields. Sugarcane production cost is becoming high due to increase in labour cost and inputs including seed. Seed is the costlier input in sugarcane cultivation and accounts for nearly 25% of the total operational cost in sugarcane. Generally, 40,000 three bud setts from 10 tons/ha of short crop (seed crop) or top 1/3 portion of healthy matured cane is recommended for sugarcane grown under irrigated conditions. Saving of seed material by changing type of seed material (sett size) and seed rate without any deleterious effect on plant stand may help in getting higher cane yield with lower cost of production. Hence, to reduce the cost of production through seed economy technologies the experiment was conducted.

MATERIALS AND METHODS

A field experiment was executed for three years from 2008-09 to 2010-11 consecutively in a sandy loam soil of Regional Agricultural Research Station, Anakapalle (Andhra Pradesh). The soil of experimental plot was neutral in reaction (p^H : 7.0), low in organic carbon (0.54%) and nitrogen (207.9 kg/ha), medium in P_2O_5 (22.7 kg/ha) and high in K_2O (305.8 kg /ha). The treatments consisted of three types of seed material *viz.,* three bud setts, two bud setts, and single bud setts, two seed rates, *viz.,* 1,20,000 buds / ha and 80,000 bud setts and two sett treatments (Carbendazim @ 0.1% for 15 minutes and Carbendazim 0.1% + GA @ 100 ppm for 15 minutes).

The experiment was conducted in randomized block design with factorial concept and replicated thrice. The variety used was 93A145. Three, two and single budded healthy cane setts having viable buds were planted after sett treatment in different treatmental plots. The crop was uniformly fertilized with recommended dose of 112 kg N, 100 kg P_2O_5 and 120 kg K_2O/ha. The crop was planted during first fortnight of February and harvested in December month during all the three years of experimentation.

RESULTS AND DISCUSSION

Per cent germination

Germination counts were recorded at 35th day after planting of different setts. Significant variation in germination percent was observed with different treatments during all the three years of experimentation (Table-1). Significantly higher germination per cent was recorded with three budded setts (64.1%) or two bud setts (63.1%) as compared to single bud setts (51.9%). Increase in germination per cent due to planting of two bud setts and three bud setts was 19.5% and 17.6%, respectively over single bud setts. Similar results were also reported by Singh *et al.* (2008).

Table 1. Per cent germination and yield attributes of sugarcane as influenced by sett size, seed rate and sett treatment

Treatment	Percent germination				NMC / ha				LMC (cm)			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
Sett size (no. of buds per sett)												
Three bud setts	61.5	60.1	64.1	61.9	82645	78018	73112	77925	302.5	253.5	260.8	272.3
Two bud setts	63.1	62.5	63.1	62.9	84163	79113	74090	79122	300.0	254.0	261.1	271.7
Single bud setts	55.4	50.6	51.9	52.6	73808	69375	64713	69299	300.8	255.6	264.0	273.5
SE(m) ±	0.5	0.4	0.6	0.5	547	885	1017	816	0.6	1.26	1.81	1.2
CD (0.05)	1.4	1.1	1.7	1.4	1526	2469	2939	2311	NS	NS	NS	0.0
Seed rate (No.of buds/ ha)												
1,20,000 buds / ha	59.4	57.2	59.8	58.8	82098	77575	72381	77351	302.0	253.5	261.2	272.2
80,000 buds / ha	60.6	58.2	59.6	59.4	78315	73005	68105	73142	300.2	255.1	263.5	272.9
SE(m) ±	0.4	0.3	0.5	0.4	446	603	908	596	0.8	0.9	1.3	1.0
CD (0.05)	NS	NS	NS	NS	1235	1682	2624	1847	NS	NS	NS	0.0
Sett treatment												
Carbendazim 0.1 % for 15 minutes	59.8	57.4	60.4	59.2	80386	75659	70538	75528	300.1	253.6	261.2	271.6
Carbendazim + GA @ 100 ppm for 15 minutes	61.3	58.4	59.1	59.6	81051	75898	70724	75891	302.7	254.9	262.5	273.4
SE(m) ±	0.4	0.3	0.5	0.4	446	603	908	596	0.6	0.9	1.3	0.9
CD (0.05)	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Decreasing the seed rate by 25% of normal seed rate or sett treatment with Carbendazim 0.1% or Carbendazim 0.1% + GA @ 100 ppm for 15 minutes did not improve the germination per cent during 2009-10 and 2010-11 years.

Number of millable canes

The effect of seed size on number of millable canes was significant (Table-1) during all the three years of experimentation. Planting of two bud setts (79,122 /ha) and three bud setts (77,925 /ha) gave significantly higher number of millable canes as compared to small seed size of single bud setts (69,299 /ha). This might be due to higher germination per cent in two bud setts and three bud setts than in single bud setts. These results are in conformity with the findings of Singh *et al.* (2008). Normal seed rate of 1,20,000 buds/ha improved the number of millable canes (72,381/ha) as compared to lesser seed rate of 80,000 buds/ha *i.e.* 25% lesser seed rate (68,105 /ha). This may be due to decrease in seed rate did not improve the tiller population to a considerable extent. Sett treatment with Carbendazim @ 0.1% (75,528 /ha) or Carbendazim @ 0.1% + Gibberellic acid @ 100 ppm for 15 minutes (75,891 /ha) did not exhibit any beneficial effect on millable cane number. These results are in conformity with Sogheir and Mohamed (2003).

Length of millable cane

Length of millable cane did not vary significantly either due to sett size or seed rate or sett treatment during all the three of experimentation (Table-1). However, the mean length of millable cane in different treatments ranged from 271.6 cm to 273.5 cm.

Table 2. Yield and quality of sugarcane as influenced by sett size, seed rate and sett treatment.

Treatment	Percent sucrose				CCS (%)				Cane yield (t/ha)				Sugar yield (t/ha)			
	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean	2008-09	2009-10	2010-11	Mean
Sett size (no. of buds per sett)																
Three bud setts	18.59	17.31	17.91	17.94	13.90	12.28	11.91	12.70	90.9	84.8	78.9	84.9	11.9	10.4	9.5	10.6
Two bud setts	18.58	17.39	17.98	17.98	13.05	12.21	12.01	12.42	92.7	85.8	80.5	86.3	12.1	10.5	9.7	10.8
Single bud setts	18.62	17.3	17.77	17.90	13.05	12.07	11.8	12.31	84.1	77.8	71.8	77.9	11.0	9.4	8.5	9.6
SE(m) ±	0.04	0.08	0.06	0.06	0.08	0.05	0.08	0.07	0.7	0.8	2.5	1.33				
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	2.1	2.4	6.3	3.6				
Seed rate (No. of buds / ha)																
1,20,000 buds / ha	18.62	17.39	17.86	17.96	13.20	12.33	11.86	12.46	92.3	86.1	80.2	86.2	12.2	10.6	9.5	10.8
80,000 buds / ha	18.57	17.28	17.93	17.93	13.07	12.16	12.05	12.43	86.2	80.5	73.8	80.2	11.3	9.8	8.9	10.0
SE(m) ±	0.03	0.06	0.05	0.047	0.06	0.04	0.07	0.057	0.6	0.7	2.1	1.13				
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	1.7	2.1	5.1	2.97				
Sett treatment																
Carbendazim 0.1 % for 15 minutes	18.58	17.32	17.78	17.89	13.17	12.28	11.9	12.45	89.4	82.6	77	83.0	11.8	10.1	9.2	10.4
Carbendazim + GA @ 100 ppm for 15 minutes	18.65	17.35	18.01	18.00	13.12	12.2	12.03	12.45	90.2	83.5	78.2	84.0	11.8	10.2	9.5	10.5
SE(m) ±	0.04	0.06	0.05	0.05	0.06	0.04	0.07	0.057	0.7	0.8	2.1	1.2				
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				

Sucrose per cent juice

Results of cane juice analysed for sucrose content at harvest, *i.e.,* 10 months age of the crop in Table-2. The differences in sucrose per cent juice due to different treatments *i.e.* seed rate or sett size or sett treatment was found to be non-significant during all the three years of study. Similar results were also reported by Singh *et al.* (1996) and Singh et al (2008). The mean percent juice sucrose in different treatments ranged from 17.93 % to 18.00 % .

Commercial cane sugar (CCS%)

Commercial cane sugar percent did not differ due to sett size or seed rate or sett treatments during all the three years of experimentation (Table-2). This may be due to non-significant variation in percent juice sucrose values in different treatments. These results were in corroboration with Singh *et al.* (2008).

Cane yield

Data related to cane yield and sugar yield are presented in Table 2. Cane yield varied significantly due to sett size during all the three years of experimentation. The pooled data also differed significantly with size of the sett. Planting of cane with two bud setts (86.3 t/ha) or three bud setts (84.9 t/ha) gave significantly higher cane yield than single bud setts (77.9 t/ha). This might be due to improved germination percentage and number of millable canes in two bud setts and three bud setts. These results are in conformity with the findings of Geddawy *et al.* (2002), Sogheir and Mohamed (2003) and Singh *et al.* (2008).

The effect of seed rate on cane yield was found significant during all the three years of field experimentation. The pooled data revealed that significantly higher cane yield was recorded with normal seed rate of 1,20,000 buds / ha (86,2 t/ha) and proved superior to lower seed rate of 80,000 buds / ha (80.2 t/ha). Decreasing the seed rate by 25% of normal quantity decreased the cane yield by 9.7%. These results are in corroboration with the findings of Singh *et al.* (2008).

Sett treatment either with Carbendazim 0.1% or Carbendazim @ 0.1% + GA @ 100 ppm for 15 minutes did not found to have any significant effect on cane yield during all the three years of experimentation.

Sugar yield

The sugar yield was obtained by multiplying the commercial cane sugar per cent with cane yield in different treatments and presented in Table 2. The sugar yield followed the same trend as that of cane yield during all the three years of experimentation.

CONCLUSION

Keeping in view of the data presented, it can be concluded that, in sugarcane cultivation 2 bud setts or 3 bud setts can be used as seed material for getting higher cane and sugar yields instead of single bud setts which was found inferior in respect of both cane and sugar yields. Irrespective of sett size, decrease in the seed rate to 25 % of normal (80,000 buds/ha) found to give reduced cane and sugar yields as compared to normal seed rate of 1,20,000 buds/ha. Sett treatment with Carbendazim 0.1 % alone or along with Gibberellic acid @ 100 ppm for 15 minutes had no beneficial effect on germination of buds or cane and sugar yields.

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System productivity and yield advantage of autumn sugarcane (*Saccharum* spp. hybrids) and linseed (*Linum usitatissimum)* intercropping under subtropics

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ABSTRACTS

Field experiments were conducted to assess the associability of linseed varieties as intercrop in autumn planted sugarcane (CoSe 92423) at Indian Institute of Sugarcane Research, Lucknow in clay loam (*Inceptisol*) soil of subtropical India. Sugarcane intercropped with linseed Cv. *Parvati* (1:3 row ratio) produced significantly higher number of millable canes (110.7 thousand/ ha) and cane yield (78.7 t/ha) *at par* with sole sugarcane. The next best system was sugarcane + linseed Cv. *Garima* (1:3) intercropping system. Significantly highest cane equivalent yield (96.6 t/ha) and LER (1.82) were recorded under sugarcane + linseed Cv. *Parvati* (1:3) intercropping system. This system also recorded the highest sugar (8.98 t/ha) and sugar equivalent yields (10.68 t/ha). The quality parameters of sugarcane were not affected by different intercropping systems, and commercial cane sugar-CCS yield followed the trend of cane production. *Parvati* a dual purpose (seed *cum* fibre) linseed variety with erect plant type, tall growing and less branches exhibited associative character as intercrop with autumn planted sugarcane.

Key words : Linseed, Autumn sugarcane, System productivity, Intercropping cane equivalent, LER

Shifting paradigm in crop diversification options encompasses several concepts to accommodate the intercrops with sugarcane in *space* and *time* for vertical land productivity. In view of dwindling land resources, changing market scenario, consumers' preferences and global competitions, new income generating opportunities need to be created through intercropping in sugarcane. Sugarcane characteristically widely spaced, initially slow growing, long duration and one time income generating crop, lends ample scope for intercropping with short duration, high value and mid-season income generating crops for household nutrition and economic security especially of small and marginal cane growers. Moreover, intercropping in sugarcane is a potent tool to prop up autumn planting of sugarcane which gives 15-20 per cent higher cane yield and 0.5 unit more sugar recovery than spring planted cane. Several crops are recommended as intercropping with autumn sugarcane (Menhi Lal and Singh, 2004). Linseed is an important oilseed cum fibre *rabi* crop, suited for intercropping in autumn planted sugarcane. However, arrays of dual purpose varieties of linseed are available with varying habits which in turns, govern its associability with sugarcane as intercrop. It is in this context that the present paper analyses the compatibility of linseed cultivars with autumn planted sugarcane to make the system highly productive and profitable.

MATARIALS AND METHODS

Field experiments were conducted during two consecutive year 2005-07 and 2006-08 to assess the associability of linseed varieties as intercrop in autumn planted sugarcane (CoSe 92423) at Indian Institute of Sugarcane Research, Lucknow. The soil of the experimental site was clay loam (*Inceptisol*) with neutral pH (7.4), low in available N (180.8 Kg/ha) and organic C (0.34%) and medium in available P (19.8 Kg/ha) and exchangeable K (215.7 Kg/ha). The experiment was laid out in randomized block design with three replications. The treatments consisted of 6 intercropping systems along with 3 sole stands *viz.,* T_1-Sugarcane at 90 cm row spacing + linseed-*Parvati* (1:3 row ratio); T_2-Sugarcane + linseed-*Garima* (1:3); T_3-Sugarcane + linseed-*Parvati* (1:4); T_4-Sugarcnae + linseed-*Garima* (1:4); T_5-Sugarcane + linseed-*Parvati* (broadcast); T_6-Sugarcane + linseed-*Garima* (broadcast), T_7-Sole sugarcane (90 cm row spacing); T_8- Sole linseed-*Parvati* 20 cm row spacing with 45 kg seed/ha) and T_9- Sole linseed-*Garima* (25 cm row spacing with 30 kg seed/ ha). Sugarcane was planted in mid October 2005 and 2006 followed by sowing of linseed as per the treatments in respective years. The recommended fertilizer doses included 150:60:60 kg NPK/ha for sugarcane and 60:40:40:30-N: P: K: S kg/ha for linseed. The harvesting of linseed was done during third week of March in both the years. All the plant protection measures were followed as per the recommendations. Juice quality parameters (brix, pol and purity) was determined following the procedures described by Gupta (1977). Sucrose percent was determined as per Meed and Chen (1977). The cane equivalent yield (CEY) was calculated on the basis of existing market prices of the component crop. The Land Equivalent yield was estimated by calculation Partial Land Equivalent yield. Full dose of P and K and 1/3 of N was applied at the time of sowing in sugarcane and rest amount of N was applied after harvest of linseed. Full doses of fertilizer P, K and S and ½ of N applied sowing of linseed and rest amount was applied after one month.

RESULTS AND DISCUSSION

Growth and yield

The data on tillering pattern clearly indicate that by inclusion of linseed as intercrop with cane exhibited significant reduction in tiller count as compared to sugarcane sole besides affecting the germination.

Sugarcane intercropped with linseed Cv. *Parvati* (1:3 row ratio) produced significantly higher number of millable canes (110.7 thousand/ha) and cane yield (78.7 t/ha) *at par* with sole sugarcane (Table 1). This was closely followed by sugarcane + linseed Cv. *Garima* (1:3) intercropping system. *Parvati* a dual purpose (seed *cum* fibre) linseed variety with erect plant type, tall growing and less branches exhibited positive associative character as intercrop with sugarcane. Moreover dual purpose linseed varieties are reckoned as irrigation responsive (Hegde and Babu, 2005) and thus more suited to sugarcane system.

Significantly highest cane equivalent yield (96.6 t/ha) was recorded under sugarcane + linseed Cv. *Parvati* (1:3) intercropping system. This system also recorded the highest yield of linseed (966.4 kg/ha).

Thus, autumn planted sugarcane (Cv. CoSe 92423) may be intercropped with linseed (Cv. *Parvati*) in 1:3 row ratio for enhancing land productivity, harnessing crop associability

Table 1. Growth and yield of component crops in Sugarcane + linseed intercropping systems (pooled/data of two years)

Cropping Systems	Germination (%)	No. of tillers (000/ha)			NMC (000/ha)	Cane yield (t/ha)	Linseed plant population (000/ha)	Linseed yield (kg/ha)	Cane equivalent yield (t/ha)
		March	May	July					
S + L P (1:3)	40.1	77.3	192.4	170.6	110.7	78.7	504.0	966.4	96.6
S + L G (1:3)	40.0	71.2	167.6	140.3	103.9	75.0	481.4	775.5	89.4
S + L P (1:4)	39.3	66.1	140.5	116.5	95.9	66.8	790.6	818.5	81.9
S + L G (1:4)	39.4	73.4	143.2	109.3	101.0	69.4	694.1	808.3	84.3
S + L P (B)	37.9	77.8	130.6	104.5	94.9	69.2	802.9	672.9	81.7
S + L G (B)	38.0	75.8	107.5	100.0	88.2	62.2	666.9	577.3	72.8
S (Sole)	37.7	198.8	257.1	218.6	123.4	83.8	-	-	83.8
LP (Sole)	-	-	-	-	-	-	1039.9	1098.8	-
LG (Sole)	-	-	-	-	-	-	818.9	890.4	-
CD (P = 0.05)	NS	26.24	36.84	18.46	15.61	7.59	124.28	232.24	8.37

S = Sugarcane, LP = Linseed Cv. Parvati, LG = Linseed Cv. Garima

Commodity Price : NMC = Number of malleable canes

Sugarcane = Rs. 1250 per tonne

Linseed = Rs. 1900 per q

Table 2. Sugarcane quality and land productivity under Sugarcane + linseed intercropping system (pooled/data of two years)

Cropping systems	^{0}Brix	Pol %	Purity (%)	CCS		SEY (t/ha)	LER
				(%)	(t/ha)		
S + L P (1:3)	18.9	16.2	85.8	11.06	8.70	10.68	1.82
S + L G (1:3)	18.8	16.3	87.0	11.21	8.41	10.02	1.77
S + L P (1:4)	18.9	16.4	87.1	11.28	7.53	9.24	1.55
S + L G (1:4)	18.6	16.5	88.5	11.40	7.92	9.61	1.74
S + L P (B)	18.8	16.3	86.9	11.19	7.75	9.14	1.44
S + L G (B)	19.2	16.3	85.1	11.04	6.87	8.05	1.39
S (Sole)	18.8	16.4	87.0	11.24	9.41	9.41	1.00
LP (Sole)	-	-	-	-	-	-	1.00
LG (Sole)	-	-	-	-	-	-	1.00
CD (P = 0.05)	NS	NS	3.34	NS	0.99	0.94	-

SEY = Sugar Equivalent Yield; LER = Land Equivalent Ratio ; PLER = Partial Land Equivalent Ratio; CCS = Commercial Cane Sugar and increasing economic profitability of sugarcane based production system.

Juice quality and yield advantage

The quality parameters of sugarcane were not affected by different intercropping systems, and commercial cane sugar-CCS yield followed the trend of cane production (Table 2).

Sugarcane + linseed Cv Parvati (1:3) intercropping system recorded highest sugar yield (8.70 t/ha), sugar equivalent yield (10.68 t/ha) and Land Equivalent Ratio (1.82). This system was closely followed by sugarcane + linseed Cv Garima (1:3) intercropping. Yield advantage of the system were reduced when intercrop linseed was broadcasted in between the rows of sugarcane.

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Tillering pattern, growth and sugarcane yield of promising genotypes under different planting seasons and fertility levels in subtropical India

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ABSTRACT

An experiment was conducted at Indian Institute of Sugarcane Research, Lucknow to assess tillering pattern, growth and yield of three promising genotypes of sugarcane (CoS 96269, CoPant 97222 and CoLk 9616)) under three fertility levels (112.5,45,45; 150,60,60 and 187.5,75,75 kg N, P_2O_5 and K_2O /ha). Sugarcane genotypes followed polynomial trend in tiller emergence. Significantly higher cane yield (78.84 t/ha) was harvested with 'CoLk 9616' as compared to 'CoPant 97222' (63.79 t/ha) and 'CoS 96269' (62.68 t/ha). Genotype 'CoLk 9616' showed the highest sugar yield (9.29 t/ha). Among the fertility levels, the highest cane (70.48 t/ha) and sugar yields (8.59 t/ha) were obtained with application of 150, 60 and 60 kg N, P_2O_5 and K_2O /ha. Summer season crop behaved in similar fashion with lower values of growth attributes, cane and sugar yields.

Key words : Genotypes, Fertility levels, Tiller population, Cane yield, Sugar yield

In sub-tropical India, favourable temperature for tillering prevails from February to June. If autumn planting of sugarcane is adopted, it gets longer period for tillering as compared to the spring and summer, which results in higher cane yield and sugar recovery. In initial stages, tillers depend upon the mother shoot for their growth. Sugarcane varieties have shown differential tillering potential. Further the tiller mortality of 25 to 62 percent have been found in plant crop of sugarcane under different planting seasons (Verma *et al.,* 1996). Thus present investigation was aimed at determining the tillering behavior, growth and yield of promising sugarcane genotypes under different fertility levels in subtropical part of India.

It has been observed that mid late varieties of crop in subtropical parts of India performs better under a medium range of fertiliser *i.e.,* 150, 60 and50 kg N, P_2O5 and K_2O/ha (Shukla, 2007) but the tillering and growth behaviour of new genotypes differ because of genetic makeup and input use.

MATERIALS AND METHODS

A field experiment was conducted at Indian Institute of Sugarcane Research, Lucknow with three sugarcane genotypes (CoS 96269, CoPant 97222 and CoLk 9616) and three fertility levels (112.5,45,45; 150,60,60 and 187.5,75,75 kg N, P_2O_5 and K_2O /ha). Nine treatments were replicated thrice under randomized block design (RBD). Similar treatments were applied in spring and summer seasons to assess the differential response under both the situations. Main plot size was kept to 6m x 6m (36m^2). The soil of the experimental field was sandy loam (14% clay, 26% silt and 60% sand) of Indo – Gangetic alluvial origin, pH 7.6, very deep (>2m) well drained, flat and classified as non calcareous *mixed hyperthermic udic ustochrept.* Initial soil chemical analysis revealed that it was low in organic carbon (0.42%) and in available nitrogen (185 kg/ha) and medium in phosphorus (26.5 kgP_2O_5/ha) and potassium (230 kg K_2O /ha) contents. Three bud setts of sugarcane were planted at 75 row spacing in spring season and at 60 cm row spacing in summer season. Planting of sugarcane in spring and summer seasons were completed in the 2nd week of February and April during both the cropping seasons, respectively. All others recommended package of practices except treatment application were adopted for growing of sugarcane crop. Harvesting of crop was completed in 2nd week of March during both the cropping seasons.

Before planting of the crop, soil samples from 0-15 cm depth were collected by core sampler of 8-cm diameter from five spots in the field. Soil samples were pooled together and the representative homogeneous sample was analyzed for determination of organic carbon (Walkley and Black method), available N ($KMnO_4$ method), 0.5 M sodium bicarbonate ($NaHCO_3$- pH 8.5)- extractable P and 1N NH_4OAC– extractable K, following Jackson (1973). Periodic shoot counting was done in the sample rows and presented in thousand /ha.

At harvest, five plants were randomly selected from each plot for estimation of growth attributes and juice quality parameters. Sucrose (%) in juice was determined by as per the method described by Meady and Chen (1997). Sugar yield was calculated after multiplying CCS (%) and cane yield.

Juice purity (%) = Sucrose per cent in juice / corrected ºBrix x 100

CCS (%) = {S- (B-S) x 0.4} x 0.73

Where S = Sucrose percent in juice

B = Corrected ºBrix

Sugar yield (tonnes/ha) = CCS (%) x cane yield (tonnes/ ha)/ 100

Critical difference (CD) was computed to determine statistically significant treatment differences.

$$\text{C. D.} = \left(\sqrt{2\ \text{VE}\ r^{-1}}\right) \times t_{5\%}$$

Where VE is the error variance, r is number of replications, $t_{5\%}$ the table value of t at 5% level of significance at error degree of freedom.

RESULTS AND DISCUSSION

Spring planting

In spring planting, tiller population in all the genotypes increased up to June and decreased afterward due to mortality (Fig 1a&b). In the month of April, CoLK 9616 produced 64400 tillers /ha which rose to 244400 /ha in the month of June. Sugarcane genotype, CoLk 9616 produced higher number of tillers as compared to CoS 96269 and CoPant 97222 at all the stages (Fig 1a). Various genotypes follow polynomial equation in tiller production. Equation for genotype CoLk 9616 depicted in Fig. 1a was obtained $y = -20.63x^2+154.3x-82.9$ ($R^2=0.765$). Among various fertilizer levels, tiller population increased significantly up to 150, 60, 60 kg N, P_2O_5 and K_2O/ ha, respectively. Polynomial equation for tiller production calculated under D_2 (150, 60, 60 kg N, P_2O_5 and K_2O/ha) was $y = -15.27x^2+118.3x - 59.68$ ($R^2=0.822$). Higher degree of correlation coefficient with fertility levels ($R^2=0.822$) as compared to genotypes ($R^2= 0.765$) showed greater importance of nutrition in tiller production.

