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Stochastic models for sugarcane yield forecasting

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ABSTRACT

Forecasting at sub-national level finds its importance in the present scenario. In this context, a Comparative study is made between Double Exponential Smoothing model and Auto Regressive Integrated Moving Average (ARIMA) model for Coimbatore data on sugarcane yield. Akaike Information Criterion and Bayesian Information Criterion are used to identify the best ARIMA model. ARIMA (1,1,1) model performs better compared to the other models of ARIMA family. The results of the ARIMA model are compared with Double Exponential Smoothing model and the best model is selected based on Root Mean Square, Mean Absolute Error and Mean Square Error values. Based on the above results, among the two models ARIMA (1,1,1) is appropriate for Coimbatore data on sugarcane yield and the model's performance is highly satisfactory in forecasting the sugarcane yield.

Key words : Sugarcane, Yield forecasting

India has emerged as one of the largest producer of sugar in the world. Sugar is the second largest agro-processing industry in the country with significant contributions to the income, employment and tax revenue of the rural areas. The sugar industry is said to be the engine of growth in the rural economy of India. Accurate forecasting of sugarcane production is very important not only at the national level, but also at the sub-national level. Such kind of exercise would enable the policy-makers to foresee the future requirements of sugarcane, its import/ export thereby supporting them to make appropriate measures in this regard. Lack of timely forecast of sugarcane production, has often proved to be a major handicap to the planners.

In early 1970's, Box and Jenkins pioneered in involving methodologies for time series modeling in the univariate case often referred to as Univariate Box-Jenkins (UBJ) ARIMA modeling. Since its inception, the univariate Box-Jenkins ARIMA approach is widely used throughout the world for different types of agricultural and industrial time-series analysis. The most significant point of this approach is that the explanatory variables in these models are the past values of the same variable. It can be used when the series is stationary and there is no missing data within the time-series. Forecasts are generated under the assumption that the past history can be translated into predictions for the future.

In the past, several studies have been carried out in literature using ARIMA models. Bajpai and Venugopalan (1996) have forecasted all-India sugarcane production by applying Regression analysis procedure and ARIMA time series modeling. Venugopalan and Srinath (1998) have used regression, univariate and multivariate time series methods for forecasting of fish catches. Prajneshu *et al.* (2002) have compared ARIMA models with structural time series models.

Univariate forecasting of state level agricultural production has been carried out by Rajaraman and Datta (2003). ARIMA models have been compared with nonparametric regression approach by Chandran and Prajneshu (2005) for forecasting oilseed production in India.

Local linear forecasts can be used to obtain Cubic smoothing splines fitted to univariate time series data by Hyndman *et al.* (2005). Forecasting has been made by Chandran and Pandey (2007) with respect to yield of each crop, area under cultivation, and production efficiency.

Univariate and multivariate ARIMA models have been used to model and forecast monthly pelagic production of fish species in Mediterranean Sea during 1990–2005 by Efthymia *et al.* (2007). Milk production in India by Pal *et al.* (2007) has been forecasted using time-series modeling techniques – Double Exponential Smoothing and ARIMA. A novel hybrid model of artificial neural networks has been proposed using auto-regressive integrated moving average (ARIMA) models in order to yield a more accurate forecasting model than artificial neural networks by Khashei and Bijari (2010). A study was undertaken by Rahman (2010) to examine the best fitted ARIMA model that could be used to make efficient forecast boro rice production in Bangladesh. Sarika *et al.* considered ARIMA methodology for modelling and forecasting country's pigeon pea production data. ARIMA model has been applied to forecast annual productivity of a set of 34 different products by Padhan (2012).

Shil *et al.* (2013) has applied ARIMA (2, 1, 0) with regressor (area) model to forecast the coconut production in Assam for

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next 10 years. ARIMA methodology was applied for modeling and forecasting of milk production of India by Paul *et al.*(2014 Nearly 25 articles using ARIMA models are reviewed. Most of the studies carried out in the past are either at national level or using district level (Tamil Nadu) data. So far studies have not been carried out using Coimbatore data, particulary using comparative models for commercial crops like sugarcane. In the present study, double exponential smoothing models are compared with ARIMA models and the results are presented.

MATERIALS AND METHODS

Use of Double Exponential Smoothing for Yield Prediction

Performance of double exponential smoothing model for Coimbatore district has been compared with ARIMA models. Sugarcane yield forecast for the district has been predicted and the results are presented in Results and discussion. The model used for the purpose is described in the following equations:

$$L_t = \sim Y_t + (1 - \sim)(L_{t-1} + b_{t-1}) \quad \ldots (2.1)$$

$$b_t = \quad (L_t - L_{t-1}) + (1 - \quad) b_{t-1} \quad \ldots (2.2)$$

$$F_{t+m} = L_t + b_t m \quad \ldots (2.3)$$

where, L_t is level of the series at time *t*

b_t is slope of the series at time *t*

~ and (=0.1, 0.2, … , 0.9) are the smoothing and trend parameters.

ARIMA Model for Sugarcane Yield Forecast

ARIMA models were popularized by Box and Jenkins (1970) in the early 1970's and their names have frequently been used synonymously with general ARIMA models applied to time series analysis and forecasting. Box and Jenkins effectively put together in a comprehensive manner the relevant information required to understand and use univariate time series ARIMA models. The basis of the Box-Jenkins approach to modeling time series is summarized in Figure 2.1 and consists of three phases: identification, estimation and testing and application.

Description of the Model

In general, an ARIMA model is characterized by the notation ARIMA (p, d, q) where p, d, q denote orders of auto-regression, integration (differencing) and moving average respectively. In ARIMA, time series is a linear function of past actual values and random shocks. A stationary ARIMA (p, q) process is defined by the equation

$$Y_t = \Phi_0 + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots\ldots\ldots + \Phi_p Y_{t-p} + £_t \mu_1 £_{t-1} - \mu_2 £_{t-2} \ldots\ldots \mu_q £_{t-q} \quad \ldots (2.4)$$

where,

Y_t = response (dependant) variable at time *t*.

$Y_{t-1}, Y_{t-2} \ldots\ldots\ldots Y_{t-p}$ = response (dependant) variable at time lags *t-1, t-2,……,t-p* respectively; these *Y*'s are independent variables.

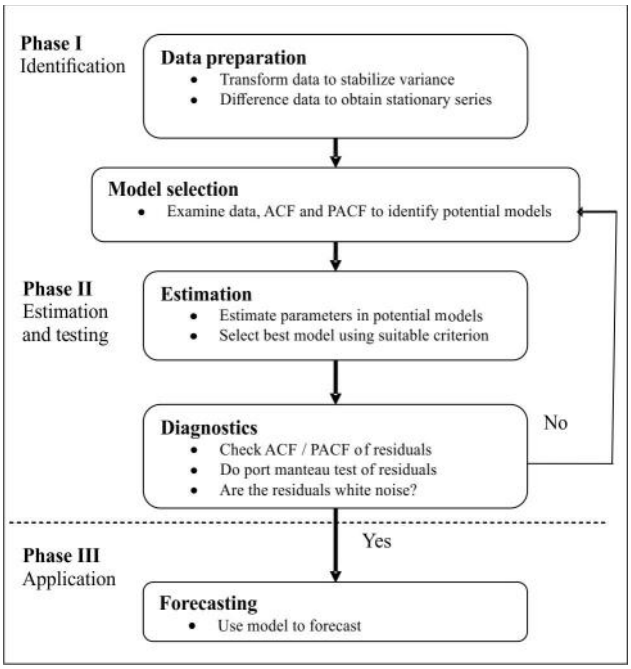

Fig. 2.1 Schematic representation of the Box-Jenkins methodology for time series modeling

$\Phi_1, \Phi_2 \ldots\ldots \Phi_p$ = coefficients to be estimated.

$£_t$ = error term at time t that represents the effects of variables not explained by the model; assumptions about the error term are same as those for standard regression model.

$£_{t-1}, £_{t-2} \ldots . £_{t-q}$ = error term that represents the effect of variables not explained by the model. The assumptions about the error term are same as those for standard regression model.

$\mu_1, \mu_2 \ldots\ldots \mu_q$ = coefficients to be estimated.

ARIMA Model Building

Identification: The foremost step in process of modeling is to check for stationarity of the series, as estimation procedures are available only for stationary series. There are two kinds, viz., stationarity in 'mean' and stationarity in 'variance'. Visual examination of data and structure of autocorrelation, and partial correlation coefficients helps to check the presence of stationarity. Another way of checking for stationarity is to fit first order autoregressive model for raw data and test whether the coefficient 'Φ_1' is less than one. If the model is found to be non-stationary, stationarity is achieved by differencing the series.

If 'X_t' denotes the original series, the non-seasonal difference of first order is

$$Y_t = X_t - X_{t-1} \quad \ldots (2.5)$$

The next step in identification process is to find initial values for orders of non-seasonal parameters, p and q. They are

obtained through significant autocorrelation and partial autocorrelation coefficients. There are no strict rules in choosing initial values. Though sample autocorrelation coefficients are poor estimates for population autocorrelation coefficients, still they are used as initial values while final models are achieved after going through the stages repeatedly.

Estimation: At the identification stage, one or more models are tentatively chosen that seem to provide statistically adequate representations of the available data. Then precise estimates of parameters for the model are obtained by least squares. Standard computer packages are available for finding the estimates of relevant parameters using iterative procedures.

