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Organic sugarcane production systems for enhanced soil health and crop productivity

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ABSTRACT

Field experiments were conducted during 2003-2013 at Indian Institute of sugarcane Research, Lucknow for evaluation and standardization of organic production modules consisting of recyclable production and protection inputs and eco-friendly crop management techniques under different sugarcane production systems namely rice-autumn (October/November) sugarcane-ratoon-wheat and sugarcane multi-ratooning system. All the crops in rotation were grown organically, however treatments *viz*., zero nutrient addition, application of farmyard manure (FYM) 20t/ha, sulphitation pressmud (SPM) 20 t/ha, FYM 10t/ha + SPM 10 t/ha, FYM 10 t/ha + *Gluconacetobacter diazotrophicus* inoculation were compared with application of recommended dose of NPK (150, 60, 60 kg/ha) only during sugarcane phase of the crop rotation. Under sugarcane multi-ratooning system all the treatments were adopted in sugarcane plant crop as well as subsequent nine ratoons. Soil of the experimental field analyzed low in soil organic carbon and contained 205 kg/ha available N, 24.5 kg P_2O_5 and 217 kg K_2O. Initial bulk density of the soil was 1.40 Mg/m^3 and the water infiltration was 4.0 mm/hr. Findings revealed that application of organics brought substantial increase in soil organic carbon (by 35-75%) at the end of the rotation under various treatments over the initial status. Findings of the experiment on crop rotation revealed that application of farmyard manure 20 t/ha+ *T. viride*+ lentil intercropping ensured highest profitability of plant and ratoon crops as B:C ratio stood highest at 2.7 and 2.6, respectively. Availability status of major nutrients (NPK) in soil after harvest of plant cane and subsequent ratoon crops under multi-ratooning experiment recorded a positive effect due to various treatments. Simultaneous increase in soil microbial biomass carbon varied from 198-217 mg C-CO_2/kg soil in different treatments against the initial value of 76. Similarly, organic treatments resulted in enhanced soil microbial biomass nitrogen (7.93 to 10.07 mg N-NH_4/kg soil) followed by chemical fertilizer application (6.82) and control (5.33) over the initial value of 3.6 mg N-NH_4/kg soil. Sugarcane yield both for plant (78 t/ha) and ratoon (69 t/ha) crops under all three production systems was recorded significantly higher with the use of organics as compared to that with the use of recommended chemical fertilizers (72 t/ha for plant crop and 58 t/ha for ratoon). Organic amendments sustained sugarcane yield at an enhanced level over that with recommended dose of chemical fertilizers up to ninth ratoon, which accrued higher profitability, B:C ratio being more than 2.0 for organics against 1.4 obtained with chemical fertilizers.

Key Words: Organic sugarcane, Ratoon, Soil health, Cane productivity, Production system

Sugarcane is a long duration (~ 12 months) nutrient exhaustive crop grown in India over an area of 5 million ha to meet country's total sugar requirement. North Indian sub-tropics contribute more than 60 % to total sugarcane acreage in the country. Farmers prefer the crop because of its immediate purchase by sugar factories and availability of ready cash with a good profit margin. However, profitability of sugarcane cultivation has drastically reduced of late owing to increased cost of cultivation and declining factor productivity (i.e. the return on investment over input factors) of monetary inputs such as fertilizers and plant protection chemicals. Continuous reduction in returns obtained from applied inputs has been found to be associated with poor soil organic carbon content (< 0.40 %) of the sandy loam soils prevalent in the sub-tropical north India (Abrol and Gupta 1998). On the other hand continuous use of heavy doses of fertilizers (as recommended 150 kg N, 60 kg P and 60 kg K/ ha is used annually) and plant protection chemicals potentially impair the soil microbial activity too, leading to poor soil health, fertility and productivity (Singh *et al*. 2007). As a result, gradual loss in factor productivity of various inputs is encountered everywhere. The soil productivity is linked with soil organic carbon. Reduced productivity of rice- wheat cropping system, the most prevalent cropping system of the region, has also been reported due to decline in soil organic carbon (Bhandari *et al*. 2002). Situation therefore warrants for adoption of resources that supply nutrients to plants through microbial mediation and in the process enrich soil organic carbon and microbial balance. Organic farming methods based on strict avoidance of synthetic fertilizers and other such inputs with emphasis on intensive use of biological resources holds promise. A growing number of experiments show that organic farming leads to higher soil quality and more biological activity in soil than the conventional farming. Organic farming systems have also been shown to use nutrients and energy more efficiently than conventionally managed system as reported by Mader *et al*. (2002). For sugarcane use of bio-manures viz. FYM (farmyard manure), SPM (sulphitation pressmud) or biogas slurry has been reported to effect sugarcane productivity equivalent to that obtained with the application of recommended doses of N, P & K through synthetic fertilizers, with a positive effect on rhizospheric microbial activity and soil physical properties (Singh *et al*. 2007). Despite this, doubts are often raised over profitable production of long duration crops through exclusive use of organic resources only (Chhonkar and Dwivedi 2004) and there exists exiguous information on combined use of such resources and their effect on the soil health and productivity.

The present investigation was carried with the hypotheses that by combined use of non-chemical (natural) nutrient resources including manures, sugar factory by products (SPM), legume intercrop and endophytic/ associative diazotrophs nutrient requirement of sugarcane crop can be adequately met leading to profitable cane yield both under the rotation of different crops with sugarcane and sugarcane plant- multi ratoon system . The major objectives were to devise nutrition module of organic sugarcane production and to assess its effect on soil microbial activity, soil physical properties and yield and economics of different sugarcane production systems.

MATERIALS AND METHODS

Experimental site and climate

Experiment I: Organic nutrient management module for sugarcane based cropping system

The field experiment was initiated during autumn season (October) of 2003 on an *inceptisol* at the farm of Indian Institute of Sugarcane Research, Lucknow (26º 56' N, 80º 52' E and 111 m above mean sea level). Climate of the experimental site is semi – arid sub –tropical, with hot humid summers and cold winters. The average annual rainfall is 976 mm, and nearly 80 % of the total rainfall is received through south-west monsoon during July to September. The soil of the experimental site was sandy loam (13.3, 24.5 and 62.25 % clay, silt and sand) in texture with bulk density 1.34 Mg/ m^3. It was low in organic carbon (0.34 %) as well as in available N (208 kg/ ha), P (20.8 kg/ ha) and K (158 kg/ ha) with pH 7.7 and EC 0.24 dS/ m.

Six treatments *viz*., i) sulphitation pressmud (SPM) 10 t/ ha + *Azotobacter chroococum*, ii) farmyard manure (FYM) 20 t/ ha + *Trichoderma viride* + lentil intercropping (1:2), iii) SPM 10 t/ ha + FYM 10 t/ ha, iv) SPM 10 t/ ha + lentil intercropping (1:2), v) FYM 20 t/ ha + *Gluconacetobacter diazotrophicus* inoculation and vi) control (no manures or fertilizer) were imposed to sugarcane plant and subsequent ratoon crops and randomized within a block with four replications. Comparison with treatment comprising synthetic fertilizers was not made to avoid chances of contamination and to follow the standards of organic farming set by IFOAM (International Federation of Organic Agriculture Movements)/ *Codex Alimentarius* Commission. Average composition of the organic resources applied to the plots is given in table 1. The plot size was 8 x 6 m and sugarcane cultivar 'CoSe 92423' was planted at 90 cm row spacing using 3- bud setts. Under the treatments involving lentil intercrop, two rows of lentil ('K 75') were grown between sugarcane rows. All the manures were applied on dry weight basis at the time of final field preparation for plant crop and at ratoon initiation for the subsequent ratoon. Sugarcane setts and soil inoculation with microbes was done at the time of planting. Soil inoculation was repeated 45 days after planting. To ward off shoot borer (*Chilo partelus*) during initial growth stages of sugarcane, neem (*Azadirachta indica* L.) cake @ 2 quintals/ ha was applied in all the treatments.

Experiment II: Organic nutrient management for sugarcane multi-ratooning system

Field experiments were conducted for ten consecutive years (2003-04 to 2012-13) at Lucknow. Soil of the experimental site was sandy loam (13.3% clay, 24.5% silt and 62.3% sand) in texture. It had initial bulk density of 1.40 Mg/m^3, aggregate size (>0.25 mm) 15.2% and infiltration rate 4.1 mm/h. The soil analyzed low in organic carbon (0.32%), with pH 7.7, EC 0.24 dS/m, available N 230 kg/ha, available P 21.5 kg/ha and exchangeable K 217.9 kg/ha, soil microbial biomass carbon (SMBC) 47.6 mg CO_2-C/kg soil/day and soil microbial biomass nitrogen (SMBN) 3.76 mg NH_4-N/kg soil/day.

Six treatments *viz*., control (zero nutrient application), vermicompost (10 t/ha), farmyard manure (10 t/ha), biogas slurry (10 t/ha), sulphitation press mud (10 t/ha) and NPK (150, 60, 60 kg/ha) were randomized within a block and replicated four times. All the resources were manually applied to field every year. Vermicompost, farmyard manure, biogas slurry and sulphitation press mud contained 1.5, 0.5, 1.2 and 1.5 % N; 0.5, 0.27, 1.2 and 0.75 % P and 0.8, 0.25, 1.01 and 0.5 % K, respectively.

Methods of soil and plant sampling and analysis

The initial and post- harvest soil samples were pulverized using wooden pestle – mortar and sieved through a 100- mesh sieve. The processed samples from each plot were analyzed separately for organic carbon (Walkley and Black, 1934), and available N was determined by the alkaline permanganate method (Subbiah and Asija, 1956). Phosphate was extracted with 0.5 M sodium bicarbonate solution (pH 8.5) and determined in the extract colorimetrically with the blue colour method. Exchangeable potassium was extracted with ammonium acetate solution and determined by flame photometer (Jackson, 1973). Soil pH was determined in 1:2.5 soil water suspensions by a glass electrode pH meter. The bulk density (BD) of soil in the initial and after ratoon harvest were measured using core sampler, mechanical analysis was done following International Pipette Method and aggregate size distribution (wet sieving) by Yodor (1936) method. Infiltration was measured *in situ* using double ring infiltrometer (Bertrand, 1965).

At final harvest, representative whole plants (aboveground portion) of plant crop and ratoon were collected from four spots in each plot. The samples were chopped, homogenized and dried at 70º C in a hot air oven. The dried samples were ground in a stainless steel Willey mill, and wet – digested in concentrated H_2SO_4 for determination of total N and in diacid mixture (HNO_3 and $HClO_4$ mixed in 4: 1 ratio) for determination of total P and K (Jackson, 1973).

For microbial analyses, soil samples were taken randomly from 0-15 cm depth by a core sampler of 8 cm diameter. After removing visible plant residues and pebbles, soil, sieved through 2 mm was stored in plastic bags at 4 ºC. All biological measurements were done within 30 days of sampling and before any measurement, soil moisture was adjusted to 60 % of water holding capacity and samples were re-incubated for 2 days at 28 ºC. Soil microbial biomass C and N (SMBC and SMBN) were determined using chloroform fumigation extraction method (Anderson, 1982).

RESULTS AND DISCUSSION

Experiment-I

Soil organic carbon and rhizospheric microbial activity

Effects of organic nutrition modules on soil organic carbon content and rhizospheric microbial activity were studied at the end of crop rotation (ratoon harvest) in the root zone soil. Data presented in table 2 reveal that at the end of the rotation organic carbon content ranged from 0.41 to 0.47 % under different nutrition modules against 0.35% in control plot and 0.34% initial value. Magnitude of enhancement in organic carbon content due to various treatments over that of initial content was found highest (38.2 %) with the application of FYM 20 t/ ha + *G. diazotrophicus* inoculation closely followed by SPM 10 t/ ha + FYM t/ ha (35.2%).

SMBC was found highest under FYM 20 t/ ha + *T. viride* + lentil intercropping (293 mg CO_2-C/ kg soil/ day) and SPM 10 t/ ha + lentil intercropping (283 mg CO_2- C/ kg soil/ day) against initial value of 106 mg CO_2-C/ kg soil/ day. Consequently the SMBN was significantly higher (4.9 mg NH_4- N/ kg soil/ day) under SPM 10 t/ ha + lentil intercropping followed by SPM 10 t/ ha + FYM 10 t/ ha (4.4 mg NH_4-N/ kg soil/ day) against initial value of 2.01 mg NH_4-N/ kg soil/ day of SMBN. These observations suggest that inclusion of lentil as an intercrop in autumn sugarcane created congenial rhizospheric environment to build up microbial biomass carbon and nitrogen pool. Similar effects could be observed with inoculation of *G. diazotrophicus* along with FYM 20 t/ ha. It was further recorded that addition of sugarcane trash, stubbles and roots in control plots also improved organic carbon, SMBC and SMBN contents over the initial levels.

Improvement in soil organic carbon content due to various organic nutrition modules to the extent of 38.2 % over the initial content and resultant increase in SMBC up to 167.9 % may be attributed to addition of ample quantity of biomass through different resources under these treatments and its concomitant decomposition under hot- humid climate of sub-tropics. It is mentionable that slight increase in organic carbon (2.9%) occurred even under control conditions, which may be due to huge quantity of biomass addition in the form of sugarcane stubbles and other crop residues. Similar to SMBC there was increase in SMBN to the extent of 143.7% under various treatments that indicates enhanced availability of nitrogen under these treatments. The SMBC content at plant crop harvest/ ratoon initiation was positively correlated with the content of organic carbon at ratoon harvest (r= 0.695). These results support the fact that high soluble C and N concentrations stimulate microbial activity, as organic substrates are sources of energy for microbes (Gaillard *et al*. 1999).

Higher increase in SMBC and SMBN contents under treatments comprising SPM 10 t/ ha + FYM 10 t/ ha or FYM 20 t/ ha + *G. diazotrophicus* or those with lentil intercropping may be interpreted as the synergistic effects of various organic resources on rhizospheric environment of the soil. Further, sugarcane is a long duration, nutrient exhaustive crop and has been found to meet its nutrient requirement through microbial mediation particularly during late stages of the crop growth. Contribution of microbes has been reported to be more pronounced in low fertility soils (Oliveira *et al*. 2006), as in this case.

At ratoon harvest contribution of microbial biomass carbon to soil organic carbon was found to range between 4.6 to 6.8% (Table 2). Microbial biomass, although small, plays a key role in controlling the nutrient cycling and energy flow due to its fast turnover (Li and Chen, 2004). It is a dynamic process, which represents the proportion of microbial carbon to the organic carbon pool and thus the biological activity in rhizospheric soil. Greater is the proportion of microbial carbon higher is the total microbial activity and better is the soil health. Moreover, the relationship between SMBC or SMBN with organic carbon or soil N were more significant where soil organic carbon content was less than 2.5 % (Anderson and Domsch, 1989). Since, soils located in subtropical India have organic carbon content up to 1 % only, these parameters are very sensitive indicators of soil quality and our findings indicate conspicuous improvement in soil microbial activity due to adoption of different organic nutrition modules in sugarcane production system. Generally, if a soil is being degraded, the microbial C- pool will decline at a faster rate than organic C and the SMBC: Organic C percentage will decrease. This indicates whether soils are accumulating or losing soil C. None of our organic nutrition module caused any reduction in the percentage of organic C present as SMBC. In fact, at ratoon harvest soils under all the tested modules were accumulating carbon. This clearly indicates the positive influence of the modules on the overall soil health. As apparent from data on contribution of microbial C to soil organic carbon FYM 20 t/ ha + *T. viride* + lentil intercropping and SPM 10 t/ ha + lentil intercropping exhibited comparatively higher percentage of microbial carbon to organic carbon in soil. These were closely followed by FYM 20 t/ ha + *G. diazotrophicus* inoculation. The observations suggest that besides organics, legume intercropping or *G. diazotrophicus* inoculation do enhance the functional entity of soil organic carbon.

Effect on soil physical properties and fertility

Significant improvement in soil physical properties such as bulk density, water infiltration rate and size of stable aggregates was recorded under all the organic nutrition modules (Table 3). The highest reduction in bulk density (7.46 %) over the initial (1.34 Mg/ m^3) was effected by use of FYM 20 t/ ha + *T. viride* + lentil intercropping or SPM 10 t/ ha + FYM 10 t/ ha or SPM 10 t/ ha + lentil intercropping treatments as observed at the harvest of plant crop. A further decline in bulk density at ratoon harvest was recorded under these treatments leading to final reduction up to 8.95 %. Similarly as compared to initial water infiltration rate (3.5 mm/ h) there was 45.7 to 60 % increase at planted sugarcane harvest due to various organic nutrition modules, the highest increase was with SPM 10 t/ ha + FYM 10 t/ ha and the lowest with FYM 20 t/ ha + *G. diazotrophicus* inoculation. However, finally at ratoon harvest infiltration rate enhanced by 88.5 % over the initial rate, under SPM 10 t/ ha + FYM 10 t/ ha closely followed by SPM 10 t/ ha + lentil intercropping (80 %). Reduced bulk density and enhanced water infiltration rate may be attributed to the simultaneous increase in mean weight diameter of water stable aggregates under organic nutrition conditions (from 0.387 to 0.458 after planted crop and from 0.391 to 0.462 mm at ratoon harvest) over the initial mean weight diameter (0.349 mm).

Sugarcane is a heavy soil- nutrient exploiting crop, as evident from the nutrient uptake data (Table 4). Uptake of N by planted crop under different nutrition modules varied from 198.3 kg/ ha to 227.7 kg/ ha against 152.6 kg/ ha removal of N under control conditions. Application of SPM 10 t/ ha + FYM 10 t/ ha resulted into the highest N removal (227.7 kg/ ha) closely followed by FYM 20 t/ ha + *G. diazotrophicus* inoculation (219.7 kg/ ha) and SPM 10 t/ ha + lentil intercropping (212.3 kg/ ha). However, in case of subsequent ratoon crop the highest N removal (284.6 kg/ ha) was recorded under FYM 20 t/ ha + *G. diazotrophicus* inoculation closely followed by N removal under SPM 10 t/ ha + FYM 10 t/ ha (271.5 kg/ ha). Removal of P by planted crop was recorded highest (41.6 kg/ ha) with SPM 10 t/ ha + FYM 10 t/ ha followed by FYM 20 t/ ha + *G. diazotrophicus* inoculation (40.8 kg/ ha) and SPM 10 t/ ha + lentil intercropping (40.6 kg/ ha), respectively as compared to 29.2 kg/ ha P removal in control conditions. Ratoon crop removed 38.3 kg P/ ha when supplied with FYM 20 t/ ha + *G. diazotrophicus* inoculation followed by SPM 10 t/ ha + FYM 10 t/ ha (36.7 kg/ ha) in comparison to 21.6 kg/ ha removal under control. Similar trend as for P was recorded for potassium removal in planted and ratoon crops, ranging from 196.3 to 216.5 kg/ ha for planted crop and 203.8 to 229.8 kg/ ha for ratoon crop against respective controls 134.5 and 107.6 kg/ ha. Significantly, higher uptake of nutrients under various organic nutrition modules over that of control indicates unrestricted availability of these in labile pool to support the crop growth and yield. Availability status of major nutrients (N, P and K) after harvest of planted and subsequent ratoon crops revealed a positive effect of various nutrition modules. The highest improvement in fertility status due to the application of SPM 10 t/ ha + FYM 10 t/ ha may be attributed to the soil ameliorating effect of pressmud rich in calcium and sulphur content fortified with cementing properties of FYM.