Table 1. Growth, yield and quality of promising sugarcane genotypes under different fertility levels in spring and summer planting seasons (mean data of two cropping seasons, *i.e.*, 2004-05 and 2005-06)

Treatment	Millable canes (000/ha)	Cane length (cm)	Cane diameter (cm.)	Cane weight (g)	Cane yield (t/ha)	Brix	Pol % juice	Purity (%)	Sugar yield (t/ha)
Spring season crop									
Genotypes									
V_1- CoS 96269	100.25	177.4	1.85	650	62.68	20.16	17.87	88.58	7.8
V_2.Co Pant 97222	93.94	183.0	1.93	761.7	63.79	19.55	17.33	88.66	7.67
V_3. CoLk 9616	119.4	177.2	1.86	670	78.84	19.28	17.03	88.25	9.29
S. E. m±	1.45	2.45	0.013	13.26	1.65	0.21	0.16	0.85	0.18
CD (P=0.05)	4.50	7.20	0.069	38.40	4.92	0.66	0.47	NS	0.52
Fertility levels (NPK kg/ha)									
D_1- 112.5, 45, 45	96.85	171.1	1.875	672	64.87	19.89	17.53	87.98	7.88
D_2- 150, 60, 60	107.1	184.6	1.91	715.8	70.48	19.99	17.62	88.09	8.59
D_3- 187.5, 75, 75	109.6	182	1.86	693.3	69.92	19.11	17.09	89.38	8.34
S. E. m±	1.45	2.45	0.013	13.26	1.65	0.21	0.16	0.85	0.18
CD (P=0.05)	4.50	7.20	0.069	38.40	4.92	0.66	0.47	NS	0.52
Summer season crop									
Genotypes									
V_1- CoS 96269	61.39	147.2	2.11	642.2	46.57	21.33	18.76	87.95	6.03
V_2. Co Pant 97222	91.50	156.7	1.96	611.1	57.33	20.93	18.23	87.09	7.18
V_3. CoLk 9616	98.9	161.3	1.97	646.7	67.00	18.89	16.78	88.83	7.79
S. E. m±	2.35	2.45	0.018	9.50	1.30	0.42	0.31	1.23	0.18
CD (P=0.05)	6.90	7.20	0.056	28.50	3.80	1.20	0.92	NS	0.55
Fertility levels (NPK kg/ha)									
D_1- 112.5, 45, 45	77.83	151.6	1.98	595.6	51.79	20.20	17.65	87.38	6.29
D_2- 150, 60, 60	87.50	158.4	2.04	641.1	58.33	20.20	17.78	88.02	7.16
D_3- 187.5, 75, 75	86.46	155.3	2.02	663.3	60.78	20.76	18.33	90.70	7.70
S. E. m±	2.35	2.45	0.018	9.50	1.30	0.42	0.31	1.23	0.18
CD (P=0.05)	6.90	7.20	0.056	28.50	3.80	NS	NS	NS	0.55

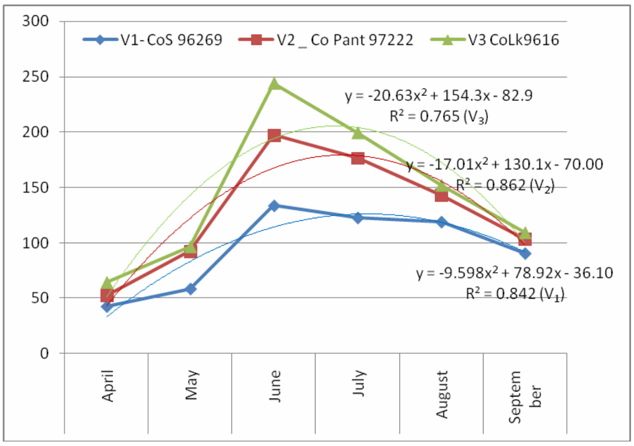

Figure 1a: Tillering pattern in promising genotypes of sugarcane in spring planting (tiller population in thousand/ha)

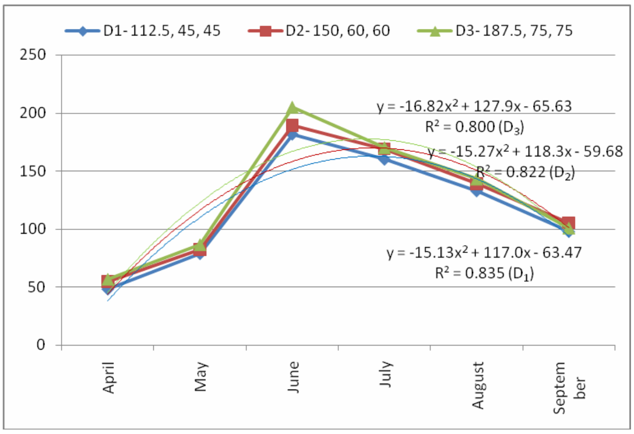

Figure 1b: Tillering pattern in sugarcane under various fertility levels in spring planting (tiller population in thousand/ha)

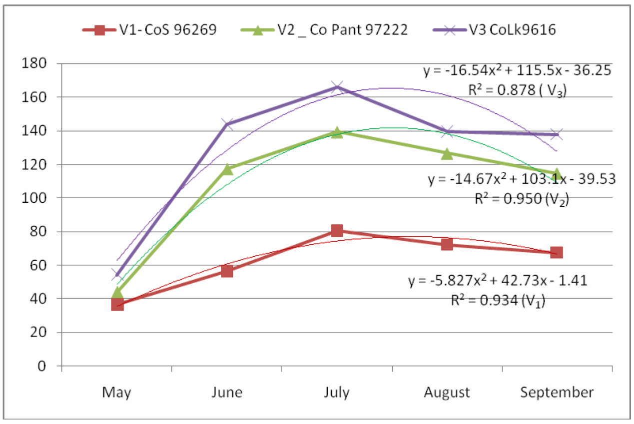

Figure 2a: Tillering pattern in promising genotypes of sugarcane in summer planting (tiller population in thousand/ha)

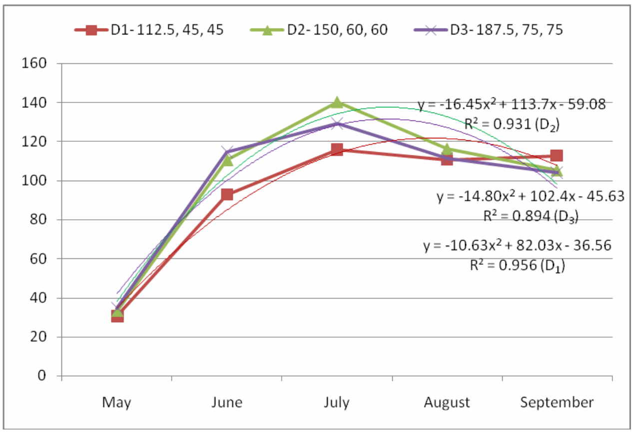

Figure 2b: Tillering pattern in sugarcane under various fertility levels in summer planting (tiller population in thousand/ha)

Significantly higher number of millable canes (119400/ha) was produced by genotype CoLk 9616 as compared to other genotypes (Table 1). Genotype CoPant 97222 produced longer (183.05 cm) and thicker canes (1.93 cm diameter) as compared to CoLk 9616 and CoS 96269. Mean individual cane weight was the product of length and diameter and significantly higher with CoPant 97222 (761.7 g). Significantly higher cane yield (78.84 t/ha) was harvested with CoLk 9616 as compared to CoPant 97222 (63.79 t/ha) and CoS 96269 (62.68 t/ha). It was 23.59% higher as compared to CoPant 97222 and 25.78% higher than CoS 96269. Different genotypes did not show tangible differences in juice quality parameters, *i.e.*, °Brix, pol% juice and purity(%). Commercial cane sugar was the product of CCS (%) and cane yield. Thus CoLk 9616 showed the highest sugar yield (9.29 t/ha-Table 1). It was because of maximum cane yield obtained with this genotype. Increasing levels of fertilizers increased cane growth attributes significantly up to 150, 60, 60 kg N, P_2O_5 and K_2O/ha. The role of nitrogen in chlorophyll formation and carbohydrate metabolism and positive interaction of nitrogen with phosphorus and potassium is well known (Shukla, 2007). It was the main reason in improving millable canes, growth and vigour of sugarcane plant. Higher cane weight was obtained up to 150, 60, 60 kg N, P_2O_5 and K_2O/ha as it had positive effects on growth and development processes (Shukla and Lal, 2002). The highest cane (70.48 t/ha) and sugar yields (8.59 t/ha) were obtained with application of 150, 60 and 60 kg N, P_2O_5 and K_2O /ha. It was due to higher number of millable canes, individual cane weight and optimum quality parameters obtained at this level. Juice quality parameters were not affected significantly by fertilizer levels.

Summer planting

In summer planting, tiller production increased up to July (Fig 2a &b). In the month of May, 54310 tillers/ha were produced by CoLk 9616 which increased up to a level of 166200/ha in the month of July. After that, mortality of tillers started and their population decreased up to September. Mortality of tillers occurred due to high temperature along with high humidity in rainy season (Shukla, 2007). Thus genotype CoLk 9616 produced higher number of tillers and maintained its superiority over others in summer planting also. Mortality of tillers in summer season crop was delayed by a month as compared to spring season crop. It was due to late emergence (periodic) of tillers in summer season crop as compared to spring season crop. Polynomial equation also fits well here and $y= -16.54 x^2 +115.5x -36.25$ ($R^2= 0.878$) obtained for genotype CoLk 9616. Number of tillers increased significantly up to 150, 60, 60 kg N, P_2O_5 and K_2O/ha. The higher degree of correlation ($R^2=0.931$) was obtained with fertility levels which showed importance of nutrition in increasing tiller production in sugarcane. In summer planting, tillering period in sugarcane reduces and crop faces maximum stress in establishment and productive tiller survival. Thus importance of nutrition here has a great scope to sustain higher number of vigorous tillers.

Higher number of millable canes (98900) was counted with sugarcane genotype, CoLk 9616. Individual cane length (161.3 cm) was significantly higher with CoLk 9616 as compared to CoPant 97222 (156.7 cm) and CoS 96269 (147.2 cm). Genotype, CoS 96269 was thicker (2.11 cm diameter) as compared to other genotypes. Single cane weight was the product of individual cane length and cane diameter. Genotype, CoLk 9616 had the highest cane weight (646.7g) as compared to others. Thus during both the planting seasons *i.e.,* spring and summer, genotypes behaved in similar fashion. In subtropical part of India, high tillering variety which produces higher number of millable canes having optimum cane weight ultimately produces higher yield. Genotype CoLk 9616 shows superiority over others during both the planting seasons. Juice quality of different genotypes did not influence significantly. The genotype, CoLk 9616 in summer planting produced significantly the highest cane (67.0 t/ha) and sugar yields (7.79 t/ha). Number of millable canes (87500/ha) at 150, 60 and 60 kg N, P_2O_5 and K_2O/ha level was significantly higher than 112.5, 45 and 45 kg N, P_2O_5 and K_2O/ha. Significant increase in cane length, diameter and weight was also observed up to 150, 60 and 60 kg N, P_2O_5 and K_2O/ha. Thus significant increase in cane (58.33 tonnes/ha) and sugar yields (7.16 tonnes/ha) were obtained with application of 150, 60 and 60 kg N, P_2O_5 and K_2O/ha. Juice quality could not be influenced significantly with fertility levels. Sugar yield was the function of cane yield and pol% juice. The higher cane yield contributed larger share in improving sugar yield as compared to cane quality parameters.

Thus genotype CoLk 9616 produced higher number of tillers, millable canes, cane and sugar yield during spring as well as summer planting. A level of 150, 60 and 60 kg N, P_2O_5 and K_2O/ha optimized cane and sugar yields during both the seasons.

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CoA 03081 – A recently released early maturing variety for East Coast Zone

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ABSTRACT

Co A 03081 is an early maturing non lodging variety with dark green foliage. It is a medium thick erect growing clone distinguished by purplish green leaf sheath, loose clasping, stem cylindrical with greenish yellow colour. The clone recorded a mean cane yield of 99.01 t/ha compared to the standards, Co 6907 (90.43 t/ha) and Co 7508 (86.62 t/ha) and CCS yield of 11.33 t/ha compared to popular standard Co 6907 (10.06 t/ha) and Co 7508 (10.18 t/ha) when tested in two plant and one ratoon crops (2007-08 to 2008-09). Percent juice sucrose and commercial cane sugar percent in Co A 03081 was on par with Co 7508 but superior to Co 6907. The percent increase in juice sucrose and CCS percent over Co 6907 was 1.36 and 1.91 respectively. The variety Co A 03081 recorded cane and sugar yields on par with 93 A 145 a recently released clone for the state under irrigated conditions and late planted rainfed conditions when tested for its performance under Agronomic cultivation trials from 2007-08 to 2008-09. It is resistant to red rot and moderately susceptible to smut. Low intensity of borers and scale insect was observed in the variety Co A03081.

Key words : Early maturing variety, Tropial India, East Coast Zone.

Development of varieties for different maturity group is of paramount importance in sugarcane cultivation to realize higher recoveries in sugar mills. The proper choice of varieties, season and suitable agronomic technologies coupled with balanced nutrient application play important role in sugarcane production. Non adoption of any one of the component leads to reduction in sugarcane production which in turn not only affects the cane growers and sugar mills, but also affected adversely the economy of the nation as a whole. The early maturing sugarcane varieties are chosen for in the beginning of crushing season for higher sugar recoveries. Besides, the influence of season is less pronounced on early maturing varieties and in late planted conditions, growing of early maturing clones facilitate recovery of higher sugar yields (M. Lakshmi Kantham, 1984).

The major constraints of cane production in the East Coast Zone include moisture stress during formative phase under assured and limited irrigated situations, water logged conditions during monsoon period, frequent occurrence of insect pests and diseases, extension of cane cultivation in rainfed areas, lodging of crop due to cyclonic storms in coastal areas and non-adoption of recommended package of practices including fertilization. Cane yield, CCS yield, juice sucrose percent and commercial cane sugar percent are the important criteria to evolve new sugarcane varieties coupled with tolerance to biotic stresses.

Certain clones have been reported to give higher number of tillers, millable canes and found promising for yield and also quality (Nagarajan, 1983). The average cane yields stagnant for three decades could be raised to about owing to the efforts of scientists evolving better varieties of cane suitable to different tracts and climatic conditions, resistance to drought and water logging conditions, pests and diseases and to early, mid season and late season plantings and harvestings (Naidu etal – 2007). As varietal development is a continuous process to identify / evolve superior clones than the currently grown clones and or to replace the old/ obsolete, experiments were conducted for a period of two years (2007-08 to 2008-09) under All India Coordinated Research Project on sugarcane at Regional Agricultural Research Station, Anakapalle to identify the most promising clones suitable for commercial cultivation.

MATERIALS AND METHODS

The clone CoA 03081 was developed through fluff supply programme from Co 8212 GC. It was tested from 1998 to 2006 at clonal as well as in station trials besides in coordinated varietal trials under AICRP on Sugarcane from 2006-07 (Initial Varietal Trial, Advanced Varietal Trial I & II plant and Ratoon crops) to 2008-09. The botanical description of the clone is given in Table No.1. Six clones including two standards Co A 03081, Co C 03061, Co C 03062, Co V 03101, Co Or 03151, Co Or 03152, Co 6907 and Co 7508 were tested in advanced yield trials in Randomized Black Design with three replications.

Each clone was grown is six rows of six meters length adopting 80 cm between rows. Fertilizers @ 112 kg N + 100 kg $P_2 O_5$ + 120 kg $K_2 O$ / ha were applied to plant crops. An additional dose of 112 kg N/ha was applied to ratoon crop. Irrigations were accorded at weekly intervals during formative phase and as and when required during grand growth period. Cultural practices viz. weeding, Earthing up, TT propping were carried out as per the schedule.

Percent juice sucrose was determined at 8th and 10th months after planting in plant crops and at 9th month in ratoon crop as per standard procedure (Meade and Chen, 1977). Cane yield and estimated sugar yields were recorded based on CCS percent. Reaction to red rot was recorded under artificial conditions by nodal and plug method using a mixture of three pathotypes of red rot viz. Cf 419, Cf 671 and Cf 997. Statistical analysis was performed as per the procedure of Panse and Sukhatme, 1978.

Table 1. Description of morphological characters for Co A 03081

S. No.	Name of the descriptor		Descriptor Status
1	Clone number	:	Co A 03081
2	Stool habit	:	Erect
3	Stem colour (exposed)	:	Yellowish green
4	Stem colour (unexposed)	:	Greenish yellow
5	Ivory marks	:	Absent
6	Weather marks (corky patches)	:	Absent
7	Internode shape	:	Cylindrical
8	Internode alignment	:	Straight
9	Pithiness	:	Absent
10	Splits on Internode	:	Absent
11	Wax on Internode	:	Medium
12	Node swelling	:	Absent
13	Root zone colour (exposed)	:	Yellow
14	Root Zone colour (unexposed)	:	Greenish yellow
15	Number of root eye rows	:	Two
16	Arrangement of root eye rows	:	Regular
17	Bud size	:	Medium
18	Bud shape	:	Obovate
19	Bud cushion	:	Absent
20	Bud germpore position	:	Sub-apical
21	Bud groove	:	Absent
22	Growth ring colour	:	Yellow
23	Leaf length	:	Medium
24	Leaf width	:	Medium
25	Lamina colour	:	Dark green
26	Leaf carriage shape	:	Open erect
27	Leaf sheath colour	:	Green with purple blotches
28	Leaf sheath waxiness	:	Light
29	Leaf sheath spines	:	Absent
30	Leaf sheath clasping	:	Loose
31	Dewlap colour	:	Greenish yellow
32	Presence/absence of ligular process	:	Absent
33	Shape of the auricle	:	Indicated
34	Percent flowering	:	Absent

RESULTS AND DISCUSSION

The chief morphological charcterests and data on cane yield, CCS yield, juice quality parameters, reaction to red rot, borers, scale insect and agronomic evaluation are furnished in 2 (a) to 5(b).

Cane Yield (t/ha): Mean data on the performance of Co A 03081 in advanced varietal trials across the locations of East Coast Zone is presented in Table 2 (a). The clone Co A 03081 recorded a mean cane yield of 99.01 t/ha when tested in two plant crops and one ratoon crop (2007-08 to 2008-09) compared to standards Co 6907 (90.43 t/ha) and Co 7508 (86.62 t/ha) respectively. The percent increase for cane yield in Co A 03081 was 9.49 and 14.3 over Co 6907 and Co 7508, respectively.

Sugar yield (t/ha): Mean data on the performance of Co A 03081 in advanced varietal trials of two plant and one ratoon crops across the locations of East Coast Zone is presented in table 2(b). The clone gave a mean CCS yield of 11.33 t/ha when tested in two plant and one ratoon crops (2007-08 to 2008-09) compared to the standards Co 6907 (10.06 t/ha) and Co 7508 (10.18 t/ha). The percent increase for CCS yield in Co

CoA03081

Table 2 (a). Mean data on Cane Yield (t/ha) in Zonal Varietal Trials

Sl. No.	Genotype Co A 03081	Zonal mean over two and plant one ratoon crops				Percent increase over Co 6907	Percent increase over Co 7508
		P_1	P_2	Ratoon	Mean		
1.	Co A 03081	108.60	100.04	83.38	99.01	9.49	14.30
2.	Co 6907 (C)	94.21	97.17	79.90	90.43		
3.	Co 7508 (C)	82.80	105.40	71.67	86.62		

Table 2 (b). Mean data on Sugar Yield (t/ha) in Zonal Varietal Trials

Sl. No.	Genotype Co A 03081	Zonal mean over two and plant one ratoon crops				Percent increase over Co 6907	Percent increase over Co 7508
		P_1	P_2	Ratoon	Mean		
1.	Co A 03081	12.08	11.68	10.22	11.33	12.62	11.30
2.	Co 6907 (C)	10.51	10.88	8.79	10.06		
3.	Co 7508 (C)	9.94	12.65	8.63	10.18		
	Mean	11.33	10.06	10.18			

Table 2 (c). Mean data on Juice Sucrose percent in Zonal Varietal Trials

Sl. No.	Genotype Co A 03081	Zonal mean over two and plant one ratoon crops				Percent increase over Co6907	Percent increase over Co7508
		P_1	P_2	Ratoon	Mean		
1.	Co A 03081	16.21	16.42	16.51	16.38	1.36	-3.64
2.	Co 6907 (C)	16.45	15.97	16.07	16.16		
3.	Co 7508 (C)	16.85	17.23	16.91	17.00		
	Mean	16.38	16.16	17.00			

Table 2 (d). Mean data on Commercial Cane Sugar percent in Zonal Varietal Trials

Sl. No.	Genotype Co A 03081	Zonal mean over two and plant one ratoon crops				Percent increase over Co 6907	Percent increase over Co 7508
		P_1	P_2	Ratoon	Mean		
1.	Co A 03081	10.76	11.49	11.38	11.21	1.91	-5.40
2.	Co 6907 (C)	11.12	11.94	11.85	11.00		
3.	Co 7508 (C)	11.42	12.05	12.05	11.85		
	Mean	11.21	11.00	11.85			

Table 3 (a). Reaction for red rot (As per AICRP on Sugarcane Technical Report of Plant Pathology) (2008-09)

S. No.	Entries	Anakapalle			
		IVT (E) (2006-07)		AVT(E) I Plant (2007-08)	
		Nodal Method	Plug Method	Nodal Method	Plug Method
1	Co A 03081	R	R	R	R
2	Co C 03061	HS	HS	HS	HS
3	Co C 03062	R	MR	HS	HS
4	Co V 03101	S	HS	S	HS
5	Co Or 03151	R	MR	R	R
6	Co Or 03152	HS	HS	HS	HS
7	Co 6907 (c)	R	HS	R	HS
8	Co 7508 (c)	R	R	R	R

Source: 1. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2006-07 (p-61)

2. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2007-08 (p-116)

3. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2008-09 (p-45)

Table 3 (b). Reaction for Smut (As per AICRP on Sugarcane Technical report of plant pathology) (2008-09)

Sl. No.	Entries	Anakapalle	
		IVT (E) (2006-07)	AVT(E) I Plant (2007-08)
1	Co A 03081	MS	MS
2	Co C 03061	MS	MR
3	Co C 03062	HS	S
4	Co V 03101	HS	-
5	Co Or 03151	HS	S
6	Co Or 03152	HS	S
7	Co 6907 (c)	HS	HS
8	Co 7508 (c)	S	-

Note: R – Resistant, S – Susceptible, MR- Moderately Resistant, MS – Moderately Susceptible, HS – Highly Susceptible

Source: 1. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2006-07 (p-68-69)

2. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2007-08 (p-117)

3. Technical Report of Plant Pathology, AICRP on Sugarcane, IISR Lucknow, 2008-09 (p-45)

Table 4 (a). Reaction to Early Shoot Borer, Internode borer and Scale insect

S. No.	Clone	(2006 – 07)			(2007 – 08)		
		ESB%	INB %	Scale %	ESB%	INB %	Scale %
1	Co A 03081	8.88	1.23	6.08	4.79	9.12	4.68
2	Co C 03061	6.56	2.22	2.69	3.48	4.23	14.00
3	Co C 03062	18.21	2.03	2.93	6.67	12.75	12.86
4	Co V 03101	19.26	2.52	3.25	5.25	9.98	10.20
5	Co Or 03151	19.43	2.19	2.68	4.68	8.00	12.76
6	Co Or 03152	8.76	4.83	3.84	4.40	9.69	1.91
	Standards						
7	Co 6907	8.97	2.09	2.57	5.40	9.95	10.43
8	Co 7508	18.95	1.36	11.52	4.55	7.57	13.24
	S.Em. ±	4.56	1.51	4.78	2.0945	1.2109	5.78
	S.E. percent	7.91	2.61	8.28	3.4412	1.8242	9.23
	C.V %	56.8	31.91	62.10	30.0	30.24	80.42

Source: Annual Report of Entomology AICRP on Sugarcane 2006-07 RARS, Anakapalle (p-113 – 114)

Table 4 (b). Reaction to Early Shoot Borer, Internode borer and Scale insect

S. No.	Clone	Average %		
		% ESB	% INB	% Scale
1	Co A 03081	6.835	5.17	5.38
2	Co C 03061	5.02	3.22	8.34
3	Co C 03062	12.44	6.25	7.90
4	Co V 03101	12.25	6.25	7.72
5	Co Or 03151	12.06	5.09	7.72
6	Co Or 03152	6.58	7.26	7.875
	Standards			
7	Co 6907	7.18	6.02	6.50
8	Co 7508	11.75	4.47	12.38

Source: Annual Report of Entomology AICRP on Sugarcane 2006-07 RARS, Anakapalle (p-113 – 114)

A 03081 was 12.62 over Co 6907 and 11.30 over Co 7508.

Percent Juice Sucrose: Mean data on the performance of Co A 03081 in advanced varietal trials of two plant and one ratoon crops across the locations of East Coast Zone is presented in table 2 (c). The standard Co 7508 recorded higher percent juice sucrose (17.00) at harvest. However, the clone Co A 03081 (16.38%) recorded maximum percent sucrose when compared to popular standard Co 6907 (16.16%) when tested in two plant and one ratoon crops during 2007-08 to 2008-09. The percent increase in juice sucrose in Co A 03081 over Co 6907 was 1.36.

Commercial Cane Sugar Percent: Mean data on the

Table 5(a). Yield attributes, quality and yield as influenced by different levels of nutrients under irrigated conditions AS 42 (2007-08 to 2008-09)

Treatments	Number of millable canes/ha		Percent juice sucrose		CCS %		Cane Yield (t/ha)		Sugar yield (t/ha)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
98 A 160	74696	75,212	18.60	17.22	13.44	11.94	86.8	86.2	11.66	10.3
Co A 03081	83333	80,178	18.27	16.85	13.27	11.75	98.1	92.2	13.02	10.8
93 A 145	82954	78,326	18.36	17.27	13.38	11.88	97.8	90.0	13.07	10.7
S.Em. ±	935	1,250	0.04	0.06		0.08	1.8	1.1		
CD (P = 0.05)	2618	3,489	0.12	0.17		NS	5.1	3.1		
Nutrient Levels										
F1: 75% recommended dose of NPK	74129	73,129	18.50	17.15	13.44	11.94	86.9	84.9	11.68	10.1
F2: 100% recommended dose of NPK	82680	79,129	18.32	17.30	13.33	11.92	96.3	90.8	12.83	10.8
F3: 125% recommended dose of NPK	84117	80,795	18.16	16.89	13.16	11.69	97.7	92.8	12.85	10.8
S.Em. ±	1691	1,250	0.10	0.06		0.08	1.8	1.1		
CD (P=0.05)	4734	3,489	0.28	0.17		0.23	5.1	3.1		
V x F	NS	NS	NS	NS		NS	NS	NS		
CV%	7.8		3.8				6.2			

Source: Annual report of Agronomy for year 2007-08 to 2008-09, AICRP on Sugarcane

Table 5(b). Yield attributes, quality and yield as influenced by different levels of nutrients under late planted rainfed conditions

Treatments	Number of millable canes/ha		Percent juice sucrose		CCS %		Cane Yield (t/ha)		Sugar yield (t/ha)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
98 A 160	65600	70,129	18.21	19.09	13.04	13.52	63.5	60.2	8.28	8.2
Co A 03081	64784	73,938	18.32	19.16	13.34	13.56	62.5	62.5	8.34	8.5
93 A 145	65493	75,994	18.30	19.08	13.18	13.54	64.1	64.4	8.45	8.7
S.Em. ±	1295	864	0.03	0.05		0.09	1.1	0.8		
CD (P = 0.05)	NS	2411	NS	NS		NS	NS	2.4		
Nutrient Levels										
F1: 75% recommended dose of NPK	62200	69,685	18.26	19.04	13.09	13.45	59.2	59.0	7.75	7.9
F2: 100% recommended dose of NPK	66615	74,321	18.36	19.28	13.24	13.66	64.6	63.4	8.55	8.7
F3: 125% recommended dose of NPK	68236	76,062	18.21	19.00	13.17	13.51	66.2	64.5	8.72	8.7
S.Em. ±	1295	864	0.03	0.05		0.09	1.1	0.8		
CD (P=0.05)	3626	2411	NS	0.16		NS	3.1	2.4		
V x F	NS	NS	NS	NS		NS	NS	NS		
CV%	6.5		4.2				7.3			

Source: Annual report of Agronomy for year 2007-08 to 2008-09, AICRP on Sugarcane

performance of Co A 03081 in advanced varietal trials of two plant and one ratoon crops across the locations of East Coast Zone is presented in table 2 (d). The standard Co 7508 recorded maximum CCS percent (11.85%) at harvest. The clone Co A 03081 (11.21%) recorded higher percent CCS compared to popular standard Co 6907 (11.00%). The percent increase for Commercial Cane Sugar Percent in Co A 03081 over Co 6907 was 1.91.