Diagnostics: Different models are obtained for various combinations of Auto Regressive and Moving Average individually and collectively. The best model is selected based on following diagnostics:

a) Low Akaike Information Criteria (AIC)

b) Insignificance of auto correlations for residuals (Q-tests)

c) Significance of the parameters

a) Low AIC: AIC is given by AIC= (-2log L +2m) where m= p+q and L is the likelihood function. Since -2 log L is approximately equal to $\{n(1+\log 2®)+n\log\pm^2\}$ where $\pm^2$ is the model MSE, AIC is written as AIC= $\{n(1+\log 2®)+n\log\pm^2+2m\}$ and b first term in this equation is a constant, so it is omitted while comparing between models. As an alternative to AIC, sometimes SBC is also used which is given as SBC= $\log\pm^2+(m\log n)/n$.

b) Insignificance of auto correlations for residuals (Q-tests): After tentative model is fitted to the data, it is important to perform diagnostic checks to test adequacy of the model and, to suggest potential improvements. One way to accomplish this is through the analysis of residuals. It has been found that it is effective to measure the overall adequacy of chosen model by examining a quantity *Q* known as Box-Pierce statistic (a function of autocorrelations of residuals) whose approximate distribution is chi-square and computed as follows:

$$Q = n\sum r^2(j) \ldots \quad (2.6)$$

where summation extends from 1 to *k* with *k* as the maximum lag considered, n denotes number of observations in the series, *r (j)* is the estimated autocorrelation at lag *j: k* is a positive integer and is usually around 20. *Q* follows Chi-square with *(k-m_1)* degrees of freedom where m_1 is number of parameters estimated in the model. A modified *Q* statistic is the Ljung-box statistic which is given as

$$Q = n(n+2)\sum r^2(j)/(n-j) \quad \ldots (2.7)$$

The *Q* statistic is compared to critical values from chi-square distribution. If model is correctly specified, residuals should be uncorrelated and *Q* should be small (the probability value should be large). A significant value indicates that the chosen model does not fit well.

Data Description:

Univariate models have also been developed for Coimbatore district data on sugarcane yield. Data for a period of 44 years (1961-2004) has been used in the study. Data for a period of 40 years has been used for model building and the remaining for validation.

RESULTS AND DISCUSSION

A comparative study is made between ARIMA and Exponential models for Coimbatore data on Sugarcane Yield. The results are presented below.

3.1. Exponential Smoothing Model

Various combinations of ~= and both ranging between 0.1 and 0.9 with increments of 0.1 are tried and Mean Square Error is least for ~= 0.3 and = 0.1. The fitted model is given as

$L_t = 0.3Y_t + 0.7\,(L_{t-1} + b_{t-1})$ … (3.1)

$b_t = 0.2\,(L_t - L_{t-1}) + 0.8b_{t-1}$ … (3.2)

$F_{t+m} = L_t + b_t m$ … (3.3)

where, L_t is level of the series at time *t*

b_t is slope of the series at time *t*

~= and (=0.1, 0.2, … , 0.9) are the smoothing and trend parameters.

m = 1, 2, ….., 5 and the initial values for level L_t and trend b_t are 89.79 and 0.41 respectively.

ARIMA Model

The stationary check of time series reveals that time series data on sugarcane yield is not stationary. Figure 3.1 represents the time series plot for non stationary sugarcane yield data. It is made stationary by using the first order differencing technique. Figure 3.2 represents the sugarcane yield data after taking first order difference. For different values of p and q (0, 1 or 2), various ARIMA models are fitted and appropriate model is chosen corresponding to minimum value of the selection criterion i.e. AIC and SBC. ARIMA (1, 1, 1) model is found to be appropriate for sugarcane yield. The estimates for parameters along with their standard errors are presented in Table 3.1. Model verification is concerned with checking the residuals of model to find out if they contain any systematic pattern which can be removed to improve the chosen ARIMA model. This is done through examining autocorrelations and partial autocorrelations of the residuals of various orders. For this purpose, various correlations upto lag 14 are computed and the same along with their significance which is tested by Box-Ljung test are provided in Table 3.2. Results indicate that none of the correlations are significantly different from zero.

Table 3.1. Final Estimates of Parameters for Sugarcane Yield

Type	Estimate	SE
AR1	0.408	0.189
MA1	0.973	0.252
CONSTANT	0.360	0.191

Table 3.2. ACF and PACF for residuals

Lag	Auto Correlation	Std.Error	Box-Ljung Statistic	Prob.	Partial auto Correlation	Std. Error
1	0.04	0.154	0.067	0.795	0.04	0.16
2	-0.197	0.152	1.742	0.419	-0.199	0.16
3	0.002	0.15	1.742	0.628	0.021	0.16
4	0.093	0.148	2.137	0.711	0.055	0.16
5	0.062	0.146	2.32	0.803	0.062	0.16
6	-0.095	0.144	2.757	0.839	-0.076	0.16
7	-0.055	0.141	2.91	0.893	-0.027	0.16
8	0.204	0.139	5.05	0.752	0.179	0.16
9	-0.238	0.137	8.076	0.527	-0.304	0.16
10	-0.179	0.135	9.848	0.454	-0.073	0.16
11	0.241	0.132	13.169	0.282	0.218	0.16
12	-0.043	0.13	13.28	0.349	-0.185	0.16
13	-0.104	0.128	13.942	0.378	-0.022	0.16
14	-0.051	0.125	14.108	0.442	0.037	0.16
15	0.077	0.123	14.505	0.488	0.032	0.16
16	0.207	0.12	17.479	0.355	0.1	0.16

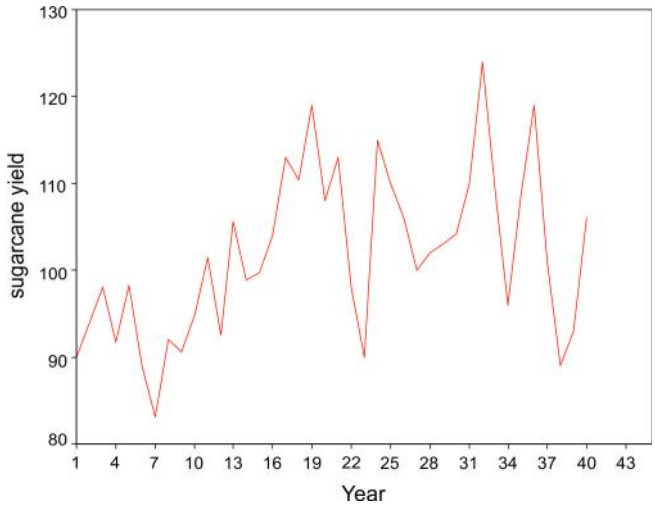

Fig. 3.1. Graph Showing Non-stationary Time Series Data on Sugarcane Yield

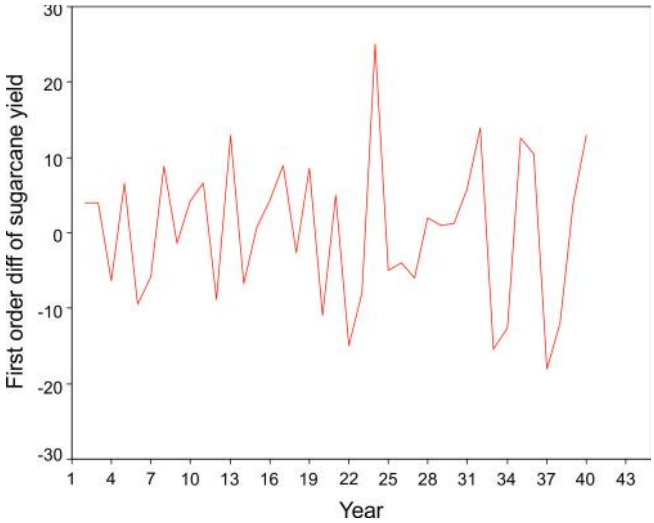

Fig. 3.2. Graph Showing First Order Difference for Sugarcane Yield

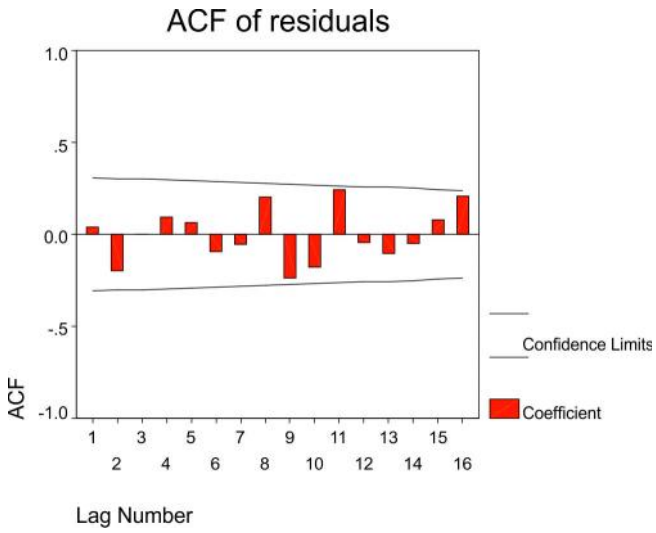

Fig. 3.3. Graph Showing ACF for Residuals

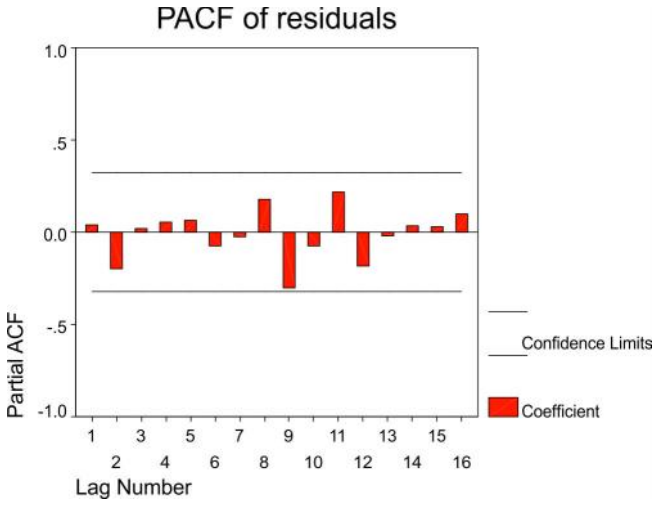

Fig. 3.4. Graph Showing the PACF for Residuals

Table 3.3. Performance of ARIMA, Exponential Smoothing Models

Year	Observed Sugarcane Yield	Forecast of Sugarcane Yield	
		Double Exponential Model *	ARIMA * (1,1,1)
2001	112	100.55 (-10.2)	107.85 (-3.7)
2002	113	100.09 (-11.4)	108.82 (-3.6)
2003	102	99.62 (-2.3)	109.43 (7.28)
2004	116	99.16 (-14.5)	109.89 (-5.26)
Goodness of Fit			
MAE		6.69	6.52
RMSE		8.70	8.05
MSE		79.673	70.089

* - The figures in brackets are the percentage of deviations of forecast values from observed values.