Positive balance of major nutrients (N, P & K) in soil at the end of crop cycle revealed soil fertility enriching effect of various nutrition modules. This indicates unlimited and adequate availability of N, P & K, nutrients required in bulk to ensure remunerative crop production, under various organic nutrition modules, further the concept that organic resources of nutrients enrich the soil, and enhance its fertility. Moreover, decomposition of organic manures in soil is accompanied by the release of appreciable quantity of CO_2, which on forming carbonic acid with soil water, is capable of dissolving certain primary minerals and making them available.

Cane productivity and economics

Economic yield of sugarcane planted and ratoon crops are the function of number of millable canes (NMC) and the average cane length at the time of harvest. All the organic nutrition modules brought about significant improvement in yield attributing characters and cane yield over that of control (Table 5). Among various modules the significantly highest number of millable canes in planted and ratoon crops (83600/ ha &115600/ ha), and cane length (220.8 & 211.6 cm) and cane yield (84.6 and 74.2 t/ ha) were produced under SPM 10 t/ ha + FYM 10 t/ ha. However, under control conditions, production of number of millable canes was 74400 and 97000/ ha; cane length 195.6 and 176.2 cm and cane yield 54.4 and 50.2 t/ ha in planted and ratoon crops, respectively. It is noteworthy that cane yield both in planted and ratoon crops obtained under various organic nutrition modules was higher than the average national sugarcane productively realized with modern cultivation practices involving synthetic fertilizers and other agricultural inputs. This indicates adequate efficiency of organics in fulfilling the crop- nutrition requirements.

Comparing the profitability under various modules, based on benefit to cost ratio, it was found that in case of planted sugarcane highest profit per rupee invested (2.7) was realized with FYM 20 t/ ha + *T. viride* + lentil intercropping. It was followed by SPM 10 t/ ha + FYM 10 t/ ha (1.8) and FYM 20 t/ ha + *G. diazotrophicus* inoculation (1.7) as against 1.3 under control conditions. Whereas, with ratoon crop SPM 10 t/ ha + FYM 10 t/ ha was found highest profit giving nutrition module with 3.0 B: C ratio followed by 2.6 under FYM 20 t/ ha + *T. viride* + lentil intercropping and 2.4 under FYM 20 t/ ha + *G. diazotrophicus* inoculation as compared to 1.8 for control.

Higher yield of planted crop and ratoon due to organic nutrition modules over the average crop productivity in the region may be attributed to enhanced nutrient availability, improved soil health and the soil physical properties that resulted in increased profitability of sugarcane production system through the combined use of organic resources of nutrients. Organic resources are not only sources of major nutrients, but they also provide other micronutrients and plant growth-promoting molecules, which together lead to good crop yields (Mader *et al*. 2002).

Experiment II

Effect of bio-manures on soil health in multi-ratooning system

Soil health as determined by physical, physico-chemical and microbial properties greatly influences the soil fertility and crop productivity more prominently in long duration high biomass producing crops like sugarcane. Substantial improvement in soil bulk density, water infiltration rate, organic carbon content, soil microbial biomass carbon (SMBC) and soil microbial biomass nitrogen (SMBN) was recorded with the application of bio-manures either alone or in combination with *Gluconacetobacter diazotrophicus (Gd)* over the

Table 1 Nutrient composition of organic resources on dry weight basis

Organic resource	Nutrient composition (%)						
	Organic carbon	N	P	K	Ca	Mg	S
Sulphitation pressmud (SPM)	40	1.60	1.00	1.20	3.20	2.00	0.50
Farmyard manure (FYM)	46	0.75	0.20	0.55	0.91	0.19	-
Lentil crop residue	45	1.99	0.21	1.20	-	-	-

Table 2 Effect of organic nutrition modules on soil organic carbon content and rhizospheric microbial activities at ratoon harvest

Treatment	Organic carbon (%)	SMBC (mg CO_2-C/ kg soil/ day)	SMBN (mg NH_4- N/ kg soil/ day)	Contribution of microbial carbon to soil organic carbon (%)
SPM 10 t/ ha + *A. chroococum*	0.43 (26.4)*	273 (157.50	4.2 (108.9)	6.34 (103.8)
FYM 20 t/ ha + *T. viride* + lentil intercropping (1:2)	0.42 (23.5)	293 (176.4)	4.3 (113.9)	6.97 (124.1)
S PM 10 t/ ha + FYM 10 t/ ha	0.46 (35.2)	274 (158.4)	4.4 (118.9)	5.95 (91.3)
S PM 10 t/ ha + lentil intercropping (1:2)	0.41 (20.5)	283 (166.9)	4.9 (143.7)	6.90 (121.8)
FYM 20 t/ ha + *G. diazotrophicus*	0.47 (38.2)	284 (167.9)	4.2 (108.9)	6.04 (94.21)
Control (no manure or fertilizer)	0.35 (2.9)	205 (93.3)	3.5 (74.1)	5.85 (88.10)
CD (P = 0.05)	0.03	11.3	0.36	-
Initial value	0.34	106	2.01	3.11

SMBC: Soil microbial biomass carbon: SMBN: Soil microbial biomass nitrogen
* Figures in parentheses indicate percent improvement over initial value.

Table 3 Soil physical properties at the harvest of planted and ratoon crops as influenced by different treatments

Treatment	Bulk density 0-15 cm (Mg/ m^3)		Soil aggregate (mean weight diameter - mm)		Water infiltration rate (mm/ h)	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
SPM 10 t/ ha + *A. chroococum*	1.25	1.25	0.431	0.442	5.3 (51.4)	6.2 (77.1)
FYM 20 t/ ha + *T. viride* + lentil intercropping (1:2)	1.24	1.22	0.442	0.456	5.2 (48.5)	5.9 (68.5)
S PM 10 t/ ha + FYM 10 t/ ha	1.24	1.22	0.458	0.462	5.6 (60.0)	6.6 (88.5)
S PM 10 t/ ha + lentil intercropping (1:2)	1.24	1.22	0.387	0.391	5.4 (54.2)	6.3 (80.0)
FYM 20 t/ ha + *G. diazotrophicus*	1.25	1.24	0.432	0.446	5.1 (45.71)	5.8 (65.7)
Control (no manure or fertilizer))	1.32	1.30	0.362	0.371	4.1 (17.14)	4.3 (22.8)
CD (P = 0.05)	0.06	0.04	0.022	0.028	0.31	0.26
Initial value	1.34	-	0.349	-	3.5	-

* Figures in parentheses indicate percent improvement over initial value.

Table 4 Effect of organic nutrition modules on nutrient removal by sugarcane planted and ratoon crops and nutrient balance at ratoon harvest

Treatment	Nitrogen (kg/ ha)			Phosphorus (kg/ ha)			Exchangeable K (kg/ ha)		
	Removal		Final balance (available)	Removal		Final balance (available)	Removal		Final balance
	Plant	Ratoon		Plant	Ratoon		Plant	Ratoon	
SPM 10 t/ ha + *A. chroococum*	198.3	217.6	210	36.3	29.3	21.3	196.3	203.8	203
FYM 20 t/ ha + *T. viride* + lentil intercropping (1:2)	207.5	234.8	223	37.8	35.4	22.6	211.7	221.7	208
S PM 10 t/ ha + FYM 10 t/ ha	227.7	271.5	254	41.6	36.7	28.1	216.5	229.3	209
S PM 10 t/ ha + lentil intercropping (1:2)	212.3	225.3	237	40.6	32.8	25.2	198.7	207.6	222
FYM 20 t/ ha + *G. diazotrophicus*	219.7	284.6	217	40.8	38.3	24.1	214.3	229.8	218
Control (no manure or fertilizer))	152.6	129.4	160	29.2	21.6	18.6	134.5	107.6	207
CD (P=0.05)	11.2	13.1	-	4.6	5.1	-	12.3	14.2	-
Initial value	-	-	208	-	-	20.8	-	-	158

Table 5 Effect of organic nutrition modules on yield attributes, yield and economics of sugarcane planted and ratoon crops

Treatment	NMC ('000/ ha)		Cane length (cm)		Cane yield (t/ ha)		B: C ratio	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
SPM 10 t/ ha + *A. chroococum*	79.2	107.0	217.7	201.3	79.1	69.5	1.6	1.1
FYM 20 t/ ha + *T. viride* + lentil intercropping (1:2)	76.7	98.5	207.8	205.6	74.1	66.7	2.7*	2.6*
S PM 10 t/ ha + FYM 10 t/ ha	83.6	115.6	220.8	211.6	84.6	74.2	1.8	3.0
S PM 10 t/ ha + lentil intercropping (1:2)	78.6	101.4	210.0	208.3	71.7	68.0	1.5**	2.3**
FYM 20 t/ ha + *G. diazotrophicus*	83.0	109.0	211.4	210.6	77.8	71.3	1.7	2.4
Control (no manure or fertilizer))	74.4	97.0	195.6	176.2	54.4	50.2	1.3	1.8
CD (P= 0.05)	4.2	9.3	16.6	15.3	5.3	9.9	-	-

B: C ratio: Benefit cost ratio
* Lentil yield – 4.5 q/ ha (Cane Equivalent yield-CEY= 12.9 t/ ha) Sugarcane @ Rs.1110/ t (2003 price)
** Lentil yield – 4.8 q/ ha (CEY = 13.8 t/ ha) Lentil @ Rs. 3200/ q

respective initial status recorded at the time of sugarcane planting (Table 6). Soil organic carbon increased from initial 0.32% to up to 0.72% due to different bio-manures, highest increase being with the use of sulphitation pressmud (10 t/ha) alone. There was gradual increase in organic carbon including microbial carbon build up in soil with the use of bio-manures with each passing ratoon crop in the system. Further at ratoon harvest, on an average SMBC accounted for 3.88 to 5.36% of the soil organic carbon content in different bio-manuring treatments which imply bolstering of soil fertility as microbial biomass plays a key role in nutrient cycling and energy flow due to its fast turnover. Similarly, there was positive correlation between SMBC measured at different stages with the content of total N of the soil which strongly indicate the positive influence of the rhizosphere on soil microbial communities which under such stimulation enhance the decomposition rates

Table 6 Effect of bio-manuring on soil health in sugarcane multi-ratooning system at the end of ninth ratoon crop

Treatment	Soil Organic Carbon (%)	Bulk density (g/cc)	Water infiltration rate (mm/hr)	Soil Microbial Biomass Carbon (mg CO_2-C/kg/day)	Soil Microbial Biomass Nitrogen (mgNO_3-N/kg/day)
Initial level	0.32	1.40	4.0	47.6	3.6
Control (zero nutrition)	0.35	1.39	4.2	136.9	3.5
Recommended NPK (150,60,60 kg/ha)	0.45	1.40	4.5	146.7	2.0
FYM (10 t/ha)	0.63	1.24	5.7	195.5	5.8
Pressmud 10 t/ha	0.67	1.23	5.9	244.4	7.7
Pressmud (10 t/ha + (*Gluconacetobacter diazotrophicus)*	0.72	1.23	5.9	278.2	7.7

of organic substrates from root biomass as sources of energy. Application of bio-manures positively influenced the SMBN too as an increase up to 179 % was recorded over the initial in related treatments against just 48% in fertilizer applied plots at harvest of 9th ratoon.

Application of bio-manures brought about substantial enhancement in soil physical properties as indicated by reduction in bulk density from 1.40, recorded at planting of sugarcane, to 1.23 g/cc at the harvest of 9th ratoon. Corresponding increase in water infiltration rate from 4.0 mm/hr. to 5.9 mm/hr. was recorded during the same period due to bio-manure addition in plant and subsequent ratoon crops, which gets corroborated with the findings that mean weight diameter of soil particles enhanced during the period and stability of water stable aggregates, needed for granular soil structure to ensure proper aeration and adequate water holding capacity of the soil amplified with the addition of bio-manures.

Monthly assessment of multi-ratooning induced effects in rhizospheric environment in the ninth ratoon crop during the growth cycle indicated that the total carbohydrates contents varied at different stages of growth with all the treatments, however the magnitudes of carbohydrate fractions were about two-fold greater in the control and NPK treated plots during the grand growth phase. Decomposition of root biomass were substantially higher with sulphitaion pressmud 10 t/ha and sulphitaion pressmud 10 t / ha + *Gd* as supported by root biomass cellulosic, hemicellulosic, total lignin, acid insoluble and acid soluble lignin contents. The root biomass residue turned increasingly more recalcitrant in control and NPK treated plots. A strong negative correlation occurred between total lignin, acid insoluble lignin, acid soluble lignin, phenols, anildies and soil enzymes (dehydrogenase, alkaline and acid phosphatase and aryl sulphatase) in control and NPK treated plots during the grand growth phase. However, 1.6-2.3 fold increase in dehydrogenase, 1.2-1.9 fold increase in aryl sulphatase and 1.4 fold increases in acid phosphatase activities in the bio-manured crops led to about 65 and 79 % decline in phenol and anilide contents during the grand growth phase. It is specified that phenols and anilides quench the available nitrogen hence their higher concentration is unfavorable for crop growth, whereas increased soil enzyme activities work favorably for nutrient availability during the growth cycle (Fig. 1). Bio-manuring also registered a strong positive correlation amidst root cation exchange capacity and the mentioned soil enzymatic activities whereas decline in range of 65-73 % was observed in the root cation exchange capacities of control and NPK treated plots. Overall, bio-manuring led to improvement in the root cation exchange capacities and increase in the root biomass compositional decomposition. The rhizospheric alterations involving breakdown of chemical recalcitrance in the bio-manured plots as compared to control and NPK plots during the grand growth phase hastens the root decomposition and influences the available nutrient pool positively rendering their greater availability to the plants.

Effect of bio-manures on sugarcane growth, yield and economics

Sugarcane yield is mainly attributed by the number of millable canes (NMC) available in the field and the composition of mother shoots, primary, secondary and tertiary tillers at the time of harvest which depends on tillering behavior since beginning and dynamics of tiller mortality during the grand growth phase characterized by stem elongation in the monsoon season. It is now well known that higher number of mother shoots and initial tillers bring about higher cane as well as sugar yield and agro-techniques supporting this help accruing greater benefits for farmers. Our findings revealed that growing sugarcane with bio-manures alone or in combination with bio-fertilizer produced similar number of millable canes as that with the use of recommended levels of NPK through fertilizers. Application of sulphitation pressmud (10 t/ha) in plant crop recorded 75.3 t/ha sugarcane yield against 76.1 t/ha obtained with NPK application and 70.9 t/ha with farmyard manure (10 t/ha). For the first ratoon crop, these treatments effected 77.9, 74.2 and 70.7 t/ha sugarcane yield, respectively. The number of millable canes due to these treatments remained at par for plant as well as first ratoon crop. Decline in cane yield with each subsequent ratoon till the ninth ratoon crop has been recorded, however it was steeper (Fig. 2) with fertilizer application as compared to that with the application of bio-manures. Sugarcane yield in ninth ratoon was recorded to be 53.2, 51.0 and 49.3 t/ha with pressmud, farmyard manure and NPK, respectively, thus implying that bio-manures are capable of sustaining sugarcane productivity for a longer period in a multi-ratooning system over that with the use of chemical fertilizers (Table 7).

Economics calculated in terms of benefit: cost (B:C) ratio clearly reveals profitability of sugarcane multi-ratooning under bio-manured condition as the benefit earned over every rupee invested was higher with bio-manures in comparison to that obtained with the use of chemical fertilizers (Table 8). The B: C ratio for plant crop was worked out to be 1.20 with recommended NPK which was surpassed with the pressmud application that accrued B: C ratio of 1.23. It is noteworthy that B:C ratio in first ratoon was higher than that of plant crop for all the treatments which brings forth the profitability of ratooning of sugarcane due to obvious savings in cost of cultivation. Bio-manuring treatments maintained or surpassed the level of profitability obtained with chemical fertilizers for all the crops and use of pressmud fetched a B: C ratio of around 2.0 up to fourth ratoon crop and thereafter continued to accrue higher benefit than the recommended levels of fertilizer clearly signifying the long term sustainability of the system.

Combined use of pressmud with *Gd* recorded higher benefit all through the 10 crops indicating thereby the synergistic interaction between these two that can be effectively tapped for enhancing the productivity and profitability of sugarcane

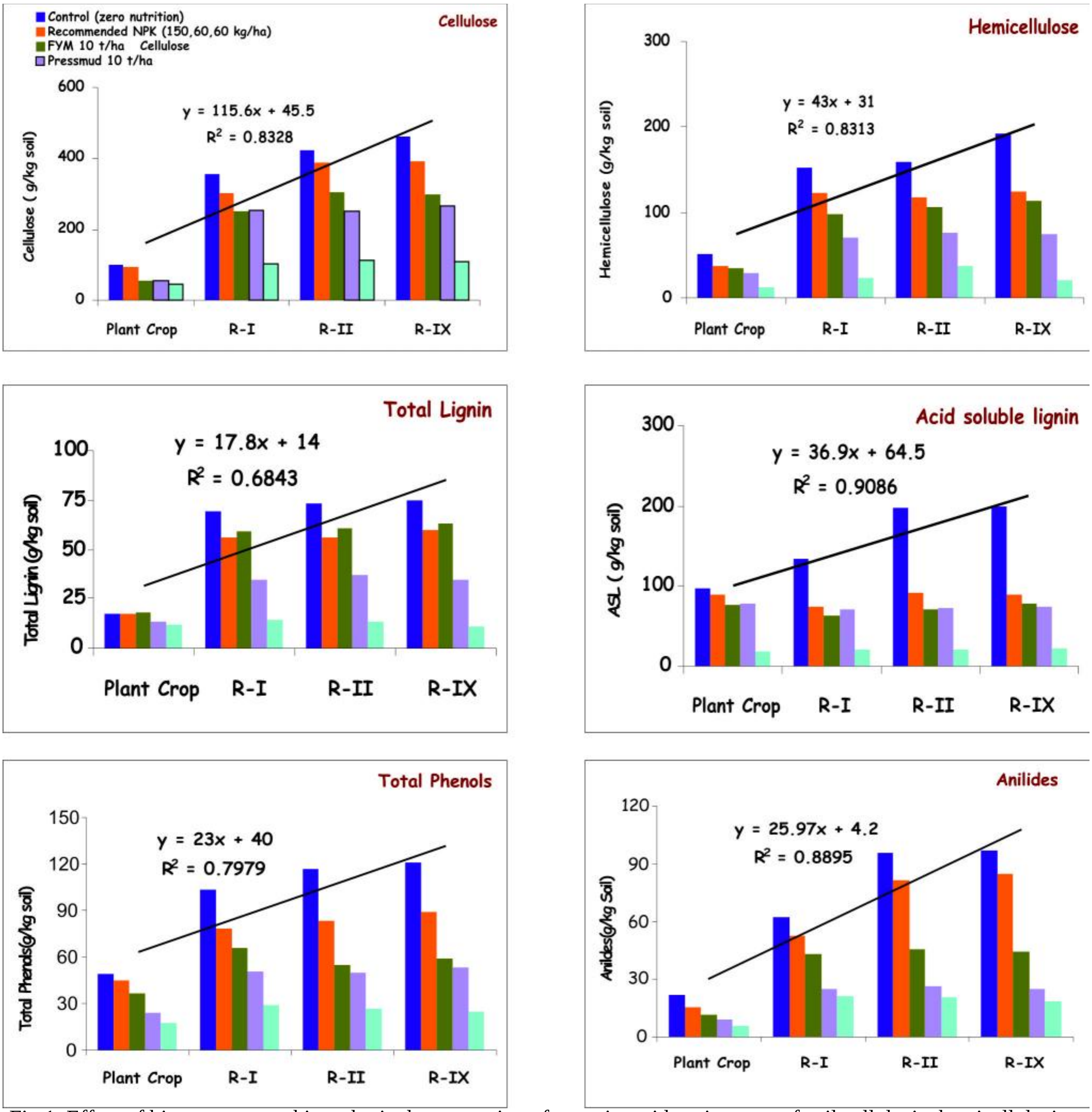

Fig 1. Effect of biomanures on rhizospheric decompostion of organic residues in terms of soil cellulosic, hemicellulosic, total lignin and acid soluble lignin, total phenols and anilide fractions in sugarcane plant- ratoon system.