Reaction of Co A 03081 for biotic stresses: Reaction of Co A 03081 and other test clones and checks was studied under artificially inoculated conditions. Among biotic constraints red rot, smut, early shoot borer, internodal borer and scale insect are important in East Coast Zone. Co A 03081 is resistant to red rot under nodal and plug methods of inoculation and moderately susceptible to smut while the popular standard Co 6907 is having only field tolerance to red rot and highly susceptible to smut in ratoons (Table 3a and 3b).

Reaction to major insect pests: Reaction of Co A03081 for borers and scale insect is furnished in Table 4a and 4b. Low incidence of borers and scale encrustation was in Co A 03081 compared to checks and other test entries when tested in Initial and advanced varietal trials during 2006-07 to 2007-08.

Performance of Co A 03081 for agronomic evaluation: The clone Co A 03081 recorded more number of millable canes, cane and sugar yields compared to recently released variety Co A 99082 (93 A 145) when tested under irrigated and late planted rainfed conditions during 2007-08 and 2008-09 (Table 5a to 5b). The clone Co A 03081 identified by central varietal sub committee for East Coast Zone. The clone was also released for commercial cultivation in Andhra Pradesh in the name of Visakha during April, 2010.

CONCLUSION

The new clone Co A 03081 with erect and non lodging growth habit, desirable morphological characters, higher cane, sugar yields, is superior to currently grown popular standards Co 6907 and Co 7508. It is resistant to red rot, moderately susceptible to smut and recorded low incidence of scale infestation. The tolerance of the clone to moisture stress and water logged conditions enables the cultivation of Co A03081 under limited irrigated, rainfed and water logged conditions. Co A 03081 recorded cane and sugar yields superior to Co A 99082 (93 A 145) under irrigated and late planted rainfall conditions.

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Identifying desirable traits for better ratoons

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ABSTRACT

An experiment was conducted with one plant and two subsequent ratoons, to identify the ratooning ability of sugarcane at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur. Twelve varieties, namely, CoSe 95436, CoS 95255, CoS 96268, CoS 8436, CoS 96258, CoSe 98231 under early CoSe 96436, CoS 94257, CoS 94257, CoS 97264, CoS 95222, CoS 94270 and CoSe 92423 under mid late groups were taken under the study. Results revealed that the reduction in cane yield in different varieties ranged from 1.30 to 23.76% in first and 45.29 to 58.41% in second ratoons than that of the plant crop. The values of correlation between yield and other traits increased in older crops (1st and 2nd ratoon) as compared to the previous one. The repeatability for each trait between the first and second ratoons was higher (0.4059 to 0.7896) than the values of plant and first ratoon (0.3457 to 0.7417). The study indicaled that a variety with higher number of millable canes, longer stalks, and more buds would be a better ratooner.

Key words : Cane traits, Ratooning ability, Repeatability, Sugarcane

Ratooning is an important practice in sugarcane growing. Acceptance of any variety by the farmers entirely depends on its ratooning ability and that is why the selection of a variety for this trait is given more emphasis by the breeders. Cultivation of sugarcane is necessarily a blend of good and healthy plant crop, followed by equally productive ratoons. In India, keeping one or two ratoons is a common practice and almost 50% of the total cane area always comes under ratoon crop. In general, ratoon crop are poor cane yielder than their corresponding plant crops. Out of several causes for poor ratoon yield, the most limiting factor is unavailability of genotypes with good ratooning potential. Though several management practices are available to raise god ratoons, the inherent potential of a variety to give better ratoon yield is of a paramount importance for sustaining high sugarcane productivity. In ratoon crop, generally, the stalk number increases while, weight of stalk decreases. The difficulties in shortening the sugarcane selection cycle and demand of good yielding clones having good ratooning ability caused some breeding programmes such as reunion conducted the selection cycle until 16 years long, with some stages include testing the ratooning ability the until third ratoon crop (Hellman and Payet, 1988).

The present study was conducted for estimating the percent increasing and decreasing cane traits and characters associated in plant as well as its subsequent ratoon crops, and repeatability to identify plant characters associated with varieties with good ratooning potential, so that varietals development and evaluation could be based on such characteristics.

MATERIALS AND METHODS

Twelve promising sugarcane varieties *viz.* CoSe 95436, CoS 95255, CoS 96268, CoS 96258, CoS 8436 and CoSe 98231 under early and CoSe 96436, CoS 94257, CoS 97264, CoS 94270, CoS 95222 and CoSe 92423 under mid late maturing groups were included in this study. The experiment was planted in randomized block design with three replications at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur (27.53ºN) at the seed rate of 12 buds/running meter. The experiment was conducted during 2002-03 to 2004-05 with one plant and two of its subsequent ratoons crops. After the harvest of the plant crop, the cane trash was removed from the field and ratooning operations like stubble shaving and breaking the ridges not he sides were carried out. All the recommended agronomic practices were followed in maintaining the crop and raising the ratoons without gap filling.

Observations on number of shoots in plant and ratoon crops, number of millable canes, stalk height (m), stalk thickness (cm), number of internodes/stalk, length of internode (cm), number of buds per stalk and stool (left behind in the soil), stalk weight (kg), cane yield (kg) were recorded. Simple correlations were worked out between the traits in each crop according to Falconer (1981). Phenotypic correlation coefficients (repeatability) between plant crop and its first and second ratoon crops were determined for yield and its components according to Herbert and Henderson (1959) and Mariotti (1971).

RESULTS AND DISCUSSION

Reduction in traits in subsequent ratoons

The data recorded on different traits for each variety in plant crop as well as in ratoon crops is given in Table-1. The reduction per cent in stools/plot ranged from 12.61% to 36.73% in second ratoon, highest reduction in stool was observed in CoS 8436. Varieties differed significantly in germination and stooling characteristics. Number of millable canes per plot reduced up to 43.53% in CoSe 95436 in second ratoon as compared to plant crop. Stalk height was slightly higher in few varieties in first ratoon as compared to plant crop, but it reduced rapidly in each variety in second ratoon. Maximum reduction in height (37.65%) was recorded in CoS 94270. The reduction in height from first to second ratoons was remarkable, it ranged from 11.68 to 37.65%. The stalks of ratoon crop were slightly thinner than the plant crop. Single cane weight reduced rapidly in second ratoon as compared to first ratoon in each variety. It may be due to reduction in height and thickness in second ratoon, thus it may be concluded that height and thickness both are more important plant characters in determining cane weight. The reduction in cane yield ranged from 1.30 to 23.76% in first ratoon and 45.29 to 58.41% in second ratoon than that of plant crop. The reduction in yield was found in each variety, but this is evident from data on yield that the variation in reduction percent was higher than other traits. Maximum variation was found in number of buds left behind the soil. Number of buds per stool increased from 1.29% to 109.6% in first ratoon than plant crop reduction was recorded in second ratoon in maximum varities.

Table 1. Response of varieties with respect to percent increase or decrease in different traits in subsequent ratoon crops of sugarcane

Sl. No.	Variety	Germination			Millable canes			Stalk height (m)			Stalk thickness (cm)			Stalk weight (kg)		
		Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon
1	CoSe95436	-15.09	-28.89	-39.62	2.41	-43.53	-42.17	2.569	-24.37	-22.43	-1.78	9.09	-10.71	-7.67	-20.26	-26.38
2	CoS 95255	-13.09	-25.83	-35.51	0.94	-26.79	-27.83	4.65	-28.89	-25.58	-20.26	-16.00	-9.50	-10.58	-18.46	-27.08
3	CoS 96268	-12.96	-35.11	-43.51	13.65	-36.78	-45.51	2.17	-14.18	-12.32	-1.78	-9.09	-10.71	-6.60	-12.07	-21.42
4	CoS 96258	-13.01	-34.38	-43.09	13.79	-32.30	-41.64	1.53	-18.80	-17.56	-9.09	-7.50	-15.90	-20.27	-21.16	-37.15
5	CoS 8436	-15.52	-36.73	-46.55	3.29	-37.58	-35.53	7.96	-27.87	-22.12	-12.86	-9.52	-21.60	-25.07	-15.59	-36.75
6	CoSe98231	-14.61	-26.13	-36.92	0.25	-38.50	-38.65	2.67	-11.68	-9.33	-7.85	-1.34	-8.70	-1.38	-21.31	-22.39
7	CoSe96436	-19.73	-30.51	-44.21	0.2	-42.11	-42.00	6.71	-28.30	-23.49	-5.00	-5.26	-10.00	-4.76	-14.40	-18.48
8	CoS 94257	-12.58	-21.97	-31.79	0.72	-28.50	-27.82	1.10	-23.00	-11.54	-10.26	-4.76	-14.50	-1.68	-21.65	-22.97
9	CoS 97264	-12.60	-12.61	-23.62	1.27	-16.30	-17.41	8.22	-24.00	-8.22	-9.91	-5.00	-14.40	-7.67	-12.99	-19.67
10	CoS 94270	-15.31	-21.28	-33.33	3.09	-32.50	-30.41	6.25	-37.65	-33.75	-9.91	-5.00	-14.40	-6.25	-17.60	-22.75
11	CoS 95222	-20.31	-13.72	-31.25	10.09	-28.90	-36.13	3.40	-25.00	22.45	-6.38	-9.09	-14.90	-6.38	-21.90	-26.89
12	CoSe92423	-14.17	-19.23	-30.70	1.52	-22.50	-21.32	6.56	-20.51	-28.00	-4.00	-0.08	-12.00	-4.84	-20.93	-24.65

Table 1. Contd.........

Sl. No.	Variety	Yiled (t/ha)			Buds/stool			Buds/stalk			No. of internodes			Length of internode		
		Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon	Plant to 1st ratoon	1st to 2nd ratoons	Plant to 2nd ratoon
1	CoSe95436	-5.44	-54.59	-57.07	64.37	-31.50	12.50	30.33	-42.80	-25.58	-10.78	-6.50	-16.6	12.87	-21.0	-10.84
2	CoS 95255	-6.16	-41.70	-45.29	109.6	-17.40	73.07	68.42	-9.37	52.63	-7.72	-15.2	-14.0	4.63	-13.2	-9.26
3	CoS 96268	-23.76	-44.60	-57.61	75.0	-47.90	-8.97	61.76	-27.20	17.65	9.34	-15.0	-7.1	8.09	0.93	9.09
4	CoS 96258	-22.06	-46.63	-58.41	52.94	-51.50	-25.88	36.84	-23.00	5.26	-18.22	-2.80	-20.5	-22.37	-15.0	3.95
5	CoS 8436	-22.61	-47.31	-57.87	1.29	-37.20	-36.48	8.51	-37.20	-31.91	21.70	-27.2	-11.46	2.32	-9.5	-11.63
6	CoSe98231	-1.30	-50.83	-51.48	64.79	-30.60	14.28	18.18	-16.90	-1.82	-4.83	-14.2	-18.36	22.34	-11.30	8.51
7	CoSe 6436	-6.86	-49.88	-53.32	20.22	-20.40	-4.37	9.30	-19.10	-11.63	20.51	-4.8	-14.74	12.93	-18.3	-7.75
8	CoS 94257	-7.65	-41.88	-46.32	11.23	-19.20	-10.14	22.92	-22.00	-4.17	-10.73	-12.0	-21.46	22.77	-4.0	17.82
9	CoS 97264	-9.21	-39.88	-45.41	2.50	-18.90	-16.87	7.02	-8.10	-1.75	3.14	-4.06	-1.05	22.34	-14.7	4.25
10	CoS 94270	-3.35	-50.54	-52.20	6.72	-30.30	-25.69	3.77	-23.60	-20.75	3.22	-25.0	-22.58	17.58	-24.2	-10.9
11	CoS 95222	-6.01	-47.02	-52.21	1.93	-8.85	-7.09	14.28	-14.20	-2.04	-25.70	-10.15	-33.21	27.27	-25.0	-4.54
12	CoSe92423	-6.13	-43.07	-46.56	18.57	-7.83	9.29	13.64	-4.00	9.09	-4.09	-16.50	-20.0	2.80	-4.5	-1.87

Correlation

The correlation coefficient between germination and other traits, *i.e.,* number of millable canes, stalk height, number of internodes, number of buds/stalk and per stool left behind in the soil, and also the cane yield was found positive and significant. Germination showed a negative association with stalk thickness and cane weight in plant as well as in its ratoon crops. The values of correlation increased in subsequent 1st and 2nd ratoon crops as compared to the plant crop. Number of millable canes showed a significant and positive association with stalk height, length of internodes, and number of buds per stool left behind in the soil and cane yield. On the other hand, it was negatively correlated with stalk thickness and stalk weight. Stalk height had a positive association with number and length of internodes, number of buds per stalk and per stool and cane yield while, it was negatively associated with stalk thickness. The magnitude of correlation between stalk thickness and number of internodes, stalk weight and yield was positive, while it showed a negative association with number of buds per stalk and per stool. Number of internodes showed a positive and significant association with number of buds/stalk and/ stool, while negative association was noticed with length of internodes. Number of buds in the stool showed a positive and significant association with yield in ratoon crops. Stalk weight had positive association with cane yield. The trend of correlation in the present study confirms with the findays of Milligan *et.al.* (1990) and Gravois (1988).

Repeatability

The values of repeatability for different traits between plant *vs.* first ratoon ranged from 0.3457 to 0.7417 (Table-2). Significant and positive values were noticed for major yield contributing components. Stalk height had the highest value (0.7417) followed by number of millable canes (0.6763), stalk thickness (0.6533) and cane weight (0.6235). Similarly, the values of the repeatability between 1st ratoon and 2nd ratoons ranged from 0.4211 to 0.7896. Highest value was found for stalk height (0.7896) followed by number of millable canes (0.7317). The results obtained confirmed the previous findings of Mariotti (1971), James and Miller (1971) and Pillai (1996). The values of repeatability between the first and second ratoons was higher than the values of plant and first ratoon. Sundara *et. al.* (1992) have also reported that the ratoon cane yield had a significant and positive association with the plant cane yield. It is clear that variety with a higher plant population at the time of harvesting would be a better ratooner. A higher plant crop population will contribute to a higher ratoon performance, because the number of millable canes at harvest will determine the number of stubbles left in field for the subsequent ratoon crops. A variety having longer stalk giving better ratoons than that of others, and it might be due to more buds in the stool, besides a higher amount of food reserves. Mukerji (1952) reported that thin and medium varieties of cane gave comparatively better ratoon stands than the thick canes. Shanmugasundaram *et al.* (1981) suggested that those varieties which had higher germination percentage gave better ratoons and shy terminator varieties gave poor ratoon. Studies conducted at Lucknow indicated that the varieties with higher plant cane yield are not necessarily good ratooners (Tripathi *et al.,* 1981). On the basis of the present study, it may be concluded that a variety with higher number of millable canes, longer stalk and more buds left behind in the soil would prove to be a better ratooner. The selection of the genotypes for developing a variety with potential ratooners must be based on these traits.

Table 2. Characters repeatability in sugarcane plant and subsequent ratoon crops

Characters	Plant Vs 1st ratoon	1st ratoon Vs 2nd ratoon
Germination	0.4887	0.5001
Number of millable canes	0.6773*	0.7317*
Stalk height	0.7417*	0.7896*
Stalk thickness	0.6533*	0.6678*
Number of internodes	0.4162	0.4211
Length of internodes	0.3457	0.4059
Number of buds/stalk (left behind in the soil)	0.6028*	0.7077*
Number of buds/stool (left behind in the soil)	0.6081*	0.7078*
Stalk weight	0.6235*	0.7139*
Cane yield	0.6572*	0.6589*

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Management of shoot borer, *Chilo infuscatellus* Snellen through integrated approach in north Bihar

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ABSTRACT

The experiments were conducted (2005-06 to 2009-10) to study the effect of integrated approaches for the management of shoot borer *Chilo infuscatellus* Snellen in north Bihar. Incidence of borer was significantly lower (2.98%) in the IAM (Integrated Approach for Management) plot as compared with 11.27% in untreated control. Significantly higher number of *incllable cane plot.* IAM programme increased the number of millable and cane yield by (30620 tones) obtained in IAM plots and over the untreated block (23360 tones). Integrated approach, when combined into a unified manner is useful for the management of shoot borer.

Key words : Shoot borer, Insecticides, Integrated, Approach for management, Sugarcane

Sugarcane has considered as a cash crop in Bihar as its area expened tremendously the problem of its insect-pest has come to the fore-front. There are several pests attack the crop at different stages of its growth. The important among them are borers, termite, Pyrilla mealy bug and white grub. Among the borers, *Chilo infuscatellus* Snellen is a serious pests of sugarcane in the state of Bihar. Efficacy of certain insecticides against shoot borer in sugarcane was studied by Chand *et al*. (2009) and they reported that phorate-10G was found superior as recorded highest germination per cent, number of millable canes (h^{-1}), yield (mth^{-1}) and lowest cumulative incidence per cent Alam *et al*. (2006) reported considerable lossess in cane weight, sugar recovery dut to several boner ponts.

The indiscriminate uses of chemical pesticides also have been resulted in adverse effects like resistance in inset pests, ecological imbalance, health hazards and resurgence of secondary pest (Sexena *et al*. 1992; Armes *et al*. 1992). The various methods like, cultural, mechanical, chemical, biological and plant host resistance have been evolved from time to time for control/suppression of pest but there is a need for holistic approach to manage the pest effectively without harming other biota present in ecosystem (Rachappa *et al*., 2000). The adoption of integrated pest management (IPM) can be more useful in sugarcane. Keeping the above in mind, the present investigations conducted to study the effect of integrated approache on the incidence of *Chilo infuscatellus* Snellen.

MATERIALS AND METHODS

The experiment was conducted from 2005-06 to 2009-10 at Sugarcane Research Farm, S.R.I., Rajendra Agricultural University, Pusa on recommended varieties of sugarcane namely, BO-130, B.O-137, B.O-147, CoP-9702 and CoP-9301 were planted 1st week of February in the field trials. One acre (4000 m^2) block was divided in two halves. One block was kept for integrated approach management (IAM) and another without integrated approaches management (WIAM). The integrated approaches for the management of pest adopted included :

1. Soil application of carbofuran - 3G @ 33 kg/ha at the time of planting.
2. Setts treated with chloropyriphos– 20 EC @ 5 ml litre^{-1} of water.
3. Collection and destruction of eggmasses at frequent interval.
4. Frequent irrigation and removal of dead hearts during hot months.
5. Need-based earthing up fallowed by irrigation.
6. Frequent integrated approaches employing cultural/ mechanical/chemical operation for the management of shoot borer.
7. Two hundred Tricho-cards (5.0x3.0 cm hard paper piece glued with *Trichogramma chilonis* Ishii) had approximately 1100 parasitized eggs at each card stapled to the ventral sides of sugarcane leaves to avoid direct

exposure of sum light to the parasitized eggs from 2nd week of March to 2nd week of May at 15 days interval. These cards were released for 5 times to manage the target pest.

8. Need-based adequate control measures of other pests during the crop season.
9. Removal of bunchy top, dry leaves from June onwards till February.
10. Propping was done during September-October to avoid fall down the plants.
11. Removal of water shoots and late shoot at frequent interval.

Agronomical practices for sugarcane cultivation were followed in both the blocks. The observations on incidence of shoot borer were recorded in both blocks. Number of millable canes (‘000ha^{-1}) and cane yield (tha^{-1}) also recorded at harvest.

RESULTS AND DISCUSSION

Data on incidence per cent, number of millable canes (‘000ha^{-1}) and cane yield (tha^{-1}), reduction per cent in incidence, number of millable canes and cane yield are presented in table 1. Perusal of data revealed that a significant reduction in the shoot borer incidence in IAM block; mean incidence over the years at 2.98 per cent being significantly lower than the corresponding value of at 11.27 in the untreated block. The per cent incidence decreased being 70.61% over untreated block during years research in the trials. It indicates that different cultural, mechanical, biological one chemical management tactics when combined into a what does it mean programme help in reduce incidence of the shoot borer pest of sugarcane. According to Sardana (2001) a significant reduction in incidence of various insect-pests like early shoot borer, top borer, stalk borer, block bug, Gurdaspur borer, pyrilla and root borer and consequent increase in cane yield upon at adoption of different IPM technologies. Patil and Hapase (1981) also reported that among the borers, early shoot borer, *Chilo infuscatellus* Snellen is very serious pest effecting sugarcane crop impending cane yield by 22-33% and sugar recovery by 2%.

It is evident from the data (Table 1) of number of millable canes and cane yield, IAM technology proved statistically superior than that of WIAM block. Mean millable canes at 113980 canes/ha in IAM block was significantly higher than the millable canes (79440/ha) in the WIAM block. Similarly, the IAM block recorded higher (64.94 t/ha) cane yield as compared to 49.61 tha^{-1} in WIAM block. Number of millable canes and cane yield increased/ha being 30620 and 23360, respectively, over WIAM block. Rana and Rana (1992) reported about 18 per cent increase in cane yield following adoption of IPM programme against weeds, diseases and arthropods pests of sugarcane in Pakistan. The large scale adoption of IPM technology in U.P. resulted in an increase of up to 18.73 tha^{-1} cane yield (Anonymous, 2005).

Thus, it was concluded that the impact of IAM technology on insect-pests incidence, millable canes and cane yield when compared to its counter parts, the WIAM block is obvious from the data of present investigation. Incidence of shoot borer decreased to the extent of 70.61% over WIAM block during years of research, while the number of millable canes and cane yield were increased to the extent of 30620 and 23360 tha^{-1}, respectively, over WIAM block.

It is evident from the result of present investigation that different pest management tactics, when combined into a

Table 1. Influence of integrated approaches for the management of shoot borer on pest incidence, NMC and cane yield

Year	Per cent incidence*			Number of millable canes* (‘000ha^{-1})			Cane yield (tha^{-1})*		
	WIAM	IAM	Per cent incidence decrease over WIAM	WIAM	IAM	No. of millable canes increase over WIAM	WIAM	IAM	Yield increase over WIAM
2005-06	8.30	2.80	66.26	90.20	120.30	25.18	50.35	64.85	22.36
2006-07	17.50	3.80	78.28	80.60	110.20	26.86	45.85	58.15	21.15
2007-08	12.20	5.20	57.37	70.20	115.70	39.32	49.35	60.20	18.02
2008-09	15.00	2.10	86.00	60.40	105.36	42.67	47.30	69.28	31.72
2009-10	3.35	1.00	70.15	95.8	118.35	19.05	55.20	72.20	23.54
Mean	11.27	2.98	70.61	79.44	113.98	30.62	49.61	64.94	23.36
SEm (±)	0.53	0.16	2.05	2.05	2.32	0.82	1.43	2.24	0.77
CD (p = 0.05)	1.63	0.49	6.32	6.32	7.15	2.53	4.41	6.90	2.37
CV (%)	9.37	11.13	5.73	5.16	4.10	5.37	5.76	6.91	6.57

* - Mean of four replications. IAM – Integrated approach management. WIAM – Without application of IAM (Control).

unified programme, were effective to manage sugarcane shoot borer. Earlier, Jaypal (2000) reported that approaches like timely irrigation, recommended dose of fertilizer, mechanical operations like removal of damaging stages of pests and crop residues, earthling up, propping of cane stalks, liberation of egg parasitoids and foliar nitrogen application to reduce the incidence of all the pests besides increasing cane yield (22-36% increase productivity) and conservation of natural enemies. According to Verma (1990) the cane yield of 63.4 to 78.4 tha^{-1} in IPM plots as compared to 40.3 to 45.3 tha^{-1} in untreated (non-IPM plots), which intensified the economic viability of the applied control measures. However, adoption of IAM tactics, needs regular monitoring of crop stage and active participation by the farmers, extension workers and scientists. The overall, impact of IAM technology that its provide ecological and economic sustainability and social stability.

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Toxicity of certain plant based insecticides against eggs and nymphs of *Dimorphopterus gibbus* (Fabricius), a black bug of sugarcane

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ABSTRACT

Toxicity of Annona 20 EC and Neem 10000 ppm was evaluated against eggs and nymphs of *Dimorphopterus gibbus* a species of black bug of sugarcane. Neem 0.5 and 0.1% and Annona 0.1%, caused 86.72, 70.28 and 64.06% mortality of eggs, respectively. Mortality of newly hatched nymphs due to insecticide film on inner surface of petridihes was 83.50, 82.72, 80.13 and 79.67% in Neem 0.5%, Annona 0.1%, Annona 0.2 %, and Neem 0.1 %, respectively in dercending order. Annona (0.2, 0.1%), and Neem (0.5, 0.1 and 0.05%) were quite toxic to eggs and nymphs of *D. gibbus*.