Figures 3.3 and 3.4 represent ACF and PACF for the residuals. From the figure it is clear that all autocorrelations and partial autocorrelations lie between 95% confidence interval. This proves that the selected ARIMA model is an appropriate model. ACF and PACF for residuals also indicate that the model is a good fit.

CONCLUSION

The performance of forecast models are tested by comparing the forecast values obtained with actual values. The results are presented in Table 3.3. The results indicate that percentage of deviations for ARIMA model are much low compared with Exponential model. Further for MAE and RMSE calculated for ARIMA model are low compared to exponential model. Based on above results it is concluded that ARIMA best suits the present data set on sugarcane yield.

REFERENCES

Bajpai PK and Venugopalan R.1996. Forecasting sugarcane production by time series modeling, Indian Journal of Sugarcane Technology, **11**(1): 61-5.

Chandran KP and Prajneshu. 2005. Nonparametric regression with jump points methodology for describing country's oilseed yield data, Journal of Indian Society of Agricultural Statistics, **59**(2): 126-30.

Chandran, KP and Pandey NK. 2007. Potato price forecasting using seasonal ARIMA approach, Potato Journal, **34**(1&2): 32-7.

Efthymia VT, Maravelias CD and Haralabous J. 2007. Modeling and forecasting pelagic fish production using univariate and multivariate ARIMA models, Fisheries Science, **73**: 979-88.

Hyndman RJ, King ML, Pitrun I and Billah B. 2005. Local linear forecasts using cubic smoothing splines, Aust. N. Z. J. Stat., **47**(1): 87–99.

Indira R and Datta A. 2003. Univariate forecasting of state-level agricultural production, Economic and Political Weekly, pp.1800-03.

Khashei M and Bijari M. 2010. An artificial neural network (p, d,q) model for timeseries forecasting, Expert Systems with Applications, **37**: 479–89.

Padhan P C. 2012. Application of ARIMA model for forecasting agricultural productivity in India, Journal of Agric. Soc. Sci., **8**: 50–56.

Pal S, Ramasubramanian V and Mehta SC. 2007. Statistical models for forecasting milk production in India, Journal of Indian Society of Agricultural Statistics, **61**(2): 80-3.

Paul R K, Wasi Alam and Paul A K. 2014. Prospects of livestock and dairy production in India under time series framework, Indian Journal of Animal Sciences, **84**(4): 462–66, April 2014.

Prajneshu, Ravichandran S and Wadhwa S. 2002. Structural time series models for describing cyclical fluctuations, Journal of Indian Society of Agricultural Statistics, **55**: 70-8.

Rahman NMF. 2010. Forecasting of boro rice production in Bangladesh: An ARIMA approach, Journal of Bangladesh Agril. Univ., **8**(1): 103–12.

Sarika M A, Iquebal and Chattopadhyay C. 2011. Modelling and Forecasting Pigeon Pea Production, Indian Journal of Agricultural Sciences, **81**(6): 520-23, June 2011.

Season and Crop Report, (1981-2007), Published by Directorate of Agriculture, Chepauk, Chennai.

Shil S, Acharya G C, Paul S C and Paul S. 2013. Trend analysis and forecasting coconut production, Journal of Plantation Crops, **41**(2): 238-41.

Venugopalan R and Srinath M. 1998. Modeling and forecasting fish catches: Comparision of regression, univariate and multivariate time series methods. Indian Journal of Fisheries, **45**(3): 227-37.

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New approaches for jaggery production in Rajasthan

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ABSTRACT

Jaggery is unprocessed natural sugar, produced through evaporating water from sugarcane juice in steel pans situated over pit furnaces. It is a vital sweetener for rural and urban people and more than 70% of total world's jaggery is produced in India. Jaggery is popularly known as 'medicinal sugar' and nutritionally it is comparable with honey. It exhibited supremacy over sugar, since it contains 80-85% sucrose and 5-15% reducing sugars and provides essential nutrients *viz.* proteins, fats, vitamins, minerals and energy. Jaggery is utilized for production of several *Ayurvedic* medicines. The medicinal and nutritive value, quality and taste of jaggery can effectively be improved by adding dried aonla shreds, dried ginger (*sonth*), turmeric (*haldi*), black pepper (*kali-march*) etc. It is used in various baked products like-chocolates, biscuits, breads, cakes, gaga, chikki, pastries, rolls etc. Jaggery can scientifically be formed through various steps viz. harvesting, pre-cleaning and crushing of cane, filtration, clarification, heating, boiling and concentration of cane juice, cooling of concentrated cane juice (*i.e*. slurry), mouldling of slurry, packaging, storage and marketing of jaggery. The jaggery should be prepared in very clean, tidy and hygienic conditions. The utensils and equipments used in jaggery making should be clean and sterilized. The floor of jaggery unit should be cemented and free from insects, flies, ants, bacteria, fungi etc. The use of injurious chemical(s) should be avoided and herbal clarificants should be used for clarification of cane juice. Sugarcane is the most important sugar crop of India and around 14.20% of the sugarcane produced in the country is being utilized for making jaggery and *khandsari*. Thus jaggery production will be greatly imperative and beneficial to sugarcane growers. Sugarcane varieties CoS-767, Co-1148, Co-66-17, Co-00421 found suitable for jaggery making in Rajasthan.

Key words: Jaggery, Furnace, Meditational sugar, Pre-cleaning, Slurry, Mouldling, *khandsari*

Sugarcane is the most important cash crop of India, which is produced for making sugar, jaggery and *khandsari*. It occupies about 5.064 million hectares and annually produces nearly 336.15 million metric tones of canes with an average cane productivity of 66.90 tones per hectare and average sugar recovery of 10.03% (season 2012-13). It is second largest agro-based industry of the country after textile industry. The production of jaggery from sugarcane is very old practice. All the sugarcane produced in the country prior to establishment of first sugar mill in 1902, was utilized for jaggery making. On the other hand, at present 14.20% of the sugarcane produced in India is being utilized for making jaggery and *khandsari*. Sugarcane is grown in every state of India. Rajasthan is also major sugarcane growing state with medium sugar recovery (9-10%) and low productivity (<50 t/ha), due to unsteady agro-ecological conditions. The main sugarcane growing districts of the state are Kota, Bundi, Baran, Jhalawar, Sawai Madhopur, Shriganganagar, Hanumangarh etc. However, in recent past the area under sugarcane is considerably reduced due to non-functional conditions of sugar mills in the state. In such circumstances, the significance of jaggery manufacturing is highly augmented and it can be most advantageous to the sugarcane-growing cultivators.

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WHAT IS JAGGERY?

The jaggery is unprocessed natural sugar that is produced by evaporating water from sugarcane juice in steel pans situated over pit furnaces, without addition any chemical(s). Jaggery is popularly known as "medicinal sugar" and nutritionally it is comparable with honey. The combination of jaggery constituents is magical, simple, natural, healthy along with wonderful taste and texture. Sugar and *khandsari* are merely sweeteners but jaggery is a vital food material as well, due to occurrence of nutrients desired for human body for rural and urban people of our country. More than 70% of the total world's jaggery is produced in India. In Rajasthan, it is regularly consumed as a sweetener and is a part of many sweet delicacies such as Jaggery Rice (*gur ka chawal or olia*). Many of the festivals are incomplete without *gur* as it is offered to the deity during worship. In the temple, we would wait to get the *gur* and roasted garbanzos at the end of worship.