Table 7 Effect of bio-manuring on cane yield (t/ha) of sugarcane plant and ratoon crop in a multi-ratooning system

Treatment	Plant Crop	Ratoon Crop								
		I	II	III	IV	V	VI	VII	VIII	IX
Control (zero nutrition)	53.0	46.3	41.9	37.6	35.0	24.8	18.5	18.7	16.0	16.0
Recommended NPK (150,60,60 kg/ha)	76.1	74.2	71.7	66.5	64.3	53.8	51.0	51.0	49.8	49.3
FYM 10 t/ha	70.9	70.7	68.3	63.3	63.0	55.0	54.9	53.5	51.5	51.0
Pressmud 10 t/ha	75.3	77.9	72.5	67.4	67.3	57.9	57.5	54.8	53.6	53.2
Pressmud 10 t/ha + (*Gluconacetobacter diazotrophicus)*	77.5	80.8	74.9	70.0	69.5	60.5	60.0	57.4	54.2	54.0
CD at 5%	2.9	9.7	5.7	5.9	4.6	4.2	4.3	5.1	4.3	2.6

Table 8 Effect of bio-manuring on economics (B: C ratio) of sugarcane cultivation in a multi-ratooning system

Treatment	Plant crop	Ratoon Crop								
		I	II	III	IV	V	VI	VII	VIII	IX
Control (zero nutrition)	0.77	1.67	0.96	0.90	0.80	0.60	0.80	0.60	0.50	0.50
Recommended NPK (150,60,60 kg/ha)	1.20	2.58	1.81	1.90	1.70	1.00	1.00	1.00	1.20	1.20
FYM 10 t/ha	1.18	2.58	1.89	1.90	1.90	1.10	1.20	1.10	1.20	1.00
Pressmud 10 t/ha	1.23	2.69	1.92	2.00	1.90	1.20	1.30	1.10	1.20	1.20
Pressmud 10 t/ha + *Gluconacetobacter diazotrophicus*	1.28	2.80	2.03	2.00	2.00	1.30	1.40	1.30	1.20	1.20

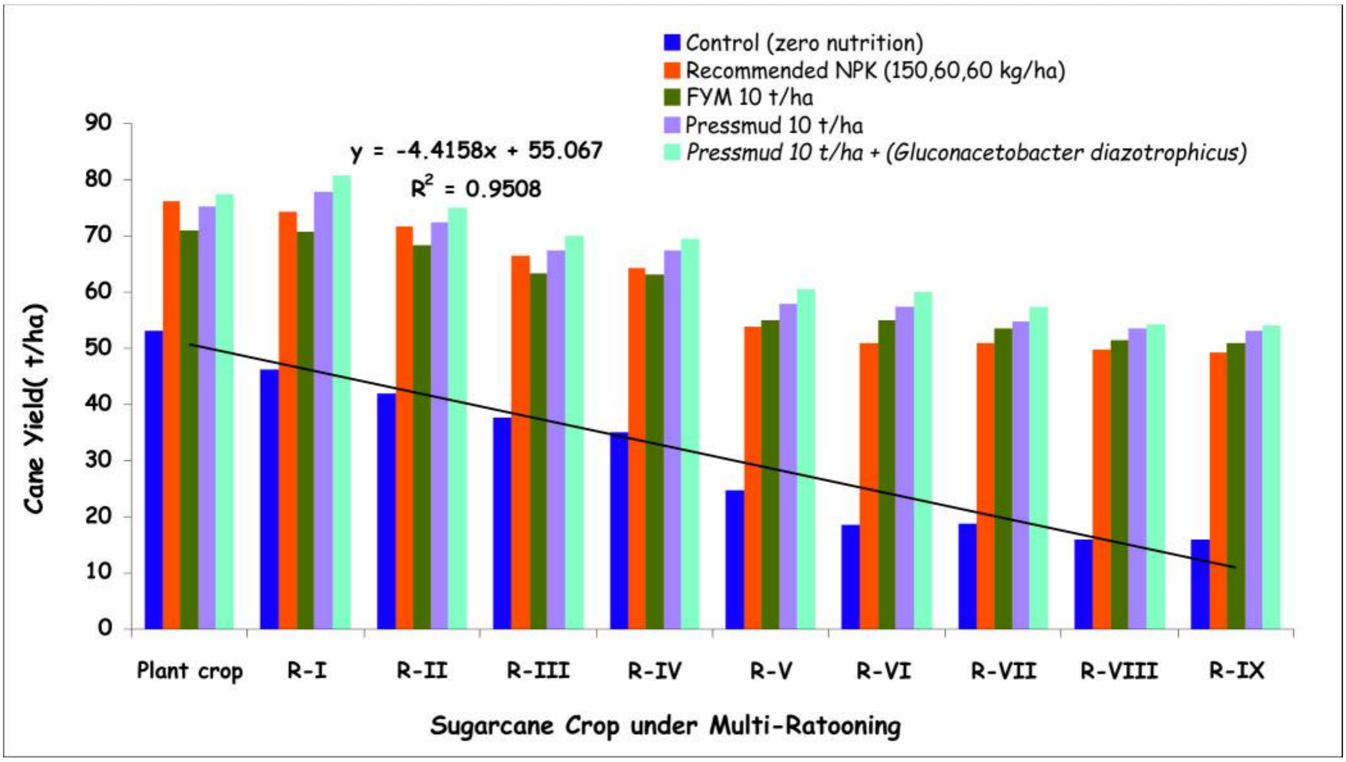

Fig 2. Effect of bio-manuring on cane yield (t/ha) of sugarcane plant and ratoon crop in a multi-ratooning system. (R: Ratoon)

cultivation in a multi-ratooning system for ensuring economic and livelihood security of sugarcane growers.

CONCLUSION

It may, therefore be concluded that cultivation of sugarcane under organic farming is feasible by supplying nutrients through organic sources involving FYM and SPM among manures and *A. chroococum* and *G. diazotrophicus* among microbes. Inclusions of leguminous intercrops further add to the profitability. In addition, significant improvement in soil health occurs due to organic nutrition of sugarcane crop. As a package for organically cultivated sugarcane under sub-tropical climate FYM 20 t/ ha + *T. viride* + lentil intercropping may be adopted for plant crop, whereas for subsequent ratoon the most profitable results may be obtained by applying SPM 10 t/ ha + FYM 10 t/ ha. Besides, bio-manuring in sugarcane multi-ratooning improves the rhizosphere micro-climate and structure as compared to inorganic fertilizers and promotes the restoration of return of easily decomposable organic compounds in the soil rhizosphere with positive influence over organic carbon content, microbial activities and soil physical properties. Sugarcane cultivation using bio-manures as source of nutrients can be ensured to be more profitable as compared to that with the use of recommended levels of NPK in multi-ratooning system. Further, more number of ratoons can be successfully raised with the use of bio-manures leading to enhanced overall productivity and profitability of the sugarcane cropping system.

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A study of the inputs use pattern of IPM and non-IPM adopters of sugarcane in Karnal district of Haryana

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ABSTRACT

Although, IPM approach is creating awareness and interest among the farmers, but its implementation at farm level is not up to the expectation in the backdrop of this, the present study was carried out with objective to study the input use pattern by IPM and non-IPM farmers in Karnal district of Haryana. The cost of cultivation for one hectare of sugarcane (Cost 'C') in IPM farmer's category was comparatively lower (Rs. 161830.73) than the non-IPM farmers category (Rs.164137.97).Human labour constituted the major share (19.03 % and 17.85 %) of the total cost of cultivation among the IPM and non-IPM farmer, respectively. The use of machine labour charges was higher, i.e., 3.71 % in non-IPM as compared to 3.65 % in IPM. The fertilizer use in IPM was 3.37 per cent and in non-IPM was 3.27 per cent of the total cost 'C'. Plant protection components accounted the highest share to the total cost in non-IPM farmers (3.19%) whereas, it was only (1.13%) in IPM farmers category. Total non-chemical pesticide used was 54.31 per cent of the total cost on pest management and chemical pesticide used was 45.69 per cent of the total cost on pest management.

Key words: IPM, Sugarcane

Sugarcane is a tropical, perennial grass with lateral shoots at the base to produce multiple stems, typically three to four metres high and about five cm in diameter. The stems grow into cane stalk, which when mature constitutes approximately 75% of the entire plant. A mature stalk is typically composed of 11–16% fiber, 12–16% soluble sugars, 2–3% non-sugars, and 63–73% water. A sugarcane crop is sensitive to the climate, soil type, irrigation, fertilizers, insects, disease control, varieties, and the harvest period. The average yield of cane stalk is 60–70 tonnes per hectare per year. However, this figure can vary between 30 and 180 tonnes per hectare depending on knowledge and crop management approach used in sugarcane cultivation. Sugarcane is a cash crop, but it is also used as livestock fodder (Perez 1997).

In the country, food production is a success story following the Green Revolution in the late 1960's. However, there have been reports of either stagnating or declining levels of crop productivity in recent years, which cause much alarm to the policy makers. Over exploitation of natural resources and excessive chemicalization are main reason which led to poor sustainability of farm production. Though, the value of integrated pest management (IPM) in sustainable agriculture has been well recognized, it is being adopted very little at field level. The Union Agriculture Ministry is concerned very much with the slow progress in IPM as there is increasing demand for chemical pesticide. In recent years, pesticide have come under sever criticisms due to their technological, resurgence and secondary outbreak of pest and potential hazards to ecology and human health. The resultant effects on farm economy have been escalation in the cost of production, increase in crop losses and reduction in farm profitability. These concerns have given rise to a demand for curtailing pesticide use in agriculture.

In conventional non-IPM cultivation of sugarcane, cost of seed, chemical fertilizer and last but not the least chemical pesticides is considerably high as compared to other crops. High yielding and hybrid varieties were responsible to heavy fertilizer dose, which gave succulence to the crop, which in turn attract insect pests on the crop making large number of spraying of the chemicals inevitable in the sugarcane field thus, making the economics of sugarcane crop least profitable.

Considering all these facts, efforts were made to formulate an eco-friendly and economical management package by selecting and using pest control practices intelligently. Use of pest avoidance tactics, enhancement of biological pest suppression and adoption of other non-chemical method of pest management would certainly be able to improve our capabilities in solving much of the pest problems.

IPM, as defined by FAO Panel of Experts, is a Pest Management System in the context of associated the environment and the population dynamics of pest species, utilization of all suitable techniques and methods to maintain the population of pest below the economic injury level (FAO, 1967). Although, IPM approach is creating awareness and interest among the farmers, but its implementation at farm level is not up to the expectations because of the problems such as the non-availability of bio-agents on time at various locations, lack of knowledge about IPM technology, etc.

Hence, an attempt was made to study "Economic analysis of integrated pest management of sugarcane in Karnal district of Haryana" with the following objective:

To study the inputs use pattern of IPM and non-IPM adopters of sugarcane

METHODOLOGY

Methodological aspects of the research study deserve significance in its scientific completion and to arrive at the useful conclusions. One of the aspects, of the present study is to examine in detail the per hectare resource use structure on IPM and Non-IPM sugarcane farm in Karnal district.

Location of the study

Karnal district of Haryana was purposely selected for the study. There are 6 blocks in the district, out of which Indri and Karnal has been purposively selected for the present study because of highest area and production of sugarcane in the district.

Sampling design

Selection of villages

The study was based on farm level data pertaining to different aspect of economics of Integrated Pest Management of sugarcane in Karnal district of the Haryana. Two blocks (Indri and Karnal) were selected for the sample study of two villages of each block. From the Indri block, Bhadson and Khanpur and from the Karnal block, Mahamudpur and Dakwala were selected randomly.

Selection of farmers

For selection of growers, a list of IPM farmers who adopted IPM technology was prepared by conducting personal interviews of the farmers with the help of specially designed schedules. From each selected village, 10 IPM and 10 non-IPM growers were selected. Thus, 40 IPM and 40 non-IPM adopted farmers making a total of 80 farmers were studied. Three categories were made of these farmers according to their land holding, *i.e.*, small (<5.4), medium (5.4-9.3) and large (> 9.3) hectares. In each category, two groups were made namely, IPM and non-IPM. In IPM group, number of selected growers under small, medium and large category was 22, 11 and 7, respectively. On the other hand, under non-IPM group, number of selected sugarcane growers was 20, 12 and 8 in small, medium and large category, respectively.

Collection of data

The primary data for the agricultural year 2012-13 were collected by survey method by conducting personal interviews of the selected farmers with the help of specially designed schedule which include the following aspects.

1. General information of the selected farmers and various aspects of farmer's family, farm assets possessed by the family, land owned, its utilization and cropping pattern, etc.
2. A detailed information about the per hectare input use pattern, cost of cultivation of sugarcane under IPM and non-IPM farms.

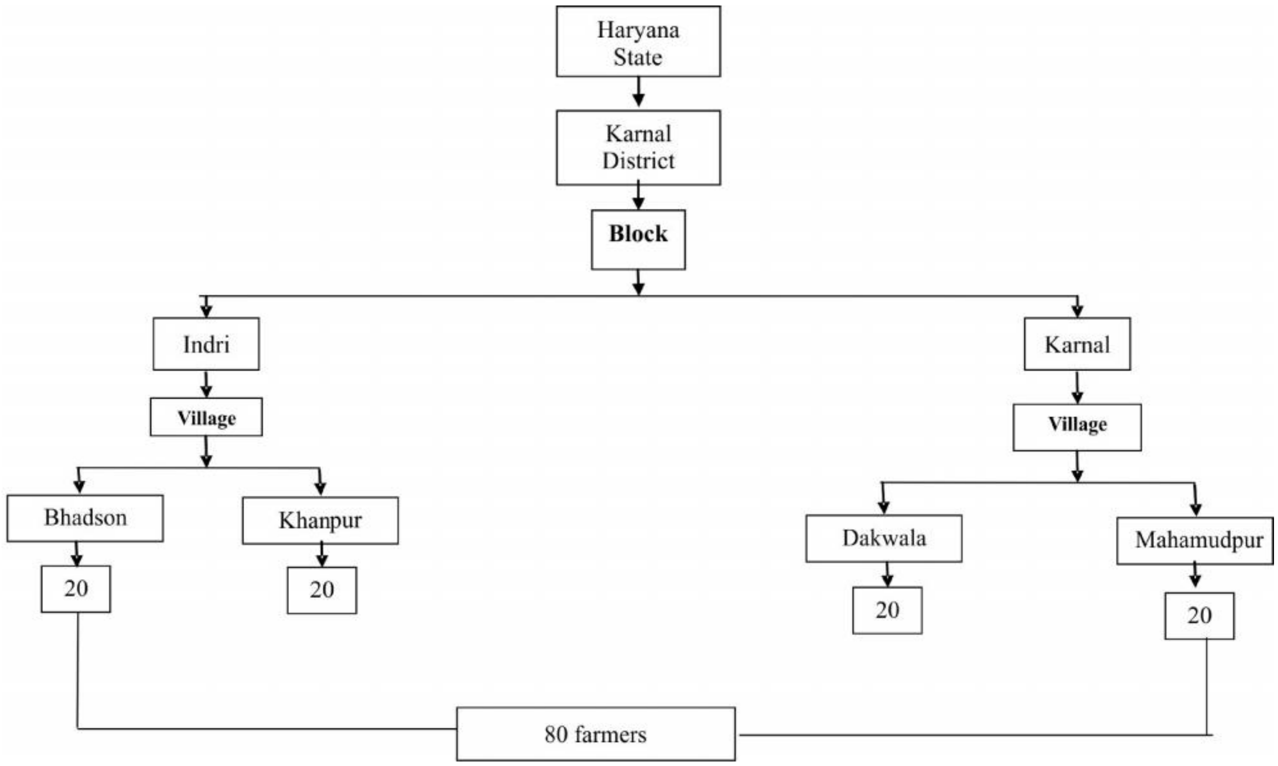

Fig. 1: Sampling procedure adopted in the study area

Table 1 Classification of selected sugarcane growers of Karnal district

Sr. No.	Cate-gories	Farm size group (in hectare)	No. of selected growers IPM	Non-IPM	Total
1.	Small	< 5.4	22	20	42
2.	Medium	5.4-9.3	11	12	23
3.	Large	> 9.3	0 7	08	15
Total			40	40	80

*Categories selected by cumulative total method

RESULTS AND DISCUSSION

Resource use structure

The economic aspects of sugarcane cultivation were worked out for the farmers who have adopted IPM technology as well as those who have followed conventional methods of plant protection (non-IPM farmers). Detailed analysis of input use of sugarcane is presented below.