Key words : Annona, Black bug, *Dimorphopterus gibbus,* Neem, Sugarcane

Incidence of two species of black bugs (*Cavelerius sweeti* Slater and Miyamoto and *Dimorphopterus gibbus* (Fabricius)) in sugarcane is most common during summer months. *D. gibbus* is commonly occurring in sugarcane throughout India (Chaudhary, 1968). Mixed population of nymphs and adult bugs is found in leaf sheath. Nymph and adults of black bug suck the sap from leaf sheath and leaves and cause a setback to the crop in tillering stage. For the control of black bugs, foliar sprays of synthetic insecticides were recommended. Synthetic insecticides not only control the pest but also invite a number of unwanted problems like development of resistance in insect to insecticides, killing of naturally occurring bio-agents, pest resurgence and secondary pests out breaks apart from environmental contamination and human health. Neem, (*Azadirachta indica*), custard apple, (*Annona reticulata*) and Karanj (*Pongamia pinnata*) based insecticides have emerged as safer alternative insecticides to synthetic insecticides during last two decades. Maximum potential of an insecticide can be exploited if insecticide targets the sessile stage in the life cycle of an insect such as egg (Smith and Salkeld, 1966). If any insecticide targets more than one stages of the pest, same may be more effective for the management of insect pest. Therefore, two plant based insecticides *viz.,* Annona 20 EC (custard apple seed oil based) and Neem 10000 ppm (neem seed oil based) were evaluated for their toxicity against eggs and nymphs of *D. gibbus.*

MATERIALS AND METHODS

Different concentrations of Annona 20 EC (1.0 and 2.0%), Neem 10000 ppm (0.025, 0.05, 0.1, and 0.5%) and dichlorvos 76 cC (0.05 percent) were prepared by dissolving required quantity of commercial formulations in distilled water. Laboratory reared two days old 30 eggs of *D. gibbus* were taken in a petridish (6 cm diameter) that constituted one replication. Eggs in petridishes were sprayed with 1 ml solution of the candidate insecticides. Upper lid of each peridish was also sprayed with 1 ml spray solution separately to form an insecticide film on inner surface of both of the lids. The spray was done with the help of hand atomizer. Untreated control was sprayed with emulsified water (triton x 1000.05%). Air dried treated eggs were kept at room temperature in the laboratory for further observations. Each treatment and untreated control were replicated thrice. Observations on nymph emergence were recorded till the nymph's emergence in untreated control stopped. Unhatched eggs were recorded as dead. Newly emerged nymphs from treated eggs were allowed to crawl on insecticide film on inner surface of petridish to study the toxicity of insecticide film on nymphs. Effect of insecticide residues film in petridishes on newly hatched nymphs was studied by keeping it in mind that just after emergence nymphs will come in contact of residues of insecticides on sugarcane leaves and cane. Data on nymph mortality were recorded 24 hours after hatching. Moribund nymphs were recorded as dead. Natural egg mortality was observed in untreated control therefore, egg mortality in treatments was corrected with the help of Abbot Formula. Data on percent egg and nymph mortality were subjected to angular transformation and then to statistical analysis (name of test).

RESULTS AND DISCUSSION

Annona 20 EC, Neem 10000 ppm and dichlorvos 76cC were evaluated for their ovicidal toxicity against eggs of *D.*

Table 1. Effect of Annona 20 EC and Neem 10000 ppm on the eggs and nymphs of *Dimorphopterus gibbus* a black bug of sugarcane

Insecticide	Concentration (%)	Egg mortality (%)	Nymph mortality (%)
Annona 20 EC	0.1	64.06	82.72
		(53.18)	(65.67)
	0.2	61.83	80.13
		(51.85)	(63.96)
Neem 10000 ppm	0.025	44.50	69.61
		(41.84)	(56.56)
	0.05	55.17	76.61
		(47.98)	(61.24)
	0.1	70.28	79.67
		(56.98)	(63.47)
	0.5	86.72	83.50
		(68.67)	(68.87)
Dichlorros 76cC	0.05	19.17	12.01
		(25.94)	(20.18)
Untreated control (Emulsified water Triton X- 100)	0.05	0.00	0.00
		(4.05)	(4.05)
S. Em ±		1.51	5.53
CD at 5% level		3.25	11.86

Figures in parentheses are angular values

gibbus. Data on egg mortality showed the highest percent egg mortality due to Neem 0.5% (86.72) followed by Neem 0.1% (70.28), Annona 0.1% (64.06), Annona 0.2% (61.83), Neem 0.05% (55.17), Neem 0.025% (44.50) and dichlorvos 0.05% (19.17). All the treatments based on botanicals were significantly superior over untreated control and dichlorvos. Neem 0.5 and 0.1% were significantly superior as ovicide over other concentrations of neem and annona as well. De-Ling Ma *et. al.* (2005) evaluated Neem based insecticides and abamectin against the eggs of rice bug *Leptocorisa chinensis* (Dallas) and reported that the Azadirachtin 0.024% was effective with 25-37 % egg mortality. Significantly low survival of eggs was recorded in Neem 0.5%, Neem 0.1%, Annona 0.2%, Annona 0.1% and Neem 0.05%.

Effect of insecticide film on newly emerged nymphs was also studied. Data on percent nymph mortality showed highest mortality due to Neem 0.5% (83.50) followed by Annona 0.1 % (82.72), Annona 0.2% (80.13), Neem 0.1 % (79.67), Neem 0.05% (76.61), Neem 0.025% (69.61) and dichlorvos 0.05% (12.01). Annona 0.2 and 0.1, Neem 0.5, 0.1, 0.05 percent were at par. Singh (1999) reported that nimcidine (0.2 %) was effective against mango hopper with about 66 % reduction in hopper population. Samal and Patnaik (2008) evaluated combinations of neem based and synthetic insecticides against *Amrasca bigutulla bigutulla* and found that the combinations of azadirachtin 0.03% and 0.09% + carbaryl 0.2% was effective. Dichlorvos 0.05% was justify it use as a cantral in view of low efficacy less effective against eggs and nymphs of black bug. It may be due to its fumigation effect which lasts for short period (Cremlyn, 1978). Mukharji and Misra (1972) evaluated 16 insecticides including dichlorovos against larvae and adults of *Tribolium castaneum* Herbst and found that dichlorvos it was less toxic. Sarup *et.al.,* (1969). Also reported that dichlorvos was less toxic to adults of mustard aphid, *Lipaphis erysimi* Kalt. All the plant based insecticides were significantly superior over untreated control.

The present study showed that 0.5% neem was mast toxic to the eggs of *D.gibbus*. For hymphs neem 0.5%, Annona 0.1 and 0.2% were most texic being on par.

From practical point of view neem 0.5% should be used as first choice as it will be toxic to both the stages of the hug. The seend choice should be Annona 0.1% as a toxic insecticide to both the stages of the inseet.

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Economics of sugarcane cultivation in Andhra Pradesh – under irrigated and rainfed condition

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ABSTRACT

The present study was an attempt to identify the important factors influencing the input use efficiency in sugarcane production. Primary data collected during 2010-11 on costs and returns involved in cultivation practices, Cost concepts, Benefit Cost Ratio (BCR) and Cobb-Douglas type of production function were employed for achieving the objectives. The total cost of cultivation per hectare in Sugarcane was Rs. 1,72,288, Rs.1,19,945 and Rs.1,08,215 respectively in irrigated plant, irrigated ratoon and rainfed conditions. There was 62 per cent higher yield in irrigated condition vis-à-vis rainfed conditions. BCR on operating cost was highest (1.53) in irrigated ratoon followed by irrigated plant (1.41) and rainfed (1.36). The most important factor influencing production were labour availability and manures usage in both irrigated and rainfed conditions.

Key words: Sugarcane, *Irrigated, Rainfed, Input use efficiency, North coastal zone, Andhra Pradesh*

With 292.3 million tonnes of Sugarcane production in 2009-10, India ranked second in the world after Brazil. The total sugarcane cultivated area in India was 4.2 million hectares (2.6 % of the total cropped area) and productivity was 70 t/ha. In India, Andhra Pradesh ranks fifth in sugarcane area with a share of 3.78 per cent (0.16 Mha). The average production was 11.71 Mt contributing to 4.0 per cent of the total production of the country, along with productivity of 74.1 t/ha (Cooperative sugar, 2011). In Andhra Pradesh, the major sugarcane growing districts in Coastal Andhra, Rayalaseema and Telangana regions are Visakhapatnam, Chittoor and Nizamabad districts respectively.

Ali baba (2005) estimated that operational cost of cultivation per hectare of sugarcane in North Coastal Zone of Andhra Pradesh was Rs. 39,398, in 2001-02. Since then the cost of cultivation was increased tremendously mainly owing to the labour charges. With this background present study was taken up with the following specific objectives**:**

1. To work out costs and returns in cultivation of sugarcane under irrigated and rainfed conditions
2. To identify the resource use pattern in sugarcane under rainfed and irrigated conditions
3. To assess the important factors of sugarcane cultivation under rainfed and irrigated conditions

MATERIALS AND METHODS

North Coastal Zone (NCZ) was selected as it has higher base of sugarcane production in state. NCZ comprises of three districts *viz.,* Srikakulam, Vizianagaram and Visakhapatnam. Primary data was collected during 2010-2011. All the districts of North Coastal Zone were selected. All sugarcane growing mandals in districts were listed and one mandal with largest area under sugarcane cultivation was selected. Two villages selected randomly from each mandal. Thus, six villages were selected. Selection of respondents is final stage of sampling. Five growers each for irrigated and rain fed sugarcane were selected at random from each village. A total 30 growers for irrigated and 30 growers for rain fed method of sugarcane cultivation were selected. Thus, making total sample size of 60 farmers.

Analytical tools

Apart from Budgeting techniques and Cost concepts following analytical tools were employed to achieve the objectives;

1) **Benefit Cost Ratio (BCR):** It is calculated as Gross returns accrued divide by total cost incurred on i^{th} enterprise by jth farmers as given below:

$$BCR_{ij} = \frac{\sum GR_{ij}}{\sum TC_{ij}}$$

2) **Cobb-Douglas Type of Production Function**: To identify the most important factors effecting the production in both Irrigated and Rain fed method of cultivation, following Cobb-Douglas type of production function was fitted;

$$Y = a_o H^{a_1} M^{a_2} N^{a_3} P^{a_4} K^{a_5} S^{a_6} e_u$$

Where, **Y**= Out put of main produce (quintals) per hectare in irrigated / rainfed

a_o = Intercept

H = Human labour (man-days/ha)

M = Manure (quintals/ha)

N = Nitrogen (kg/ha)

P = Phosphorous (kg/ha)

K = Potassium (kg/ha)

S = Seed rate (tones/ha)

e_u = Error term

a_1 to a_6 are the elasticities of production

RESULTS AND DISCUSSION

I. Comparative Costs and returns in cultivation of Irrigated and Rain fed Sugarcane

Table 1 reveals that the total cost of cultivation of sugarcane (per hectare) in irrigated conditions in plant crop was Rs. 1, 72,286 with variable cost (Cost A_1) Rs. 1,05,198 (61.06 % of total cost), in ratoon crop total cost of cultivation was Rs. 1,19,945 with variable cost 64,556 (53.82% of total cost). Under rainfed condition it was Rs. 1,08,215 with variable cost 64,269 (59.39 % of total cost). Under irrigated conditions, out of the total operational cost (Cost A) 76 per cent (Rs.84, 947) was incurred on labour charges and 24 per cent (Rs.26, 825) was spent on materials in plant crop. In under rainfed condition 69 per cent (Rs.47, 117) was incurred on labour charges and 31 per cent (Rs.21, 169) was spent on materials. This shows the labour-intensive nature of sugarcane under irrigated conditions. Among the operational costs in irrigated plant crop harvesting and transport charges was highest Rs.28,500 (25.5%), followed by seed material and planting Rs.20,900(18.7%), TT Propping Rs.11,903(10.65%) *etc.* Similar kind of trend was noticed in other methods. Whatever may be the method the higher costs were incurred on labour related activities than material related. That shows the key ness of the labour in sugarcane cultivation. BCR was highest (1.53) in irrigated ratoon followed by irrigated plant (1.41) and rainfed (1.36). Where as, net returns per hectare was Rs. 43,002, Rs.34,244 and Rs.23,131 in irrigated plant, irrigated ratoon and rainfed conditions.

Rama rao *et al.* (2011) estimated that variable cost of cultivation (per hectare) of sugarcane in North Coastal Zone during 2009-10 was Rs 95,725 with BCR of 1.49. In present study variable cost of cultivation (per hectare) of sugarcane in North Coastal Zone was Rs 1, 05,198. Thus, there was increase of nearly Rs. 10,000 per hectare ***ie.,*** 10 per cent in

Table 1. Cost of cultivation of Sugarcane under irrigated and rainfed conditions (Rs/ ha)

		Irrigated		Rainfed
SN	Operations	Plant	Ratoon	Plant
1	Land preparation/ratoon initiation	5,220	1,180	4,100
2	Ridge formation	1,375	0	0
3	Seed material and planting	20,900	2,100	20,500
4	FYM and Fertilizers application	8,215	6,240	7,260
5	Inter-cultivation & Weeding	12,100	15,074	5030
6	Irrigation Charges	12,363	10,200	0
7	TT Propping	11,903	7,700	7,800
8	Plant Protection	5,122	3,200	2,100
9	Harvesting & Transport	28,500	18,862	17,480
Cost A1		**1,05,198**	**64,556**	**64,269**
Interest on working Capital		6,575	4,035	4,017
Cost A		**1,11,773**	**78,591**	**68,286**
A2(A1+Rent paid for leased in Land)		1,05,198	54,556	64,269
A2+Family Labour		1,12,018	70,876	70,389
B1(A1+Interest on Capital Assets)		1,05,198	64,556	64,269
B2(B1+Rental Value of Owned Land)		1,49,804	94,196	90,489
C1(B1+Family Labour)		1,12,018	70,876	70,389
C2 (B2+Family Labour)		1,56,624	1,09,041	98,377
C3 (C2+10 % of C2)		1,72,286	1,19,945	1,08,215
Yield (T/Ha)		78	52	48
Rs Per Tone		1900	1900	1900
Total Returns		**1,48,200**	**98,800**	**87,400**
BCR (on Cost A_1)		1.41	1.53	1.36
BCR (On Cost C)		0.71	0.65	0.59
Net returns (Rs /-) per ha (on Cost A_1)		**43,002**	**34,244**	**23,131**

one year. The major contributor for this increase was labour wages, on an average it increased nearly 20 per cent *i.e.* from Rs. 150-200/- to 200-250 /- per day.

II. Comparative Resource Use Pattern in cultivation of Irrigated and Rain fed Sugarcane:

The per hectare productivity (Tonnes/Ha) under irrigated and rainfed condition was 78 and 48 respectively (Table 2). Thus, there was 62 per cent higher yield in irrigated conditions in comparison with rainfed condition. Except potassium, all the resources use was higher in irrigated condition than rainfed condition. This was reflected in the cost of cultivation of sugarcane. Usage of potassium higher in rainfed condition is because of potassium gives the crop resistance to drought condition.

III. Production function estimates in cultivation of Irrigated and Rain fed Sugarcane

The Cobb-Douglas type of production function was fitted to the observations for the estimation of elasticities of important variables contributing to the yield of sugarcane plant crop in both irrigated and rainfed conditions. The analysis of variance in respect of the production function showed significant variance indicating the overall significance of estimated production function (Table 3). The value of coefficient of multiple determinations (R^2) in irrigated condition was 0.78, which suggest that the six resources included in the production function had jointly explained as high as 78 per cent of total variation. R^2 was 0.69 in rainfed method, which suggests that the six resources included in the production function had jointly explained as high as 69 per cent of total variation. That shows the variables taken into consideration were crucial factors in irrigated than in rainfed conditions. This is because irrigated sugarcane is being in more under controlled conditions than rainfed, which is vulnerable to natural vagaries.

Except, seed rate under rainfed condition all other variables found significant. In both conditions, elasticities for human labour (a_1 is 0.92 and 0.65 in rainfed and irrigated conditions respectively) were found more crucial than any other factor. That is why 76 per cent and 69 per cent of operation cost in irrigated and rainfed condition were incurred on labour charges (Table 1). Negatively significant was noticed in Nitrogen (a_3 = - 0.39) in irrigated condition and Phosphorous (a_4 = - 0.03) in rainfed condition. That shows as one per cent increase in the Nitrogen over recommended dose results in decrease in the out put to the tune of 0.39 per cent. Similarly, one per cent increase in Phosphorous over recommended doses results in the decrease in the out put by 0.03 per cent. The elasticities of all variables are higher in irrigated condition than rainfed condition except Nitrogen and Potassium. That shows the more response of rainfed sugarcane for Nitrogen, Potassium than Phosphorous in comparison with irrigated conditions.

Table 2. Comparative resource use in Sugarcane (per Ha) under irrigated and rainfed conditions

S.N	Resources Particulars	Units	Irrigated		Rainfed
			Plant	Ratoon	Plant
1	**Human Labour**	Mandays	478	263	248
2	**Manure**	Quintals	120	70	45
3	**Nitrogen**	Kilograms	198	278	170
4	**Phosphorus**	Kilograms	176	62	152
5	**Potassium**	Kilograms	60	18	92
6	**Seed Rate**	Tons	11	6	10
7	**Productivity**	Tons / hectare	78	52	48

Table 3. Cobb-Douglas production function estimate for sugarcane under irrigated and rainfed conditions

S.N	Particulars	Method of Cultivation	
		Irrigated	Rainfed
1	**Human Labour (X_1)**	0.65 * *	0.92 * *
		(0.1852)	(0.3102)
2	**Seed Rate (X_2)**	0.38 *	- 0.08 *
		(0.0492)	(0.1982)
3	**Manure (X_3)**	0.52 * *	0.39 * *
		(0.0289)	(0.0298)
4	**Nitrogen (X_4)**	-0.39 *	0.29 *
		(0.0518)	(0.0391)
5	**Phosphorus (X_5)**	0.33 * *	-0.03 *
		(0.0445)	(0.0398)
6	**Potassium (X_6)**	0.15 * *	0.21 * *
		(0.0232)	(0.0376)
7	**Intercept**	- 2.59 *	- 2.87 *
		(0.5354)	(0.8927)
	R^2	**0.78**	**0.69**
	F Value	**268**	**117**

Note: 1) * and **indicates significance at 5 and 1 per cent respectively

2) Figures in parenthesis are standard errors for the respective regression coefficients

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Computation of compound growth rates for sugarcane using non-linear growth models

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ABSTRACT

Measuring the growth of any entity over a time period is important for understanding the past behavior and for future planning. 'Compound growth rate' is one of the frequently used methods for calculating the growth rate. Among the agricultural crops sugarcane is a multi-product crop, every fraction of which finds economic use either as a food, fodder, fuel or fiber and plays a major role in the rural economy. India produces more than 26 million tonnes of sugar through more than 516 sugar mills and nearly 45 million people are engaged in the production of cane and sugar. The present study has been carried out to compute the compound growth rates of area, production and productivity of sugarcane crop in India. All India sugarcane data production, productivity and total area cultivated during the period of 1930-2006 has been used for the computation of growth rates. The deficiencies in the existing method of calculating the compound growth rate has been pointed out. As an alternate, methodology using the non-linear growth models has been discussed for computing the compound growth rates. The parameters of the model have been estimated using non-linear estimation procedure. In the present study three popular growth models Logistic, Gompertz and Monomolecular have been used for estimation of the parameters. The results of the parameter estimates and goodness of fit measures indicated that among the three models Logistic model is appropriate for the present study. The compound growth rates have been calculated for Logistic model. The results of compound growth rates for sugarcane production data is 2.96%. For area and productivity of cane, the growth rates have been estimated as 1.73% and 1.12% respectively.

Key words : Compound growth rates, Groath models, Sugarcane

Sugarcane occupies a very prominent position on the agricultural map of India covering a large area in tropics as well as in sub-tropics. It is the major agro-industrial crop in India next to textiles. Sugar is still the most preferred sweetener and most widely used calorific food, especially in the developing countries. Hence it becomes important to study the growth rate of this crop for making decisions regarding import, export and price fixation etc.

The usual method is to assume a multiplicative error term to the nonlinear geometric model. The model is to be linearized by means of logarithmic transformation. The parameters are estimated by the method of least squares. Several research workers have used the non linear geometric model for computation of compound growth rates for food grains, pulses and cash crops (Debnarayan Sarkar et al. 2002, Kamal Vatta and Meenu Aggarwal, 2000; Sanjay Kumar Dashora et al. 2000; Shiv Kumar et al. 2002; Mohammad Taher Ahmadi Shadmehri, 2008). But the current method has a number of draw backs. The proper method is to use non-linear growth models and the parameters are estimated using non-linear estimation procedures after which the growth rates should be computed. The present study aims at overcoming the drawbacks of the above method. Finally the growth rates have been calculated using the model that best suits the data. Previously similar methodology has been used to calculate the growth rates of total food grain production (Prajneshu and Chandran, 2005) and Potato production (Prajneshu and Chandran, 2006) of India. The total cultivable area, production, productivity of sugarcane crop has been considered and its growth rates have been computed.

MATERIALS AND METHODS

All India sugarcane production (million tonnes), total area (million hectares) under cane cultivation and sugarcane productivity (tonnes/hectare) for a period of 76 years [1930-2006] has been used for the study. The secondary data on sugarcane production, productivity and area was collected from Co-operative Sugar and Indian Sugar journals. The analysis has been performed using the SPSS software. Three popular non linear growth models Logistic, Gompertz and Monomolecular have been tried. The parameters of the models were estimated employing Levenberg-Marquart's algorithm.

Further the normality of the residuals has been analyzed by using Shapiro-Wilk test. The goodness of fit of the models were tested using R^2, MAE, MSE & RMSE. Based on the above results the model that best suits the data has been identified and finally growth rates have been calculated.

2.1 Existing method of calculating the Compound growth rates and its drawbacks:-

The Malthus model is given by

$$Y_t = Y_0 (1+r)^t$$

The usual method is assume a multiplicative error term and the model is linearised by means of logarithmic transformation. The parameters are estimated by the 'method of least squares'. Finally the compound growth rates are estimated by

$$\hat{r} = \exp(\hat{B})$$

The above method has the following difficulties [Prajneshu and Chandran, 2005]

1. In the Malthus model the response variable Y_t tends to infinity as 't' tends to infinity.
2. The assumption of the multiplicative error term does not hold good in reality.
3. The third drawback is that the R^2, which is a measure of goodness of fit and the standard error, could be found out only for the new linearised version of the model and not the original model.

2.2 Suggested alternative method for computation of Growth rates

To overcome the above said drawbacks the following methodology Prajneshu and Chandran (2005), has been adopted. The exponential model given by equation (1) is replaced by more realistic growth models like Logistic, Gompertz and Monomolecular. A special feature of these model is that they are' Mechanistic' in nature in which the parameters have specific biological interpretation. A mechanistic model usually arises as a result of making assumptions about the type of growth, writing down differential or difference equations that represent these assumptions, and then solving these equations to obtain a growth model. The models are given by

2.2.1 Logistic Model

The parameters of this model have a simple physical interpretation. The mathematical form of the model has been presented in equation 3.

$$Y_t = c/(1+b\exp(-at)) + e, \quad b = c/y(0)-1$$

Where Y_t denotes the sugarcane production during the time 't',
'a' denotes the intrinsic growth rate,
'b' denotes the different functions of the initial value Y (0),
'c' denotes the carrying capacity of the model and
'e' is the error term.

2.2.2 Gompertz Model

This is another widely used growth model having sigmoid behavior which is given by equation 4. Unlike the logistic model, it is not symmetrical about its point of inflection.

$$Y_t = c\exp(-b\exp(-at)) + e, \quad b = \ln[c/y(0)]$$

Where Y_t denotes the sugarcane production during the time 't',
'a' denotes the intrinsic growth rate,
'b' denotes the different functions of the initial value Y (0),
'c' denotes the carrying capacity of the model and
'e' is the error term.

2.2.3 Monomolecular Model

Monomolecular model which is given by equation 5 has no point of inflection and climbs steadily at a decreasing rate. It has been used in the past to represent the later portions of a life history.

$$Y_t = c-(c-a)\exp(-bt) + e$$

Where Y_t denotes the sugarcane production during the time 't',
'a' denotes the intrinsic growth rate,
'b' denotes the different functions of the initial value Y (0),
'c' denotes the carrying capacity of the model and
'e' is the error term.

The parameters are estimated using Non-linear estimation procedure. For the present study Levenberg-Marquart's algorithm has been employed in estimating the parameters. A number of widely separated initial values were tried to ensure that convergence of the parameters were 'global' and not 'local'.

2.2.3 Computation of Compound Growth Rates

The compound growth rates have been calculated by

$$d[\log(y)]/dt,$$

i.e. $y^{1}dy/dt$

For Monomolecular, Logistic and Gompertz models, compound growth rates pertaining to the period $(t_i t_{i+1})$, i = 0, 1,……., n-1, where n denotes number of data points is given by,

$R^{M}_{t} = a\,[c/Y_t - 1]$

$R^{L}_{t} = a\,[1 - Y_t/c]$

$R^{G}_{t} = a \ln [c/Y_t]$

The required compound growth rate over a given period of time may be obtained by computing arithmetic mean. However, it may be kept in mind that in "Nonlinear modeling", convergence to biologically meaningful values is not always guaranteed. In such cases 'Non-parametric regression methodology' (Chandran and Prajneshu, 2004) may be applied.

2.3 Goodness of Fit

The following measures of goodness of fit have been used to judge the adequacy of the model developed. The coefficient of determination R^2 which is the most commonly used method is given by

i) $R^2 = 1 - \sum (y_i - \hat{y}_i)^2 / \sum (y_i - \bar{y})^2$

ii) Mean Absolute Error (MAE) = $\sum | y_i - \hat{y}_i | / n$

iii) Mean Squared Error (MSE) =

$$\sum (y_i - \hat{y}_i)^2 / (n - p)$$

iv) Root Mean Square Error (RMSE) =

$$\left[\sum (y_i - \hat{y}_i)^2 / n\right]^{1/2}$$

Here 'n' denotes the total number of observed values and 'p' denotes the number of model parameters.

2.4 Examination of residuals

As a measure of goodness of fit the residual analysis of the models is carried out. The main assumptions made in the models are

1. Errors are random.
2. Errors are normally distributed.

To test whether the residuals are normally distributed Shapiro-Wilk test has been performed. If the fitted model is correct, the residuals should exhibit tendencies that tend to confirm or at least should not exhibit a denial of the assumptions. The procedure for carrying out the Shapiro-Wilk test has been explained in brief.

2.4.1 Test for Normality (Shapiro-Wilk test)

The Shapiro-Wilk test is used test the normality of the given observation.