COMPOSITION OF CANE JUICE AND JAGGERY

Cane juice contains following ingredient:

Water	: 77-80%
Sucrose	: 20-22%
Glucose	: 0.4-0.9%
Organic & inorganic compounds	: 1.0-1.9%
Total solids	: 20-24%

Jaggery contains following ingredient (per 100g of jaggery):

Sucrose	: 80-85g
Reducing sugars	: 5-15g
Proteins	: 400mg
Fats	: 100mg
Total Minerals	: 0.6-1.0g
Iron	: 11.4 mg
Calcium	: 8.0 mg
Phosphorus	: 4.0 mg
Moisture	: 3-10g
Energy	: 383 kCal

(Source: IISR, Lucknow)

OBJECTIVES OF JAGGERY PRODUCTION

The jaggery is very nutritious and healthy food and used as a main sweetener for rural and urban people. Jaggery exhibited supremacy over sugar in many ways, as:

- It contains about 80-85% sucrose and 5-15% reducing sugars.
- Jaggery provides necessary nutrients like-proteins, fats, vitamins (B-complex and folic acid), minerals (calcium, iron, phosphorus, magnesium, potassium and traces of zinc, copper etc., which are not present in sugar).
- It is an important source of energy (383 kCal energy per100 g of jaggery).
- Jaggery is an essential ingredient in various baked products such as-chocolates, biscuits, breads, cakes, pastries, rolls, *gajak, chikki* etc.
- It is utilized for production of several *Ayurvedic* medicines and syrups for treating throat and lungs infections, relaxation of muscles, nerves, blood vessels, maintaining blood pressure, increase hemoglobin, prevents anemia.
- The molasses present in jaggery acts as laxative and improves the digestion.
- It used as medicine to women and domestic female animals just after delivery.
- Although, sucrose recovery in jaggery production is 3-5 % lower in comparison to sugar industry but it is compensated by recovery of reducing sugars, proteins, fats and minerals, which are lost during sugar production in sugar mills.

METHODOLOGY OF JAGGERY PRODUCTION

The production of jaggery is very old method. In the bingeing of nineteenth century, maximum sugarcane produced in India was utilized for jaggery making. The jaggery is formed by two methods *viz. Desi* method and improved scientific method.

A. LOCAL METHOD OF JAGGERY PRODUCTION

The jaggery making at small scale is not required extraordinary expertise and giant equipments. The farmers adopt a very simple procedure, which involves special iron vessels and a single machine to manufacture jaggery. The jaggery recovery in *desi* method is lower and the hygienic conditions are not up to the mark. The majority of jaggery units are located in rural areas. The persons involved in jaggery making have no scientific knowledge and awareness for hygiene. Furnaces are open and the cane juice is exposed to dust and dirt. The splashing juice on *kachcha* floor of jaggery unit attracts insects, ants and flies, which sometimes fall into the boiling juice pans. The juice settling tanks and cooling pans are mostly masonry structures, made up of bricks and stones, loaded with bacterial and fungal contamination, which cause fermentation of cane juice and slurry. The following steps are involved in this method for preparing jaggery:

Step 1: Cutting Sugarcane from Fields

Fresh sugarcanes are cut from the fields, the top of the canes are chopped off, and the upper green leaves are used for livestock feeding. The canes are brought to the place where the juice is extracted from the canes. The improper harvesting of canes leaving long stubbles in the field reduces jaggery production per hectare.

Step 2: Feeding the Grinder to Extract Juice

Earlier canes were crushed in bullock operated wooden pestle-mortar assembly, which was replaced, by stone and then double iron roller crushers. Later three rollers cane crushers and open pan furnaces became popular for jaggery and *khandsari* manufacturing since independence, which usually leave 20-25% juice in bagasse. In rural areas, farmers using a bullock drawn or small power run machine (called *kolhu* or *charkhi*), where at one side four or five canes are fed to extract juice from the sugarcane. The extracted sugarcane juice is collected in a tank or *naand* and then it transferred to the iron vessel.

Step 3: Boiling the Juice

Next step involved is boiling the extracted juice, which is supplied to a large iron vessel (usually called *kadai*), which is heated by burning fuel under the vessel. The heating unit is nothing but a small pit above which this vessel is situated; there is a man who keeps on adding fuel to the heating unit from a small aperture. The bagasse obtained after juice extraction from the canes is dried in sunlight and dried leaves of sugarcane collected from the field are mixed and used as a fuel for heating cane juice. The juice is boiled in the vessel for at least 3-4 hours, until the liquid juice becomes a semi-solid paste.

Step 4: Adding Ingredients

The inefficient and direly clarification technique with over consumption of injurious chemicals makes jaggery making even more harsh. Alum and phosphoric acid are used for sedimentation of impurities and golden yellow colour of quality jaggery, respectively. When juice becomes a semi-solid paste (*i.e.* slurry), small amount of sodium carbonate is added as a reducing agent, which helps in preparing jaggery balls.

Step 5: Tray Feeding

After stirring well until the juice becomes a semi-solid paste, the paste is feed to an iron tray or masonry structure (made up of bricks and stone), commonly known as *chak*. With the help of a long wooden stick, at one end, which contains a flat block, they blend well repeatedly in the tray, until more thickening comes.

Step 6: Making Jaggery Balls

With help of a wet cloth, hot jaggery paste is made as balls. The precautions are taken to prepare the jaggery balls that the balls should be made as quickly as possible, since the paste gets to the solid state within a little span of time. The size and weight of jaggery balls may vary from one farmer to another. Usually, 1.0 kg, 2.5 kg or 5.0 kg jaggery balls are prepared.

Step 7: Storage and Marketing

The jaggery balls are stored at cool and dry place or sold as a complete bullock-cart. However, in rural areas the farmers do not have capacity to store jaggery for a long time due to their poor financial conditions. For a single feed of vessel, nearly 100 kg of jaggery can be produced, for which they can get a market price of around Rs.20-30 thousands.

B. MODERN SCIENTIFIC METHOD OF JAGGERY PRODUCTION

The jaggery producers of Rajasthan should adopt the modern scientific technology for making quality jaggery at low cost of production. In this method, jaggery is produced in very clean, tidy and hygienic conditions. The utensils and equipments used in jaggery production keeps clean and sterilized. The cemented floor of jaggery unit remains free from insects, ants, flies, bacteria, fungi etc. The utilization of harmful and costly chemical(s) is avoided and herbal clarificants are used for clarification of cane juice. This process of jaggery production involves various steps as: harvesting, pre-cleaning and crushing of canes, filtration, clarification, heating, boiling and concentration of cane juice, cooling of concentrated cane juice (*i.e.* slurry), mouldling of slurry, packaging, storage and marketing of jaggery. The details of various steps involved in quality jaggery production are:

Step 1: Harvesting of Canes

The completely ripened canes (possessing more than 16% sucrose in cane juice) are harvested. The dry leaves are removed from the canes and the green top leaves are used as fodder for the domestic animals. The canes should be harvested properly (*i.e.* from the ground level), because jaggery production per unit area will be reduced if very long stubbles are left in the field and more soil particles shall be mixed in cane juice, if harvesting is done below ground level.

Step 2: Pre-cleaning of Canes

To improve quality of jaggery, the canes should be cleaned thoroughly under high-pressure water guns to eliminate soil and dust particles, waxes, insects and other impurities present on sugarcane stalk. Some power drawn abrasive peeler of saw tooth type peeling unit have been developed for this purpose, which consists of four peeling blades (possessing 15 cm long 22-25 tapered teeth) attached at uniform spacing inside a square frame of 15cm. It can peel canes having diameters up to 3.5cm with peeling depth of 0.2 cm. The peeling unit has efficiency of 85% with capacity of 100 kg canes per hour.

Step 3: Crushing of Canes

After pre-cleaning canes are crushed with the help of sugarcane crushers to extract cane juice. The cane juice is collected in clean stainless steel or plastic containers. The various types of crushers are available in the market. These crushers can be categorized on the basis of various aspects, such as:

Based on Power Source: They may be animal drawn and power operated. At present power, operated crushers are mostly used due to higher crushing power and decline in availability of farm animals. A power operated horizontal crusher has relatively better extraction percentage as well as capacity (Devdas, 1985).

Based on Number of Rollers: On the basis of rollers present in the crushers, there may be two roller, three roller and four roller crushers. The three roller horizontal crusher exhibited best performance of about more than 65% (Anonymous, 1995).

Based on Orientation of Rollers: On the basis of roller orientation, the crushers are of two types *viz.* vertical and horizontal. The horizontal crushers were observed to be 2-4 % more efficient in juice extraction than the vertical crushers (Babu and Anwar, 1995).

Step 4: Filtration of Cane Juice

After extraction, the cane juice is filtered. The juice filtration is carried out through a five-layered filter. The juice travels through the underground pipes and directly reached to the stainless steel juice-settling tank. It is settled for approximately 20 minutes. By this process, all course impurities like-bagasse particles, leaves, dust particles etc. are removed from the cane juice.

Step 5: Clarification of Cane juice

The clarification of cane juice is necessary for making light coloured, crystalline, hard, less hygroscopic and hygienic jaggery. Earlier clarification was mostly furnished by heating method. Alum used for sedimentation of impurities, exhibited greater improvement in colour, while utilization of phosphoric acid exhibited the best golden yellow colour of quality jaggery (Anonymous, 1950). Sodium hydrosulphate makes the colour of jaggery very attractive, but for health point of view, the utilization of detrimental chemical(s) degrades the quality of jaggery, hence their use should be avoided. The herbal clarificants should be used for clarification of cane juice. The mucilaginous extract from vegetative clarificants *viz. Doela* (wild okra), okra, falsa or semal (40-60 grams of stem and roots of green plant per quintal of cane juice) or 70-75 grams of caster or groundnut or 30-40 grams of soybean seeds per

quintal of cane juice are supplemented prior to heating the cane juice for its clarification.

Step 6: Heating, Boiling and Concentration of Cane juice

The juice is transferred from settling tank to boiling pans (*i.e.* vessels) situated over pit furnaces. The sugarcane juice is now heated up to 80^0 C by firing under the boiling pan. All impurities float up during boiling, which are removed by scamming. After that, it set to boiling. While boiling, the sugarcane juice gets concentrated and after evaporating almost all the water, pasty crystalline yellow substance known as slurry, is left in the boiling pan, which becomes solid after cooling. The cane juice is concentrated until the striking temperature reached. Scientifically, the striking point for solid jaggery is 116-118^0 C depending upon the varieties, paddling and allowed to cooling.