Input use pattern by small, medium, large and overall IPM and Non-IPM growers

The input use pattern in the production of sugarcane by small IPM and non-IPM farmers is presented in Table 1. It is evident from the Table 1 that the IPM farmers used more of

Table 1 Input use pattern of small, medium, large and overall growers (2012-13)

Items	Small growers IPM Growers	Small growers Non - IPM Growers	Medium growers IPM growers	Medium growers Non - IPM Growers	Large growers IPM growers	Large growers Non - IPM Growers	Overall growers IPM growers	Overall growers Non - IPM growers
Human labours (man days)								
Hired								
Male	38.17	36.75	39.46	37.14	39.27	38.26	38.97	37.38
	(33.24)	(34.46)	(32.47)	(30.99)	(30.53)	(32.09)	(32.03)	(32.44)
Female	33.24	29.31	34.19	30.58	35.16	31.54	34.20	30.48
	(28.95)	(27.48)	(28.14)	(25.52)	(27.54)	(26.46)	(28.11)	(26.45)
Sub-total	71.41	66.06	73.65	67.72	74.43	69.80	73.17	67.86
	(62.19)	(61.94)	(60.60)	(56.51)	(57.87)	(58.55)	(60.14)	(58.89)
Family								
Male	23.30	22.25	25.39	27.71	28.72	25.86	25.80	25.27
	(20.29)	(20.86)	(20.89)	(23.12)	(22.33)	(21.69)	(21.21)	(21.93)
Female	20.12	18.34	22.48	24.42	25.46	23.56	22.69	22.11
	(17.52)	(17.20)	(18.50)	(20.38)	(19.80)	(19.76)	(18.65)	(19.19)
Sub-total	43.42	40.59	47.87	52.13	54.18	49.42	48.49	47.38
	(37.81)	(38.06)	(39.39)	(43.50)	(42.13)	(41.45)	(39.86)	(41.12)
Total human labour	114.83	106.65	121.52	119.85	128.61	119.22	121.66	115.24
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Machine (hrs)	18.46	19.95	19.35	19.47	21.16	21.54	19.70	20.28
Seed (qtl)	80	80	87.50	87.50	87.50	87.50	85	85
Manures (qtls)	200	200	240	240	240	240	226.67	226.67
Fertilizers (kg)								
Nitrogen	188.50	188.50	188.50	188.50	188.50	188.50	188.50	188.50
Phosphorus	57.50	57.50	57.50	57.50	57.50	57.50	57.50	57.50
Potash	15	10	20	15	25	20	20	15
Total fertilizers	261	256	266	261	271	266	266	261
Plant Protection								
Liquid insecticides (litres)	5	5.375	5	5.375	5	7.375	5	6.04
Water soluble powder (kg)	1.25	0	1.25	0	1.25	0	1.25	0
Trichograma chilonis (lakh/ ha.)	1.50	0	1.50	0	1.50	0	1.50	0
Plant Products	1.50	0	1.50	0	1.50	0	1.50	0
Yield (qtls)	800	750	875	750	875	800	850	783.33

Figures in parentheses indicate the percentage to the total land holding.

the human labour, fertilizers, whereas in case of non-IPM farmers, the use of machine labour and plant protection chemical was higher. The IPM farmers used on an average of small, medium, large and overall, 114.83, 121.52, 128.61 and 121.66 man days/ha of human labour as against 106.65, 119.83, 119.22 and 115.24 man days/ha by the non-IPM farmers respectively. Similarly, the use of machine labour in small, medium, large and overall was 18.46, 19.35, 21.16 and 19.70 hours on IPM farm, while in case of non-IPM farms, its use was higher, *i.e.*, 19.95, 19.47, 21.54 and 20.28 hours, respectively. In case of seed and manures, small category farmers used equal quantity under both group, *i.e.*, 80 qtls/ha and 200 qtls/ha and in case of medium and large category, *i.e.*, 87.50 qtls/ha and 240 qtls/ha whereas in Overall it was 85 and 226.67 qtls/ha seed and manures, respectively in IPM and non-IPM group. The per hectare use of the fertilizers, *i.e.*, N and P in case of IPM and non-IPM was same in small, medium, large and overall 188.50 kg/ha and 57.50 kg/ha and K was used in amount of 15, 20, 25 and 20 kg/ha, respectively while their application in case of non-IPM farms was 10, 15, 20 and 15 kg/ha, respectively. Thus, total use of fertilizers by IPM farmers was found to be higher in all categories, *i.e.*, 261, 266, 271 and 266 kg/ha than those of non-IPM farmers in which it was 256, 261, 266 and 261 kg/ha, respectively. However, in case of plant protection chemicals, equal quantity of insecticides were used under small as well as medium farmers of non-IPM group, *i.e.*, 5.375 litre/ha and in large category (7.375 litre/ha). The overall insecticide used by non-IPM group was 6.04 litre/ha as compared to small, medium, large and overall categories in which equal quantity was used, *i.e.*, 5 litre/ha on the IPM farms.

The use of biological agent *Trichogramma* cards plant products (Nimboli extract) and water soluble powder was equally used by all categories of IPM farmers, *i.e.*, 1.50 lac/ha, 1.50 litre/ha and 1.25 kg/ha, respectively. Small farmers obtained 800 q/ha yield, medium as well as large category farmers obtained equal quantity of yield, *i.e.*, 875 q/ha whereas overall average yield obtained was 850 q/ha as compared to non-IPM farmers in which equal quantity of yield was obtained in small and medium category, *i.e.*, 750 q/ha, 800 q/ha and in case of large category and overall average it was 783.33 q/ha, respectively. Similar findings were also reported by Kunnal *et al.* (2004)

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Variability, heritability and genetic advance among the somaclones of sugarcane (*Saccharum* spp. complex)

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ABSTRACT

The material of the experiment was the sugarcane variety 'CoSe 93232', that was used to produce plantlets through tissue culture technique. Variability and performance of 25 somaclones obtained from tissue culture derived plants of sugarcane was studied on field in clonal generation first. Eighteen of the somaclones exhibited significantly higher cane yield per clump than control. For quality of cane juice only three somaclones in sucrose content and CCS % better than control. Cane yield per clump, number of tillers and number of millable canes per clump had high genotypic coefficient of variation. The moderate genotypic coefficient of variation was noted in single cane weight. Other attributes namely: Stalk diameter, stalk height, CCS %, sucrose %,, brix % and purity % in juice revealed low GCV. Similar trend was observed for phenotypic coefficient of variability (PCV) but extent of magnitude was higher than genetic coefficient of variability. Heritability estimate were found higher for sucrose %, brix %. Moderate value of heritability was recorded for number tillers per clump, whereas values were low for other traits.

Key words: Variability, Heritability, Genetic Advance

The conventional breeding programme is limited to the gene pool of the species and it is difficult to trace out the presence or absence of specific genes. During a cross, many undesirable traits are transferred to the progeny. In order to improve sugarcane and to enhance the rate of production, advanced technology has to be adopted. Among an emerging technology, biotechnology has taken prominent place and rightly so because of its potential, plant tissue culture has made considerable impact in plant improvement. The technique was found to be best suited for the rectification of specific defects of well adopted varieties. Somaclones resistant to smut, rust etc. had been isolated and it was also possible to improve some of agronomic traits of the commercial varieties through this approach (Sreenivasan *et al.* 1987a, 1987[b]). Unfortunately sugarcane doesn't flower regularly or produce viable seed in North India due to the short inductive photoperiod available and therefore, hybridization and breeding work is hampered (Maurya 1977). One major advantage of biotechnology is that the incompatibility barriers do not exist. Conventional breeding methods have to be supplemented with biotechnological methods either to increase their efficiency or to be able to achieve the objective, which is not possible through the conventional methods. Keeping above aspects in view the variety 'CoSe 93232', having high yield potential and quality with good ratooning ability,has been used for tissue culture for creating genetic variability in the variety and to develop somaclones with high yielding, high sugar content and resistance to diseases and pests.

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MATERIALS AND METHODS

The present investigation was conducted at G.S. Sugarcane Breeding and Research Institute, Seorahi (Kushinagar), Uttar Pradesh. The tops (apical part of cane) of cv 'CoSe 93232' were taken for in vitro culturing. The outer mature leaves were removed till a spindle of 1.5 cm diameter was obtained. Spindles were surface sterilized with 0.1 % $HgCl_2$ (Mercuric chloride) under sterile condition. After rinsing the spindles thrice with in sterile water. Leaves were removed and then the inner most leaf whorls were cut obliquely in small pieces of about 0.5 cm. These pieces were used as the explants, which were put on the medium in the conical flask on MS (1962) medium supplemented with different levels of 2, 4-D in the medium. The calli were maintained on the low concentration of 2,4-D in the medium for two months. In order to induce embryogenic greenish callus mass was transferred on liquid medium on cotton bridge containing only cytokinins viz. BAP and Kn (Lacking 2, 4-D) for plant regeneration. Profuse roots with good length were obtained in the ½ MS medium containing IBA (0.5 mg/1) and NAA (1.50 mg/1). After hardening of plantlets these were transplanted in the field. Twenty five somaclones were randomly taken on the basis of morphological variations exhibited by somaclones. These somaclones were planted clonally in R.B.D. design with donor variety 'CoSe 93232' as standard. The variability for different characters was estimated as suggested by Burton (1952), heritability was calculated as per Burton and De vane (1953) and genetic advance was calculated as per Robinson *et al.* (1949).

RESULTS AND DISCUSSION

The variance due to treatment or somaclones derivatives from the callus of cv 'CoSe 93232' were highly significant for all the 11 characters. The highest values were recorded for number of tillers followed by cane yield/clump and brix in juice but substantial variability was also recorded in all the characters. It indicated significant variability among the callus derived 25 somaclones of cv 'CoSe 93232'. The mean values of 25 somaclones,grand mean, rangeand SE values for all the 11 characters are calculated and presented in Table 1.

The genotypic, phenotypic and environmental coefficients of variability for all the characters were computed and presented in Table 2. Phenotypic coefficients of variability, in general, were higher than genotypic coefficient of variability and much higher than environmental coefficient of variability.

The estimates for heritability and genetic advance for all the 11 traits were calculated and presented in Table-3. High heritability (%) values were recorded for sucrose percent in juice at both the stages,ie; January (96.14%) and March (96.87%). Brix in juice at both the stages January (92.18%) and March (91.87%), CCS % (91.05), Stalk diameter (80.12%). Number of tillers showed moderate heritability. Other characters namely; number of millable canes per clump, stalk height, number of inter nodes, single cane weight, cane yield per clump. The genetic gain as percent of mean was the highest for cane per clump followed by number of tillers, number of millable cane per clump, single cane weight, stalk diameter and brix in juice, moderate gain for sucrose percentage in juice, stalk height and CCS yield. For number of internode and purity percentage at both the stages, the values were low (in descending order).

In the somaclones highly significant differences were recorded for all the characters, which reflected presence of substantial inbuilt genetic variability for these traits. The

Table 1 Mean and range performance for 11 attributes in 25 soma clones along with the parent variety ('CoSe 93232') in Sugarcane.

Soma-clones	No. of tillers	No. of millable canes/ clump	Stalk height (m)	Stalk diameter (cm)	No. of internodes	Single cane weight (kg)	Yield clump (kg)	Brix % in juice		Sucrose % in juice		Purity %		CCS %
								Jan.	March	Jan.	March	Jan.	March	
SC-1	11.16	7.98	2.04	2.17	23.60	0.65	5.29	18.97	20.08	16.33	17.65	84.68	87.95	12.22
SC-2	10.94	9.12	0.07	2.26	23.91	0.69	6.20	18.09	19.54	15.56	16.86	86.09	87.63	11.52
SC-3	13.26	10.48	2.15	2.24	23.88	0.71	7.14	20.34	20.55	16.82	17.55	82.70	85.27	11.93
SC-4	12.67	10.22	2.35	2.37	26.10	0.81	8.16	19.26	19.79	16.32	17.52	84.76	88.54	12.59
SC-5	15.91	12.17	2.37	2.21	25.77	0.78	9.41	18.65	19.62	15.61	16.80	83.71	85.63	11.47
SC-6	13.49	9.92	2.45	2.32	25.65	0.85	8.17	19.10	19.65	16.43	17.41	86.14	88.60	12.05
SC-7	14.03	11.98	2.50	2.33	24.98	0.79	8.72	17.94	18.89	15.41	16.73	85.91	88.60	11.61
SC-8	15.18	12.42	2.43	2.34	26.66	0.80	9.53	19.52	20.45	16.68	17.41	85.45	87.13	11.89
SC-9	12.62	10.83	2.24	2.67	24.99	0.89	9.23	20.40	20.58	17.54	17.91	85.93	87.51	12.32
SC-10	13.11	10.02	2.21	2.72	25.39	0.89	9.47	20.69	21.09	17.78	18.45	85.98	87.60	12.69
SC-11	13.64	10.42	2.36	2.42	24.62	0.79	8.10	18.38	19.02	15.43	16.45	83.97	86.63	11.25
SC-12	12.13	9.89	2.25	2.38	25.11	0.78	7.21	19.21	19.76	16.36	17.26	85.23	87.40	11.86
SC-13	13.47	10.64	2.22	2.26	24.81	0.74	7.73	20.41	21.20	17.45	18.92	85.47	89.26	13.15
SC-14	10.37	8.84	2.28	2.33	25.29	0.79	6.47	20.10	20.47	17.14	17.87	85.23	87.47	12.29
SC-15	15.62	13.31	2.14	2.38	25.13	0.75	9.60	18.93	19.66	16.22	17.11	85.69	87.19	11.74
SC-16	13.58	10.75	2.21	2.46	25.04	0.79	8.22	19.67	19.88	16.52	17.22	84.32	86.43	11.79
SC-17	15.36	11.99	2.26	2.32	25.12	0.78	8.94	20.19	20.31	17.25	18.10	85.01	86.81	12.56
SC-18	15.59	11.29	2.02	2.37	24.58	0.70	7.62	19.82	20.38	16.73	17.63	84.40	87.03	11.79
SC-19	15.17	12.16	2.13	2.34	24.59	0.73	8.63	19.03	20.01	16.04	17.14	85.33	87.59	11.67
SC-20	14.93	10.46	2.21	2.52	24.74	0.81	8.18	20.05	20.46	17.09	17.95	85.23	87.88	12.37
SC-21	9.98	8.19	2.16	2.30	24.54	0.73	5.96	19.99	20.25	16.84	17.76	84.17	87.73	12.24
SC-22	11.61	9.92	2.25	2.36	25.15	0.79	7.69	18.60	19.03	16.00	16.87	86.09	89.25	11.72
SC-23	14.25	12.58	2.19	2.43	24.49	0.77	9.34	19.99	20.11	17.13	17.80	86.73	88.54	12.32
SC-24	13.96	11.88	2.38	2.35	26.86	0.80	9.55	18.82	19.49	16.38	17.16	85.54	87.10	11.80
SC-25	11.99	9.43	2.01	2.19	23.15	0.64	6.30	18.53	19.36	16.03	17.14	84.66	88.80	11.86
CoSe 93232 (Check)	11.39	10.14	2.35	2.43	24.62	0.73	6.57	18.58	19.49	15.80	16.97	85.03	87.23	11.65
Mean	13.38	10.66	2.24	2.36	24.91	0.77	7.98	19.37	19.95	16.50	17.45	85.13	87.57	12.02
Range	9.98-15.91	7.98-13.31	2.01-2.50	2.17-2.72	23.15-26.86	0.64-0.89	5.29-9.60	17.94-20.69	19.02-21.20	15.41-17.78	16.45-18.92	83.71-86.73	85.27-89.25	11.25-13.15
SE±	1.308	1.306	0.013	0.082	0.688	0.052	7.616	0.310	0.327	0.083	0.141	0.973	0.959	0.183

Table 2 Coefficients of variation for 11 attributes in 25 soma clones derived from CV 'CoSe 93232' in sugarcane

Characters		GCV	PCV	ECV
No. of tillers/clump		10.89	16.26	2.57
No. of millable canes/clump		9.51	17.17	2.56
Stalk height		4.48	8.16	0.02
Stalk diameter		4.67	6.61	0.01
No. of internodes		2.95	4.49	0.71
Single cane weight (kg)		6.55	10.30	0.004
Yield/clump (kg)		12.96	20.64	1.64
Brix in juice	January	3.84	4.31	0.14
	March	3.02	3.82	0.16
Sucrose % in juice	January	3.94	4.18	0.05
	March	3.16	3.82	0.03
Purity %	January	0.68	1.55	1.42
	March	0.56	1.77	2.18
CCS t/ha		3.45	3.93	0.05

Table 3 Mean heritability and genetic advance for 11 attributes in 25 soma clones derived from CV 'CoSe 93232' in sugarcane.

Characters		Mean	Herita-bility	Genetic advance	G.A. in % over mean
No. of tillers/clump		13.28	70.85	4.33	32.64
No. of millable canes/clump		10.66	54.79	2.67	25.09
Stalk height		2.44	58.82	0.27	12.12
Stalk diameter		2.36	80.12	0.36	15.66
No. of internodes		24.91	69.50	2.19	8.79
Single cane weight (kg)		0.77	63.89	0.14	17.95
Yield/clump (kg)		7.98	66.12	2.99	37.55
Brix in juice	January	19.37	92.18	2.54	13.14
	March	19.95	91.87	2.67	13.28
Sucrose % in juice	January	16.50	96.14	2.28	13.80
	March	17.45	96.87	1.94	11.09
Purity %	January	85.13	40.74	1.31	1.54
	March	87.13	52.08	1.82	2.08
CCS %		87.57	91.05	1.41	11.70

maximum phenotypic coefficient of variation was recorded for cane yield per clump, number of millable cane per clump, number of tillers whereas single cane weight, cane yield per clump, number of tillers and number of millable canes per clump had high genotypic coefficient of variation. These traits were major contributing traits for cane yield. The above findings were similar to those reported by Khan (1990), Rajput (1993), Singh *et al.*, (1995). Kadian *et al.*, (1997), Kundu and Gupta (1997), Tyagi and Singh (1998), Singh *et al.*, (2002).

The present findings revealed that cane yield per clump of 18 somaclones were significantly greater than control. Somaclones 15 exhibited the highest cane yield per clump (9.6 kg/clump). A significant increase in cane yield over control was also shown by Soma. 24, 8, 10, 5, 23 and Soma 9 in the same magnitude i.e. more than 9 kg per clump. The data further indicated that number of tillers, stalk height and number of internodes were the main components of cane yield per clump. As regard quality aspects of cane juice, it was found that more than 75 % clones had sucrose content greater than the check cv 'CoSe 93232' and for commercial cane sugar more than 50% somaclones were better than the check. Somaclone 13, 10, 17 exhibited more than 18% sucrose content as compared to 16.97% sucrose content in check ('CoSe 93232'). Similarly, commercial cane sugar was more than 12.5% in somaclone 13, 10, 4 and 17 in comparison with the check 'CoSe 93232' (11.65%).

The range in variation in the somaclones observed in the present study indicated the potential mechanism for producing genetic variability in sugarcane. . Somaclonal variation has its origin as a natural process in the survival strategy to plants (Walbot 1985, Poething 1989, Edwards *et al.*, 1990). However, *in vitro* culture, especially callus, cell suspension and protoplast cultures, such variation may be accentuated. In asexually propagated crop like sugarcane regeneration after callusing creates variation that could be tapped for cane yield and quality improvement in sugarcane.

High heritability in board sense indicates lesser influence of environment in the gene expression. Sucrose percentage in juice at both the stages, brix in juice at both the stages, commercial cane sugar and stalk diameter showed high estimates of heritability. On the other hand number of tillers indicated moderate degree of heritability and other attributes had low values. These results are in conformity with Nair *et al*. (1984), Singh *et al.* (2002), Gupta and Chatterjee (2002).

High estimates of genetic advance were observed for cane yield per clump followed by number of tillers, number of millable cane per clump, single cane weight, stalk diameter and brix in juice. Other attributes indicated low genetic gain. These findings are in agreement with those of Khan (1990), Hemaprabha (1993), Bakshi Ram *et al.*, (1994), Singh *et al.*, (1994) and Gupta and Chatterjee (2002).