The null hypothesis is given by,

The Null hypothesis

H_0: The residuals are normally distributed against

H_1: The residuals are not normally distributed

The test statistic is given by

$W = S^2/b$

Where

$$S^2 = \sum a(k)\, \{x_{(9n+1-k)} - x_{(k)}\},$$

$$b = \sum (x_i - \bar{x})^2$$

In the above the parameter k takes the values

k= {1, 2, ……., n/2 when n is even

{1, 2, ……., (n-1)/2 when n is odd

and $x_{(k)}$ is the k^{th} order statistic of the set of residuals. H_0 is rejected at level α if W is less than the tabulated value.

RESULTS AND DISCUSSION

The results of the nonlinear growth models for sugarcane production, area, productivity are presented in Table 1, 2&3. From the results of the three tables, with respect to the Gompertz and Monomolecular model even though convergence has taken place, it is noticed that the estimate of carrying capacity 'c' is extremely high. Further the standard errors of estimates of parameter 'c' for the models are also very high. A perusal into the goodness of fit values for sugarcane production indicates that RMSE, MAE and MSE with respect to the monomolecular model are very high. Thus Gompertz and Monomolecular models are found to be inappropriate for describing the data set under consideration. With respect to the logistic model the parameter estimates and its standard error values are low model compared to the other two models. Further the R^2 values are slightly higher for logistic model. The RMSE, MAE and MSE values are much better for logistic model in comparison with the

Table 1. The results of Non-linear Growth Models for Sugarcane Production

		Logistic		Gompertz		Monomolecular	
		Estimate	S.E	Estimate	S.E	Estimate	S.E
1)	**Parameter**						
	c	633.768	156.793	5601.24	8144.66	121874.18	14976509.37
	b	32.999	3.34	32.532	4.124	0.9400	9.135
	a	0.038	0.0038	0.0077	0.003	0.00002	0.003
2)	**Goodness of Fit**						
i)	R^2	0.9532		0.9515		0.90087	
ii)	RMSE	18.470		18.811		26.916	
iii)	MAE	13.758		13.916		21.979	
iv)	MSE	359.837		373.263		764.154	
3)	**Examination of the residuals**						
i)	Shapiro Wilk test	0.946**		0.938**		0.937**	

** Significant at 1% level; S.E – Standard Error; RMSE – Root Mean Square Error; MAE – Mean Absolute Error; MSE – Mean Square Error

Table 2. The results of Non-linear growth models for total area cultivated

		Logistic		Gompertz		Monomolecular	
		Estimate	S.E	Estimate	S.E	Estimate	S.E
1)	**Parameter**						
	c	13.336	7.499	204.434	691.066	934.713	67778.02
	b	1.2022	0.0591	1.199	0.065	0.949	0.093
	a	0.0215	0.003	0.0039	0.003	0.00004	0.0033
2)	**Goodness of Fit**						
i)	R^2	0.94302		0.94276		0.92423	
ii)	RMSE	0.2371		0.238		0.274	
iii)	MAE	0.194		0.195		0.227	
iv)	MSE	0.059		0.060		0.79	
3)	**Examination of the residuals**						
i)	Shapiro Wilk test	0.988**		0.987**		0.983**	

** Significant at 1% level; S.E – Standard Error; RMSE – Root Mean Square Error; MAE – Mean Absolute Error; MSE – Mean Square Error

Table 3. The results of Nonlinear Growth Models for Sugarcane Productivity

		Logistic		Gompertz		Monomolecular	
		Estimate	S.E	Estimate	S.E	Estimate	S.E
1)	**Parameter**						
	c	312.629	407.436	371332.353	8304289.1831	10962.238	786029.187
	b	30.814	0.952	30.995	1.0032	28.663	1.258
	a	0.0133	0.003	0.0012	0.0033	0.000049	0.0036
2)	**Goodness of Fit**						
i)	R^2	0.92831		0.92795		0.91433	
ii)	RMSE	3.381		3.389		3.696	
iii)	MAE	2.660		2.674		2.931	
iv)	MSE	12.054		12.116		14.406	
3)	**Examination of the residuals**						
i)	Shapiro Wilk test	0.985**		0.985**		0.984**	

** Significant at 1% level; S.E – Standard Error; RMSE – Root Mean Square Error; MAE – Mean Absolute Error; MSE – Mean Square Error

monomolecular model. The results of Shapiro Wilk test indicate that the residuals satisfy normality condition 1% level of significance. Based on the above results logistic model is found to be more appropriate for the present study. Even though the R^2 and Shapiro Wilk test values are almost same for the three models, based on the low values of parameter estimates and its standard error logistic model is found to be more suitable for the present data set. Since Gompertz and Monomolecular models are found to be inappropriate, compound growth rates are calculated based on Logistic model alone. The results of Compound growth rates for sugarcane production, area, productivity in terms of Logistic model are presented in Table 4. From Table 4, the results of sugarcane production indicate that the annual

Table 4. Computation of Compound Growth rates for Sugarcane Production, Area and Productivity.

Year	Logistic model					
	Production (million tonnes)		Area (million hectares)		Productivity (tonnes/hectare)	
	Predicted Value of Yt	Annual Growth rate	Predicted Value of Yt	Annual Growth rate	Predicted Value of Yt	Annual Growth rate
1930	33	0.04	1.2	0.02	30.81	0.01
1931	34.21	0.04	1.23	0.02	31.19	0.01
1932	35.46	0.04	1.25	0.02	31.56	0.01
1933	36.75	0.04	1.27	0.02	31.95	0.01
1934	38.09	0.04	1.3	0.02	32.33	0.01
1935	39.47	0.04	1.33	0.02	32.72	0.01
1936	40.9	0.04	1.35	0.02	33.12	0.01
1937	42.38	0.04	1.38	0.02	33.51	0.01
1938	43.91	0.04	1.4	0.02	33.91	0.01
1939	45.49	0.04	1.43	0.02	34.32	0.01
1940	47.12	0.04	1.46	0.02	34.73	0.01
1941	48.8	0.04	1.49	0.02	35.15	0.01
1942	50.54	0.03	1.52	0.02	35.57	0.01
1943	52.33	0.03	1.55	0.02	35.99	0.01
1944	54.19	0.03	1.57	0.02	36.42	0.01
1945	56.1	0.03	1.6	0.02	36.85	0.01
1946	58.07	0.03	1.64	0.02	37.29	0.01
1947	60.11	0.03	1.67	0.02	37.73	0.01
1948	62.21	0.03	1.7	0.02	38.17	0.01
1949	64.37	0.03	1.73	0.02	38.62	0.01
1950	66.6	0.03	1.76	0.02	39.08	0.01
1951	68.9	0.03	1.8	0.02	39.54	0.01
1952	71.27	0.03	1.83	0.02	40	0.01
1953	73.71	0.03	1.86	0.02	40.47	0.01
1954	76.22	0.03	1.9	0.02	40.94	0.01
1955	78.8	0.03	1.93	0.02	41.42	0.01
1956	81.46	0.03	1.97	0.02	41.9	0.01
1957	84.19	0.03	2.01	0.02	42.39	0.01
1958	87.01	0.03	2.04	0.02	42.88	0.01
1959	89.9	0.03	2.08	0.02	43.38	0.01
1960	92.87	0.03	2.12	0.02	43.88	0.01
1961	95.92	0.03	2.16	0.02	44.39	0.01
1962	99.05	0.03	2.2	0.02	44.9	0.01
1963	102.27	0.03	2.24	0.02	45.42	0.01
1964	105.57	0.03	2.28	0.02	45.94	0.01
1965	108.95	0.03	2.32	0.02	46.46	0.01
1966	112.42	0.03	2.36	0.02	47	0.01
1967	115.98	0.03	2.4	0.02	47.53	0.01
1968	119.62	0.03	2.44	0.02	48.07	0.01
1969	123.35	0.03	2.49	0.02	48.62	0.01
1970	127.17	0.03	2.53	0.02	49.17	0.01
1971	131.08	0.03	2.58	0.02	49.73	0.01
1972	135.07	0.03	2.62	0.02	50.29	0.01
1973	139.15	0.03	2.67	0.02	50.86	0.01
1974	143.32	0.03	2.71	0.02	51.43	0.01
1975	147.58	0.03	2.76	0.02	52	0.01
1976	151.92	0.03	2.81	0.02	52.59	0.01
1977	156.35	0.03	2.85	0.02	53.17	0.01
1978	160.87	0.03	2.9	0.02	53.77	0.01
1979	165.47	0.03	2.95	0.02	54.36	0.01
1980	170.16	0.03	3	0.02	54.97	0.01
1981	174.93	0.03	3.05	0.02	55.58	0.01
1982	179.78	0.03	3.1	0.02	56.19	0.01
1983	184.71	0.03	3.15	0.02	56.81	0.01

Table 4. Countd....

Year	Logistic model					
	Production (million tonnes)		Area (million hectares)		Productivity (tonnes/hectare)	
	Predicted Value of Yt	Annual Growth rate	Predicted Value of Yt	Annual Growth rate	Predicted Value of Yt	Annual Growth rate
1984	189.72	0.03	3.21	0.02	57.43	0.01
1985	194.81	0.03	3.26	0.02	58.06	0.01
1986	199.98	0.03	3.31	0.02	58.7	0.01
1987	205.21	0.03	3.37	0.02	59.34	0.01
1988	210.52	0.03	3.42	0.02	59.98	0.01
1989	215.89	0.03	3.48	0.02	60.63	0.01
1990	221.33	0.02	3.53	0.02	61.29	0.01
1991	226.83	0.02	3.59	0.02	61.95	0.01
1992	232.4	0.02	3.64	0.02	62.62	0.01
1993	238.01	0.02	3.7	0.02	63.29	0.01
1994	243.69	0.02	3.76	0.02	63.96	0.01
1995	249.41	0.02	3.82	0.02	64.65	0.01
1996	255.18	0.02	3.88	0.02	65.34	0.01
1997	260.99	0.02	3.94	0.02	66.03	0.01
1998	266.84	0.02	4	0.02	66.73	0.01
1999	272.73	0.02	4.06	0.01	67.43	0.01
2000	278.64	0.02	4.12	0.01	68.14	0.01
2001	284.59	0.02	4.18	0.01	68.86	0.01
2002	290.55	0.02	4.24	0.01	69.58	0.01
2003	296.54	0.02	4.3	0.01	70.3	0.01
2004	302.54	0.02	4.37	0.01	71.03	0.01
2005	308.55	0.02	4.43	0.01	71.77	0.01
2006	314.57	0.02	4.49	0.01	72.51	0.01

growth rates were slightly higher and constant during thirties. After which there was a slight decline in the annual growth rates during forties. But the trend continued to be the same for a very long period of time, till the end of eighties. There is again a slight decrease in growth rates. If the same trend in the past is maintained, in future, the growth rates are likely to remain constant for a still longer period or at least for a same period as in the past. With respect to sugarcane area, the annual growth rate has remained constant from the beginning till the end of nineties. In the beginning of the year two thousand, the growth rate has decreased slightly. In future the growth rate would remain constant for a long period as in the past. For sugarcane productivity, the annual growth rates have remained constant throughout the entire period. In order to know the overall growth rate for a period of 76years, arithmetic mean is taken for the compound growth rates obtained for individual years. The compound growth rates estimated for sugarcane production, area and productivity are 2.96%, 1.76% and 1.12% respectively.

CONCLUSION

Nonlinear models which are more realistic in nature could replace the Malthus model for calculation of compound growth rates. With development of nonlinear estimation procedures and the availability of software packages to readily accomplish the task, more accurate results could be produced without much difficulty using nonlinear growth models.

The data on sugarcane production, area and productivity has showed an increasing trend over years. But the growth rates in area and production have shown a decrease over the years and that of productivity has remained constant which may be due to the agronomical practices and market factors. Using the Logistic model, the compound growth rate calculated for sugarcane production during the period 1930-2006 is 2.96% and for area and sugarcane productivity the compound growth rates are 1.73% and 1.12% respectively.

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Training impact on sugarcane development personnel : attitudinal change and their correlates

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ABSTRACT

The study was conducted to assess the change in attitude of sugarcane development personnel of sugar mills due to knowledge imparted them in various areas of sugarcane production technologies under different training programmes organized at IISR. A sample of 152 sugarcane development personnel received training at IISR during the period 2008-2010 were considered as target group to assess attitude change due to training intervention. To measure the attitude of sugarcane development personnel sugarcane attitude scale was developed as per the prescribed procedures. Data on personal profile of the trainees and attitude were recorded with the help of pre-structured questionnaire. Pre and post attitude score was calculated to measure the change in attitude of development personnel. Correlation coefficients was calculated to see the association of personal profile variables with the attitudinal change.

Key words: Attitude, Personal profile, Sugarcane and Correlates

Sugarcane and sugar productivity in any mill zone areas much depend upon the attitude of sugarcane development personnel working there. At the same time sugarcane development personnel must be well equipped in sugarcane production technologies and must possess positive and progressive attitude towards the potential of technologies in accruing economic benefit to the sugarcane farmers. Realizing the importance of much needed interventions IISR regularly organizes training of 3 days to one month durations for cane development personnel of sugar mills situated in different regions of the country. Training module is developed and oriented as per the need of the trainee participants. Training is implemented to impart “360 degree angle” knowledge in sugarcane cultivation, marketing, processing and human skill enrichment. The findings of several study conducted in the past indicates that gain in knowledge leads to development of positive or favourable attitude towards the subject. This assumption was pre requisite in deciding theoretical and practical sessions on sugarcane training. The sessions were moduled/oriented to provide opportunity to trainee participants for broadening cognitive domain as well as attitude in sugarcane production technologies. If development personnel have positive attitude, they will certainly desire to know more and more and vise-a-versa is also true. As a result, they will be more equipped and efficient to disseminate the improved technologies among the cane growers. Assuming the symbiotic relationship between know-how and attitude in agriculture, a number of studies have been done in the past to develop and assess the attitude. Under the present study effort was made to assess the impact of training imparted on change in attitude of sugarcane development personnel. The personal profile of the participant trainee was also analyzed and their correlation with attitudinal change was established.

MATERIALS AND METHODS

The study was conducted during the period 2008-2010. To develop and strengthen the human resource skills in Indian sugar industry IISR organized in-house/residential trainings of 3 days to one month durations for cane development personnel of sugar mills situated in different regions of the country. Training module was developed and oriented as per the need of sugar industry. Training was implemented to impart “360 degree angle” knowledge in sugarcane cultivation, marketing, processing and human skill enrichment. The participants of these trainings were considered as respondents of the study and a total of 152 respondents were selected purposively for collecting data. An attitude scale was developed by following standard steps for development of attitude scale *viz.,* items collection, editing of items, obtaining judges opinion, final selection of items, reliability and validity test of scale (Likert, 1932 and Edward, 1957). A questionnaire was developed to record data on personal profile and attitude of trainee participants. Frequency and percentage were calculated to categorize the respondents on the basis of personal profile.

Attitude measurement: For measuring the attitude of sugarcane development personnel, the scale was presented in a format of 3 point continuum, *viz*., SA(Strongly Agree), A (Agree), and NA (Not Agree). For positive statements, the score 3, 2, 1 and for negative statements, the score assigned were 1, 2, 3. The attitude score of the individual respondent was obtained by summing up the scores for all the items in the scale. The minimum and maximum possible scores was 66 and 198, respectively.

Pre and post attitude score was calculated to measure the attitude of participants or cane development personnel. To see the association of personal profile of respondents with the attitudinal change correlation coefficient was calculated.

RESULTS AND DISCUSSION

Personal Profile of the respondents/trainee participants

Results presented in the table 1 indicate that average age of the participant trainees was 39.04 years. Majority of the trainees (69.70 %) were in middle age group (31-50 years), moreover more than 90% of the cane development personnel in sugar mills are either in young or middle age group i.e. upto 50 years of age. This is quite encouraging to note that Indian sugar industry much rely on young shoulder who can promise bright and sustained future. Majority of the respondents (55.26%) were graduate followed by post graduate (40.79 %). This holds the notion that highly educated and qualified cane development personnel of sugar mills have potential to acquire more and more cognitive domain in sugarcane technologies (Moris, 1983). As far as service experience is concerned 50.00, 37.50 and 5.26 per cents of the trainees were having service experience in sugarcane, sugarcane along with agriculture and agriculture, respectively. However, 7.24 per cent trainees were not having any experience that means they were new entrants to sugar industry. Monthly salary of the trainees varied from Rs.10,000-40,000. Majority(44.74%) of them were getting monthly salary in the range of Rs. 15,001-25,000 followed by 31.58 per cent were in the range of 10,000-15,000. However, 23.68 per cent of them were getting salary more than Rs. 25, 000 per month. Majority (86.18 %) of them were from the rural background followed by 13.82 per cent of the respondents having urban background. Most of them (46.06%) were utilizing one information source for getting the information related to sugarcane, agriculture, etc. followed by three and two sources. Majority of the trainees (77.63%) have already received up to 5 trainings during their service period. Further, it was observed that the most of the trainees (37.50 %) were engaged in development along with marketing works followed by 28.93 per cent in development work, 9.87 per cent in development plus administration, and 9.20 per cent in administrative work, an equal numbers (3.96%) of trainees in research plus development, and marketing. Research work was assigned to the few trainees (1.97%) only.

Attitudinal Change

It was observed that the average pre-training attitude score of trainees was 141.59 while it was 171.86 after imparting training. Average difference in pre and post-training attitude scores was 30.27 (21.38%). Increase in attitude score was

Table 1: Personal Profile of the Trainee participants

N=152

Sl. No.	Variables	Categories	Frequency
1.	Age	Young (up to 30years)	32 (21.05)
		Middle (31-50 years)	106 (69.70)
		Old (above 50 years)	14 (9.25)
		Average age (years)	39.04 years
2.	Education	Graduate	84 (55.26)
		Post Graduate	62 (40.79)
		Doctorate	6 (3.95)
3.	Service Experience	Only Agriculture	8 (5.26)
		Only Sugarcane	76 (50.00)
		Sugarcane & Agriculture both	57 (37.50)
		No Experience	11 (7.24)
4.	Monthly salary	Low (Rs 10,000.- 15, 000)	48 (31.58)
		Medium (Rs. 15, 001-25, 000)	68 (44.74)
		High (Above Rs. 25, 000)	36 (23.68)
		Range	10,000-40,000
5.	Back Ground	Rural	131 (86.18)
		Urban	21 (13.82)
6.	Sources of Information	Nil	17 (11.18)
		One source	70 (46.06)
		Two sources	24 (15.79)
		Three sources	31 (20.39)
		All 4 sources	10 (6.58)
7.	Training Received	Up to 5	118 (77.63)
		5-15	15 (9.67)
		15-25	7 (4.61)
		>25	12 (7.89)
8.	Work Assigned	Development	44 (28.93)
		Marketing	6 (3.96)
		Administration	14 (9.20)
		Research	3 (1.97)
		Development + Marketing	57 (37.50)
		Marketing + Administration	2 (1.32)
		Research + Development	6 (3.96)
		Development+ Administration	15 (9.87)
		Development + Marketing + Administration	5 (3.29)

Figures in parentheses are in percentage

Table 2: Attitudinal Changes after imparting training

N=152

Sl. No.	Particulars	Score
1	Average pre-training attitude score	141.59
2	Average post-training attitude score	171.86
3	Average difference in post and pre-training attitude score	30.27
4	Increase in attitude score (%)	21.38
5	't' value	29.6151**

** Highly significant ($p<0.01$)

found to be highly significant as indicated by the highly significant 't' value (29.6151). The increase in attitude level of trainees was achieved as a result of their exposure and learning of recent development in sugarcane production technology during training. At the same time the conviction level of trainee respondents about benefits of latest sugarcane production techniques gone high due to consolidated learning experience imparted them. This reflects that training imparted to development personnel result into change in attitude towards sugarcane production technologies in positive direction (Table 2).

Association of personal profile variables with the attitudinal changes

It is evident from the results presented in the table 3 that Variables like service experience (0.2742), salary, information source utilization and training received exerted highly significant and positive influence on changing the attitude of the trainees. It is also evident that training could succeed in changing the attitude of trainees in positive direction

Table 3: Association of personal profile variables with the attitudinal changes

N=152

Sl. No.	Variables	'r' value
1.	Age	-0.1542
2.	Education	0.2132*
3.	Service Experience	0.2742**
4.	Salary	0.3085**
5.	Background	-0.0337
6.	Information source utilization	0.3367**
7.	Training Received	0.3622**
8.	Work Assigned	0.0286

** Highly significant ($p<0.01$)

irrespective of the age, background and work assigned which is clearly indicated by the non-significant 'r' values (-0.1542, -0.0337 & 0.0286). However, the education is also exerting positive influence but moderately. The information source utilization, training received, salary, service experience and education may be modulated or consolidated to harness the positive benefits in changing the attitude of cane development personnel in favorable direction.

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Trend of sugar recovery and sugar losses in factories due to low recovery in a crushing period of sugarcane - estimation and analysis

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ABSTRACT

Annual compound growth rates of sugar recovery and sugar production were estimated to measure the growth in different period during last sixty years for all the State of India. Annual compound growth rate of recovery in India was positive during seventies and eighties during last sixty years. But there were highest negative sugar recovery growth during sixties and nineties of 0.4 % per year in India. During 2001-2010, all the states in India registered negative annual compound growth rates of sugar recovery except Bihar, Maharashtra, Gujarat, Karnataka and Pondicherry. Bihar had highest growth in sugar recovery of 0.288% per year where lowest growth was estimated in West Bengal of – 2.478 % per year. The annual compound growth rates of sugar recovery in different states are not uniform during 1951-2008. Important sugar producing states registered negative annual compound growth (%) of sugar recovery i.e. UP (-0.034), Maharastra (-0.049), and Karnataka (-0.004) and Bihar (-0.16). The annual compound growth rates of sugar production in different states are not uniform during 1951-2010. In India, the highest annual compound growth rate (8.23%) was estimated during1951-1960 and lowest was recorded in 19061-1970 (3.8 %).

Key words: Sugar recovery, Sugar losses, Compound growth rate.

In India sugarcane is cultivated all over the country from latitude 8^0 N to 33^0N, except cold hilly areas like Kashmir Valley, Himanchal Pradesh and Arunachal Pradesh .There are two distinct sugarcane growing belts (tropical and subtropical) in the country which are characterised by marked difference in climatic and agricultural conditions. The tropical sugarcane belt comprises of Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Orissa and Kerala, The subtropical belt consists of Uttar Pradesh, Haryana, Punjab, Bihar, Rajasthan, West Bengal, Assam and part of Madhya Pradesh .

India by contributing 18.59% area and 17.16% production ranks second among sugarcane growing countries of the world for both area and production of sugarcane (2009). In this country, sugarcane is an important cash crop in agriculture sector which shares 5.23% of the total value of agricultural out put and occupies only 2.25% of country's gross cropped area (2009).

In India, sugar industry is the second largest agro-based industry in India and contributes significantly to the socioeconomic development of rural population. It supports 50 million farmers and their families and provides direct employment to over 0.5 million skilled and semi-skilled persons in sugar mills and integrated industries (Solomon, 2011). The Indian sugar industry plays a leading role in global sugar market being the world's second largest producer after Brazil, producing nearly 15 and 25% of global sugar and sugarcane, respectively. The sugar industry which encompasses 599 operating sugar mills, 309 distilleries and 180 cogeneration plant and numerous pulp, paper and chemical making units is supported by four leading sugarcane research institutions, twenty-two state sugarcane research stations, world class sugar machinery manufacturers, suppliers and technical experts (Solomon, 2011).

Taking 1950 –51 as a base year (start of the planning era), sugarcane production in India has been rising progressively and peaked during 1999- 2000. However, there are fluctuations in area and production too in a cyclic manner . These fluctuations are influenced by price of sugarcane and its products, return from competing crops, proper and timely marketing of cane and the weather conditions at the time of planting. Due to the fluctuations in sugarcane production there is dip or very high production in every five years. In both the situations industry suffers. In deficit years crushing period shortens and sugar mills are to stop early in peak recovery period and in case of excess production mills run for extended period of very low sugar recovery in summer.

Sugarcane area, production and productivity in tropical and subtropical zones of India and also in different states within these zones are characterized by enormous differences. Due to high productivity (94.39 t/ha) tropical zone contributed 52% in India's total cane production from 42.3% area. Subtropical zone though occupying higher cane area (58.6%) contributed only 48% in cane production because of lower productivity (56.04 t/ha). Due to high sugar recovery in the arid Deccan plateau and high proportion of cane crushing, tropical zone contributed 66% in India's total sugar production from 42.3% area h in tropical zone (Fig. 1,2 and 3).

After attaining peak cane productivity (71.2 t/ha) and production (299.3 million tonnes) in 1999-2000 there has been progressive decline in successive years and during 2003-04 the production and productivity came down to 233.86 million tonnes and 59.4 t/ha, respectively. The analysis of cane area and productivity data indicated that this decreasing trend of production is mainly attributed to drastic fall in yield of Maharashtra, Karnataka and Andhra Pradesh along with reduction in cane area in all the tropical states. Continuous drought due to scanty rains and severe incidence of woolly aphid in Maharashtra brought down cane yield level from 90 t/ha in 1999-2000 to 51.3 t/ha in 2003-04. Similarly the cane yields of Karnataka and Andhra Pradesh which were 101 and 80.8 t/ha, respectively during 1999-2000 reduced to only 66.7 and 72.0 t/ha in 2003-04. During 2010-11, cane area increased up to 4.94 million hectare and produced 339.17 million tonnes of cane with productivity of 68.6 t/ha. Sugar production this year is estimated to be around 24.2 to 24.5 million tones. Sugar production in the country fluctuate in erratic fashion in the country during last ten years from 12.69 million tones to 28.36 million tones. Sugar recovery is also one of the important factor for this erratic behavior.

In the present study, an efforts has been made to identify the pattern of sugar recovery during a crushing season and reasons for low recoveries in different states of India. We have also tried to quantify the recoveries at micro level for an efficient planning and development of sugar industry in sugarcane growing states of India. Sugar losses due to low recovery in a crushing period are also estimated for different states of the country and problem discussed.

MATERIALS AND METHODS

The data of sugar recovery and sugar production was collected from 1951 to 2010 from Anon (2011). Weekly data of sugar recoveries for different states were collected from Cooperative Sugar Press News for the period 1992-93. Average sugar recovery of a months was calculated by taking the mean of four weeks values. Month wise sugar recovery of each states were calculated and presented in table 2 for the sugarcane crushing season 1992-93.