For heat economy, efficient modified bottom pans are manufactured and 3 or 4 boiling pans are arranged in a series (line) and flue gases pass under all the boiling pans one after another and then escape through chimney. Indian Institute of Sugarcane Research, Lucknow has developed thermally efficient two-pan and three-pan furnaces (Singh *et al.* 2013). The processing time in these furnaces is comparatively less than the conventional furnaces. These furnaces have 2 or 3 pans for pre-heating of cane juice so that the processing time is reduced. The modified pans have also been developed for two pan furnace (Anwar S.I., 2010), which efficiently saves bagasse for evaporating per kilogram of water from the cane juice and producing per kilogram of jaggery as well as reducing time in jaggery production. A Waste Heat Recovery System (WHRS) has also been incorporated in IISR designed two-pan furnace for recovery of waste heat for bagasse/jaggery drying and/ or space heating (Anwar S. I., 2008). The material mainly used as fuel in furnaces for heating the cane juice may be dried bagasse, dry leaves of sugarcane, straw etc.

Step 7: Cooling of Concentrated Cane Juice

Once the striking point reached the concentrated cane juice, (*i.e.* slurry) is poured into cooling pan made up of wood or iron. The slurry is cooled here for some time and then puddle with the help of ladle. At the moment, when the shining of slurry disappeared, it is ready for moulding.

Step 8: Mouldling of Slurry

The jaggery is produced in many shapes, sizes and weights. They may be cubical, square or rectangle shapes. Generally, in rural areas, the jaggery is moulded in 1.0 kg, 2.5 kg or 5.0 kg packing, possessing cylindrical or rectangle shapes. Besides these different types of jaggery moulding frames are also available in the market. Many of them shapes are not attractive in look and pose problem in moulding, packaging, handling and distribution. To overcome such problems, Indian Institute of Sugarcane Research, Lucknow has developed jaggery moulding frames for producing 1"x1"x1" sized jaggery cubs weighing about 20-22 grams each. These cubs are very attractive and easy for packaging and marketing. For uniformity in shape and size of quality jaggery and ensuring consumer's acceptability, the concentrated semi-solid mass (*i.e.* slurry) after puddling in cooling pan, is poured in moulding frames and leveled with ladle. After an hour, solid jaggery set down in the form of bricks and cube shapes having 1.10 g/cc bulk density and 10.50% porosity, which is suitable for storage and marketing.

The process for making quality jaggery powder has been standardized at Anakapalle. Under this process, fresh juice is heated up to striking point of 120-122^0 C. The hot mass is removed and allowed to cool down with mixing. It is transferred from pan to platform and left without stirring for crystal formation. Immediately after solidification, the powder is made manually by using wooden scrapers and sieved through 1-3 mm sieves. It is dried up to about 1% moisture content and packed in polyethylene packets.

The process for manufacturing liquid jaggery was standardized at Kolhapur. Under this process the striking temperature of 105-106^0C is suitable for producing good quality liquid jaggery with minimum crystallization and microbial growth. Addition of citric acid @ 0.04% minimized the crystallization with increase in glucose and fructose in the liquid jaggery. Usually, it is packed in glass bottles.

Step 9: Packaging of Jaggery

The jaggery should be packed in attractive plastic bags. It protects jaggery from insects, dust particles, moisture and direct contact with hands, while handling and distribution. Jaggery packed in film, polyethylene, craft paper, aluminum coated paper or hessian with lined polyethylene film exhibited minimum loss in weight during storage (Anonymous, 1974). The composition, weight, name of manufacturing agency, date of manufacturing, date of packaging and health related aspects of jaggery etc. may be printed on the packet for enhancing its marketing.

Step 10: Storage and Marketing of Jaggery

The maximum returns can be obtained by selling jaggery in off-season. Thus, jaggery should be stored in cool and dry places to avoid direct contact to moisture, because micro-organisms exhibited maximum growth at 10% moisture content and 30^0C temperature. The moisture content of freshly prepared jaggery ranged from 4-11%, while the optimum moisture for storage should be 7-8%. The jaggery packed in polyethylene or gunny bags could be kept at 18-22^0C temperature and 55-60% relative humidity. At very low temperature (1.5-3.0^0C) the jaggery can also be stored at very high relative humidity (92-95%). Gundu Rao and Ramaiah (1961) suggested air conditioning (15^0C temperature and 50% relative humidity) of jaggery storage godown and recommended 1.5 to 2.0 tones units of air conditioner for 9x9x9 meter size godown. The jaggery packets can be stored and marketed easily. Jaggery marketing can be facilitate and enhanced by highlighting health related benefits of jaggery consumption over sugar.

VALUE ADDITION

The medicinal and nutritive values, quality and taste of the jaggery products can effectively be improved by adding dried aonla shreds, dried ginger (*sonth*), turmeric (*haldi*), black pepper (*kali-mirch*), asafetida (*heeng*), caraway (*ajvaayan*) seeds etc. The value addition should be done before moulding. The value added jaggery can be prepared in even smaller size and individually packed for fetching better profits.

SUGARCANE VARIETIES FOR HIGH JAGGERY PRODUCTION

The following sugarcane varieties have been found superior and more suitable for high jaggery production in Rajasthan (Table 1):

Table 1 Sugarcane Varieties Suitable for High Jaggery Production in Rajasthan

Variety	Maturity group	Cane yield (t/ha)
CoS-767	Midlate	80-100
Co-1148	Midlate	75-100
Co-66-17	Early	70-75
Co-00421	Early	65-75

PRECAUTIONS DURING JAGGERY PRODUCTION

1. The jaggery should be produced in very neat, clean and hygienic conditions.
2. All the utensils and equipments used in jaggery making should be clean and sterilized.
3. The floor of jaggery unit should be cemented and free from insects, ants, flies etc.
4. The stainless steel settling tank should be used, because in masonry structures the cane juice and slurry may be contaminated by bacteria and fungi.
5. The use of harmful chemicals should be avoided and herbal clarificants should be used for clarification of the cane juice.
6. The moulding should be done as fast as possible because the slurry paste became solid within a short period.
7. The canes should be harvested appropriately (*i.e.* on the ground level).
8. The jaggery producers must be properly trained through various awareness training programmes, for various aspects of jaggery making.

JAGGERY PRODUCTION: CONSTRAINTS AND THEIR REMEDIES

In India, jaggery industry facing many problems. Some of the serious constraints are:

Juice Extraction Efficiency: The efficiency of cane juice extraction of the cane crushers is less 60 %, which reduce the jaggery production per unit area. Hence, there is a great need to develop gearbox type efficient 3-4 horizontal roller scientifically improved crushers, to improve the juice extraction efficiency more than 70 %.

Availability of High Jaggery Producing Varieties/ Hybrids: Although, more than 600 varieties have been developed so far in sugarcane, but there is very limited availability of high jaggery producing varieties and hybrids of sugarcane. To improve jaggery and *khandsari* industry there is an urgent need to develop such varieties and hybrids, which can produce high jaggery and *khandsari.*

Uncertainty in Market Prices: There is very uncertainty in market rates of jaggery and *khandsari,* since if the production is high the prices goes down and *vice-versa,* results into narrow margin of profit to the jaggery producers, therefore they don't want to take a risk and sale out jaggery immediately at whatever may be the market price.

Decreasing Consumer Awareness: In order to increase per capita consumption of jaggery, special attention and campaign for consumer awareness towards consumption of jaggery at national level needs to be initiated. There is a scope to increase jaggery consumption by introducing and making various value added products. Jaggery can be used in manufacturing bakery products, chocolates, confectionary, beverages etc. The use of sugar can be replaced or minimized by jaggery wherever possible.

Poor Storability: Jaggery is very critical to store. The non-sucrose constituents *viz.* salts, proteins, glucose, fructose and reducing sugars present in jaggery are hygroscopic in nature, which can absorbed moisture from the atmosphere and non-availability of proper storage structures are major reasons of poor storing ability of jaggery. About 10-25 %, losses may occur during storage of jaggery. To reduce economical losses of jaggery, high production technology and quality packaging along with appropriate storage technique and storage structures should make available to the jaggery producers. The cold storage godowns are being used in West Godavari and Visakhapatnam districts of Andhra Pradesh and Muzaffarnagar district of Uttar Pradesh.

Scarcity of Labour: In jaggery industry, large number of labourers is required for various unit operations of jaggery processing. The unavailability of labour and higher wages is the severe problem. To overcome acute labour problems and for hygienically jaggery production, there is an urgent demand for automization of jaggery processing. The small capacity (<50 TCD) auto or semi- auto economically viable plants will solve the problem of scarcity of labour and their high wages.

Fuel Shortage: The conventional method of jaggery manufacture is based on bagasse fuel. There is an enormous problem in availability and storage bagasse. The erratic and off-season rains wet and decays bagasse and thereby shorten the fuel stock. The efficient furnace is required for complete combustion of bagasse and fuel economy. It will save precious bagasse fuel and farmers will get additional advantage by selling it. Briquetting of bagasse can overcome the problems of its storage and decaying during rainy season.