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Sustainable sugarcane production through weed management practices in clay loam soils of Rajasthan

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ABSTRACT

A field experiment was conducted on clay loam soil at Agriculture Research Station, Kota during cropping seasons of 2009-10 to 2011-12 to find out effective binding weeds management technique in sugarcane. All weed management practices caused significant reduction in weed density over weedy check. Amongst various weed control techniques, pooled analysis showed that the minimum weed intensity (36.2 weeds / m^2) was observed in hoeing at 30, 60 and 90 days after planting (DAP) and this treatment also received maximum weed control efficiency (85.15 %) which was closely followed by Atrazine @ 2.0 kg / ha as pre-emergence (PE) + Dicamba @350 g / ha at 75 DAP (81.17 %) and Metribuzine @ 1.25 kg / ha PE + Dicamba @ 350 g / ha at 75 DAP (80.63 %). All weed management treatments did not influence significantly germination and cane girth in sugarcane. However, significantly increased yield attributes, cane yield, sugar yield and economics over weedy check. Number of millable canes and cane yield were recorded highest under Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP (1,14,900 / ha and 79.20 t / ha) closely followed by Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (1,10,800 / ha and 74.20 t / ha) and manual hoeing at 30, 60 and 90 DAP (1,04,800 / ha and 72.0 t / ha) respectively, which was significantly superior over weedy check and at par with rest of treatments. Whereas, CCS recorded significantly higher in treatment of Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (10.2 0 t / ha) over weedy check (8.30 t / ha) and at par with rest of treatments. The net return (Rs 97,004 / ha) and B: C ratio (2.58) were recorded significantly higher under weed management technique of Atrazine @ 2.0 kg a.i. / ha PE + Dicamba @350 g / ha at 75 DAP over rest of the treatments, closely followed manual hoeing at 30, 60 and 90 DAP (Rs 87,530 / ha and 2.55) and Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (Rs 88,561 / ha and 2.48).

Key words: Binding weeds, Commercial cane sugar, Sugarcane yield and Weed control efficiency.

Sugarcane (*Saccharum* spp. hybrid complex) is the second most important industrial crop of India which is cultivated in an area of about 5.04 million hectare with an average productivity of 71.67 tones per hectare (Navnit Kumar 2012). We are also the second largest producer of sugarcane in the world after Brazil. Despite having the largest sugar consumption base in the world, India is self-sufficient with respect to its sugar requirement and has been able to generate exportable surpluses and reducing the foreign exchange outgo. India today tops among the sugar producing countries of the world both in production as well as consumption with the adoption of improved production technologies. Broadly speaking, in Rajasthan, the low sugar recovery as well as cane production is governed by various factors at the farmers' field both crop specific as well as policy based, out of which, inadequate weed control at early crop growth stage (upto 60 days) is the major reason responsible for this and so effective integrated weed management approach has been evolved. To popularize the sugarcane crop, it is imperative to increase the yield potential of it and ultimately also to increase the income of the farmers from this crop. Early experiment with sugarcane confirmed the need to control weeds and enhance efficiency of herbicides treatments for their control. Some herbicides have little effect on crop growth in comparison with effect of competition from weeds. However, herbicides may cause some damage to sugarcane before they are registered the new chemicals are tested on sugarcane. High weed infestations are the key factors to cause great losses in yield of sugarcane. The reduction in sugarcane yield due to weed ranged from 40-67 %, the highest being in those areas where farmers are not adopted to improved weed management technologies (Singh *et al*. 2010). The conventional method of weed control is time consuming, expensive and laborious, but effectiveness of herbicidal weed control in clay loam soils of this region is medium in spring planting sugarcane after its application. It is effective in checking weed growth (WCE 97-100%) and increases cane yield and saves 50 % cost as compared to manual hoeing. Therefore, integrated approach of mechanical and chemical methods of weed control could prove to be more effective, feasible and economically viable. Keeping these facts in view,

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the present investigation was undertaken to find out the effective and suitable integrated weed management approach for spring planted sugarcane in clay loam soils of Rajasthan.

MATERIAL AND METHODS

A field experiment was conducted on clay loam soil at Agriculture Research Station, Kota during cropping seasons (spring) of 2009-10 to 2011-12 to find out effective binding weeds management technique in sugarcane. Ten treatments *viz.* T_1 – weedy check,T_2 – Hoeing at 30, 60 and 90 days after planting (DAP),T_3 – Atrazine @ 2 kg / ha as pre -emergence (PE) followed by post –emergence (Po.E) 2,4-D @ 1 kg / ha at 60 DAP ,T_4 - Atrazine @ 2 kg / ha after 1st irrigation and hoeing followed by 2,4-D @ 1 kg / ha at 75 DAP,T_5 – Metribuzine @ 1.25 kg / ha PE followed by 2,4-D @ 1.0 kg / ha at 75 DAP,T_6 – Atrazine @ 2.0 kg / ha + Almix 20 g / ha at 75 DAP,T_7 – Metribuzine @ 1.25 kg / ha + Almix 20 g / ha at 75 DAP, T_8 – Atrazine @ 2.0 kg / ha + Ethoxysulfuron 50 g / ha at 75 DAP,T_9 – Atrazne @ 2.0 kg / ha + Dicamba 350 g / ha at 75 DAP and T_{10} - Metribuzine @ 1.25 kg / ha + Dicamba 350 g / ha at 75 DAP were tested with three replications in randomized block design. The soil of experimental field was clay loam in texture with a pH of 8.10, high in available nitrogen (367 kg / ha), potassium (282 kg / ha) and medium in available phosphorus (22 kg / ha) and deficient in available zinc (0.55 ppm). The crop was fertilized with 200 kg N, 60 kg P_2O_5 and 40 kg K_2O / ha and followed other zonal package of practice as and when required. The average annual rainfall received during crop season was about 865 mm. Sugarcane variety CoPK-05191 was planted as spring in the second week of March of respectively years. Plot size for each treatment was 6m x 4.5m = 27m^2. The crop treatments wise were harvested manually in second to third week of February of respective years. Data on weed density and dry weight of weeds were transformed using x+0.5 & arc sign, respectively before statistically analysis. WCE, weed density, weed index, yield attributes, cane yield, quality parameter and economics were workout as per standard statistical procedure and using formulae.

RESULTS AND DISSCUSION

Weed Management

Major weed flora

The major weed flora noted in the experimental plots was *Convolvulus arvensis* L, *Cynadon dactylon, Cyperus rotundus* L, *Digera arvensis* L, *Echinochloae crusgalli* L, *Euphorbia hirta* L, *Sorghum helepense, Vicia indica, Ipomoea hispida, Euphorbia indica* L, *Dactylocternium aegyptium* pers, (grasses), *Celensia argentea, Chenapodium album* L, *Amaranthus viridis* L, *Portulaca oleraceae* L, *Phyllanthus ninuri* L, *Commelina bengalensis* L, and *Trianthema portulacastrum* L. The grasses, sedges and broad leaves weeds constituted 32.8, 42.0 and 25.2 per cent of total weed flora respectively. Irrespective of weed management practices, weed density and dry weight of weeds were higher during the three years. The crop experienced severe weed competition during three the years, which might be due to favorable weather conditions leading to vigorous growth of weeds.

Weed density, Weed dry matter and Weed control efficiency

The pooled analysis showed that all weed management practices caused significant reduction in weed density. Amongst various weed control techniques, pooled analysis showed that the minimum weed intensity (36.2 0 weeds / m^2) was observed in hoeing at 30, 60 and 90 DAP and this treatment also received maximum weed control efficiency (85.15) which was closely followed by Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP (81.17) and Metribuzine @ 1.25 kg / ha PE + Dicamba @ 350 g / ha at 75 DAP (80.63). The lowest dry weight of weeds was recorded under hoeing at 30, 60 & 90 DAP (35.65 g / m^2) followed by the application of Atrazine @ 2 kg / ha after 1st irrigation and hoeing followed by 2,4-D @ 1 kg / ha at 75 DAP, which was significantly lower over weedy check and at par with rest of weed control treatments indicated the excellent control of problematic weeds such as *Cynodon dactylon, Chenapodium album, Euphorbia indica, Vicia indica, Dactylocternium aegyptium and Cyperus rotundus* were observed in spring planted sugarcane (Table 1). The effective control of weeds under these treatments resulted in the highest weed-control efficiency. The highest weed index (32.32 %) was recorded in the weedy check. The lowest weed index (6.09 %) was observed in Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP treatment as the minimum weed competition due to better effect of this on weed. Similar results were also reported by Buragohain (1993) and Griffin *et al.* (2011).Application of Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP provided higher weed control efficiency (81.17 %), lower weed dry matter (77.15 g / m^2) and lower weed population (58.46 / m^2) , respectively and lower wed index. Weed index is the reduction in crop yield due to presence of weeds in comparison with 3 manual hoeing, which are ideal parameters to judge the effectiveness of weed control practice. The results are in accordance with the finding of Griffin *et al.* (2011) and Odero and Gilbert (2011)

Crops

Growth & Yield attributes

Weed management practices had non significant effect on germination and cane girth (Table 1). However, the highest germination (44.37%) was recorded under application of Atrazine @ 2 kg / ha PE followed by 2,4-D @1 kg / ha at 60 DAP. All weed management treatments significantly increased number of tillers, millable canes and cane length over weedy check. Numer of tillers population and cane length recorded significantly higher under Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP (1,58,400 / ha and 220 cm) closely

Table 1 Effect of weeds management practices on weed density; weed control efficiency, germination and tillers population in sugarcane (Pooled data of 3 years)

Treatment	Weed density (No / m^2)	Weed dry weight (g / m^2)	Weed control Efficiency (%)	Weed index (%)	Germinatio (%)	Tillers (000 / ha)
T_1 - Control (weedy check)	308.5	242.05	-	32.32	42.37	111.3
T_2 -Hoeing at 30, 60 and 90 DAP	36.2	35.65	85.15	9.09	42.00	152.40
T_3 - Atrazine @ 2 kg / ha PE followed by 2,4 -D @ 1 kg / ha at 60 DAP	79.1	74.46	74.46	6.31	44.37	158.40
T_4 - Atrazine @ 2 kg / ha after 1st irrigation and hoeing followed by 2,4-D @ 1 kg / ha at 75 DAP	54.07	61.90	77.97	17.30	41.97	145.10
T_5 -Metribuzine @ 1.25 kg / ha PE followed by 2,4-D @ 1.0 kg / ha at 75 DAP	159.5	99.83	48.18	17.68	42.90	129.90
T_6 -Atrazine @ 2.0 kg / ha PE +Almix @ 20 g / ha at 75 DAP	132.63	135.73	56.94	14.65	41.67	154.90
T_7 -Metribuzine @ 1.25 kg / ha PE + Almix@ 20 g / ha at 75 DAP	117.76	128.33	61.74	19.70	40.20	149.70
T_8 -Atrazine @ 2.0 kg / ha PE+ Ethoxysulfuron @ 50 g / ha at 75 DAP	116.51	151.13	62.55	17.30	44.06	140.40
T_9 - Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP	58.46	77.15	81.17	00	43.93	158.10
T_{10} -Metribuzine @1.25 kg / ha PE + Dicamba@350 g / ha at 75 DAP	60.01	66.15	80.63	18.94	42.57	139.50
SEm ±	41.79	29..50	-	-	1.37	10.97
CD (P=0.05)	125.37	87.9	-	-	4.08	32.80

DAP: Days after planting; PE: Pre-emergence

Table 2 Effect of weeds management practices on yield attributes, cane yield, CCS and economics of sugarcane (Pooled data of 3 years)

Treatment	NMC (000/ha)	Cane girth (cm)	Cane length (cm)	Cane yield (t / ha)	CCS (t/ha)	Net Return (Rs / ha)	B:C ratio
T_1 - Control (weedy check)	80.1	8.35	190	53.6	8.3	60,590	2.30
T_2 -Hoeing at 30, 60 and 90 DAP	104.8	9.22	225	72.0	9.1	87,530	2.55
T_3 - Atrazine @ 2 kg / ha PE followed by 2,4 -D @ 1 kg / ha at 60 DAP	110.8	9.15	217	74.2	10.2	88,561	2.48
T_4 - Atrazine @ 2 kg / ha after 1st irrigation and hoeing followed by 2,4-D @ 1 kg / ha at 75 DAP	93.7	9.10	215	65.5	9.3	75,726	2.37
T_5 -Metribuzine @ 1.25 kg / ha PE followed by 2,4-D @ 1.0 kg / ha at 75 DAP	99.8	8.35	217	65.2	9.0	76,737	2.43
T_6 -Atrazine @ 2.0 kg / ha PE +Almix @ 20 g / ha at 75 DAP	104.3	8.75	216	67.6	9.5	79,332	2.42
T_7 -Metribuzine @ 1.25 kg / ha PE + Almix@ 20 g / ha at 75 DAP	99.0	8.57	212	63.6	9.4	73,529	2.37
T_8 -Atrazine @ 2.0 kg / ha PE+ Ethoxysulfuron @ 50 g / ha at 75 DAP	96.2	8.27	214	65.5	9.6	77,530	2.45
T_9 - Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP	114.9	9.20	220	79.2	9.4	97,004	2.58
T_{10} -Metribuzine @1.25 kg / ha PE + Dicamba@350 g / ha at 75 DAP	97.2	9.00	215	64.2	9.4	74,450	2.38
SEm ±	8.06	0.60	3.80	3.07	0.40	3,217	0.05
CD (P=0.05)	24.2	1.80	11.32	9.2	1.2	9,536	0.14

DAP: Days after planting; PE: Pre-emergence followed by Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (1,58,100 / ha and 217 cm) and manual hoeing at 30, 60 and 90 DAP (1,52,400 / ha and 225 cm), respectively over weedy check (1,11,300 / ha and 190 cm) and at par with rest of treatments due to complete weed free environment to crop throughout the growing season. Atrazine, being broad-spectrum herbicide when supplemented with Dicamba at 75 DAP suppress the weed growth for a longer period. This improvement in growth and yield parameters of sugarcane might be attributed to the reduction in competitiveness of the weeds with the crop for the available inputs i.e. light, water, nutrients, space etc., which ultimately favored better environment for growth and development of the crop. Number of millable canes were recorded highest under Atrazine @ 2.0 kg / ha PE + Dicamba @ 350 g / ha at 75 DAP (1,14,900 / ha) closely followed by Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (1,10,800 / ha) and manual hoeing at 30, 60 and 90 DAP (1,04,800 / ha) respectively, which was significantly superior over weedy check and at par with rest of treatments (Table 2). This might be due to greater availability of nutrients, increase in biomass and efficient control weeds which reduced the nutrients uptake by weeds. Severe weeds infestation decrease the growth of yield attributes in weedy check. Results are in accordance with the findings of Griffin *et al.* (2011), Odero and Gilbert (2011) and Singh and Kumar (2013) in sugarcane. The superior performance of Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP, Atrazine @ 2 kg / ha PE followed by 2, 4-D @ 1 kg / ha at 60 DAP and manual hoeing at 30, 60 and 90 DAP could be attributed to the reduced weed crop competition in the initial stages and removal of late-emerged weeds by post emergence application of Dicamba and 2, 4-D as well as manual hoeing at 60 DAP. This resulted in more millable and cane weight in these treatments. Bauerle *et al*. (2011) also reported such effects on growth and yield attributes characters of sugarcane.

Yield and Quality

All the weed control treatments increased cane yield and commercial cane sugar (CCS) yield significantly over the unweeded treatments (Table 2).Cane yield (79.2 t / ha) was recorded significantly highest under application of Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP closely followed by Atrazine @ 2 kg / ha PE followed by 2,4D @ 1 kg / ha at 60 DAP(74.2 t / ha) and manual hoeing at 30, 60 and 90 DAP (72.0 t / ha), respectively over weedy check (53.6 t / ha) and at par with rest of treatments. The increase in sugarcane yield by application of Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP, Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP and manual hoeing at 30, 60 and 90 DAP over weedy check was 47.76,38.43 and 34.33 percent, respectively due to the poor weed competition at initial stage of growth which resulted in higher number of tillers & millable canes. CCS recorded significantly higher in treatment of Atrazine @ 2 kg / ha PE followed by 2, 4-D @ 1 kg / ha at 60 DAP (10.2 t / ha) over weedy check (8.3 t/ha) and Metribuzine @ 1.25 kg / ha PE followed by 2,4-D @ 1.0 kg / ha at 75 DAP (9.0 t / ha) and at par with rest of treatments. Similar findings has also been reported earlier by Srivastava (2001), Srivastava and Chauhan (2006), Singh *et al.*(2010) and Bauerle *et al*. (2011) in which all the weed control treatments gave the higher cane yield over control.

Economics

All weed management techniques, significantly influenced the net returns of sugarcane over weedy check (Table 2). The net return (Rs 97,004 / ha) and B: C ratio (2.58) were recorded significantly higher under weed management technique of Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP over rest of the treatments , closely followed manual hoeing at 30, 60 and 90 DAP (Rs 87,530 / ha and 2.55) and Atrazine @ 2 kg / ha PE followed by 2,4-D @ 1 kg / ha at 60 DAP (Rs 88,561 / ha and 2.48) owing to minimized cost of weeding by use of post- emergence herbicides i.e. Dicamba and 2,4-D . This might be due to increased in millable canes and cane girth under congenial weed free environment in the said treatments resulted higher cane yield per unit area ultimately increased profit. Whereas, the lowest B: C ratio (2.30) was recorded under weedy check, which may be because of more infestation weeds in crop resulted in lower cane yield. The highest cost of cultivation (Rs 61,395 / ha) was recorded under Atrazine @ 2.0 kg / ha PE + Dicamba @350 g / ha at 75 DAP, whereas lowest cost of cultivation (Rs 46,608 / ha) was recorded under weedy check. Results are in accordance with the findings of Bauerle *et al*. (2011)

Based on the 3 years study, it may be concluded that application of Atrazine @ 2.0 kg / ha as pre-emergence + Dicamba 350 g / ha at 75 DAP was found better with respect to weed control efficiency, millable canes, cane yield, CCS and economics, which is registered at par with hoeing at 30, 60 & 90 days after planting for satisfactory weed control in spring planting crop of sugarcane in clay loam soil of south east Rajasthan.

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Evaluation of some promising sugarcane varieties under saline stress condition

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ABSTRACT

Ten promising sugarcane varieties viz; 'CoSe 01424', 'CoSe 01434', 'CoSe 03234', 'CoSe 96436', 'CoS 03251', 'CoS 07250', 'CoS 95255', 'CoS 97261' and 'UP 49' were evaluated for their resistance to saline stress condition during spring seasons of 2009-10, 2010-11 and 2011-12. One quintal of artificially maintained saline soil of 8.0 dsm^{-1} EC were taken in the glazed pots and cane setts were planted. Growth parameters such as shoot population and number of millable canes/clump were decreased significantly due to salinity stress. Varieties 'CoSe 01424', 'CoSe 01434' and 'CoS 07250' produced more shoots and NMC under salinity showing their salt endurance nature. These varieties also maintained higher cane yield/clump under saline soil condition along with minimum yield reduction percent (below 12%). Sucrose percent in juice was not affected significantly due to salinity.