Annual compound growth rates of sugar recovery and sugar production were calculated based on the data collected from Indian Sugar (2011) during 1951-2010. In order to estimate compound growth rates of sugar recovery and sugar production, exponential equations were fitted using time as an independent variable and sugar recovery and sugar production as dependent variables.

$$y = ab^x$$

$$\text{Compound Growth Rate (\%)} = (b-1)\ 100$$

A detailed examination of the sugar recovery pattern and sugar losses due to low recovery for different months of each states were estimated and further analysised and compared. Potential and constraints with regard to sugar production were identified for the purpose of better planning of research and development activities in the country.

RESULTS AND DISCUSSIONS

Improving sugar recovery from sugarcane is the most important factor for industry and a challenge to scientists and technologists. Increasing the sugar content of cane is not as easy as increasing the yield of cane (Panje, 1968). But, within limits, a wisely - managed crop which gives good yields of cane can also be made to develop a reasonable good sugar content (Panje, 1968). Sugar recovery in sugarcane growing districts of India fluctuates between 5.75 to 11.45 per cent affecting sugar production in the country in an erratic fashion (Kumar and Misra, 2002). If one looks into the recovery scenario of the country for the past 60 years, it will appear that the recovery has been ranging from 9.33 to 10.55 per cent with 0.073 per cent annual compound growth rate only. Trend of sugar recovery in India is almost static (Graph 1) during 1951-2010. The most favorable sugar recoveries are generally obtained in the arid Deccan plateau (Kumar and Misra, 2002). Sugar recovery mainly depends on sugarcane variety, condition of the crop at the time of harvest, weather conditions prevailing during the crop growth and duration of the crushing season (Rao, 1979). Besides this, sugar recovery is also influenced by biotic and a biotic stresses. Post harvest management of sugarcane also plays an important role in realizing better sugar recovery by the sugar factories.

(1) Trend of sugar recovery in different states of India

Annual compound growth rate of recovery in India was positive in seventies and eighties over the period of last sixty years. But there were high negative sugar recovery growth during sixties and nineties at the rate of 0.4% per year in India (Table 1). During 2001-2010, all the states in India registered negative annual compound growth rates of sugar recover except Bihar, Maharashtra, Gujarat, Karnataka and Pondicherry (Table 1). Bihar had highest growth in sugar recovery of 0.288% per year where lowest growth was estimated in West Bengal of -2.478% per year. During 1991-2000, similar trend were also observed in all the states. Major sugar producing states, Maharashtra, Uttar Pradesh and Karnataka, had positive growth in sugar recovery during this period. During 1981-1990, the major sugar producing states, Maharashtra and Uttar Pradesh had negatives growth rates. However the all the tropical states of India had positive growth rates in India (Except Maharashtra) with more than one per cent in Andhra Pradesh and Gujarat (Table 1). During sixties all most all the states had negative growth rates except Orissa. During last sixty years, Punjab and Bihar had highest growth rates in sugar recovery (1.8% per year) during 1971-1980 after that both the states had negative rates. Highest negatives growth was observed in West Bengal (- 4.65 % per year) during 1981-1990. Peak growth in sugar recovery was attained in India during 1971-80 and 1981-1990.

Overall annual compound growth of last fifty eight years (1951-2008) was also estimated to measure growth in sugar recovery in different states of India (Table 3). The annual compound growth rates of sugar recovery in different states are not uniform during 1951-2008. Important sugar producing states registered negative annual compound growth (%) of sugar recovery *i.e.* UP (-0.034), Maharastra (-0.049) and Bihar (-0.16) (Table 3). This is an alarming situation for the country. The situation therefore, warrants serious and immediate effects to minimize losses at farmers, processors, traders and consumers level to improve the sugar recoveries in these states. However Gujarat registered positive annual compound growth (%) of sugar recovery with 0.272 % followed by Tamil Nadu (0.13), Andhra Pradesh (0.11), Orissa (0.11), Karnataka (0.018) and Kerla (0.02) in tropical India. In sub-tropical India, Haryana (0.35), Punjab (0.09), Madhya Pradesh (0.085) registered positive annual compound growth (%) of sugar recovery. If these trends are projected for planning and location of new capacities, the sugar basket is likely to be largely confined to UP, Maharstra, Tamil Nadu, Gujrat, Karnataka, Andhara Pradesh, Punjab and Haryana in order of their importance.

(2) Improving sugar recovery : a challenge to technologists and scientists

Improving sugar recovery from sugarcane is the most important factor for industry and a challenge to scientists and technologists. The behavior of sugar recovery pattern is a normal type curve during the crushing season from September to May in tropical and November to April in both tropical and sub-tropical India (Graph 2-4). Recovery is mainly influenced by climate, variety and the efficiency of the factory.

Maharashtra and Gujarat are having the most favourable climate for sugar recovery. The efficient cooperative sugar factories also contribute in enhancing the recovery in the country i.e., more than 11 per cent in the last few years. In Gujarat, sugar recovery starts from 9.5% in the month of November, reaches a maximum of around 12 percent in the month of February and declines around 11 per cent in April (Table 2). Karnataka and Tamil Nadu have the longest crushing season of sugarcane in the country starting in the month of September and ending in May (1992-93). In Karnataka, sugar recovery starts from 8.33 percent in February and ending with 10.8 per cent in April. On the same lines in Tamil nadu, recovery starts from 8.81 percent in September, reaching a maximum of 10.55 per cent in March and ending in May with 7.33 recovery per cent.

Punjab is the only State in sub-tropical India where crushing starts in October with a recovery of 7.45 per cent , attaining peak in January-February (9.46 per cent) and ending with 8.71 per cent in April. Uttar Pradesh, Haryana and Bihar start their crushing in the month of November with recovery around 8.0 percent, reaching a maximum of around 9.5 per cent in January -February and ending in April with a recovery 8.1 per cent. There is a need to improve the sugar recovery per cent in the incline and decline phases of recovery curve. Planners, Scientists and Technologists should come out with appropriate technologies for increasing recovery in decline phase by introducing chemicals, varieties, agronomic practices and factory to improve its efficiency. Similarly in incline phase, there should be late ripening varieties and effective chemicals for sustaining the recovery especially in area having surplus cane.

Sugar recoveries can be improved by (I) Growing as normal, healthy and full-season crops as possible, (ii) saving and conserving within them such sugar as they naturally develop and (iii) Calendering the crops and stipulating the time of their harvest in a such a way that only crops as they become ripe are used for the interaction of sugar. In creasing the sugar content of cane is not as easy as increasing the yield of cane (Panje, 1968). But, within limits , a wisely - managed crop which gives food yields of cane can also be made to develop a reasonable good sugar content. In the present study, an efforts was made to identify the pattern of sugar recovery during a crushing season and reasons for low in different states of India. There is a considerable scope to improve sugar recovery by minimizing sugar losses at various stages of crop growth harvesting and processing of cane (Solomon, 1997).

(3) Sugar recovery in different districts of India

During sixty years, it appears that the recovery has been ranging between 9.33 to 10.55%. The recovery did increase to 10.0 and above from 2000 to 2010 but it was below 10% during 1994-1995 to 1998-1999. The highest sugar recovery of more than 11 % has been continuously recorded in Maharashtra state up to 2009-2010. Gujarat had also more than 11% in 1988-89 and during 1991-1992 up to 1994-1995. Lowest recovery was initially not limited to any particular state and states like Assam, Pondicherry, West Bengal, Kerala and Rajasthan Punjab, Haryana, Uttar Pradesh and Andhra Pradesh have been recording lowest recoveries during last fifteen years.

Co-efficient of variation was calculated to measure the stability of sugar recoveries in different states and are presented in table 3. The maximum stability in sugar recovery was found in Assam (2.61%) and Rajasthan (4.47%) followed by Madhya Pradesh (4.78%), Uttar Pradesh (5.59%) and Haryana (16.94%). It indicated that there is minimum variation in sugar recoveries between the districts of state in Sub-topical India. In contrary, Bihar (17.08 %) registered maximum variability in sugar recoveries of districts. It is due to old sugar factories located in the different part of state. The variation in sugar recovery was highest in Orissa (19.89%) followed by Kerala (15.74%), Gujarat (9.89%), Tamil Nadu (6.48%), Andhara Pradesh (8.73%), Maharastra (8.23%) and Karnataka (8.17%) within the districts of states (Table 3). It indicated the variability in sugar recovery among the districts of states.

The districts which are giving more than 10% recoveries in the country are Solapur, Nashik, Aurangabad, Ahmed Nagar, Beed, Dhule, Pune, Satara, Sangli, Kolhapur, Parbani, Yavatmal of Maharastra, Surat and Valsad in Gujarat, Nizamabad in Andhra Pradesh, Coimbatore and Dharmpuri in Tamil Nadu and Bellary, Mandya and Dharwad in Karnataka (Table 3). The district which are having low sugar recovery (less than 8.75 %) are Bhagalpur, Nawada,Hazaribag, Gaya, Patna, Vaisali, Aurangabad, Madhubani, Darbhanga, Samastipur, Muzaffarpur, Sitamarhi, E.Champaran, W.Champaran, Siwan, Saran, Gopalganj, Ballia, Azamgarh, Ghazipur, Palghat, Pattanamtitta (Table 3).

It, therefore, appears that where as one hand the sugar plants in same parts of the country are undergoing modernization and making efforts to improve their over all

Table 1 : Annual compound growth rate (%) of sugar recovery in different states of India

States	1951- 1960	1961-1970	1971-1980	1981- 1990	1991- 2000	2001- 2010
Uttar Pradesh	0.09	0.094	-0.07	-0.27	0.08	-0.585
Uttrakhand	-	-	-	-	-	-0.197
Bihar	-1.2	-1.44	1.8	-0.18	-0.48	0.288
Haryana	-	-0.32	0.21	1.67	-1.0	-0.853
Punjab	-1.2	-1.44	1.8	-0.18	-0.48	-0.483
Madhya Pradesh	1.2	-0.42	-0.43	0.99	-0.28	-0.237
Rajasthan	0.5	-0.78	0.24	-0.87	-0.82	-1.362
West Bengal	-1.97	-0.25	-1.79	-4.65	-0.07	-2.478
Assam	-	-0.54	-0.62	-0.085	-0.25	-
Maharahtra	0.10	-1.027	0.09	-0.08	0.22	0.040
Andhra Pradesh	- 0.01	-1.06	-1.57	1.09	-0.02	-0.690
Gujarat	-	-1.33	0.31	1.49	-0.74	0.001
Karnataka	-0.96	-0.38	-0.55	0.18	0.14	0.110
Orissa	0.48	0.37	-0.12	0.73	-0.40	-0.042
Tamil Nadu	0.24	-1.56	-0.13	0.52	-0.56	-0.706
Kerla	0.24	-1.56	-0.13	0.52	-0.56	-
Pondichery	-	-	-	-	-	0.103
India	-0.011	-0.408	0.101	0.099	-0.349	-0.198

performance, perhaps an equal number of factories are not undertaking any developmental activities with the result that fall their performance is equally rapid and thus leading static sugar recoveries, for the past many years. It may, therefore, be pertinent if instead of putting more sugar factories, full scale efforts are made to rejuvenate the existing sugar plants particularly in the region of Bihar, Uttar Pradesh, Andhara Pradesh and Karnatka (Bhagat, 1992).

(4) Sugar production and losses due to low sugar recovery during a crushing period

Annual compound growth of last sixty years (1951-2010) were estimated for different period to measure growth in sugar production in different states of India (Table 4). The annual compound growth rates of sugar production in different states are not uniform during 1951-2010. In India, the highest annual compound growth rate (8.23 %) was estimated during1951-1960 and lowest was recorded in 1961-1970 (3.8 %). The growth in sugar production in the country in last five decades was measured between 4 to 5 % per annum. Growth in sugar production during 2001 – 2010 was registered positive in all most all the tropical states in India except Andhra Pradesh and Pondicherry. Growth in sugar production during 2001 – 2010 was registered negative in all most all the sub-tropical states in India except Madhya Pradesh. In India, highest annual compound growth was recorded of 6.81 % in Karnataka followed by Maharashtra (3.532 %) in 2001-2010. During 1991-2000, highest annual compound growth was recorded of 9.38 % in Orissa followed by Andhra Pradesh (6.33 %) and lowest was recorded in Assam (- 6.30). During 1981-1990, all most all the states registered positive growth rates in sugar production except Rajasthan, West Bengal and Kerala. Highest growth rate was found in Haryana (14.28 %) followed by Punjab (12.75 %) in 1980-1990.

During 1971-1980, all the states in India registered positive growth in sugar production except in Bihar. During last sixty years, Bihar had negative growth in sugar production. The highest growth of 11.92 % was found in Gujarat. Similarly all the states had positive growth in sugar production except in Bihar, Madhya Pradesh, Rajasthan and West Bengal during 1961-70. All the states had positive growth in sugar production except in Tamil Nadu during 1951-1960. Maharashtra, Andhra Pradesh, Gujarat, Karnataka and Orissa states in the country which never had negative growth in sugar production in the country (Table 4).

Table 5 reveals that most of tropical states start sugarcane crushing during first week of October while subtropical region starts crushing from the month of November and December. Country produced 69.18% sugar in three months *i.e.,* December to February. A total of 69.18% sugar was produced

Table 2: Trend of sugar recovery in different states of India during a crushing period (based on the data of 212 sugar factories in 1992-93)

States	September	October	November	December	January	February	March	April	May
Andhra Pradesh	-	-	7.35	8.67	9.68	10.4	10.21	10.49	-
Assam	-	-	-	7.6	7.77	8.35	6.11	-	-
Goa	-	-	7.75	9.33	9.82	9.85	7.54	-	-
Gujarat (Saurashtra)	-	-	9.65	8.62	9.1	9.52	8.99	-	-
Gujarat (South)	-	7.62	9.29	10.97	11.83	12.36	12.29	10.99	-
Haryana	-	-	9.07	9.8	9.79	10.16	10.1	8.56	-
Karmataka	8.33	9.38	9.58	10.27	10.74	10.95	10.82	10.88	-
Kerala	-	8.88	9.05	8.8	-	-	-	-	-
Madhya Pradesh	-	-	8.09	9.06	9.83	10.56	-	-	-
Maharashtra (North)	-	-	8.68	9.92	10.77	10.77	10.4	9.75	-
Maharashtra(South)	-	-	9.81	11.06	11.48	11.77	11.79	11.79	7.25
Orissa	-	-	6.66	8.49	9.48	10	8.94	7.34	-
Pondicherry	-	-	-	8.68	9.61	11.07	9.81	7.75	-
Punjab	-	7.45	8.88	9.77	9.46	9.29	9.43	8.71	-
Rajasthan	-	-	-	-	8.85	9.78	-	-	-
Tamil Nadu	8.81	8.58	8.28	8.58	9.31	10.17	10.55	8.75	7.33
U.P.(Centeral)	-	-	8.13	9.21	9.58	9.77	10.06	10.1	-
U.P.(West)	-	-	7.79	9.06	9.31	9.41	9.83	-	-
U.P.(East) and Bihar	-	-	8.77	9.31	9.56	9.72	10.19	8.31	-
Tropical India	**8.57**	**8.62**	**8.61**	**9.40**	**10.18**	**10.69**	**10.13**	**9.72**	**7.29**
Subtropical India	**-**	**7.45**	**8.46**	**9.37**	**9.48**	**9.81**	**9.92**	**8.92**	
India	**8.57**	**8.03**	**8.53**	**9.38**	**9.83**	**10.25**	**10.03**	**9.32**	**7.29**

Table 3: Sugar Recovery in Different Districts of India

S.N.	State	Compound Growth Rate (%) of Sugar Recovery (1951-2008)	No. of Districts	Average Sugar Recovery Along with CV (in%)	Average Sugar Recovery (%) of District
1.	Punjab	0.09	11	9.04 (10.73)	Patiala(9.14), Ludhiana(9.03), Sangrur(9.31), Amritsar(9.01), Faridkot(7.15), Gurdaspur(9.85), Ropar(9.92), Kapurthala(9.81), Jalandhar(9.77), Firozpur(9.21) , Mansa(7.26)
2.	Haryana	0.35	10	8.92 (16.94)	Kurukshetra(9.72), Ambala(9.83), Jind(9.36), Karnal(9.93), Rohtak(9.71), Hissar(6.74), Sonipat(9.93), Faridabad(9.29), Panipath(9.14), Kaithal(5.56)
3.	Uttar Pradesh	- 0.034	36	8.90 (5.59)	Ballia(8.63), Azamgarh(8.52), Ghazipur(8.57), Varanasi(9.08),Jaunpur(6.89), Kanpur(8.57), RaeBareli(9.54), Barabanki(8.53), Bahraich(8.59), Faizabad(9.41), Gonda(9.29), Basti(9.27), Gorakhpur(8.58), Deoaria(8.92), Hardoi(8.63), Sultanpur(8.72), Lahimpur(9.51), Shahjahanpur(8.72), Piliphit(8.83), Barelly(8.88), Rampur(8.95), Moradabad(8.68), Bijnour(9.10), Dehradun(8.26), Nainital(9.11), Saharanpur(9.07)), Muzaffarnagar(8.92), Bulandshahar(8.68), Meerut(9.34), Aligarh(8.85), Mathura(8.85), Etah(9.10), Sitapur(9.30), Budaun(9.44), Farrukhabad(9.27), Ghaziabad(9.84)
4.	Bihar	- 0.16	15	7.80 (17.08)	Nawada(7.39), Gaya(6.18), Patna(5.75), Vaisali(7.24), Madhubani(7.74), Darbhanga(7.47), Samastipur(10.12), Muzaffarpur(7.25), Sitamarhi(9.64), E.Champaran(8.52), W.Champaran(9.18), Siwan(6.04), Saran(8.83), Gopalganj(8.52), Prnia(7.9)
5.	Madhya Pradesh	0.085	8	9.50 (4.78)	Sehore(9.72), Gwalior(9.93), Indor(9.42), Khandawa(9.35), Ratlam(9.28), Madsaur(8.64), Ujjain(9.45), Morena(9.97)
6.	Rajasthan	- 0.14	3	8.95 (4.47)	Bundi(9.34), Chittaurgarh(8.97), Sriganganagar(8.54)
7.	Assam	- 0.279	2	8.12 (2.61)	Golaghat(7.97), Karimganj(8.27)
8.	Maharastra	- 0.049	22	10.02 (8.23)	Osmanabad(9.69), Solapur(10.31), Nashik(10.69), Aurangabad(10.3), Ahmednagar(10.63), Beed(10.01), Dhule(10.16), Pune(10.45), Satara(11.33), Sangli(11.22), Kolhapur(11.45), Jalna(9.67), Parbhani(10.28), Nanded(9.59), Latur(9.45), Amravati(8.03), Yavatmal(10.49), Buldana(9.38), Jalgaon(9.82), Nagpur(8.98), Wardha(9.49), Akola(8.98)
9.	Gujarat	0.272	7	9.55 (9.89)	Junagadh(8.52), Surat(10.85),Valasad(11.31), Bharuch(9.23), Amreli(9.10), Kheda(9.47), Rajkot(8.79)
10.	Orissa	0.11	5	7.83 (19.89)	Ganjam(8.85), Sambalpur(8.88), Korput(8.85), Badamba(5.34), Nayaganj(7.25)
11.	West Bengal	- 0.788	2	6.715 (0.11)	Birbhum(6.71), Nadia(6.71)
12.	Andhara Pradesh	0.11	17	8.89 (8.73)	Chittoor(9.00), Krishana(9.65), E.Godavari(9.47), W.Godavari(9.57), Nalgoda(7.40), Cuddapath(7.86), Vishakhapatnam(9.12), Srikakulam(8.75), Ananthpuram(8.46), Nellore(7.87), Vizinagaram(8.94), Nizamabad(10.17), Medak(9.56), Karimnagar(9.81), Kurnool(8.66), Guntur(8.06), Khamam(8.87)
13.	Tamil Nadu	0.13	12	9.38 (6.48)	Chengalpattu(8.93), South Arcot(9.30), NorthArcot(9.81), Salem(9.23), Dharampuri(10.31), Coimbatore(10.06), Periyar(9.61), Triuchirapalli(9.55), Thanjour(9.11), Madurai(9.81), Nellikattabomman(8.75) Pasumponmutramlinganam(9.16),
14.	Karnataka	0.018	14	9.52 (8.17)	Kolar(8.76), Bijapur(9.52), Belgaum(10.72), Bellary(10.14), Bidar(9.98), Shimonga(9.40), Uttarkannad(8.12), Hassan(9.37), Mandya(10.58), Maysore(8.83), Raichur(9.52), Chitradunga(9.45), Dharwad(10.38), Gulbarga(8.56)
15.	Kerala	0.02	2	7.43 (15.74)	Palghat(8.26), Pattanamthitta(6.6)

in three months *i.e.,* December, January and February in India. In Maharashtra, a total of 42% sugar was produted in only two months *i.e.,* January and February. Maharashtra started producing sugar from 3.3 thousand tones in October reached peaked in January and ended in the months of April with only 0.7 thousand tonnes of sugar. Where as in Uttar Pradesh, a total of 87% sugar was produced in December, January, February and March during a crushing period. In Andhra Pradesh, highest sugar of 32% was produced in the month of January. Almost whole sugar was produced during November to March in Gujarat in a crushing period. Only two states Tamil Nadu and Karnataka had the longest period of crushing in India where as shortest period is in sub-tropical states in India of four months.

Uttar Pradesh is highest sugar producing state in subtropics but sugar production was minimum in the month of October (0.5 thousand tones). The highest sugar production was found in the month of February (1051.9 thousand tones)

Table 4: Annual compound growth rate (%) of sugar production in different states of India

States	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
Uttar Pradesh	6.39	0.20	1.99	7.41	4.24	-1.977
Uttrakhand	-	-	-	-	-	-4.492
Bihar	5.06	-3.09	-0.41	2.64	-2.01	-1.404
Haryana	-	6.88	4.49	14.28	1.80	-6.345
Punjab	25.38	7.93	6.60	12.75	2.25	-7.079
Madhya Pradesh	11.28	-6.86	5.23	5.35	-0.70	3.214
Rajasthan	9.22	-1.81	7.44	-4.91	-3.08	-1.224
West Bengal	3.37	-2.04	5.68	-14.76	-1.28	-3.964
Assam	-	5.12	3.72	3.82	-6.30	-
Maharahtra	16.27	9.89	7.35	3.54	5.28	3.532
Andhra Pradesh	14.19	5.98	0.25	4.73	6.33	-2.226
Gujarat	-	14.70	11.92	5.69	4.29	3.917
Karnataka	9.33	6.64	6.72	6.31	5.39	6.811
Orissa	3.79	18.98	9.47	1.53	9.38	1.538
Tamil Nadu	-2.03	12.19	3.63	7.03	4.30	0.758
Kerla	13.76	3.92	0.67	-6.42	4.54	-
Pondichery	-	-	-	-	-	-2.255
India	8.23	3.80	4.61	5.71	4.37	4.104

and reduced to 8.0 thousand tones in the month of May. Haryana and Punjab produced 16.4 and 20.1 thousand tones sugar respectively in the month of November and the highest sugar production was in the month of January and it was 130.8 and 130.0 thousand tones, respectively in Harayana and Punjab. The sugarcane crushing was closed early in the month of March in Punjab while Haryana produced 18.6 thousand tones of sugar in the month of May (Table 5).

The sugar losses dur to low recovery in early and late period of crushing was measured for different states of the country and are presented in table 6. A total of 6.66 (903.24 thousand tones of sugar) was lost in India due to low recovery. The maximum loss was observed in the month of December (2.41%) followed by November (2.02%). The highest sugar loss of 10.95% was observed in the state of Maharashtra followed by 7.89% in Andhra Pradesh and 6.29% in Bihar. The lowest sugar loss was observed in 1.88% in Haryana and 0.98% in Orissa. The highest sugar loss was observed in the month of November in Maharashtra of 4.47%.