CONCLUSION

The jaggery is a vital sweetener, usually known as "medicinal sugar" and nutritionally it is comparable with honey. It is superior over sugar, since it contains about 80-85% sucrose, 5-15% reducing sugars, proteins, fats, vitamins, minerals (calcium, iron, phosphorus, magnesium, potassium and traces of zinc and copper (which are not available in sugar). Jaggery is utilized for production of several *Ayurvedic* medicines for various diseases. The medicinal and nutritive values, quality and taste of jaggery can effectively be improved by adding dried aonla, dried ginger (*sonth*), turmeric (*haldi*), black pepper (*kali-mirch*) etc. It is used in various baked products *viz.* chocolate, biscuit, bread, cake, pastries, rolls etc. The various steps involved in jaggery production are: harvesting, pre-cleaning and crushing of canes, filtration, clarification, heating, boiling and concentration of cane juice, cooling of concentrated cane juice (slurry), mouldling of slurry, packaging, storage and marketing of jaggery. The jaggery should be produced in very clean, tidy and hygienic conditions *i.e*. free from insects, ants, flies, bacteria, fungi etc. The use of injurious chemicals should be avoided and herbal clarificants should be used for clarification of cane juice. Rajasthan is an important sugarcane growing state. However, in recent past area under sugarcane is considerably reduced due to non-functional conditions of sugar mills in the state. In such situations, jaggery production is highly significant and advantageous to the sugarcane-growing cultivators.

REFERENCES

Anwar S I. 2010. Fuel and energy saving in open pan furnace used in jaggery making through modified juice boiling/ concentrating pans. *Energy Conservation Mgmt.* **51**:360-364

Anwar S I. 2008. Waste heat recovery system for open pan jaggery furnaces. *Agril. Engin. Today*, 32(4):19-22.

Anonymous 1995. *Annual Progress Report IISR Lucknow Centre of AICRP on Processing, Handling and Storage of Jaggery and Khandsari for* 1992-95.

Anonymous 1974. *Agricultural Research at Anakapalle, APAU, Hyderabad*, pp. 52-56.

Anonymous 1950. An Improved Method of Manufacture and Storage of *Gur*. CSRS, Pusa.

Babu B. and Anwar S.I. 1995. *Technical Bulletin (IISR/JRS/94/9) AICRP on Processing, Handling and Storage of Jaggery and Khandsari.*

Devdas C T. 1985. *Annual Report of PHT Scheme*, TNAU, Coimbatore.

Gundu Rao S R. and Ramaiah, N A. 1961. *Proceeding of Annual Report STAI*, **29**(Pt.2):137-138

Singh J, Anwar S I., Singh R D and Kumar D. 2013. Catalogue of equipments and technologies developed for processing, handling and storage of jaggery. *IISR, Lucknow*. p.56.

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Intercropping studies in sugarcane under Coastal zone of Andhra Pradesh

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ABSTRACT

Field studies were conducted at Regional Agricultural Research Station, Anakapalle during 2011-12 and 2012-13 to find out remunerative intercropping system in sugarcane. Thirteen intercrops were tested in sugarcane under paired method of planting. Cane yield of sugarcane decreased significantly due to intercropping with cucumber, ridge gourd and tomato but was uneffected due to intercropping with greengram and french bean during both the years. Quality parameters such as sucrose % and CCS % did not varied significantly due to intercropping of different crops in sugarcane. Highest benefit cost ratio was recorded in sugarcane intercropped with palak (2.05), bhendi (2.03) and ridge gourd (2.02) during 2011-12 and cluster bean (2.61), ridge gourd (2.40) and bhendi (2.23) during 2012-13. Significantly higher sugarcane equivalent yields were recorded in sugarcane intercropped with ridge gourd (117.6 t/ha) followed by sugarcane intercropped with palak (116.8 t/ha) and bhendi (116.0 t/ha) during first year of study where as cluster bean (150.7 t/ha) and ridge gourd (143.2 t/ha) recorded highest sugarcane equivalent yield during second year.

Key words: Sugarcane, Intercropping

The main objective of intercropping is to get increased total productivity per unit area and time, besides equitable and judicious utilization of land and other resources. The inclusion of short duration high value crops in sugarcane based cropping systems as intercrops helps not only in increasing the land utilization efficiency, reducing the production cost, but also minimize the use of costly inputs and to make the system sustainable. Most of the farmers particularly in north coastal zone are growing different vegetable crops as inter crops in sugarcane but an in-depth study of different crops and their relative economic significance with reference to both time and space is required to enable identification of the most efficient crops in this region. Hence, present study was carried out to find out profitable intercropping system in sugarcane and its effect on yield and quality of sugarcane.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh during 2011-12 and 2012-13 with thirteen different intercrops and sole sugarcane under paired method of planting thus constituting 14 treatments tested in randomized block design with three replications. An early maturing variety '97 A 85' ('Visakha') was planted in paired rows (60/120 cm) and intercrops were sown on the space available in between the two paired rows. Recommended doses of fertilizers were applied to sugarcane and intercrops separately as per the schedule and crop protection measures were followed as and when required. Intercrops were harvested at their physiological maturity and the yield data was recorded. The data on number of millable canes, cane yield and juice quality parameters viz., per cent sucrose, CCS% were recorded at the time of harvesting of sugarcane and data was analyzed statistically. Economic analysis was done to find out profitable intercropping system by calculating the benefit cost (B : C) ratio.

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RESULTS AND DISCUSSION

Cane yield

Sole sugarcane recorded significantly higher cane yield of 104.8 t/ha and 102.5 t/ha during 2011-12 and 2012-13 respectively. Among different inter cropping systems, intercropping of field bean (103.9 and 101.3 t/ha) and green gram (100.5 and 101.3 t/ha) did not effected the cane yield significantly during both the years. Lowest cane yields were recorded in sugarcane intercropped with cucumber followed by tomato during both the years (Tabel 1). Reduction in cane yield due to growth habit of intercrops under intercropping system was also reported by Randhava (1976) and Kothari *et al* (1987).

Juice sucrose (%)

Cane juices were analyzed for sucrose content at harvest (Table 1). Percent juice sucrose did not vary significantly due to intercropping in sugarcane. However, highest per cent juice sucrose was recorded in sugarcane intercropped with cucumber (18.5) during first year and with field bean (17.2) during second year of study.

Commercial cane sugar (%)

Commercial cane sugar percent was calculated treatment wise. Significant variations were not found due to different

Table 1 Cane yield, quality and economics of sugarcane as influenced by intercropping systems during 2011-12 and 2012-13

Treatment	Cane yield (t/ha)		Sucrose per cent		CCS per cent		Sugarcane equivalent yields (t/ha)		BCR	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Sugarcane + Bhendi	95.5	98.9	17.57	16.6	13.08	12.5	116.0	128.6	2.03	2.23
Sugarcane+ Clusterbean	95.0	98.6	16.37	16.3	11.87	12.3	103.4	150.7	1.80	2.61
Sugarcane+ Frenchbean	95.9	99.1	17.29	16.7	12.17	12.8	99.7	99.1	1.73	1.71
Sugarcane + Field bean	103.9	101.3	16.85	17.2	12.00	13.1	107.5	101.3	1.87	1.75
Sugarcane + Palak	98.4	100.9	17.39	16.7	12.90	12.6	116.8	113.3	2.05	1.98
Sugarcane + Fenugreek	96.4	99.2	16.73	16.6	12.00	12.4	99.6	106.6	1.76	1.88
Sugarcane + Coriander	96.0	99.1	16.14	16.0	11.60	11.9	109.9	115.5	1.93	1.87
Sugarcane+ Watermelon	92.1	98.1	17.38	16.0	12.70	12.1	109.7	98.1	1.91	1.70
Sugarcane+ Muskmelan	91.1	97.2	17.21	16.0	12.53	12.0	91.1	97.2	1.60	1.68
Sugarcane + Cucumber	87.2	93.1	18.50	16.8	14.10	12.9	101.3	118.1	1.81	2.10
Sugarcane+ Ridgegourd	89.0	98.4	16.81	16.6	12.30	12.6	117.6	143.2	2.02	2.40
Sugarcane+ Tomato	88.9	96.4	18.31	15.5	13.20	11.6	93.0	111.0	1.63	1.94
Sugarcane+ Greengram	100.5	101.3	17.95	16.1	12.70	12.4	108.7	114.7	1.93	2.04
Sugarcane	104.8	102.5	18.15	16.6	14.00	13.0	104.8	102.5	1.97	1.90
SEm +	3.12	0.78	-	-	-	-	1.72	1.08	-	-
C.D (0.05)	6.4	2.26	NS	NS	NS	NS	5.0	3.14	-	-

intercropping systems in sugarcane. CCS % followed the similar trend as that of per cent sucrose. Hasure et al (2005) at Kolhapur, Maharastra observed that none of the juice quality parameters (brix, commercial cane sugar, sucrose and purity percentage) of sugarcane differed significantly due to intercropping in sugarcane.

Sugarcane equivalent yield (t/ha)

Significantly higher cane equivalent yields were recorded in sugarcane intercropped with ridge gourd (117.6 t/ha) followed by palak (116.8 t/ha) and bhendi (116.0 t/ha) as compared to sole sugarcane (104.8 t/ha) during 2011-12. During 2012-13 season sugarcane intercropped with cluster bean recorded significantly higher cane equivalent yield of 150.7 t/ha followed by sugarcane intercropped with ridge gourd (143.2 t/ha) . Higher cane equivalents are due to better yield coupled with higher market price of intercrops. Significantly lower cane equivalent yields were observed in sugarcane intercropped with muskmelon (91.1 t/ha and 97.2 t/ha) during both the years which was due to poor yield of muskmelon as well as sole crop. Increased total productivity in terms of cane equivalent yields due to intercropping in sugarcane was also reported by Mahadevaswamy and Martin (2002) at Coimbatore.