Key words: Number of millable canes (NMC), Shoot population, Cane yield.

Sugarcane is one of the important cash crops of tropical as well as sub-tropical India. In modern times salinity poses a serious threat to the sugarcane cultivation in India. Salinity is mostly caused by the accumulation of soluble salts which are generally the chlorides (Cl_2), sulphate (SO_4) and bicarbonates (HCO_3) of calcium and magnesium. These salts may either come either from the parent material during soil genesis or due to irrigation by salty water. Under saline soil condition, sugarcane plants are unable to absorb water and minerals from the soil because of osmotic imbalance. Salinity induces growth reduction by changes in dry matter allocation, water stress, ion exchange process or by a combination of all these factors (Greenway and Munns 1980). Reduction in growth is frequently associated with alteration in gas exchange parameters (Yeo *et al.* 1988; Hazemkalaji and Nalborezyk 1991).

Transpiration rate of photosynthesis are severely affected when salinity is coupled with water stress (Farquhar *et al.* 1982; Tieszen 1991; Akhtar *et al.*2001). Short term effect of salinity on sugarcane growth and physiology were observed by various workers (Liu 1967; Kumar and Naidu 1993; Sharma *et al.* 1997). Similarly, the long term effect of salinity on growth, photosynthesis and osmotic characters have also been studied by Vasantha *et al.*(2010) using eight sugarcane varieties ('Co 85019', 'Co 94012', 'Co 94008', 'Co 86032', 'Co 97010', 'Co 95007', 'Co 97009' and 'Co 95016'). Salt stress and water stress exert physiological, biochemical, molecular and genetical effects on plants (Cushman *et al.* 1990; Tiwari *et al.* 1997; Saxena *et al.* 1990). Keeping this in view, a pot experiment was conducted utilizing ten promising sugarcane varieties namely - 'CoSe 01424', 'CoSe 01434', 'CoSe 03234', 'CoSe 96436', 'CoS 03251', 'CoS 03261', 'CoS 07250', 'CoS 95255', 'CoS 97261' and 'UP 49' under artificially maintained saline soil to access their potentiality towards salt tolerance.

MATERIALS AND METHODS

A pot experiment was conducted with ten promising sugarcane varieties namely; 'CoSe 01424', 'CoSe 01434', 'CoSe 03234', 'CoSe 96436', 'CoS 03251', 'CoS 03261', 'CoS 07250', 'CoS 95255', 'CoS 97261' and 'UP 49', during the spring seasons of 2009-10, 2010-11 and 2011-12 at the research farm of U.P. Council of Sugarcane Research, Shahjahanpur. Sowing of the experiments was done in the first week of March, each year. Six one budded setts were planted in each glazed pot containing 100 kg of soil. Electrical conductivity of 8.0 dsm^{-1} was maintained throughout the crop season by mixing appropriate quantities of sodium chloride, calcium chloride and sodium sulphate in the normal soil. Control pots contained the normal field soil. The experiment was carried out in complete randomized block design with three replications. Recommended agronomical practices were followed throughout the crop growth.

Shoot population was recorded just before the onset of monsoon while the data on the number of millable canes and cane yield were recorded at harvest. Sucrose percent in juice was measured at 10th month of crop age using standard methods of analysis (Meade and Chen 1977). Salinity tolerance capacity of each variety was computed on the basis of its relative cane yield under saline soil condition and the yield reduction percent over the normal soil (control).

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Table 1 Effect of salinity on growth, yield and quality of ten promising varieties of sugarcane (Pooled data of 3 years)

S.N.	Varieties	Shoots/ clump			NMC/Clump			Cane Yield (kg/clump)			Yield reaction (%)	Sucrose (%)		
		N	S	Mean	N	S	Mean	N	S	Mean		N	S	Mean
1	'CoSe 01424'	9.40	7.60	8.50	7.43	5.77	6.80	1.755	1.572	1.664	10.37	16.98	16.88	16.93
2	'CoSe 01434'	8.40	7.00	7.70	6.97	5.43	6.20	1.583	1.400	1.491	11.56	16.77	16.63	16.70
3	'CoSe 03234'	8.83	6.50	7.66	5.53	4.63	5.08	1.312	1.069	1.190	18.52	17.51	17.33	17.42
4	'CoS 03251'	8.30	6.43	7.36	6.97	4.53	5.75	1.453	1.227	1.340	15.55	16.76	16.61	16.68
5	'CoS 03261'	7.83	6.40	7.11	5.63	4.43	5.03	1.501	1.228	1.364	18.19	16.72	16.60	16.66
6	'CoS 07250'	9.40	7.53	8.46	8.43	4.73	6.58	1.741	1.533	1.637	11.95	16.83	16.69	16.76
7	'CoS 95255'	9.63	7.83	8.73	5.77	4.17	4.97	1.702	1.367	1.534	19.68	17.93	17.67	17.80
8	'CoSe 96436'	7.63	6.17	6.90	6.10	4.53	5.31	1.543	1.333	1.438	13.61	16.72	16.57	16.64
9	'CoS 97261'	10.20	8.07	9.13	5.97	4.63	5.30	1.571	1.309	1.440	16.67	16.83	16.62	16.71
10	'UP 49'	7.30	6.20	6.75	5.23	3.97	4.60	1.504	1.214	1.359	19.28	16.82	16.59	16.70
	Mean	8.69	6.97		6.40	4.68		1.584	1.345			16.99	16.82	
	SE/CD for T	0.668/1.445			0.495/1.040			0.227/0.477				0.242/NS		
	SE/CD for V	0.217/NS			0.156/NS			0.472/NS				0.076/NS		
	SE/CD for T x V	0.972/NS			0.700/NS			0.321/NS				0.342/NS		

N - Normal soil S - Saline soil

RESULTS AND DISCUSSION

Shoot/clump

The data presented in Table 1 revealed that shoot/clump was affected significantly due to salinity. Under normal soil (0.6 dsm^{-1} EC), variety CoS 97261 gave highest number of tillers/clump followed by 'CoS 95255', 'CoSe 01424' and vCoS 07250'. However, under saline soil of 8 $dsm^{-1 EC}$, varieties 'CoS 97261', 'CoS 95255', 'CoSe 01424' and 'CoS 07250' produced more shoots than rest of the varieties, the minimum being in varieties 'CoS 96436' and 'UP 49'. Interaction between treatment (T) x variety (V) for shoots/clump was found non-significant.

Number of millable canes/ clump

Number of millable canes (NMC) was significantly higher in normal soil than in saline soil in all the varieties tested. The results showed that varieties 'CoS 07250', 'CoSe 01424', 'CoSe 01434' maintained higher NMC as compared to other genotypes tested indicating their endurance capacity for salinity. Interaction between T x V was not found significant.

Cane Yield

Cane yield/clump was reduced significantly due to salinity. Under saline soil condition, variety 'CoSe 01424' expressed the highest cane yield (1.573 kg/clump), followed by 'CoS 07250' (1.533 kg/clump) and 'CoSe 01434' 1.400 kg/clump). These varieties showed minimum yield reduction percent (below 12%) indicating higher tolerance against salinity than other varieties tested. Vanantha *et al.* (2010) have shown that certain growth characters such as transpiration rate, rate of photosynthesis, leaf water potential and dry matter accumulation depressed due to salinity and varied with the variety.

Sucrose percent

Sucrose % in juice at 10^{th} month crop age was found almost similar in saline and normal soils. However, higher sucrose % in juice was recorded in varieties 'CoS 95255' and 'CoSe 03234', while it was minimum in varieties 'CoSe 96436' and 'UP 49', indicating that the quality trait was not affected significantly due to salinity.

On the basis of above observations, it may be concluded that varieties 'CoSe 01424', vCoSe 01434' and 'CoS 07250' are suitable for cultivation under saline soil condition.

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Physio- agronomic analysis of sugarcane (*Saccharum* spp. hybrid complex) varieties under different planting geometry

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ABSTRACT

A field experiment was conducted during the spring season of 2012 – 13 at Pusa (Bihar), to study the effect of plating geometry and varieties on physio – agronomic characteristics of sugarcane (*Saccharum* spp. hybrid complex). The rate of increase of dry matter, AGR and RGR was very rapid rate in between 150 – 180 DAP, which gradually decreased with advancement of crop age. The maximum dry matter of individual plant was accumulated at 150 cm row spacing followed in order by 120 cm row spacing. The effect of planting geometry with respect to brix, pol and purity percentage were found to be non significant. However, comparatively higher values was observed under 90 cm row spacing at 270 and 300 DAP. The maximum sugar yield (11.18 t/ha) was observed at 90 cm row spacing which was 2.6, 27.3 and 54.4% higher than 30: 120, 120 and 150 cm row spacing, respectively. Among varieties, the significantly highest dry matter accumulation was recorded with 'BO 139' followed in order by 'CoP 9301' at all the stages of growth. Varietal differences in respect to brix, pol, purity, juice recovery and CCS percent and TC: TS ratio was found to be significant and a higher value was obtained due to the variety 'CoP 9301'. Though significantly higher sugar yield (10.68 t/ ha) was registered by BO 153.

Key words: Dry matter accumulation, Juice quality, Planting geometry, Sugarcane varieties

Sugarcane (*Saccharum* spp. hybrid complex) is an important commercially grown sugar crop of tropical and sub tropical region of India, having wide range of industrial uses and is cultivated on about 5.0 m ha with the annual production of 341.2 mt along with the productivity of 68.2 t/ha (ISMA 2014). Higher productivity of sugarcane mainly depends on biomass productivity. Biomass potential of a variety is achieved when growth and development phase match with the management practices and congenial environmental conditions. Plants accumulated on an average 1.27, 34.5 and 97.8% dry matter at 70, 150 and 230 days after planting, respectively, although rate of dry matter production was the highest between 70 - 150 DAP, the maximum amount of dry matter accumulation was observed between 150 – 230 DAP (Kumar *et al*. 2010). Among the various agronomic management practices planting geometry play a significant role for improving biomass and sugar productivity of sugarcane varieties by enhancing the availability of optimum solar radiation to the ground surface. Wider row spacing provides greater scope for overall growth and development of individual plant. The availability of more space and sunlight for a longer period under wider row spacing significantly increases the biomass production and provide considerable scope for mechanization of field operation from planting to harvesting. Juice quality is the resultant of accumulation of photosynthetic sucrose. The best quality sugarcane variety would be the one which has higher brix, pol, purity and juice recovery percentage, soft, lower starch and molassegenic substances, low colouring matter and low colloidal substances in juice. Thus, it is important to select sugarcane varieties along with its specific geometry for optimum productivity. Keeping this in view, present experiment was carried out to select suitable varieties along with its planting geometry for higher productivity, juice quality and sugar recovery of sugarcane.

MATERIALS AND METHODS

The field experiment was conducted during the spring season of 2012 – 13 at Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar. The experimental soil had 225, 11.9 and 120 kg/ha, available N, P and K, respectively, with pH 8.3. Treatments comprising 4 planting geometry (120, 150, 30: 120 and 90 cm row to row distance) and 4 varieties ('BO 139', 'BO 153', 'CoP 9301' and 'CoLk 94184') were replicated thrice in split plot design. Planting geometry was kept in main plot and varieties in sub plot. The recommended fertilizer dose was 150 kg N, 37.1 kg P and 49.8 kg K/ha. Half of total N and full dose of P and K were applied as basal and remaining N in 2 splits, after first irrigation and earthing up. Other inputs and operation were practised as per recommendation. Crop was planted in last week of February and harvested in the following year in the last week of January. The planting was done in furrow at a different row distance

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using same seed rate of three budded setts. The total rainfall of 851.4 mm was received during the crop period. For taking record on dry matter accumulation, two plants were removed from each plot at every stage and fresh weight was recorded. The samples were cut into fine pieces from each plot and 100g homogenous material from each sample were kept in paper bags. The samples were first sun dried and then oven dried at 70^0 C to get constant weight per plant per treatment. Absolute growth rate (AGR) in terms of dry matter was calculated using the formula $AGR = W_2 – W_1 / t_2 – t_1$, where, W_1 and W_2 are the dry weights (g) of the plant at times t_1 and t_2 in days, respectively. The relative growth rate (RGR) is expressed in g/g/day and mathematically expressed by using standard formula $RGR = lnW_2 – lnW_1/ t_2 – t_1$, where lnW_1 and lnW_2 indicates the natural logarithm of dry weights (g) of the plant at times t_1 and t_2 respectively. Whole cane samples were taken at 270 and 300 days after planting and cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1964). Sugar yield was calculated as; sugar yield (t/ha) = [S – 0.4 (B - S) x 0.73] x cane yield (t/ha)/100; where, S and B are sucrose and brix per cent in cane juice respectively.TC: TS ratio is the ratio of tonnes of cane required to produce one tonne of sugar. This is a measure of quality which was determined by dividing cane yield (t/ha) by estimated commercial cane sugar (t/ha).

RESULTS AND DISCUSSION

Dry matter accumulation

From the perusal of Table 1 it was evident that on an average plants accumulated 13.1, 20.2, 44.1, 66.9, 81.4, 90.7 and 96.1 per cent of the total dry matter produced upto 120, 150, 180, 210, 240, 270 and 300 DAP, respectively. In general, the dry matter per cane increased with advancement in cane age. The dry matter accumulation in the sugarcane took place with faster rate upto 210 DAP thereafter, the rate of accumulation reduced drastically upto harvest (330 DAP). Significant variation on dry matter was observed at 120, 150 and 180 DAP only. Though, comparatively higher values at all the stages were observed at 150 cm row spacing. Among the row spacing adopted, higher amount of dry matter production per plant was observed at 150 cm row spacing. This might be due to availability of more space per plant at wider row spacing create less competition for other growth factors like moisture, nutrients and sun light as the plant population at wider row spacing was less than the 90 cm row spacing. This results support the findings of Kannan *et al.* (2007).

Significant variation in dry matter accumulation was observed among the varieties in all the stages of observations (Table 1). The variety ‘BO 139’ had registered the highest dry matter accumulation per plant at all the stages of growth which was followed by ‘CoP 9301’. This was mainly due to significantly higher cane thickness of the variety ‘BO 139’ leads to higher dry matter accumulation under this variety at all the stages of growth as well as at harvest.

Absolute growth rate

The data on absolute growth rate (AGR) has been recorded in between 120 – 150, 150 – 180, 180 – 210, 210 – 240, 240 – 270, 270 – 300 and 300 – 330 DAP (Fig 1). AGR increased till 150 – 180 DAP and declined thereafter following an exponential relationship with time. Since AGR is a function of dry matter accumulation by the plant; it followed the similar trend because the rate of dry matter partitioning was lesser at the advance stage of crop. AGR of sugarcane increased with 236 per cent in between 150 – 180 DAP and reduced later in between 180 and 330 DAP. Planting geometry had significant influence on AGR in between 120 – 150 DAP only. Planting

Table 1 Influence of planting geometry and variety on dry matter accumulation in spring sugarcane

Treatment	Dry matter accumulation (g/plant)							
	120 DAP*	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP	300 DAP	330 DAP
Planting geometry								
120 cm	40.6	56.3	131.5	202.1	248.2	276.8	293.6	305.9
150 cm	52.4	93.7	169.1	238.9	285.3	314.5	331.9	344.7
30:120 cm	34.6	49.4	119.9	190.2	231.9	259.9	276.1	287.5
90 cm	34.2	50.2	123.0	193.4	238.9	267.1	283.4	295.4
SEm (±)	2.76	4.38	9.27	13.99	17.50	20.13	21.30	22.16
CD (P=0.05)	9.6	15.2	32.1	NS	NS	NS	NS	NS
Variety								
BO 139	74.5	104.8	185.2	257.4	303.8	333.6	351.0	363.6
BO 153	30.2	48.3	117.2	182.6	229.2	258.1	275.2	288.1
CoP 9301	31.6	51.4	123.5	195.1	240.3	268.1	284.5	298.1
CoLk 94184	25.4	45.1	117.6	189.5	231.0	258.5	274.3	283.7
SEm (±)	1.29	1.75	3.36	5.04	7.10	7.32	7.74	8.05
CD (P=0.05)	3.8	5.2	9.8	14.7	20.7	21.4	22.6	23.5

*Days after planting

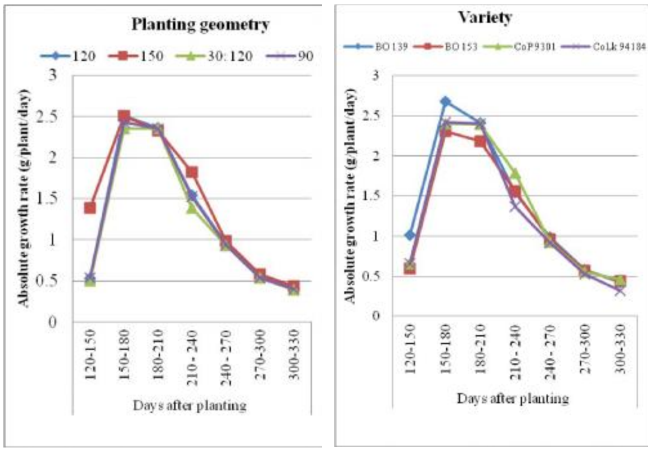

Fig 1 Effect of planting geometry and variety on absolute growth rate in spring sugarcane

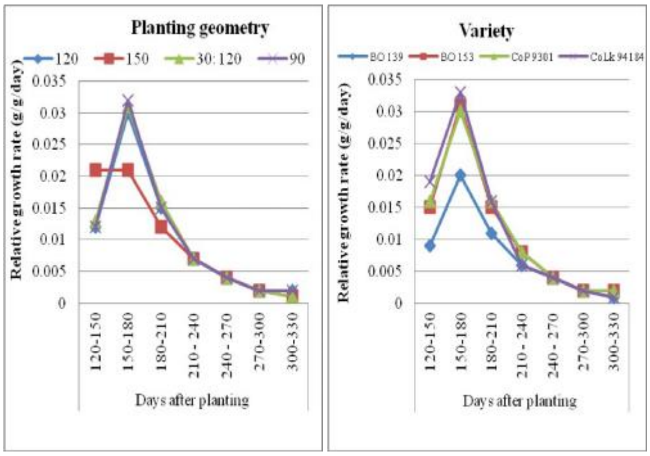

Fig 2 Effect of planting geometry and variety on relative growth rate in spring sugarcane

of sugarcane at row distance of 150 cm resulted in significantly higher AGR of 1.38 g/plant/day followed in order by 90 cm (0.53 g/plant/day).

Significant variation in AGR was observed among the varieties in between 120 – 150, 150 – 180 and 300 – 330 DAP. In between 120 – 150 DAP and 150 – 180 DAP, 'BO 139' showed highest AGR of 1.01 g/plant/day and 2.68 g/plant/day, respectively, which was significantly superior to rest of the varieties. However, values of AGR in between 300 – 330 DAP was maximum under the variety 'CoP 9301' (0.46 g/plant/day) which was significantly superior to 'CoLk 94184' (0.32 g/plant/day) and statistically similar to rest of the varieties.