Sugar recovery loss level was found different during each month due to loss in early period of cane crushing sugar loss level depends upon sugar recovery and quantity of cane

Table 5: Trend of sugar production (000 tonnes) in different states of India (2003-04)

States	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-05	Aug-04	Sep-04	Total
Andhra Pradesh	0.8	47.3	170.9	260.6	225.2	144.9	33	3.6	-	-	-	-	886.3
Assam	-	-	-	-	-	-	-	-	-	-	-	-	0
Bihar	-	0.9	83.4	99.6	80.9	8.6	0.2	-	-	-	-	-	273.6
Chhattisgarh	-	-	0.7	5.4	5.4	3	2.8	-	-	-	-	-	17.3
Goa	-	0.8	3.7	3.8	1.7	-	-	-	-	-	-	-	10
Gujarat	0.4	166.2	225.6	208.3	206.8	174.6	86.6	-	-	-	-	-	1068.5
Haryana	-	16.4	124.2	130.8	122.2	114.3	55.7	18.6	-	-	-	-	582.2
Karmataka	136	224.8	286.7	266.3	92.3	32.1	1.8	-	-	9.4	23.4	45.2	1118
Kerala	-	-	-	-	-	-	-	-	-	-	-	-	0
Madhya Pradesh	-	4.3	21.11	29.8	26.6	9	2.3	-	-	-	-	-	93.11
Maharashtra	3.3	656.8	1127	975.3	359.8	51	0.7	-	-	-	-	-	3173.9
Orissa	-	0.4	3.3	10.3	16	8.8	2.3	-	-	-	-	-	41.1
Pondicherry	-	-	2.9	4.1	5	4.4	3.8	-	-	-	-	-	20.2
Punjab	-	20.1	118.1	130	85	44.2	-	-	-	-	-	-	397.4
Rajasthan	-	-	0.5	2.7	2.5	3	0.7	-	-	-	-	-	9.4
Tamil Nadu	33.3	17.1	79.8	186	216.1	195.1	97.7	16.6	-	17.6	33.2	26.4	918.9
Uttar Pradesh	0.5	300	1005.8	1043	1051.9	863.2	279.1	8	-	-	-	-	4551.5
Uttarcnchal	-	10.1	78.3	98	88.3	57.9	42.3	13.2	-	-	-	-	388.1
West Bengal	-	-	1.7	2.7	2.1	0.4	-	-	-	-	-	-	6.9
Total	174.3	1465	3333.71	3456.7	2587.8	1715	609	60	0	27	56.6	71.6	13556.41

Table 6: Sugar loss (000 tones) due to low recovery in different states of India (2003-04)

States	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Total
Andhra Pradesh	0.24	14.16	29.65	20.12	1.93	3.87	69.97
	(0.03)	(1.60)	(3.35)	(2.27)	(0.22)	(0.44)	(7.89)
Bihar	–	0.13	7.20	6.16	3.73	–	17.22
		(0.06)	(2.63)	(2.25)	(1.36)		(6.29)
Goa	–	0.13	0.20	0.01	–	–	0.38
		(1.71)	(1.95)	(0.12)			(3.77)
Gujarat	0.12	22.33	23.61	9.04	–	–	55.11
	(0.01)	(2.00)	(2.01)	(0.85)			(5.16)
Haryana	–	1.76	4.40	4.76	–	–	10.92
		(0.30)	(0.76)	(0.82)			(1.88)
Karmataka	19.50	28.13	17.80	5.11	–	–	70.54
	(1.72)	(2.52)	(1.59)	(0.46)			(6.31)
Madhya Pradesh	–	1.01	2.30	2.06	–	–	6.06
		(1.08)	(3.22)	(2.21)			(6.51)
Maharashtra	0.71	141.78	124.27	55.01	21.51	4.41	347.69
	(0.02)	(4.47)	(3.92)	(1.73)	(0.68)	(0.14)	(10.95)
Orissa	–	0.12	0.34	–	–	–	0.46
		(0.72)	(0.25)				(0.98)
Pondicherry	–	–	0.63	0.15	–	–	1.14
			(3.10)	(2.53)			(5.63)
Punjab	–	4.77	10.76	–	–	–	15.53
		(1.20)	(2.71)				(3.91)
Rajasthan	–	–	0.05	0.26	–	–	0.30
			(0.51)	(2.73)			(3.24)
Tamil Nadu	6.22	3.68	14.90	21.86	7.78	–	54.44
							(5.92)
Uttar Pradesh	0.09	53.84	83.90	56.84	4.60	–	236.28
	(0.002)	(1.18)	(1.84)	(1.25)	(0.91)		(5.19)
Uttarcnchal	–	2.30	6.13	5.18	3.77	–	17.19
		(0.54)	(1.58)	(1.34)	(0.97)		(4.43)
India	26.88	273.96	326.84	186.94	80.34	8.28	903.24
	(0.20)	(2.02)	(2.41)	(1.38)	(0.06)	(0.6)	(6.66)

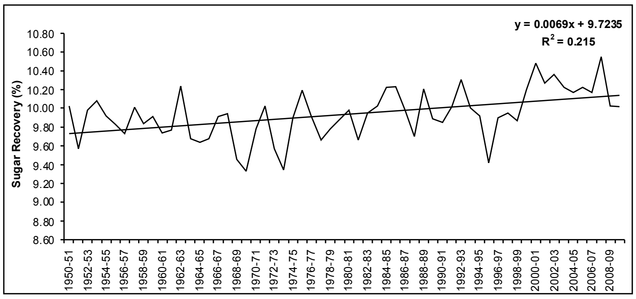
( ) – Sugar loss are presented in per cent

crushed. As well as maturity point comes near sugar loss level reduces. Highest sugar loss was observed in the month of December *i.e.* 3.35% in Andhra Pradesh and 2.21% in the tropical status like Gujarat, while highest sugar loss was found in November month in Karnataka and Maharashtra 2.52 and 4.47% respectively. Highest sugar loss of 10.95% was observed in Maharashtra of tropical region due to high proportion of cane crushed in this state. Uttar Pradesh is main state in subtropics where cane crushing starts in the month of October and peak crushing period is in the month of December (1.84%). The highest sugar loss was observed in the month of in December (1.84%). The highest sugar loss was observed in Haryana (0.82%) during January and Punjab (2.71%) in the month of December.

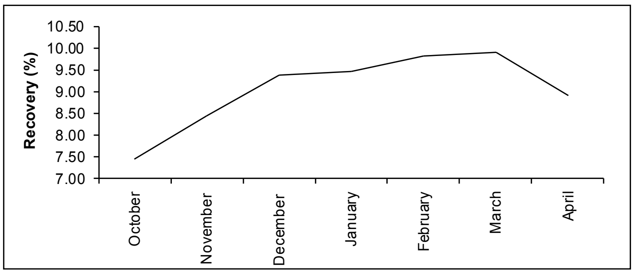
(5) Constraint for sugar recovery and sugar productivity in India

The major constraint for sugar recovery and low sugar productivity in different parts of the country are discussed as follows.

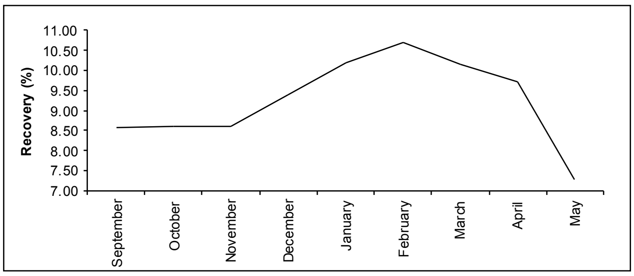
In the districts Bhagalpur, Nawada, Hazaribag, Gaya, Patna, Vaisali,Aurangabad of Bihar, lowest quantity of cane and sugar produced indicate the weakest sugar industry network in the state. Sugar and sugarcane production in this state are restricted because of poor crop management, inefficient sugar factories, operating on an average only for 33 days in a season. It may also be due to the majority of sugar factories being very old which need modernization. The zone suffers due to severe water logging during rainy season and drought during post monsoon period. Majority of cane growers are poor having small land holdings and do not have capacity to give sufficient inputs to the crop. They may be educated in the latest technologies. There is an urgent need for modernization and re-habitation of the sugar industry. The states suffers due to severe water logging during rainy season and drought during post monsoon period. Majority of cane growers are poor having small land holdings and do not have capacity to give sufficient inputs to the crop. They may be educated in the latest technologies. There is an urgent need for modernization and rehabitation of the sugar industry.



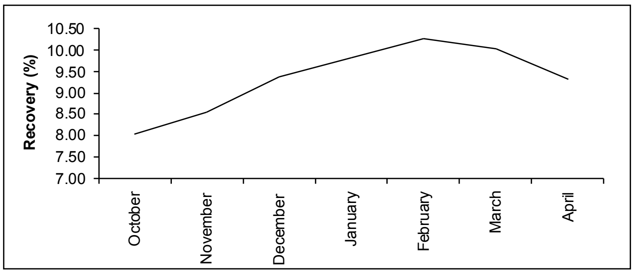
Graph 1 : Trend of sugar recovery (%) in India



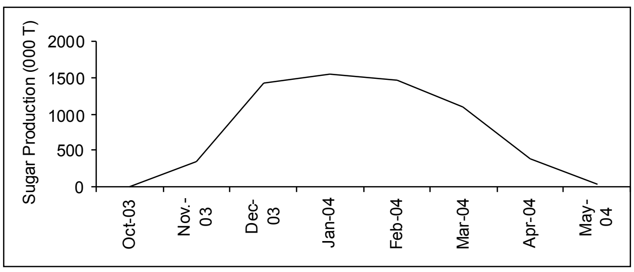
Graph 2 : Trend of sugar recovery in sub-tropical India



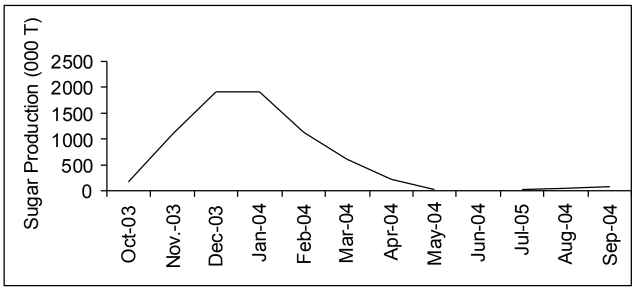
Graph 3 : Trend of sugar recovery in tropical India



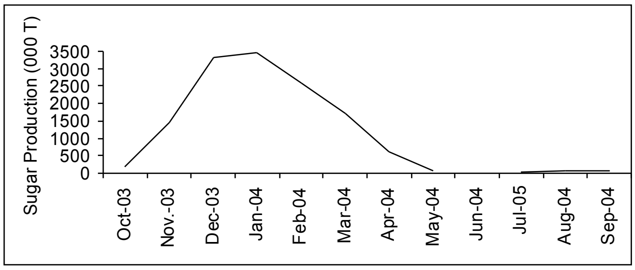
Graph 4 : Trend of sugar recovery in India



Graph 5 : Sugar Production in Sub-tropical India



Graph 6 : Sugar Production in Tropical India



Graph 7 : Sugar Production in India

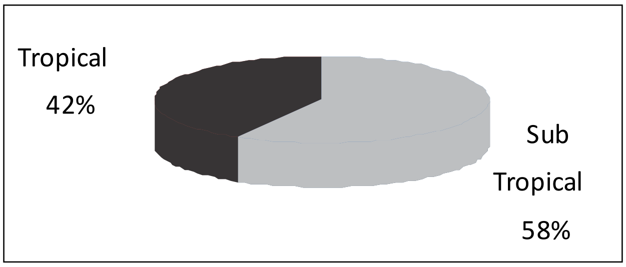


Fig. 1 : Sugarcane area : Tropical vs Sub-tropical India

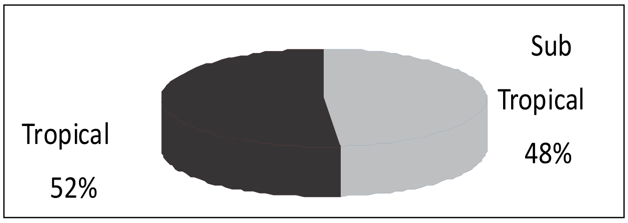


Fig. 2 : Sugarcane production : Tropical vs Sub-tropical India

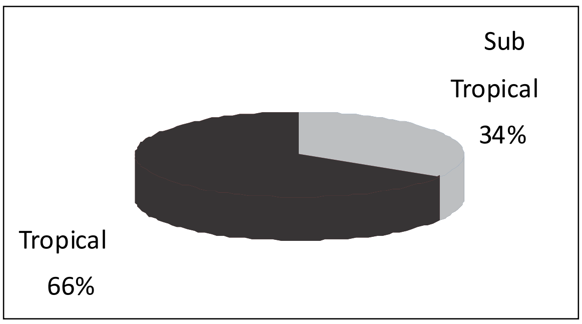


Fig. 3 : Sugar production : Tropical vs Sub-tropical India

In the districts Madhubani, Darbhanga, Samastipur, Muzaffarpur, Sitamarhi, E.Champaran, W.Champaran, Siwan, Saran, Gopalganj, of Bihar and Ballia,Azamgarh,Ghazipur of UP. The major constraints influencing poor sugar recovery in the districts are : (1) Flooding and imperfect drainage condition, limiting soil aeration, yield and quality of sugarcane. (2) Salinity or sodicity hazards occuring in patches. (3) Low availability of essential inputs. (4) Lack of knowledge and adoption of modern technologies.

In the sub-tropical cane growing states of Uttar Pradesh, Punjab, Bihar and Haryana, optimum ripening conditions of temperature, humidity, sunshine and photoperiod exist during October-November and then from end January to March during which period cool dry weather conditions prevail favouring ripening and, sucrose accumulation. However, during the months of December and January, the ripening process slows down due to low temperature conditions, the temperature dipping to as low as 2.5°C and higher humidity because of winter rains and subsequently less sunshine period. Due to these conditions, the overall sugar recovery for the season is affected.

In the districts of Tamil Nadu Karnataka and A.P., Major constraints of cane cultivation are: (1) Coarse soil texture and low to medium AWC, resulting in severe drought situation during crop growth period. (2) Nutrient imbalance, resulting into deficiency of N, P and Zn. (3) The soils of the coastal belt of the region are showing tendency of becoming saline.

In Maharastra and Gujarat, Major constraints for cane cultivation are: (1) Prolonged dry spell periods, adversely affecting the crop growth and leading to crop failure in some seasons. (2) Deficiency of N, P and Zn, leading to nutrient imbalance

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Short Communication

Assessing various herbicidal weed control measures for enhanced sugarcane yield in Odisha

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Sugarcane (*Saccharum* hybrid complex) is an important agro-industrial crop grown primarily for sugar production in India, and plays a pivotal role in agricultural and industrial economy of the country. Here, the crop is cultivated to an extent of 4.96 million hectares, producing nearly 337 million tonnes with the productivity of 67.9 tonnes/hectare. In India, the crop is cultivated broadly under two distinct agro-climatic conditions commonly referred to as tropical and sub-tropical belts. The Area, production and productivity of sugarcane in the tropical and sub-tropical belts are 2.18 and 2.78 m ha, 178 and 159 m t and 81.65 and 57.19 t/ha, respectively. Out of several sugarcane crop management practices required for sugarcane growing in to tropical climate of Odisha, non-adoption of weed control measures at the early part of the sugarcane growth lead to drastic reduction in cane yield and its quality. Losses up to 40% in cane yield were observed due to weeds infestation. Sugarcane, being a long duration and wide spaced crop weeds pose a serious threat to the crop at all the growth stages. Weed competition decreased millable stalks by 32% and stalk thickness by 15% and sugar yield by 31% compared to weed-free plots (El Shafai, *et al.*, 2010). Keeping these points in view, an experiment was thus carried out to study the effect of various herbicidal weed control measures in sugarcane crop.

A field experiment was conducted at the research farm of Sugarcane Research Station, Nayagarh (Odisha) for two consecutive years *i.e.* 2008-09 & 2009 – 2010 in the same plan of layout. The experimental site was located at 20^0 54"90' N latitude and 80^0 07" 56' E longitude. The soil of the experimental field was sandy loam in texture with low organic carbon content (0.481%) and slightly acidic (pH- 6.3) in reaction. The available N status of the soil was low (240 kg/ha.) whereas available P (11.2 kg/ha.) & K (137 kg/ha.) contents were in medium range. The experiment consisted of 10 treatments *i.e.* T_1- control (weedy check) no weeding and hoeing, T_2 - hoeing at 30,60,90 DAP (days after planting), T_3-atrazine @2kg *a.i./ha* (PE) followed by 2,4-D 1kg *a.i*/ha at 60 DAP, T_4-atrazine @ 2kg *a.i/ha* after 1st irrigation & hoeing followed by 2,4-D 1kg *a.i*/ha at 75 DAP, T_5- metribuzine@ 1.25kg *a.i* /ha (PE) followed by 2,4-D 1kg *a.i*/ha at 75 DAP, T_6- atrazine @2kg *a. i./ha* (PE)+ almix 20g/ha at 75 DAP, T_7- metribuzine@ 1.25 kg *i.e.*/ha (PE))+ almix 20g/ha at 75 DAP, T_8-atrazine @2kg *a.i./ ha* (PE)+ ethoxysulfuron 50g *a.i*/ha at 75 DAP, T_9 -atrazine @2kg *a.i./ha* (PE)+ dicamba 350 g *a.i.*/ha at 75 DAP and T_{10}- metribuzine@ 1.25 kg *a.i.*/ha (PE))+ dicamba 350 g *a.i.*/ha at 75 DAP was laid out in randomized block design with three replication . The sugarcane variety Co 87044 was planted at 80 cm row spacing and applied as per the recommended doses of 250 – 100- 60 kg/ ha N, P_2O_5 & K_2O, respectively besides 10 t/ha well decomposed FYM. The crop was managed as per the standard package of practices. The dates of planting and harvesting were 28.01.2008 and 18.12. 2008 during 2008-09 and 25.01.2009 and 29.12.2009 during 2009- 10, respectively. The observations on number of weed/m^2 and weed dry weight g/ m^2 at 60 and 120 days after planting, while number of millable canes, single cane weight, cane yield and quality (sucrose) at harvest were recorded. The observations thus recorded were statistically analyzed and presented in the following para.

The results presented in Table 1 revealed that at 60DAP, treatment consisted of three hand hoeing at 30, 60, & 90 days after planting (T_2) was superior to all other treatments involving various combinations of herbicides application with the lowest weed population of 10.12/ m^2 with corresponding weed dry weight of 9.48 g / m^2. Similar results were reported by Mishra *et al.* (2011) who observed lower weed biomass in sugarcane by three hand weedings. Post emergence application of metribuzine @ 1.25 g *a.i.* along with dicamba @ 350 g *a.i.* /ha at 75 DAP (T_{10}) was next in order with weed population of 12.85 /m^2 and weed dry weight of 9.44 g/m^2, respectively. Efficiency of metribuzine in sugarcane has been reported by Sundara (2000) and Gana (2009). Atrazine @ 2 kg *a.i.* /ha (PE) followed by 2, 4 D @ 1 kg *a.i.* /ha at 60 DAP (T_3) were next in order with weed population and dry matter yield at 13. 71/ m^2 and 10.51 g/ m^2, respectively. These three treatments were statistically at par. At 120 DAP, three hand

Table 1. Effect of herbicidal weed control practices on weed population and dry matter, cane yield attributes and its yield and quality

Treatments	Weed number/m² (60 DAP)	Weed dry wt g/m² (60 DAP)	Weed number/m² (120 DAP)	Weed dry wt g/m² (120 DAP)	Single cane Weight (kg)	NMC ('000/ha)	Cane yield (t/ha)	Sucrose (%)
T_1: control (weed check) no weeding and hoeing	95.47	98.92	100.08	134.21	1.05	45.63	46.84	17.19
T_2: Hoeing at30,60,90 DAP	10.12	9.48	14.85	17.43	1.44	89.29	113.01	17.74
T_3: Atrazine @2kg *a.i.*/ha(PE) followed by 2,4-D 1kg *a.i.*/ha at 60 DAP	13.71	10.51	31.61	35.18	1.02	70.65	78.41	16.74
T_4: Atrazine @2kg *a.i.* /ha after 1st irrigation & hoeing followed by 2,4-D 1kg *a.i.*/ha at 75 DAP	20.76	16.77	40.22	27.83	1.11	66.06	66.73	17.99
T_5: Metribuzine@ 1.25kg *a.i.*/ha (PE) followed by 2,4-D 1kg *a.i.*/ha at 75 DAP	18.47	10.77	19.90	22.22	1.05	58.79	72.61	17.19
T_6: Atrazine @2kg *a.i*/ha.(PE)+ Almix 20g/ha at 75 DAP	15.79	23.52	29.87	41.82	0.98	75.43	94.27	17.12
T_7: Metribuzine@ 1.25kg *a.i.* /ha (PE))+ Almix 20g/ha at 75 DAP	23.42	23.80	37.61	79.18	0.96	56.28	87.36	17.32
T_8: Atrazine @2kg *a.i.*/ha(PE)+Ethoxysulfuron 50g *a.i.*/ha at 75 DAP	19.53	25.96	28.13	49.31	1.15	68.29	84.63	17.95
T_9: Atrazine @2kg *a.i.*/ha(PE)+ Dicamba 350 g *a.i.*/ha at 75 DAP	16.21	9.45	25.34	29.38	1.27	87.67	100.48	18.32
T_{10}: Metribuzine@ 1.25kg *a.i.*/ha (PE))+ Dicamba 350 g *a.i.*/ha at 75 DAP	12.85	9.44	19.87	18.85	1.34	84.66	102.08	16.77
SE m(±)	2.159	1.499	2.055	2.864	0.05	1.57	1.63	0.14
CD (P=0.05)	6.414	4.454	6.105	8.509	0.13	4.37	4.54	0.38

weedings (T_2) was found to be superior with minimum weed infestation (14.85/ m²) and weed dry weight (17.43 g/ m²). This was closely followed by and at par with post emergence application of metribuzine@ 1.25 g *a.i.* /ha along with dicamba @ 350 g *a.i.* /ha at 75 DAP (T_{10}) with weed population of 19.87 /m² and weed dry weight of 18.85 g/m², respectively. Use of metribuzine@ 1.25kg *a.i* /ha (PE) followed by 2, 4 D 1kg *a.i*/ha at 75 DAP was next in order with weed population and dry weight of 19.90/m² and 22.22g/m², respectively.

Predominant weed species found in the experimental field consisted of grasses like *Echinochloa colonum*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Cyperus rotundus*, *Mimosa pudica*, *Phyllanthus niruri* and *Celosia argentia etc.* Among the various weed species *Cyperus rotundus and Echinochloa colonum* were the predominant weed flora.

The data on yield attributes and yield of sugarcane is presented in Table 1. The various treatment combinations have significant effect on yield parameters like single cane weight and number of millable canes/ha.The highest single cane weight (1.44 kg) was obtained in the treatment where three hand weedings were taken up at 30, 60, and 90 days after planting of sugarcane crop and it was significantly superior to all other treatment combinations. Among various herbicidal weed control methods, combined use of metribuzine @ 1.25 kg *a.i.*/ha(PE) + dicamba 350 g *a.i.* /ha at 75 days after planting was the best which produced average single cane weight of 1.34kg and was closely followed by the treatment using atrazine @ 2kg *a.i.* /ha (PE) + dicamba 350 g *a.i.*/ha at 75 DAP which could produce average single cane weight of 1.27 kg. The control treatment where, no weeding and hoeing was taken up yielded the canes with lowest weight (1.05 kg).

Highest millable canes (89.29 '000/ha) were produced in T_2 *i.e.* three hand weedings at 30, 60 and 90 DAP which was followed by post emergence application of atrazine @ 2 kg *a.i.*/ha + dicamba 350 g *a.i.* /ha at 75 DAP (87.67'000 millable canes/ha) and both the treatments were at par. Use of metribuzine @ 1.25 kg *a.i.* /ha. (PE) + dicamba 350g *a.i.* /ha at 75 days after planting (T_{10}) was next in order in terms of number of millable canes (84.66 '000/ha). These treatments superseded the other methods of herbicidal weed control method. Hand weeding at 30, 60 & 90 days after planting (T_2)

produced the highest cane yield of 113.01 t/ha, which was significantly superior to all other treatment combinations. Combined application of metribuzine @ 1.25 kg *a.i.* /ha (PE) + dicamba @ 350 g *a.i.*/ha at 75 DAP was next in order (102.08 t/ha.) and was closely followed by use of atrazine @ 2 kg *a.i.* /ha (PE) + dicamba 350 g *a.i.* /ha at 75 DAP (100.48 t/ha). The control plot registered the lowest cane yield (46.84 t/ha) where no weeding and hoeing was done. Vlitos (1954) supported this mentioning and thus reported that mechanical methods not only eliminate weed competition, but also perform the important function of aerating the soil and breaking any hard crust thus creating a favourable crop growth environment. The sucrose content of the cane was maximum (18.32%) with combined use of atrazine @ 2 kg *a.i.* /ha (PE) + dicamba 350g *a.i.*/ha. at 75 DAP and was at par with the treatment where atrazine @ 2kg *a.i.* /ha was applied after 1st irrigation & hoeing followed by 2, 4 D @ 1 kg *a.i.* /ha at 75 DAP (17.99%) and at 17.95% with application of atrazine @ 2kg *a.i.* /ha (PE) + ethoxysulphuron 50 g *a.i.*/ha at 75 DAP. Thus, it may be concluded that manual weeding not only controls the weed flora but also produced better cane yield in sugarcane growing.

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Short Communication

Managing initial planting density for enhanced productivity of sugarcane plant-ratoon system in sub-tropical India

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As per national projection, we will have to produce 415 million tonnes of sugarcane with a recovery of 11% to meet the domestic demand of sugar in the country (Singh and Singh, 2004). These projections assume cane productivity of 100 t/ha over an area of 4.2 million hectares. The jump of 35.7 t/ha (about 64.3 t/ha at present against the target of 100 t/ha for 2020 AD) with a period of eleven years is a very big and challenging task. The possibility of achieving the above target of sugarcane production under meager scope of enhancing the cane acreage, the only option is through increasing the productivity particularly from ratoon cane since it occupies more than 50% of the cane acreage and yields only 30% of the sugarcane production (Sundara, 1987). In sugarcane agriculture, ratoons crops are popularly grown since it reduces 25-30% production cost in terms of many advantages like preparation of fields, seed cane, sett cutting, planting *etc.* besides saving in irrigation water and crop maintenance through reduced crop duration. Thus, the cost of cultivation of sugarcane ratoon is much lower than the plant cane. However, the productivity of ratoon cane remains lower as compared to plant crop. Out of several reasons associated with low yield of ratoon cane, gaps in between the adjoining clumps coming from plant cane is the major factor which is entirely responsible for low number of stalks per unit area resulting into poor yields. Gaps in ratoon are the resultant of either poor stand of plant crop or sprout failure of stubbles after plant cane harvest. Several agro-techniques *viz.,* trash mulching, polythene mulching, intercropping of potato and wheat, spraying of growth hormones on stubbles *etc.* have been used (Kanwar and Kaur, 1981 and Verma and Yadav, 1988) to enhance stubble bud sprouting but much success could not be achieved in this direction. Managing initial planting density could reduce most of the gaps in plant cane itself which may improve the clump population in subsequent ratoon cane. Keeping these points in view, a study was initiated at the Indian Institute of Sugarcane Research, Lucknow to manage initial planting density for enhanced yield in sugarcane plant-ratoon system.