Economics of intercropping system

Highest cost benefit ratio were recorded in sugarcane intercropped with palak (2.05), bhendi (2.03) and ridge gourd (2.02) as compared to sole sugarcane (1.97) during first year where as sugarcane intercropped with cluster bean (2.61), ridge gourd (2.40) and bhendi (2.23) recorded higher cost benefit ratio as compared to sole sugarcane (1.90) during second year. Inter cropping sugarcane with muskmelon, tomato, french bean found to be less remunerative compared to sole sugarcane (Table 1). Shinde *et al* (2009) were also reported the profitability of intercropping systems in sugarcane in terms of benefit cost ratio.

CONCLUSION

Studies on different intercropping systems in sugarcane in Coastal zone of Andhra Pradesh during 2011-12 and 2012-13 indicated that cluster bean, ridge gourd and bhendi vegetables were remunerative intercrops with higher benefit cost ratio and with less effect on cane yield of sugarcane.

REFERENCES

Hasure R R, Kadam U A, Nigade RD, More S M. 2005 Studies on planting geometry and intercrops on yield contribution characters, cane yield, quality and economics of seasonal sugarcane (Co 86032). Cooperative Sugar;**36**(12): 983-88.

Kothari S K, Singh J P and Singh V. 1987 Intercropping of mint species in spring planted sugarcane under tarai conditions of Uttar Pradesh. Indian J. Sugarcane Technol. **4**:1-16.

Mahadevaswamy M and Martin G J. 2002 Production potential of wide row sugarcane intercropped with aggregatam onion (*Allium cepa*) under different row ratios, fertilizer levels and population densities. Indian J of Agron. **47** (3): 361-66.

Randhawa K S. 1976. Intercropping in sugarcane pays. Indian Farming **26**(2) : 7-9.

Shinde N, Patil B L, Murthy C and Desai M N R. 2009. Profitability analysis of sugarcane based intercropping systems in Belgaum district of Karnataka. Karnataka J. Agric. Sci., **22**(4) : 820- 23.

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Evaluation of new sugarcane genotypes under spring planting season

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ABSTRACT

A field experiment was conducted for three consecutive cropping seasons (Spring) during 2009-10, 2010-11, 2011-12 at Sugarcane Research Station, Gorakhpur, India to evaluate the performances of ten sugarcane varieties / genotypes viz., 'UP 05125', 'CoSe 05452', 'CoSe 06455', 'CoSe 06456', 'CoS 06241', 'CoS 06246', 'CoS 06280', 'CoS 07240', 'CoS 07250', 'CoS 07282' with two early standards ('CoS 96268' and 'CoJ 64') and three mid-late standards ('CoS 767', 'CoS 96275' and 'CoSe 92423') in respect to qualitative and quantitative inherited characters. The experiment was laid out in Randomized Block Design with three replications. Among the ten varieties / genotypes with five standards studied, sugarcane variety 'UP 05125' was the most desirable variety for germination %, sucrose %, cane yield, CCS% and CCS t/ha at harvest.

Key words: Sugarcane, Spring Planting

Cane yield and its components are the most important traits in sugarcane productivity. Stalk weight and number of millable canes (NMC) are the two important components of cane yield. The differences in these traits among sugarcane genotypes/ varieties is due to their differences in genetic constitution and response to the environmental factors in which they were grown. These traits were widely studied by Nassar *et al.* (2005), El-shafai and Ismail (2006), Manjunath *et al.* (2007) (Kumar and Singh 2003). The information on adaptability and performance stability of sugarcane varieties/ genotypes over environments is important for assessing crop production. India is one of the leading nation regarding area and production of sugarcane in the world (Mohanty *et al*. 2012). The cane area increased from 1.17 million ha in 1930-31 to 5.025 million ha by 2011-12, marking almost a fourfold increase. During this period the productivity went up from 30.9 to 68.1 t/ha, sugarcane production increased from 36.35 million ton to 342.56 million ton and sugar production reached 26.5 million ton from 0.12 million ton (Nair 2012). Development of varieties for different maturity group is of great importance in sugarcane cultivation to realize higher recoveries in sugar mills. The proper choice of varieties, season and suitable production technologies coupled with balanced nutrient application play an important role in sugarcane production. Non adoption of any one of the components lead to reduction in sugarcane production which in turn not only affects the cane growers and sugar mills but also adversely affects the economy of the nation as a whole.

Sugarcane productivity is low in Uttar Pradesh even though it is one of the leading state in area and production with an average production of 60 t/ha and CCS % is 9.5. The cane yield and sugar per unit area are low in Uttar Pradesh due to lack of adequate number of high yielding varieties, resistant to diseases and pest (Singh *et al.* 1978). Nagaragan (1983) and Nazir *et al.* (1997) reported that higher cane yield is the function of higher genetic potential of a variety. Certain researchers reported that adoption of newly released varieties and techniques in cultivation will improve the economic condition of the state as well as of the farmers. The stagnant cane yield over the three deceases could be raised by the efforts of scientists evolving better varieties of sugarcane suitable to different tracts & climatic conditions, pests & diseases and to early, mid season and late season plantings (Naidu *et.al.* 2007). Keeping in view the importance of varietal aspect in sugarcane, the present study was undertaken to compare the qualitative and quantitative inherited characters of nine sugarcane varieties/ genotypes and five standards being cultivated throughout the country with locally evolved commercial variety 'UP 05125'.

MATERIALS AND METHODS

The present investigation was carried out to evaluate the performance adoptability of the sugarcane varieties/ genotypes viz., 'UP 05125', 'CoSe 05452', 'CoSe 06455', 'CoSe 06456', 'CoS 06241', 'CoS 06246', 'CoS 06280', 'CoS 07240', 'CoS 07250', 'CoS 07282' with two early standards ('CoS 96268' and 'CoJ 64') and three mid-late standards ('CoS 767', 'CoS 96275' and 'CoSe 92423') during three crop seasons viz. 2009-10, 2010-11 and 2011-12 under spring planting at Sugarcane Research Station, Gorakhpur, India. The trial was laid out in

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Randomized Block Design with three replications. Recommended cultural practices of sugarcane were adopted as and when required throughout the three crop seasons. The crop was harvested manually at its physiological maturity. Data pertaining to germination %, sucrose % in juice (November and December), CCS % and CCS t/ha were recorded at harvest according to standard procedures (Meade and Chen 1977) and are presented in table 1 and 2.

The collected data was subjected to standard statistical analysis. The mean data of three crop seasons (2009-10, 2010-11, 2011-12) on qualitative and quantitative traits viz. germination %, NMC, cane yield (t/ha), sucrose % in juice (November and January), CCS% and CCS t/ha at harvest were also recorded in spring planted crop and are presented in table 1 and 2.

RESULT AND DISCUSSION

Sugar content is an important objective of sugarcane breeding programs (Jackson 2005). However, comparison of cultivars released in different years indicate that sugarcane breeding programs have delivered increased sugar yields via improvements in cane yield with much smaller contributions

Table 1 Uniform Regional Varietal Trial (Spring) Data of Three Crop Season (2009-10, 2010-11, 2011-12)

Varieties	Germination %				N.M.C (000)				Yield(T/ha)			
	09-10	10-11	11-12	Mean	09-10	10-11	11-12	Ave.	09-10	10-11	11-12	Mean
'UP 05125'	44.69	46.98	46.50	46.06	146	146	149	147	78.79	84.91	82.28	81.99
'CoSe 05452'	42.19	40.95	41.64	41.59	129	133	135	132	64.55	75.19	80.83	73.52
'CoSe 06455'	38.84	44.28	46.25	43.12	136	140	140	139	73.23	77.50	80.56	77.10
'CoSe 06456'	35.32	43.58	44.62	41.17	150	146	151	149	77.87	80.64	83.33	80.61
'CoS 06241'	33.94	42.95	42.96	39.95	157	150	148	152	76.29	78.61	81.57	78.82
'CoS 06246'	37.75	42.06	41.64	40.48	149	147	146	147	73.79	80.93	81.94	78.89
'CoS 06280'	41.36	39.84	39.56	40.25	157	130	131	139	78.51	78.06	72.43	76.33
'CoS 07240'	35.07	45.38	45.45	41.97	154	145	131	143	79.62	81.48	81.30	80.80
'CoS 07250'	37.61	45.87	46.28	43.25	131	134	154	140	74.81	80.83	84.53	80.06
'CoS 07282'	41.98	44.34	43.38	43.23	155	132	134	140	77.59	84.44	81.57	81.20
'CoS 96268'	37.82	39.55	38.59	38.65	123	128	113	121	69.25	69.44	67.77	68.82
'CoS 96275'	35.39	41.50	39.28	38.72	157	143	119	140	73.70	72.03	71.39	72.37
'CoS 767'	34.07	41.15	40.52	38.58	121	126	122	123	66.85	70.83	69.09	68.92
'CoSe 92423'	34.49	41.43	36.92	37.58	118	121	115	118	72.88	70.46	70.28	71.21
'CoJ 64'	36.85	40.33	36.01	37.76	125	126	110	120	68.88	69.69	66.30	68.29
CD	3.77	6.70	4.21	-	6.11	6.63	4.31	-	5.27	6.50	5.46	-
CV	2.38	-	2.93	-	14.40	15.09	9.19	-	6.510	8.373	7.046	-

Table 2 Uniform Regional Varietal Trial (Spring) Data of Three Crop Season and their Average (2009-10, 2010-11, 2011-12)