Relative growth rate

Planting geometry resulted in a significant increase the relative growth rate in between 120 – 150 and 150 – 180 DAP only. The results shown in Fig 2 revealed that the rate of RGR was much higher in between 150 – 180 DAP and declined thereafter sharply with time. RGR of sugarcane reduced to just half in between 180 – 210 DAP as compared to 150 –180 DAP. Similar trend was observed in later stages. Sugarcane variety 'CoLk 94184' recorded highest RGR in between 120 – 150, 150 – 180 and 180 – 210 DAP and there was no definite trend was observed after 210 DAP (Fig 2). No definite trend in RGR values was recorded because of the reason that there was very low rate of increase in dry matter beyond a certain limit.

Quality parameter

The quality traits of sugarcane, viz., brix, pol, purity (Table 2), CCS per cent, juice recovery and TC: TS ratio (Table 3) did not undergo significant changes due to different spacing. The difference in quality indices between 270 and 300 days after planting was obviously due to advancement of the crop age and decline in environmental temperature. The average brix percentage at 270 and 300 DAP was obtained as 19.11 and 19.46% respectively whereas in case of pol the respective

Table 2 Effect of planting geometry and variety on brix, pol and purity percentage juice in spring sugarcane

Treatment	Brix (%)		Pol (%)		Purity (%)	
	270 DAP	300 DAP	270 DAP	300 DAP	270 DAP	300 DAP
Planting geometry						
120 cm	19.04	19.36	16.87	17.18	88.57	88.73
150 cm	19.01	19.21	16.71	17.03	87.86	88.65
30:120 cm	19.16	19.56	16.98	17.40	88.56	88.95
90 cm	19.24	19.71	17.06	17.59	88.63	89.24
SEm (±)	0.237	0.225	0.211	0.203	0.673	0.870
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Variety						
BO 139	18.93	19.07	16.61	16.82	87.71	88.20
BO 153	18.98	19.23	16.82	17.11	88.58	88.97
CoP 9301	19.47	19.92	17.28	17.81	88.72	89.41
CoLk 94184	19.07	19.62	16.91	17.46	88.64	88.99
SEm (±)	0.093	0.126	0.091	0.098	0.252	0.294
CD (P=0.05)	0.27	0 .37	0.27	0.29	0.74	NS

Table 3 Effect of planting geometry and variety on CCS per cent, juice recovery, TC: TS ratio and sugar yield of spring sugarcane

Treatment	CCS (%)		Juice recovery (%) at 300 DAP	TC : TS ratio	Sugar yield (t/ha)
	270 DAP	300 DAP			
Planting geometry					
120 cm	11.67	11.89	59.2	8.41	8.78
150 cm	11.52	11.78	56.6	8.49	7.24
30:120 cm	11.75	12.06	63.9	8.26	10.90
90 cm	11.81	12.21	61.0	8.19	11.18
SEm (±)	0.111	0.166	2.17	0.115	0.628
CD (P=0.05)	NS	NS	NS	NS	2.17
Variety					
BO 139	11.44	11.61	58.6	8.61	9.49
BO 153	11.64	11.86	60.6	8.43	10.68
CoP 9301	11.98	12.36	63.1	8.09	8.49
CoLk 94184	11.71	12.11	58.4	8.22	9.44
SEm (±)	0.067	0.074	0.99	0.054	0.255
CD (P=0.05)	0.19	0.22	2.9	0.16	0.74

values were 16.91 and 17.30% which resulted into 88.41 and 88.89% purity coefficient and 11.69 and 11.99% CCS in the respective stages. Though the above values were comparatively higher at 90 cm row spacing followed by 30:120 cm (paired rows) spacing and the minimum value was at 150 cm row spacing irrespective of the period of investigation, this might be due to more proportion of mature stalks and retarded vegetative growth during the month of December under 90 cm row spacing and sugar formed in cane leaves due to process of photosynthesis was diverted mainly as sucrose in the stalk due to tough competition for moisture, nutrients and sunlight at close spacing leading to higher values of quality parameters at appropriate stages. However, reverse was the trend in case of wider spacing where plant attend its maturity in quite later duration due to abundance of nutrients, moisture and light in absence of optimum plant population leading to succulent nature of plant under the treatment which was evident from the comparatively lower cane : top ratio at 150 cm row spacing. This finding confirms the findings of TejPratap *et al.* (2006) and Rana *et al.* (2006) who observe non-significant differences in juice quality in terms of sucrose per cent juice and CCS per cent under different planting geometry.

Like brix, pol, purity and CCS percentage, the effect of planting geometry on juice recovery per cent at 300 DAP and TC: TS ratio was also non-significant. Though, the mean juice recovery and TC: TS ratio was obtained as 60.2% and 8.34, respectively.

Analysis of variance indicated that varieties differ significantly among themselves for all the quality parameters (Table 2 &3) irrespective of the stages of observation, except as in case of purity it was only significant at 270 days after planting. At 270 DAP, significantly higher value of brix (19.47%) and pol (17.28%) were recorded due to the variety CoP 9301 and minimum (18.93%) and (16.61%) brix and pol percentage respectively, with 'BO 139'. However, at 300 DAP it followed almost same trend as 270 DAP. Quality traits of varieties are the outcome of genetic, environmental and agronomic interferences. Since all the genotypes were grown under similar agronomic condition, the observed variation in quality

parameters of varieties could be attributed to their biochemical activities and external environmental factors to which these were exposed during the course of maturation. Kamat and Pandey (2004) also reported higher sucrose in juice under 'CoP 9301' at 300 days after planting.

Commercial cane sugar per cent was also significantly affected among the varieties (Table 3). 'CoP 9301' recorded maximum CCS per cent and there were 11.98 and 12.36% during 270 and 300 days after planting, respectively. However, minimum CCS per cent was recorded with the variety 'BO 139' (11.44 and 11.61%) during both the stages of observation. This might be substantiated by the fact that CCS per cent was totally related to brix and pol per cent were improved by varieties; significant variation in CCS per cent was obvious. The similar observations have been made by More *et al.* (2009). Similarly, juice recovery at 300 DAP was also maximum with the variety 'CoP 9301' (63.1%) which was significantly more than that observed under 'BO 139' (58.6%) and 'CoLk 94184' (58.4%). The TC: TS ratio which indicates the tonnes of cane required to produce one tonne of sugar was also found to be significantly affected among the varieties and significantly higher TC: TS ratio was observed under the variety 'BO 139' (8.61) which was followed in order by 'BO 153' (8.43).

Sugar yield

Sugar yield is one of the most important considerations for sugarcane growers as well as sugar factory owners. The commercial cane sugar yield (sugar yield) which is considered as recoverable sugar is directly affected by cane yield and

CCS per cent in juice, which in turn, are governed by its brix and sucrose content. Sucrose content in juice was affected by brix and content of reducing sugar. Higher the sucrose, higher will be the available sugar. Moreover, higher amount of reducing sugar leads to reduction in available sugar which ultimately lowers down the amount of commercial cane sugar. In this study the sugar yield was calculated on the basis of CCS per cent obtained at 300 DAP and cane yield.

Row spacing had significant effect on sugar yield (Table 3). Sugarcane planted at 90 cm row spacing yielded 54.4, 27.3 and 2.6% higher than that of planted at 150, 120 and 30:120 cm row spacing, respectively. Since the CCS per cent was not affected by planting geometry, the significant effect on it was solely due to cane yield on which the effect of planting geometry was significant. Singh *et al.* (2006) obtained higher tonnage of sugar at closer spacing. Whereas Patel *et al.* (2006) obtained higher sugar yield under paired row planting.

Sugar yield also varied significantly with different varieties (Table 3). The variety 'BO 153' exhibited significantly higher sugar yield (10.68 t/ha) and it was registered 25.8, 13.1 and 12.5% more sugar yield than 'CoP 9301', 'CoLk 94184' and 'BO 139'. This was because of the fact that sugar yield is a function of cane yield and CCS per cent, thus the increase in all the related quality traits and cane yield brought significant variation in sugar yield. Several workers (Kumar *et al.* 2012, Shukla 2007 and Singh *et al.* 2006) also reported similar results.

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Soil macro-and micro nutrient status in sugarcane growing soils of Haridwar district, Uttarakhand (India)

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ABSTRACT

A study of sugarcane growing soils of Haridwar district, Uttarakhand (India) was carried out to determine macro and micro-nutrient status and working out nutrients availability index. Samples from surface (0-15 cm) & sub-surface (15-30 cm) soil strata randomly collected from three representing sugar mill command areas viz. Laxmi Sugar Cooperative Ltd., Uttam Sugar Mills Ltd. and Rai Bahadur Narain Singh Sugar were analysed for physico-chemical properties. The mean value of soil pH, EC and organic carbon content were7.2, 0.21 dSm^{-1} and 0.56 %, respectively across the district. The soils were classified as low for available nitrogen and medium for available phosphorus and potash on the basis of nutrient index values. The mean value of DTPA extractable Zn, Cu, Fe and Mn were 1.15, 1.05, 32.57 and 18.47 mg kg^{-1}, respectively. Results indicated that organic carbon had significant and positive correlation with available N (r=0.988) and P (r=0.479). DTPA- extractable Zn had significant and positive correlation with available P (r=0.367), Cu with available K (r=0.289), Fe with available P (r=0.0.255), K (r=0.274) & Zn (0.463) and Mn with Zn (0.387) & Fe (r=0.523).

Keywords: Available nutrients, macro and micro nutrients, nutrient index and organic carbon.

Sugarcane cultivation in India with efficient management of inputs and resources proves to be a vehicle of rural prosperity and ensures livelihood for millions. The crop is widely cultivated both under tropical and sub-tropical regions of the country. The sub-tropical states namely Uttar Pradesh, Punjab, Haryana, Uttarakhand and Bihar register lower yields (60-70 t/ha) as compared to that obtained in tropical states (90-110 t/ha). Soil health and nutrient management along with climatic factors play major role for sugarcane yield as the crop remains in the field for 12-18 months and an average crop of sugarcane removes 208, 53, 280, 30, 3.4, 1.2, 0.6 and 0.2 kg N, P, K, S, Fe, Mn, Zn, and Cu, respectively from the soil to yield about 100 tonnes of cane per hectare (Singh and Yadav 1996). In subtropical region, sugarcane is regularly cultivated with input intensive and exhaustive crop rotation of rice -wheat which often aggravates imbalanced mining of nutrients leading to deterioration in soil fertility and productivity. Under such a scenario, determination of soil health parameters is necessary for nutrient management of crops. Since, Uttarakhand, an important sugarcane growing state of sub-tropical region of India, envisage 1.1 lakh hectare area under the crop with 61.1 t/ha productivity and Haridwar district is one of the important sugarcane growing district of the state, analysis of soil samples from various sugar mill command areas was done to assess the soil fertility status that would facilitate balanced scheduling as well as management of fertilizer nutrients to promote sugarcane productivity and production in the state in particular and in sub-tropical states in general.

MATERIALS AND METHODS

The present investigation was carried out to assess macro and micro- nutrient status in sugarcane growing soils of Haridwar, Uttarakhand (India). Soil samples from surface (0-15 cm) and sub-surface (15-30 cm) layers were collected from three representative sugar mill command areas viz. Laxmi Sugar Cooperative Ltd, Uttam Sugar Mills Ltd. and Rai Bahadur Narain Singh (RBNS) Sugars. Total sixty soil samples were collected, considering ten surfaces and ten sub-surface soil samples from each sugar mill command area. All the soil samples were air dried, grounded and passed through 2 mm sieve for chemical analysis. Soil pH and electrical conductivity (EC) were determined by pH and conductivity meter using 1:2.5 soil water suspensions (Jackson 1973). The representative soil samples were analysed for organic carbon (Walkley and Black 1934), available nitrogen (Subbiah and Asija 1956), available P (Neutral and alkaline soil pH (by Olsen *et al.* 1954) and acidic soil pH (by Bray and Kurtz 1945) available K (Jackson 1973) and DTPA extractable Fe, Mn, Zn & Cu (Lindsay and Narvell 1978) were determined on an Atomic Absorption Spectrophotometer. Nutrient Index (NI) for N, P & K was worked out following the procedure described by Motsara *et.* al., (1982) and NI values were categorized as under:

Range of NI	Fertility status
<1.67	Low
1.67-2.33	Medium
>2.33	High

RESULTS AND DISCUSSION

Soil properties of surface soil

Values for surface soil pH, EC, organic carbon (%) content varied from 6.1 to 7.9, 0.09 to 0.72 dSm^{-1} and 0.27-0.81 %, respectively with compounding mean of 7.9, 0.21 dS/m and 0.56 %. The soils were slightly acidic to moderately alkaline in reaction. The majority of soils had normal electrical conductivity. The low EC may be ascribed to leaching of salts to lower horizons because most of the sugarcane growing soils of the district are light in texture and well percolated. Of the total soil samples analysed 26.7, 63.3 and 10% were low, medium and high in organic carbon content, respectively. Prevalence of medium and low status of organic carbon content in the sugarcane growing soils of Haridwar district may be due to mono culture of sugarcane and exhaustive cropping systems followed in the region on the other hand, higher content of organic carbon in certain areas may be attributed to the difference in soil properties, crop management practices and recycling of farm biomass.

Availability of major nutrients viz. nitrogen (N), phosphorus (P) and potash (K) varied widely from 207.0-297.9, 7.72-30.08 and 74.04-202.94 kg/ha with mean value of 258.6, 14.45 and 119.83 kg/ha, respectively (Table1). Available nitrogen in 80% of the studied area was found low and remaining 20% area fell in medium category. Low status of nitrogen in soil may be due to the fact that N is lost through various mechanisms like NH_3 volatilization, nitrification, succeeding de-nitrification, leaching, runoff (De Datta and Buresh 1989) and high nitrogen requirement of the sugarcane crop. The available P was categorised low, medium and high for 16.7, 70.0 and 13.3 % of the collected soil samples, respectively. Moderate availability of P in most of the soils may be attributed to adequate application of phosphatic fertilizers to the sugarcane and other crops of the cropping system in the district resulting in build up of P in these soils. The sugarcane growing soils of the district were classified as low and medium for 33.3 and 66.7 % samples for available K. Most of the soils were moderate in availability of K. Medium to low availability of K may be attributed to medium and poor prevalence of potassium rich minerals in these soils. Bhanu and Sindhu (1991) also observed that the soils of Punjab are medium to high in available K.

DTPA-extractable Zn, Fe Cu and Mn contents in these sugarcane growing soils varied widely from 0.48-3.76, 11.52-55.44, 0.40-2.16 and 9.60-47.66 mg/kg with mean value of 1.15, 18.47, 1.05 and 18.47 mg/kg, respectively (Table1). The highest (1.50 mg/kg) soil zinc was recorded at Uttam sugar mill command area followed by 1.03 and 0.88 mg/kg at Laxmi sugar and RBNS sugar mill command area. Similar trend of Fe was also observed in different sugar mill command areas of Haridwar district. RBNS sugar mill command area recorded highest 1.54 mg/kg Cu followed by 1.10 and 0.52 mg/kg at Uttam sugar and and Laxmi sugar mill command area.

Table 1 Range and mean value of various soil characteristics in surface soil (0-15 cm) under different sugar mill command areas of Haridwar district of Uttarakhand

Soil characteristics	Name of sugar mill			Haridwar district
	Laxmi Sugar	Uttam Sugar	RBN Sugar	
pH	6.7-7.6	6.1-7.3	7.0-7.9	6.1-7.9
Mean	*7.3*	*6.7*	*7.5*	*7.2*
EC (ds/m)	0.12-0.32	0.09-0.22	0.17-0.72	0.09-0.72
Mean	*0.20*	*0.14*	*0.27*	*0.21*
Organic carbon (%)	0.33-0.73	0.27-0.84	0.48-0.81	0.27-0.84
Mean	*0.55*	*0.51*	*0.62*	*0.56*
Available N (kg/ha)	216.3-288.5	207.0-304.2	241.5-297.9	207.0-304.2
Mean	*254.4*	*251.5*	*267.5*	*257.8*
Available P (kg/ha)	7.72-30.08	9.68-28.38	8.68-23.94	7.72-30.08
Mean	*14.87*	*15.09*	*13.39*	*14.45*
Available K (kg/ha)	74.04-98.60	110.64-162.18	125.08-202.94	74.04-202.94
Mean	*84.33*	*135.54*	*139.61*	*119.83*
Zn (mg/kg)	0.60-1.84	0.60-3.76	0.48-2.04	0.48-3.76
Mean	*1.03*	*1.50*	*0.88*	*1.15*
Cu (mg/kg)	0.52-1.16	0.40-2.0	1.04-2.16	0.40-2.16
Mean	*0.52*	*1.10*	*1.54*	*1.05*
Fe (mg/kg)	13.52-44.94	15.76-55.44	11.52-41.82	11.52-55.44
Mean	*29.37*	*40.38*	*27.97*	*32.57*
Mn (mg/kg)	10.64-17.48	10.84-47.66	9.60-20.74	9.60-47.66
Mean	*13.81*	*24.99*	*16.61*	*18.47*

Likewise, Mn trend was also found in different sugar mill command areas. Considering the critical limit 0.6 mg/kg for available zinc, 10 % analysed soil samples were found to be deficient. Poor status of zinc in soils may be attributed to low organic carbon content and high soil pH. Zinc is one of the most important component of recommended package in most of these soils. Considering 4.5, 0.2 and 2.5 mg kg^{-1} critical limits of Fe, Cu and Mn, none of the surface soil samples were found below the critical limits.

Soil properties of sub-surface soil

Sub-surface soil pH, EC and organic carbon varied from 6.2-8.0, 0.07-0.48 and 0.13-0.66 with an average value of 7.3, 0.15 dSm^{-1} and 0.33%, respectively (Table2). In general, soil pH in sub-surface soil recorded high as compared to surface soil whereas, EC and organic carbon values were found lower in sub-surface soil (Table1 &2). Available N, P and K varied from 166.2-269.7, 6.67-16.70 and 66.65-154.46 kg ha^{-1}, respectively. Likewise, DTPA extractable Zn, Fe, Cu and Mn varied from 0.36-2.52, 9.04-42.84, 0.32-1.84 and 9.20-32.84 mg kg^{-1} with an average value of 0.75, 25.80, 0.92 and 15.28 mg kg^{-1}. Available N, P, K and DTPA extractable Zn, Fe, Cu and Mn values were found lower as compared to that in surface soil layers.

Relationship between soil properties and available nutrients

Study showed that soil pH had positive and significant correlation with electrical conductivity(r=0.284*) whereas, it had significantly negative correlation with available phosphorus (r=0.265*) (Table 3). Electrical conductivity had significant positive correlation with organic carbon (r=0.370**), available N (r=0.355**) and zinc (r=0.282*). Organic carbon had significant positive correlation with available N (r=0.988**) and available P (r=0.479**) which indicates the importance of organic matter in promoting the availability of these nutrients in the soils. Similar kind of relationship between available nitrogen and available phosphorus with organic carbon were also reported by Verma *et al.* (2014) in sugarcane growing soils of Haryana. Significant and positive correlation was found between available N and available P (r=0.4935). The available P had significant positive correlation with Zinc (r=0.36**) and Fe (r=0.255*). Available K had positive correlations with Copper (r=0.289*) and Iron (r=0.274*). The DTPA extractable zinc was significantly correlated with iron (r=0.463**) and manganese (r=0.287*). Similarly Iron was found significantly correlated with manganese (r=0.523**).