Key words : Sugarcane plant-ratoon, Plant population, Gaps, Seed rate

Field experiments were conducted for plant and ratoon canes as one crop cycle during 2007-08 and 2008-09 at the Indian Institute of Sugarcane Research, Lucknow, located at 26.56^{0}N, 80.52^{0}E and 111 meter above mean sea level with semi arid sub-tropical climate having dry hot summers and cold winters. The experimental field was sandy loam (13.8% clay, 23.6% silt and 62.9% sand) in texture, moderately alkaline in reaction (pH 8.1), low in available organic carbon (0.43%) and nitrogen (193.5 kg/ha) and medium in available phosphorus (21.7 kg/ha) and potassium (239.7 kg/ha). The planting density treatments *viz.,* T_1 : 30,000 three-bud setts/ha; T_2 : 40,000 three-bud setts/ha; T_3 : 50,000 three-bud setts/ha and T_4 : 60,000 three-bud setts/ha, were tried in randomized block design with six replications using test variety of sugarcane CoSe 92423 in the study. Before planting of experimental crop, soil samples from 0-15 cm depth were collected by core sampler of 8 mm diameter from 5 spots in the field. These samples were pooled together and representative homogeneous samples drawn for determination of initial soil fertility status following Jackson (1973). The crop was planted as per treatment scedule on 3rd March, 2007. These seed cane setts were placed horizontally, end to end, in 10 cm deep furrows opened 75 cm apart with tractor drawn furrow opener. Before placing setts in the furrows half the dose of required nitrogen *i.e.* 150 kg /ha and 60 kg each of P_2O_5 and K_2O were applied in furrows beneath the cane setts using urea (46.4 % N), single super phosphate (16% P_2O_5) and muriate of potash (60 % K_2O), respectively. Chlorphyriphos 20% EC @ 5 litres/ha dissolved in 1600 litres of water was spayed over cane setts before covering them to guard against termite and early shoot borer. The field was irrigated after 45 DAP with 7.5 cm irrigation water. The crop received three pre-monsoon irrigations *i.e.* up to the month of June. When soil moisture attained a workable stage, inter row spaces were intercultured manually using hand hoe. In the last week of June, remaining dose of 75 kg N/ha through urea was top-dressed uniformly along cane rows. The plant crop was harvested on 11th March, 2008 close to the ground level by specially designed steel chopper. After irrigation, when soil moisture attained a workable condition, half the dose of required nitrogen *i.e.* 200 kg/ha was applied along ratoon stubble rows as side dressing while remaining N dose

Table 1. Effect of levels of seed cane planting density (3-bud setts/ha) on plant and subsequent ratoon crops of sugarcane

Treatment	Plant cane (2007-08)							Ratoon cane (2008-09)							
	Germination % at 45 DAP	No. of gaps / ha at 45 DAP	Shoots (000/ha)	Millable canes (000/ha)	Cane yield (t/ha)	CCS % cane	Sugar yield (t/ha)	No. of clumps (000/ha)	Gaps at ratooning (%)	Shoots (000/ha)	Millable canes (000/ha)	Cane yield (t/ha)	CCS % cane	Sugar yield (t/ha)
T_1	32.66	6534	134	103	65.07	10.90	7.09	20.46	35.60	234	107	63.88	11.30	7.22
T_2	32.69	4374	157	110	73.09	11.05	8.08	23.77	24.90	258	114	72.24	11.25	8.13
T_3	34.09	26.74	181	116	80.05	11.20	8.97	27.25	18.50	284	123	78.35	11.40	8.93
T_4	35.21	1389	198	125	86.30	11.08	9.56	31.19	9.10	306	132	86.09	11.45	9.86
CD(P=0.05)	NS	-	15.9	5.23	5.54	NS	0.73	3.88	4.82	12.62	5.56	4.66	NS	0.79

CCS : Commercial Cane Sugar, DAP : Days after planting

Treatment details : T_1 : 30,000 three-bud setts/ha; T_2 : 40,000 three-bud setts/ha; T_3 : 50,000 three-bud setts/ha; T_4 : 60,000 three bud setts/ ha.

was top-dressed in the first week of May as top-dressing. The crop was grown and maintained as per agronomical practices followed in plant cane.

Observations on germination of cane buds, stubbles population, gaps in between adjoining clumps, number of tillers and millable canes, yield and yield attributes etc. in plant and ratoon canes were recorded at their respective growth and harvesting stages following standard procedures. At harvest, five canes were selected randomly for determination of CCS % cane as per Meade and Chen (1977). Sugar yield was assessed after multiplying CCS % cane with the yield of plant and ratoon canes. The data of plant and ratoon canes were statistically analyzed separately. Various treatments were compared under randomized block design. The critical difference (CD) was computed to determine statistically significant treatment differences.

Experimental data presented in Table-1 clearly revealed that after attaining non-significant germination of cane buds (33.66%, on an average) at 45 DAP (days after plating), the gaps in between two adjoining cane plants were observed in the range of 1389 (T_4) as minimum to the maximum of 6534 (T_1) per ha in different treatments. In general, such gaps in plant cane do occur due to one or other factors *viz*., insufficient or excess soil moisture, planting with stale cane, setts with damaged or no buds, depth and time of planting, attack of termite on cane setts, rains after planting, planting with shy germinator cane varieties, environmental temperature *etc*. which are practically not feasible to avoid or manage in commercial planting. The treatments *viz*., planting of 60000 three-bud setts /ha (T_4) produced significantly higher number of shoots, millable canes and cane yield than that of other planting density treatments (T_1, T_2 and T_3) in the study. Every successive increase in planting density from T_1 through T_4 increased the above growth and yield of cane significantly. In general, in sugarcane planting in sub-tropical India, about 40000 three-bud setts /ha (T_2) are planted. In the present study, reducing the seed rate from 40000 three-bud setts /ha (T_2) to 30000 three-bud setts /ha (T_1) decreased the cane yield by 12.33 % , while increasing the seed rate @ 10000 and 20000 three-bud setts /ha as in the case of T_3 and T_4 increased the cane yield significantly and it was higher to the tune of 9.52 % and 18.07 %, respectively. Increasing the seed rate as in the case of T_3 and T_4 treatments lowered the intensity of gaps in between adjoining cane plants and thereby resulted to significantly higher number of tillers and millable canes as compared to T_1 and T_2 treatments. Yadav (1991) reported that the most significantly related factor is the number of millable canes (stalks) per unit of area at harvest. Ouality of cane (CCS%) although did not differ significantly due to different treatments of planting density. However, sugar yield was significantly higher in T_4 treatment as compared to others, and accordingly exhibited the similar trend as in the case of cane yield obtained under different treatments.

Data presented in Table 1 further showed that increasing the seed rate in plant cane (T_1 through T_4) triggered to significant improvement in clumps population in susequent ratoon raised from it, and thus decreased the gaps in order of 35.60%, 24.90%, 18.50% and 9.10% as recorded under T_1, T_2, T_3 and T_4 tratments, respectively. Resultantly, increasing the seed rate in plant cane proved instrumental in minimizing gaps of subsequent ratoon and thereby increased the number of tillers and millable canes and yield of cane and sugar, significantly with every successive increase in planting density from T_1 through T_4 treatments. Accordingly, the ratoon cane yield dreased by 11.57% when seed rate in plant cane curtailed to 30000 three-bud setts /ha (T_1) from 40000 three-bud setts /ha (T_2). On the contrary, it increased to the tune of 8.46% and 19.17% by planting 50000 three-bud setts

/ha (T_3) and 60000 three-bud setts /ha (T_4), respectively in plant cane over planting of 40000 three-bud setts /ha (T_2). Conclusively, it is worth mentioning that successive increase in planting density in plant cane had a positive impact on the yield of subsequent ratoon indicating thereby that the yield under T_4 treatment was almost similar both in plant and ratoon cane crops.

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Short Communication

Economizing seed cane quantity by reducing sett size and bud number with sett treatment in sugarcane cultivation

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Sugarcane (*Saccharum* sp. complex) is one of the most efficient converters of solar energy into sugars and other renewable forms of energy. It is cultivated commercially by planting portions of cane stalk known as seed pieces, cane setts or seed cane. The true seed of sugarcane is called fluff and used for raising seedling which is required for selection in plant breeding programme, when new varieties are evolved. In normal course, for commercial cultivation, a huge quantity (6-8 t/ha) of cane stalk cuttings having 3-bud pieces are required for planting one ha land. Such planting material ranges from 22 to 25% of the total production cost, and that is one of the major items of expenditure in sugarcane cultivation (Srivastava *et.al.,* 1981). On an average, 10% sugarcane produce is used as planting material. In other words, we are loosing1.5 million tonnes of sugar annually by burying it in the soil as a planting material. Therefore, one of the major items of expenditure in sugarcane production is seed cane which is required for its planting in huge quantity. Saving of seed cane material by reducing sett size and bud numbers and sett treatment with GA_3 application may help in getting higher cane yield with lower cost of production on seed cane. In light of above, the present experiment was conducted.

A field experiment was conducted at the research farm of Sugarcane Research Station, Nayagarh (Odisha) during the year 2010-11. The experimental site was located at 20^0 54" 90' N latitude and 80^0 07" 56' E longitude. The soil of the experimental field was sandy loam in texture with low organic carbon content (0.481%) and slightly acidic (PH- 6.3) in reaction. The available N status of the soil was low (240 kg/ ha), whereas available P (11.2 kg/ha) and K (137 kg/ha) contents were in medium range. The experiment was laid out with 12 treatments *i.e.* $A_1B_1C_1$, $A_1B_1C_2$, $A_1B_2C_1$, $A_1B_2C_2$, $A_2B_1C_1$, $A_2B_1C_2$, $A_2B_2C_1$, $A_2B_2C_2$, $A_3B_1C_1$, $A_3B_1C_2$, $A_3B_2C_1$ and $A_3B_2C_2$ where, A_1 – 3 budded setts, A_2 – 2 budded setts, A_3 – 1 budded setts and B_1 – 1,20,000 buds/ha, B_2 – 80,000 buds/ ha; C_1- Sett treatment with carbendazim and C_2- Sett treatment with Carbendazim + GA_3 (100ppm) in randomized block design with three replication keeping test variety of sugarcane Co Or-03-151 in the study. The crop of sugarcane was planted at 80 cm row spacing and fertilized with recommended doses of N, P_2O_5 & K_2O *i.e.* 250– 100- 60 kg/ ha besides 10 t /ha well decomposed FYM. The crop was irrigated as and when required and was managed as per the standard package of practices. The date of planting and harvesting were 25.01.2010 and 20.12. 2010, respectively. The observations on germination percentage, number of tillers at 120 DAP, single cane weight, millable canes and total cane yield were recorded.

Observation on germination percent of the sugarcane buds of different treatments was recorded at 30 days after planting (Table 1). It was found that the germination percentage varied from 58.0 to 74.4 %. Planting of 80,000 buds/ha with three budded setts treating them with Carbendazim and 100ppm solution of GA_3 recorded the highest germination percentage (74.4 %), whereas 80,000 buds/ha with single budded setts treated with Carbendazim alone registered the lowest germination count (58.0%). Similarly, 80,000 buds/ha with two budded setts treated with Carbendazim and 100 ppm solution of GA_3 was the second best treatment with 73.8 % germination of the setts and was at par with $A_1B_2C_2$. Similar results were also reported by Singh *et al.* (2008). Number of tillers per plot was counted at 120 days after planting of the crop. It was observed that the three and two budded setts could produce number of tillers which were at pr with each other irrespective of the number of buds/ ha and the sett treatment. The highest number of tillers/ha was produced in the treatment where 80,000 buds/ha with two budded setts were planted with Carbendazim treatment (96.37'000/ha) and this was closely followed by planting of 80,000 buds/ha with two budded setts treated with Carbendazim and 100ppm solution of GA_3 (95.77'000/ha). However, the single budded setts neither with planting density of 80,000 nor 1, 20,000 buds/ha could produce tillers at par to that of three or two budded setts (Table 1).

Highest single cane weight (1.55 kg) was obtained with

Table 1. Effect of sett size, seed rate and sett treatment on growth and yield of sugarcane

Treatment	Germination (%)	Tillers at 120 DAP ('000/ha)	Single cane weight (kg)	NMC ('000/ha)	Cane yield (t/ha)
$A_1B_1C_1$	65.4	89.10	1.24	78.2	81.6
$A_1B_1C_2$	69.0	91.97	1.26	75.6	80.4
$A_1B_2C_1$	62.9	85.27	1.36	75.6	84.7
$A_1B_2C_2$	74.4	93.40	1.23	73.4	80.4
$A_2B_1C_1$	61.3	96.37	1.22	77.2	82.4
$A_2B_1C_2$	71.3	95.77	1.24	78.1	83.1
$A_2B_2C_1$	61.7	86.27	1.36	76.3	87.0
$A_2B_2C_2$	73.8	92.67	1.55	80.3	93.7
$A_3B_1C_1$	60.0	71.43	1.25	59.8	65.4
$A_3B_1C_2$	70.7	65.00	1.25	63.4	61.5
$A_3B_2C_1$	58.0	69.37	1.27	58.0	64.8
$A_3B_2C_2$	72.0	69.57	1.31	60.5	64.1
CD (P=0.05)	9.20	14.42	0.11	12.58	10.59

where, A_1 – 3 budded setts, A_2 – 2 budded setts, A_3 – 1 budded setts and B_1 – 1,20,000 buds/ha, B_2 – 80,000 buds/ha; C_1- Sett treatment with carbendazim and C_2- Sett treatment with Carbendazim + GA_3 (100ppm).

DAP: days after planting ; NMC: number of millable canes

planting of 80,000 buds/ha with two budded setts treated with Carbendazim and 100ppm solution of GA_3 ($A_2B_2C_2$) which was significantly superior to all other treatment combinations. Plantation of 80,000 buds/ha with two or three budded setts treated with Carbendazim alone ($A_1B_2C_1$ and $A_2B_2C_1$) was next in order which registered single cane weight of 1.36 kg in both the treatments. In rest other treatments the single cane weight hovered around 1.22 to 1.31 kg and were statistically at par with each other. Count on the total number of millable canes per plot was recorded and the data was converted to number of canes per hectare. It was observed that highest number of millable canes (80.30'000 canes/ha) were obtained in the treatment where 80,000 two budded setts treated with Carbendazim and 100ppm solution of GA_3 were taken up as planting material. The treatments involving two or three budded setts whether planted at a sett density of 120000 or 80,000 buds/ha whether treated with Carbendazim alone or in combination with100ppm solution of GA_3 could produce number of millable canes that ranged from 73.4'000 ($A_1B_2C_2$) to 78.1'000/ha ($A_2B_1C_2$) and were statistically at par with each other but superior to that of plantation of single budded setts. Cane yield was an interaction effect between single cane weight and total number of millable canes/ha. So, it was quite obvious that 80,000 buds/ha from two budded setts treated with Carbendazim and 100ppm solution of GA_3 ($A_2B_2C_2$) could produce the highest cane yield of 93.7 t/ha. The treatment next in order was $A_2B_2C_1$ *i.e.* planting of 80,000 buds/ha with two budded setts treated with Carbendazim alone which recorded cane yield of 87.0 t/ha. The cane yield followed the same trend as that of number of net millable canes. The yield level varied between 80.4 to 84.7 t/ha in the rest of the treatments where two or three budded setts were taken as planting material irrespective of the planting density and sett treatment (Table 1). Planting of single budded setts could not produce cane yield at par to other treatments. These results are in conformity with the findings of Geddawy *et al.* (2002), Sogheir and Mohamed (2003) and Singh *et al.* (2008).

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Short Communication

Chemical control of termites and shoot borer in sugarcane

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Subterranean termites are the major problem with sugarcane crop from its germination through shoot emergence to maturity stages. During germination period, bud damage occurrs to the tune of 30-60% in light soils of Punjab, Haryana, Uttar Pradesh and Bihar (Avasthy, 1967). Off late, Ahmed in Pakistan (Ahmed, 2005) has recorded 90-100 per cent loss of buds during germination period. *Microtermes obesi,* and *Odontotermes obesus* are the frequently recorded species from sugarcane crop in Haryana. For the control of termites, many methods have been adopted, among which chemicals are successful and dominated means of the control since the emergence of epoch-making chemical group (organochlorines) which opened new horizons in termite control. Because of several adversities found associated with organochlorines, these have now been/ are being replaced with comparatively safer chemicals such as imidacloprid and bifenthrin. However, the farmers have shown preference for the dry formulations like granules and dusts over the wet ones because of their easy applicability. With this in view, granular formulation of sevidol 4:4 G was tested for its bioefficacy against mainly termites and shoot borer in sugarcane.

Two year field experiments during 2007-08 and 2008-09 were conducted at the research farm of CCS Haryana Agricultural University, Regional Research Station, Uchani, Karnal. Susceptible commercial cultivars CoH 110 and CoH 119 were chosen for the research experiments which were laid out in randomized block design with three replications of each treatment and check. The crop was sown on March 9 in 2007 and on February 21 during 2008-09. The plot size for each treatment and untreated check was 15x4.5 m. Three budded setts @ 58000 ha^{-1} were planted in furrows drawn at a spacing of 75 cm. The bioefficacy of three doses of Sevidol 4:4 G @ 15.0 kg , 18.75 kg and 22.0 kg ha^{-1} each applied at planting as well as at 40 days after planting (first irrigation) was studied and compared with the standard recommended emulsifiable concentrate chloropyriphos 20 EC (Dursban 20EC) applied @ 6.25L (1.25 kg a.i.) ha^{-1} in 1500 litres of water and an untreated control. For sett and soil treatment with standard, at planting, the chemical was applied over seed setts placed in furrows using a sprinkler can while the sevidol formulation in various dosages was applied as sand mix in furrows while at 40 days after planting the treatments were given as sand mix along the rows followed by light irrigation.

Observation on germination was recorded 40 days after planting (DAP). Sett damage due to termites was also recorded at 40 DAP by digging out setts in a six m row length at two places in a plot. Termites and early shoot borer and root borer damage to mother shoots and tillers was examined at 60, 90, and 120 DAP from two middle rows of each plot. In similar manner, damage to millable canes due to termite and root borer was recorded at maturity in eight months old crop. At harvest, millable canes from each plot were weighed on 100 cane weight basis. The data was subjected to analysis of variance and critical differences between the treatments compared with untreated check and standard recommended formulation of the test insecticide.

Data on germination, termite and shoot borer damage and cane yield recorded from two year research trials is presented in Table 1. Spray application over setts in furrows with Chlorpyriphis 20 EC or Sevidol 4:4 G applied as sand mix in furrows at the time of sowing resulted in significantly improved germination of cane setts over the untreated check.. The increase in germination during first year was on a par due to this treatment and standard recommended insecticide chlorpyriphos which recorded 35.2 per cent germination during 2007-08. During the second year, however, the furrow application of Sevidol 4:4 G @ 18.75 kg ha^{-1} and 22.0 kg ha^{-1} recorded higher germination than standard recommended Chlorpyriphis 20EC applied @ 1.25 kg a.i. ha^{-1} at the time of planting. The average shoot emergence in all the plots which received Sevidol treatments at 40 days after planting was considerably lower than the corresponding treatments applied at the time of planting. The germination in these treatments ranged from 30.6 (22.0 kg ha^{-1}) per cent to 31.4 per cent (15.0 kg ha^{-1}) during 2007-08 and 33.4 (15.0 kg ha^{-1}) to 34.7 per cent (22.0 kg ha^{-1}) during second year. The shoot emergence in second year was slightly higher than that recorded during first year due to differences of planting period, variety and field.

Table 1. Effect of sevidol 4:4 g on germination, incidence of termite and shoot borer and yield of sugarcane

Year	2007-2008						2008-09					
Treatment	Germi-nation % 40 DAP*	Termite incidence at days after planting (%)			SB** damage (%) 90 DAP*	Yield/ ha (MT)	Germi-nation % 40 DAP*	Termite incidence at days after planting(%)			SB** damage (%) 90 DAP*	Yield/ ha (MT)
		40	90	Maturity				40	90	Maturity		
Sevidol 15 kg/ha at planting	34.9	9.3	-	-	3.9	76.3	37.6	5.3	-	-	1.6	85.7
Sevidol 18.75 kg/ha at planting	35.1	7.6	-	-	2.3	81.2	39.3	2.9	-	-	0.4	88.4
Sevidol 22.5 kg/ha at planting	33.7	8.9	-	-	2.4	80.7	40.1	0.8	-	-	0.7	89.5
Sevidol 15 kg/ha at 40 DAP	31.4	12.3	-	-	2.6	74.9	33.4	6.3	-	-	1.3	82.3
Sevidol 18.75 kg/ha at 40 DAP	30.9	10.5	-	-	1.2	76.9	34.2	6.9	-	-	-	83.9
Sevidol 22.5 kg/ha at 40 DAP	30.6	10.9	-	-	0.4	76.3	34.7	5.7	-	-	-	85.3
Chlorpyriphos 6.25 L/ha at planting	35.2	5.3	-	-	3.2	79.2	38.6	3.3	-	-	2.1	87.3
Chlorpyriphos 6.25 L/ha at 40 DAP	30.8	14.8	-	-	4.7	74.6	34.5	7.8	-	-	1.6	82.9
Untreated check	31.8	11.6	-	-	9.3	74.2	33.7	7.1	-	-	5.2	80.2
CD at 5%	3.37	2.12	-	-	3.3	5.3	3.8	3.5	-	-	4.1	6.7

DAP*= Days after planting SB**= shoot borer

The termite damage was moderate during germination. It was seen to decline during formative phase with the growth of the crop and was not noticed after 60 days of planting in plots receiving treatments at planting or at 40 DAP, while shoot borer, *Chilo infuscatellus* activity was strictly limited to formative stage. Damage to setts during germination was significantly lower in the treated plots than the untreated one. Quite low incidence of termites was evident in plot which received Chlorpyriphos spray application (Dursban 20 EC) @ 1.25 kg a.i. as sett and soil treatment or Sevidol treatments @ 18.75 kg and 22.0 kg ha^{-1} as sand mix in furrows at the time of planting. Sevidol applied @ 15.0 kg ha^{-1} was slightly inferior than the remaining treatments in controlling termites. At maturity phase of crop growth, no termite or root borer incidence was noticed in the experimental plots. In second year research trial slightly superior performance of Sevidol @ 18.75 kg and 22.5 kg ha^{-1} over Dursban 20 EC as spray @ 1.25 kg a.i. ha^{-1} over setts in furrows in controlling termites was evident. The shoot borer incidence in the crop, during both the years, was below economic threshold and was drastically reduced in plots receiving sevidol application @ 18.75 kg and 22.5 kg ha^{-1} at 40 days after planting followed by Dursban 20 EC as spray @ 1.25 kg a.i. ha^{-1} over setts in furrows at planting as also at 40 days after planting.

Sett and soil treatment with Dursban 20EC at standard recommended dosage and sand mix furrow application of sevidol 4:4 G at all the three dosages registered significantly higher cane yield over the untreated check. Comparable yields were recorded with application of sevidol 4:4 G @ 18.75 kg and 22.5 kg a.i. ha^{-1} that also appeared on a par with those obtained following application of standard recommended dosage of Dursban 20 EC. Almost similar trend in yield increase due to treatments was also evident in the second year trial. Root borer incidence was not evident in the crop during both the years.

Based on research data of two years, the chemical was put to location testing at farmer fields in six districts of Haryana the results of which are summerised in Table 2. The observations made on germination/ tillering and incidence of termites and shoot and root borers indicated that sett and soil application of Sevidol 4:4 G applied @18.75 kg/ha protected cane seed against termites as effectively as standard recommended insecticide chlorpyriphos @ 6.25 L/ ha. Shoot borer incidence was invariably below economic threshold and was adequately controlled when sevidol application was made at 45 DAP. Root borer incidence remained negligible in the experimental plots.

No phytotoxic effects of either of the three dosages of Dursban in the form of necrosis, injury to leaf tips or leaf surface or wilting of leaves were observed during experimentation

Table 2. Bioefficacy of Sevidol against termites and shoot borer at farmers fields

Rohtak (Mr.Dilbag, Vill.Bambahya)

Insecticides	% termite damage at DAP*				% shoot borer at DAP*	
	40	**60**	**90**	**Maturity**	**60**	**90**
Sevidol at Planting	3.0	-	0.49	-	4.2	7.2
Sevidol 45 DAP	9.2	-	-	-	2.3	6.3
Chlorpyriphos	5.1	-	0.54	-	4.7	9.7
Control	**11.0**	**4.8**	**2.33**	**0.97**	**6.3**	**12.3**

Sonipat (Mr. Shiv Kumar, Ashadpur)

Sevidol at Planting	4.4	0.35	0.59	2.1	4.7	5.3
Sevidol 45 DAP	9.3	2.17	1.96	0.7	3.4	1.9
Chlorpyriphos	3.7	-	-	1.6	3.7	4.6
Control	**8.7**	**3.86**	**1.9**	**3.1**	**7.3**	**4.8**

Panipat (Mr. Salim, Nawada Paar)

Sevidol at Planting	1.54	-	-	-	6.5	4.3
Sevidol 45 DAP	4.9	0.33	-	-	3.9	2.7
Chlorpyriphos	0.59	-	-	-	7.2	3.8
Control	**4.3**	**1.03**	**-**	**0.61**	**11.7**	**5.4**

Karnal (Mr. Samsher Singh, Kunjpura)

Sevidol at Planting	0.67	-	-	0.15	1.9	6.3
Sevidol 45 DAP	3.14	-	0.16	-	0.48	4.1
Chlorpyriphos	0.54	-	-	-	2.67	7.8
Control	**4.21**	**-**	**0.69**	**0.32**	**4.1**	**10.6**

Kurukshetra (Sugarmills Farm, Shahbad)

Sevidol at Planting	0.19	1.34	0.67	-	7.2	12.3
Sevidol 45 DAP	1.63	0.27	0.44	-	5.3	9.2
Chlorpyriphos	0.33	0.67	0.43	-	6.9	13.4
Control	**1.45**	**2.97**	**1.97**	**0.63**	**10.4**	**15.3**

Yamunanagar (Mr. Avneet, Radour)

Sevidol at Planting	3.2	0.34	-	-	2.6	6.1
Sevidol 45 DAP	6.4	2.12	0.67	-	1.01	2.6
Chlorpyriphos	2.9	1.38	0.19	-	2.0	7.6
Control	**5.9**	**3.19**	**2.33**	**0.97**	**4.9**	**11.7**

Since application of Sevidol 4:4 G was done as soil treatment at the time of crop planting and just after germination of crop (40 days after planting), as such no adverse effects of the chemical on natural enemies of the pests (spiders, earwigs, coccinellids etc.) were observed due to their temporary shifting to the neighbouring fields during field preparation (prior to the treatment).

The results of the research trials pointed out to effectiveness of 4:4 G @ 18.75 kg and 22.5 kg ha^{-1} in controlling termites in sugarcane crop in semiarid subtropics. The increase in yield due to treatments perhaps be directly attributed to increased germination and shoot number by way of controlling termite and shoot borer damage. Maximum germination was achieved when soil was treated with this dosage as this treatment kept termite incidence at low and recorded germination better than the lower dosage and almost equal to that achieved with the higher dosage. Plots receiving this treatment recorded higher yield than most of other treatments including standard. During 2007-08 shoot borer incidence was comparatively higher but was effectively controlled by insecticidal treatments. Shoot borer incidence was invariably low during 2008-09. During both the years, it was controlled more effectively when Sevidol @ 18.75 kg ha^{-1} and 22.5 kg ha^{-1} was applied at first irrigation i.e. at 40 days of planting. The differences in shoot borer incidence between the treatments, however, remained non significant. Thus, in sugarcane areas showing damage occurrences of both termite and shoot borer, the chemical @ 18.75 kg ha^{-1} may be applied at the time of sowing while in areas where shoot borer alone is a problem during pre-monsoon period, it may be applied at first irrigation i.e. at 40 days of planting.

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