Table 2 Range and mean value of various soil characteristics in sub- surface soil (15-30 cm) under different sugar mill command areas of Haridwar district of Uttarakhand

Soil characteristics	Name of sugar mill			Haridwar district
	Laxmi Sugar	Uttam Sugar	RBN Sugar	
pH	7.0-7.7	6.2-7.3	7.1-8.0	6.2-8.0
Mean	*7.5*	*6.8*	*7.5*	*7.3*
EC (ds/m)	0.07-0.13	0.09-0.19	0.12-0.48	0.07-0.48
Mean	*0.11*	*0.12*	*0.21*	*0.15*
Organic carbon (%)	0.13-0.45	0.15-0.66	0.26-0.52	0.13-0.66
Mean	*0.30*	*0.32*	*0.36*	*0.33*
Available N (kg/ha)	169.3-228.9	166.2-269.7	194.4-244.6	166.2-269.7
Mean	*201.5*	*204.5*	*212.9*	*206.3*
Available P (kg/ha)	6.67-12.69	6.67-16.39	6.67-16.70	6.67-16.70
Mean	*8.46*	*9.50*	*9.07*	*9.01*
Available K (kg/ha)	66.65-87.23	96.61-140.27	93.13-154.46	66.65-154.46
Mean	*72.79*	*119.52*	*120.43*	*104.25*
Zn (mg/kg)	0.48-1.24	0.44-2.52	0.36-1.52	0.36-2.52
Mean	*0.80*	*0.85*	*0.59*	*0.75*
Cu (mg/kg)	0.32-0.96	0.32-1.84	0.88-1.64	0.32-1.84
Mean	*0.65*	*0.90*	*1.20*	*0.92*
Fe (mg/kg)	10.32-36.94	10.60-42.84	9.04-36.12	9.04-42.84
Mean	*22.66*	*31.84*	*22.89*	*25.80*
Mn (mg/kg)	9.20-14.42	9.64-32.84	9.92-17.46	9.20-32.84
Mean	*11.68*	*20.58*	*13.57*	*15.28*

Table 3 Simple correlation (r values) amongst the different soil properties

	EC	OC	Available N	Available P	Available K	Zn	Cu	Fe	Mn
pH	0.284*	-0.095	-0.106	-0.265*	-0.164	-0.030	-0.156	0.018	0.155
EC		0.370**	0.355**	0.230	0.117	0.282*	0.204	0.155	0.143
OC			0.988**	0.479**	0.130	0.200	-0.205	-0.002	0.023
Available N				0.493**	0.147	0.213	-0.214	0.014	0.024
Available P					0.227	0.367**	0.030	0.255*	-0.062
Available K						0.244	0.289*	0.274*	0.154
Zn							0.193	0.463**	0.387**
Cu								0.171	0.051
Fe									0.523**

** significant at 0.01 level; * significant at 0.05 level

Nutrient index

Nutrient index values in surface soil for available N varied from 1.1 to 1.3 with an overall district average of 1.2 which falls under low fertility status. The low fertility status of available nitrogen may be attributed to the low content of organic carbon as a result of intensive cultivation, regular occurrence of flash floods and soil being loose and rocky to some extent and poor restoration of organic carbon in the soil. Prasuna Rani et al (1992) also reported low status of nitrogen in surface soils that could be due to low amount of organic carbon in Andhra Pradesh soils. The available P nutrient index varied from 1.9 to 2.0 with an overall district average value of 1.97 that represents medium phosphorus availability in the soils. Medium soil fertility status of phosphorus may be due to balanced application of phosphatic fertilizers in the crops. Available potash nutrient index varied from 1.0 to 2.0 with an overall district average of 1.67 that represent medium soil fertility status. Available potash medium fertility status in these soils may be due to the medium prevalence of potassium rich minerals like *illite* and *feldspar*. These results corroborate the findings of Singh *et al.* (2001) who reported medium to high fertility status of available Potash and low in nitrogen in the soils of Uttar Pradesh.

Table 4 Nutrient index values in different sugar mill command areas of Haridwar

Sugar mill	Nutrient index /nutrient status					
	N		P		K	
Laxmi Sugar	1.1	Low	2.0	Low	1.0	Low
Uttam Sugar	1.3	Low	2.0	Medium	2.0	Medium
RBNS Sugar	1.2	Low	1.9	Medium	2.0	Medium
Haridwar district	1.2	Low	1.97	Medium	1.67	Medium

The present nutrient assessment study of sugarcane growing soils of Haridwar district, Uttarakhad indicated that soils had slightly acidic to moderately alkaline pH reaction, neutral electrical conductivity, low available nitrogen and medium available phosphorus and potash. DTPA extractable iron, copper and manganese were found above their critical limits in soils whereas, zinc at certain places was found deficient. Further, the varying soil test results of macro and micro nutrients of sugarcane growing soils of the district indicates that it is urgently required to apply balanced nutrients through organic and inorganic sources on the basis of site specific soil test results for enhancing sugarcane productivity, profitability and production.

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Use of Data Reduction Technique for Sugarcane Yield Forecast

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ABSTRACT

Data reduction techniques are applied where there is a goal to aggregate or amalgamate information contained in large data sets into manageable (smaller) information. In the present study principal component analysis is used for data reduction. Sugarcane data for a period of 40 years has been used for the study. In order to avoid multicollinearity, yield forecast is developed using principal component regression model. The results are compared with the linear regression model. The results of the new model are satisfactory.

Key words : Sugarcane yield forecast

Forecasts or estimates of most probable production are made while the crop is still standing in the field, whereas the actual production is estimated at or soon after harvest. Forecasts and estimates of yield of commercial crops like sugarcane, cotton or jute are of considerable importance to trade and industry, because availability of raw materials during the season is the basis of all calculations of manufacturing processes. With increasing emphasis on 'planned' production, still greater value will come to be attached to reliable estimates of yield, while still in an emergency, like the present, arising out of war conditions, accurate forecasts and estimates of production are a paramount need for ensuring the sufficiency of food grains and their equitable distribution in different areas. Moreover, in India, where tax on agriculture land reforms is the principle source of Government revenue, Government administration is especially interested in forecasting and estimation of crop yields.

Several studies have been carried out in past to develop suitable forecast models for various crops using multiple-regression technique (Khatri and Patel 1981; Mandal and Kar 1993; Werker and Jaggard 1998; Mall and Gupta 2000; Kandiannan *et al*. 2002a, 2002b). Wheat yield has been forecasted using weather variables (Khistaria *et al*. 2004; Varmola *et al*. 2004a, 2004b). Historical data on weather variables from different agro-climatic zones have been used for developing models for prediction of coconut yield (Kumar *et al*. 2009). The use of weather variables as such involves multi-collinearity among the variables which would inflate the variances of regression coefficients. It has been observed that regressions based on different subsets of data produce very different results, raising questions of model stability. Multicollinearity in the data causes serious problems in estimation, prediction and interpretation. Further the estimated regression coefficient may be unrealistic in magnitude or sign.

In order to overcome the above drawbacks attempt has been made to forecast the yield of hybrid sorghum using Principal Components of biometrical characters for two or more periods (Jain *et al*. 1984). The results showed that principal component model performed better compared to the linear regression model. Studies have been conducted on yield forecasting of apple on the basis of bud examination. The results indicated that regression analysis through principal component method provided better precision for estimates of regression coefficients, than through ordinary least square method (Kumar and Awasthi 2000). Principal Component technique has been used in prediction of milk yield in cattle (Dalal *et al*. 2005; Dinesh and Gandhi 2005). The authors have concluded that principal component analysis should be used to predict the breading value of life time milk yield as compared to multiple regression analysis, as this technique removes the dependency among the independent variables and hence decreases bias in accuracy of prediction.

For sugarcane crop, studies have been carried out in the past using multiple regression technique (Jha *et al*.,1981; Chandrahas *et al*. 1983; Singh and Bapat 1988). Plant biometrical characters have been used as independent variables in these studies. So far studies have not been initiated using principal component technique. To overcome the gaps, in the present study principal components of weather variables have used for forecasting sugarcane yield.

MATERIALS AND METHODS

The present study has been conducted at Coimbatore district. Daily data on weather parameters such as X_1 – Maximum temperature (^{0}C), X_2 –Minimum temperature (^{0}C),

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X_3 – Relative humidity in the Morning (%), X_4 – Relative humidity in the Evening (%) , X_5 – Dry Bulb in the Morning (^{0}C), X_6 – Dry Bulb in the Evening (^{0}C), X_7 – Wet Bulb Morning (^{0}C), X_8 - Wet bulb Evening(^{0}C) , X_9 – Rainfall (mm), X_{10} – Evaporation (mm/day), X_{11} – Solar Radiation (cal/cm^2/day), X_{12} – Sun Shine (hours) for period of 40 years has been collected from weather station located at Sugarcane Breeding Institute, Coimbatore. The parameters have been used as independent variables in development of multivariate models.

The sugarcane yield (tonnes/hectare) figures of Coimbatore district for a period of 40 years (1961-2004) have been used as dependant variables for developing the models. The yield figures which are used as dependent variable have been collected from Season and Crop Report (1981), issued by State Government of Tamilnadu.

The data for a period of 40 years (1961-2000) has been used in developing forecast models and remaining four years (2001-2004) data has been used for validation of models.

Principal Component Analysis:

Principal component analysis is a linear dimensionality reduction technique, which identifies orthogonal directions of maximum variance in the original data, and projects the data into a lower-dimensionality space formed of a sub set of highest variance components. The purpose of principal component analysis is to derive a small number of linear combinations of a set of variables that retain as much of information in the original variable as possible. The small number of principal components is used in place of original variables for building regression model. Principal component analysis can also be viewed as a technique to remove multicollinearity in the data. In most of the practical cases variables under study are highly correlated. So it is necessary to transform the original set of variables to a new set of uncorrelated variables called principal components.

In this technique, the original set of variables is transformed into a new set of uncorrelated random variables. These new variables are linear combination of original variables and are derived in decreasing order of importance so that first principal accounts for as much as possible variation in the original data.

The detailed estimation procedure of method is presented by Johnson and Wichern (2002). The same have been briefed below for readers' convenience.

Let $x_1, x_2, \ldots, x_p$ are variables under study, then first principal component is be defined as

$$z_1 = a_{11}x_1 + a_{12}x_2 + \ldots + a_{1p}x_p \quad \ldots (2.1)$$

such that variants of z_1 is as large as possible subject to the condition that

$$a_{11}^2 + a_{12}^2 + \ldots + a_{1p}^2 = 1 \quad \ldots (2.2)$$

This constraint is introduced because this is not done, then Var(z_1) is increased simply by multiplying any $a_{1j}s$ by a constant factor. The second principal component is defined as

$$z_2 = a_{21}x_1 + a_{22}x_2 + \ldots + a_{2p}x_p \quad \ldots (2.3)$$

Such that Var(z_2) is as large as possible next to Var(z_1) subject to the constraint that

$$a_{21}^2 + a_{22}^2 + \ldots + a_{2p}^2 = 1 \text{ and } \operatorname{cov}(z_1, z_2) = 0 \quad \ldots (2.4)$$

The first few principal components account for most of the variability in the original data.

These few principal components replace initial p variables in subsequent analysis, reducing the effective dimensionality of the problem. An analysis of principal components reveals relationships that were not previously suspected and thereby allows interpretation that would not ordinarily result. Principal component analysis is more of a means to an end rather than an end in itself because this frequently serves as intermediate steps in much larger investigations by reducing the dimensionality of the problem and providing easier interpretation. It is a mathematical technique, which does not require user to specify the statistical model or assumption about distribution of original variates. Principal components are artificial variables and so it is not possible to assign physical meaning to them. Since principal component analysis transforms original set of variables to new set of uncorrelated variables, it is worth stressing that if original variables are uncorrelated, then it is not necessary in carrying out principal component analysis.

Justification for Use of Principal Components Analysis in Forecasting:

The most important use of principal component analysis is reduction of data. It provides the effective dimensionality of the data. If first few components account for most of the variation in the original data, then first few components' scores are utilized in subsequent analysis in place of original variables.

Multiple regression will be misleading if independent variables are highly correlated. Principal component analysis is the practical technique to solve the problem. Regression analysis is carried out using principal components as regressors in place of original variables which is referred as principal component regression.

Yield Forecast Model Using Principal Component Regression:

Regression model has been developed for yield forecast using principal component scores generated from principal component analysis which are used as independent variables replacing the original weather variables.

RESULTS AND DISCUSSION

The proportion of total variance accounted for by the first principal component is

$$\frac{a_1}{a_1 + a_2 + a_3 + \ldots + a_{12}} = \frac{330.03}{353.602} = 0.933 \quad \ldots (3.1)$$

Continuing, the first four components account for a proportion of total variance

$$\frac{a_1 + a_2 + a_3 + a_4}{a_1 + a_2 + a_3 + \ldots + a_{12}} = \frac{352.003}{353.602} = 0.995 \quad \ldots (3.2)$$

Hence the twelve weather variables are replaced sufficiently by first four principal components.

The Eigen vectors for the first four principal components are presented in Table 3.1.

Table 3.1 Eigen Vector Values

	Prin1	Prin2	Prin3	Prin4
X_1	0.009	0.061	0.196	0.115
X_2	0.005	0.004	0.158	0.109
X_3	0.002	0.025	0.251	0.206
X_4	0.004	0.032	0.153	0.202
X_5	0.0001	0.455	0.796	0.244
X_6	0.016	0.064	0.076	0.210
X_7	0.002	0.102	0.152	0.114
X_8	0.0791	0.872	0.404	0.195
X_9	0.001	0.074	0.092	0.759
X_{10}	0.035	0.038	0.096	0.361
X_{11}	0.002	0.017	0.077	0.172
X_{12}	0.996	0.0721	-0.031	0.008

Calculation of Principal Component Scores

Principal component scores (P_1, P_2, P_3, and P4) are obtained by multiplying eigen vector values for the four principal components with weather variables. Equation 3.3 gives the equation for calculation of first principal component score denoted by P_1.

$P_1 = 0.009X_1 + 0.005X_2 + 0.002\,X_3 + 0.004\,X_4 + 0.00007\,X_5 + 0.016\,X_6 + 0.002X_7 + 0.079\,X_8 + 0.0006\,X_9 + 0.035X_{10} + 0.002X_{11} + 0.99X_{12}$ … (3.3)

By substituting value of weather variable for the particular year, principal component scores are obtained. Similarly P_2, P_3, P_4 are obtained using second, third and fourth principal component values of the eigen vectors.

Yield forecast using Principal Component Regression Model

The yield forecast model is developed using yield (Y) as dependant variable, principal components P_1, P_2, P_3, P_4, previous year yield (P_6) as independent variable and is given by equation 3.4. Year (P_5) is also included as an independent variable in order to account for the technology changes.

$Y = 59.210 + 0.244\,P_1^{**} + 0.081\,P_2 - 0.810\,P_3 - 1.733\,P_4 + 0.520^{**}\,P_5 + 0.367^{**}\,P_6$ … (3.4)

The adequacy of regression model is tested using F-test. The results of ANOVA are presented in Table 3.2. The results show that F-values are significant at 1% level. This indicates that the model is highly adequate.

Table 3.2 Results of ANOVA for the regression equation

Model	Sum of Squares	Df	Mean Square	F - value	Sig.
Regression	2467.303	6	411.217	8.509	0.000
Residual	1546.396	32	48.325		
Total	4013.699	38			

**- Significant at 1% level

The significance of regression co-efficients are tested using t-test. The results of which are presented in Table 3.3. Among the regression co-efficients, first principal component and trend are significant at 1% level.

Table 3.3 Results for t-test and partial regression coefficients

Variables	Unstandardized Coefficients		t-value	Sig.
	B	Std. Error		
Constant	59.210	47.592	1.244	0.222
P_1	0.244	0.069	3.521**	0.001
P_2	0.081	0.303	0.268	0.790
P_3	-0.810	0.807	-1.004	0.323
P_4	-1.733	1.353	-1.280	0.210
Year	0.520	0.167	3.108**	0.004
PYY	0.367	0.141	2.604*	0.014

**- Significant at 1% level

The percentage of deviation along with goodness of fit values is presented in Table 3.4. The results show that deviation from actual values is minimum for the year 2002 and is highest for year 2003. The first two values are negative which shows that percentage of deviation values are less than actual values, followed by other two values which are positive. The positive deviation values indicate that predicted values are slightly higher than actual values. Goodness of fit value shows that the model is able to explain 61% of variation in yield.

Table 3.4 Performance of the Principal Component model

Year	Observed Yield (tonnes/hec)	Predicted Yield (tonnes/hec)	% of deviation (±)
2001	112	110.27	-1.546
2002	113	112.52	-0.428
2003	102	111.74	9.549
2004	116	119.35	2.888
Goodness of Fit			
R^2	0.615	-	-
MAE	4.858	-	-
RMSE	6.296	-	-
MSE	46.86	-	-

Yield forecast using Linear Regression Model

The yield forecast model developed using partial regression coefficients is given by equation 3.5.

$Y = 574.765 + 0.053\,X_1 + 4.56\,X_2 + 6.33\,X_3 - 13.54\,X_4^{*} - 13.81\,X_5^{*} + 1.56\,X_6 - 6.57\,X_7 + 0.81\,X_8$ … (3.5)

The goodness of fit for the model is calculated using R^2, MAE and RMSE and are presented in Table 3.5 along with percentage of deviation values. The coefficient of determination values show that yield forecast model is able to explain 72% of variation in yield. The percentage of deviation values are highest for year 2001 followed by 2003. Deviation value is minimum for the year 2002. All the deviation values are positive which shows that they are slightly higher than actual values.

Table 3.5 Performance of Multiple Regression Model

Year	Observed Yield (tonnes/hec)	Predicted Yield (tonnes/hec)	% of deviation (±)
2001	112	127.70	14.017
2002	113	114.25	1.103
2003	102	116.18	13.899
2004	116	122.44	5.550
Goodness of Fit			
R^2	0.717		
MAE	4.42		
RMSE	4.72		
MSE	38.56		

CONCLUSION

On comparison of both models the R^2 values of regression model are slightly higher than principal component model. But the percentages of deviation values are very high for regression model compared to the principal component model. The deviation values for the year 2001 and 2003 are very high. Based on the above results it is concluded that principal component model is better than linear regression model.

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Indian Institute of Sugarcane Research
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INDIAN JOURNAL OF SUGARCANE TECHNOLOGY

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1.a Articles on original Research completed, not exceeding 4000 words (up to 15 typed pages, including references, tables, etc).The article should present a connected picture of the investigation and should not be split into parts.

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