Varieties	Sucrose Nov.				Sucrose Jan.				CCS %				CCS(t/ha)			
	9-10	10-11	11-12	Mean	9-10	10-11	11-12	Ave.	9-10	10-11	11-12	Mean	9-10	10-11	11-12	Ave.
'UP 05125'	16.27	15.58	17.43	16.43	17.23	18.18	18.06	17.82	11.89	12.73	12.59	12.40	9.37	10.81	10.74	10.31
'CoSe 05452'	15.10	15.58	15.82	15.50	16.96	16.29	17.48	16.91	11.93	11.33	11.94	11.73	7.82	8.60	9.65	8.69
'CoSe 06455'	16.78	15.05	15.46	15.76	17.18	16.94	17.78	17.30	11.70	11.85	12.52	12.02	8.57	9.18	10.09	9.28
'CoSe 06456'	16.26	15.36	15.94	15.85	16.33	17.28	17.48	17.03	11.28	12.00	12.57	11.95	8.78	9.68	10.47	9.64
'CoS 06241'	13.71	16.43	15.17	15.10	16.85	16.94	17.32	17.04	11.78	11.76	12.17	11.90	8.98	9.24	9.93	9.38
'CoS 06246'	14.49	13.32	15.74	14.52	16.09	16.29	16.88	16.42	11.12	11.28	12.35	11.58	8.21	9.13	10.12	9.15
'CoS 06280'	15.83	15.37	15.44	15.55	16.93	16.25	17.11	16.76	11.77	11.27	12.06	11.70	9.24	8.79	8.70	8.91
'CoS 07240'	13.43	14.50	15.21	14.38	15.46	16.93	17.13	16.51	10.51	11.73	11.90	11.38	8.37	9.56	9.67	9.20
'CoS 07250'	14.26	14.09	15.15	14.50	16.16	18.00	17.68	17.28	11.14	12.50	12.57	12.07	8.33	10.10	10.63	9.69
'CoS 07282'	14.99	15.34	16.20	15.51	17.15	17.52	16.93	17.20	11.78	12.25	12.16	12.06	9.14	10.34	9.87	9.78
'CoS 96268'	15.15	16.20	15.77	15.71	17.66	18.35	17.37	17.79	10.90	12.77	12.76	12.14	7.55	8.87	8.65	8.36
'CoS 96275'	13.86	16.45	15.15	15.15	17.05	16.35	16.43	16.61	12.24	11.40	12.07	11.90	8.16	8.21	8.66	8.34
'CoS 767'	14.74	14.38	15.74	14.95	15.73	16.03	16.12	15.96	11.05	11.20	12.24	11.83	7.38	7.93	8.45	7.92
'CoSe 92423'	13.87	14.76	15.37	14.67	15.79	17.20	16.46	16.48	10.92	12.02	11.73	11.56	7.96	8.47	8.24	8.22
'CoJ 64'	15.15	16.06	15.73	15.65	17.05	17.94	17.11	17.37	11.61	12.48	12.21	12.10	7.99	8.69	8.10	8.26
CD	2.55	2.57	3.29	-	2.08	2.60	1.72	-	-	0.50	0.40	-	1.17	3.92	2.29	-
CV	0.64	0.67	1.04	-	0.59	0.74	0.49	-	-	0.70	3.65	-	2.48	3.49	4.16	-

from sugar content. The data on qualitative and quantitative traits viz., germination %, NMC, cane yield (t/ha), sucrose % in juice, CCS %, CCS t/ha at harvest are presented in table 1 and 2.

The mean of three years data in Uniform Regional Varietal Trial (Spring) showed that germination % (46.06) and cane yield (81.99 t/ha) were highest in variety 'UP 05125' in comparison to all the test entries studied while in number of millable canes (NMC) variety 'UP 05125' was superior in comparison to two early standards viz. 'CoS 96268', 'CoJ 64' and three mid-late standards viz., 'CoS 96275', 'CoS 767', 'CoSe 92423', respectively. The mean of three years data in U.R.V.T. (Spring) also showed that in comparison to all test entries studied, sugarcane variety 'UP 05125' was superior for sucrose % in juice in the month of Novermber (16.43%) & January (17.82%), CCS% (12.40%) and CCS t/ha (10.31) at harvest, respectively.

Sugar productivity in its broader sense requires consideration of not only cane yield but also a number of direct and indirect components. Information on genetics of characters of commercial importance such as sucrose accumulation, yield attributes or disease resistance is very meagre. Scanty information wherever available does not permit generalization in directed breeding programme (Stevenson 1965). The spectacular, progress made so far in sugarcane is due to the intensive selection practiced on genetically highly variable populations. All the major countries, where sugarcane breeding is undertaken, have their own system of selection. Even in India different research stations follow different pattern giving emphasis to their specific requirement. The major differences are related to the basis of selection and the stage of selection. None of the available system can be considered superior to others under all conditions. The characters for selection are cane yield, sugar content, sugar yield, fibre content, disease resistance, ratooning, insect tolerance and habit. In practice, selection indices are not generally used in sugarcane, because of the insufficient genetic information, although attempts to work out selection indices were made on several occasions (Ethirajan 1966). Most of the economically important characters in sugarcane have a low repeatability (George 1962, Mariotti 1974, Rao *et.al.* 1967, Skinner 1966). Critical selection for major economic characters, for quality and cane yield is done when the number of entries have reduced to a manageable size at clonal stage. Mariotti (1972) observed that high cane yields in clonal stage are not strongly associated with any of components at the seedling stage and therefore, no selection should be done for yield components in seedling stage.

Miller *et.al.* (1978) used selection indices developed by them and reported high genetic gains for stalk yield, when the index was based on stalk height, stalk diameter, stalk number and stalk yield. In many studies, sucrose stalk yield relationship is found to be negative (Rao and Narasimhan 1963, Herbert 1965, Ethirajan 1966). Sugar yield is estimated from stalk weight, brix and sucrose percent. However, stalk yield and its components have much more role in determining sugar yield than brix and sucrose percent (Miller 1977). Quality attributes appear to be independent of stalk yield components and by adopting appropriate selection intensities and methodologies, it may be possible to select simultaneously for both high stalk yield and quality. Special efforts are sometimes required to build up genetic stocks or promising clones of commercial acceptability which possess high level of resistance to one or most of the available races of a pathogen. The present study demonstrated that germination %, cane yield, sucrose % in juice (November & December), CCS % and CCS t/ha at harvest was highest in sugarcane variety 'UP 05125' in comparison to all the test entries. Hence, newly released sugarcane variety 'UP 05125' was adopted for commercial cultivation in the state of Uttar Pradesh.

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REFERENCES

El-Shafai A M A and AMA Ismail. 2006. Effect of row spacing on yield and quality of some promising sugarcane varieties. *Egypt. J. of Appl. Sci*. **21** (II).

Ethirajan A S. 1966. Evaluation of plant attributes concerned with yield in sugarcane and assessing their behaviour in succeeding clonal population. Ph.D thesis, Madras University.

George E F. 1962. Applications of a grade score in determining the potential of sugarcane crosses. *Proc. Int. Soc. Sugarcane Technol.* **11**: 498-04.

Herbert L P. 1965. Association between yield components and yield of sugarcane varieties in Louisiana. *Proc. Int. Soc. Sugarcane Technol.* **12**: 760-63.

Jackson P A. 2005. Breeding for improved sugar content in sugarcane. *Field Crops Research* **92** (2-3): 277-90.

Kumar Niraj and Singh J R P. 2003. Relative performances of sugarcane varieties with respect to cane yield and juice quality. *Cooperative Sugar* **34** (II): 869-71.

Manjunath B L, H M Wasnik and V S Korikanthimath. 2007. Selection of sugarcane varieties for higher yield and recovery in west coast region. *Journal of Farming Systems Research and Development* **13**(2): 266-68.

Mariotti J A. 1972. On the effectiveness of some genetic parameters used in the selection of sugarcane populations. *ISSCT Sugarcane Breeders Newsletter* **29**: 8-15.

Mariotti J A. 1974. The effect of environments on the effectiveness of clonal selection in Sugarcane. *Proc. Int. Soc. Sugarcane Technol.* **15**: 89-5.

Meade G P. and Chen J C P. 1977. Cane sugar Hand book. 10th Edition John Wiley Inter Science. John Wiley and Sons, New York.

Miller JD, NI James and PM Lyrne 1978. Selection indices in sugarcane. *Crop Science* **17**: 369-72.

Mohanty M, Biswal S and Mishra PJ 2012. Enhancing productivity of sugarcane (Saccharum Spp. hybrid complex) by optimizing sub-soiling and preparatory tillage operations in east west zone of India. Indian *Journal of Sugarcane Technology* **27** (02): 73-5.

Nagarajan R 1983. Studies on genotype environment interaction in selected sugarcane cultivars for various yield and quality attributes. TNAU, Ph.D., 185 P.

Naidu NV, Rajaba Rao N, Raja Rajeswari N and Charumathi M 2007. 97A 85- An early maturing promising pre-release sugarcane clone suitable for Andhra Pradesh. *Proceedings of SISSTA*: 1-6.

Nair NV 2012. Sugarcane agriculture in India- 100 years and beyond. *Perspectives in Sugarcane Agriculture*: 9-23.

Nazir MS, Ali H Saeed , M Ghafar and M Tariq 1997. Juice quality of different sugarcane genotypes as affected by pure and blend plantation. *Pakistan Sugar J.* **12**: 12-4.

Nassar AM, KS El- Sogheir and BSH Ramadam 2005. Effect of nitrogen levels on yield and juice quality of some sugarcane varieties (Saccharum spp. L). Sugar Crops Res. Inst., Res. Centre, Giza, Egypt. *Egypt. J. Agric. Res.* **83**(2): 681-92.

Rao JT and R. Narasimhan 1963. Recent currents in sugarcane breeding. *Indian Sugar* **13**: 135-37.

Rao JT, TN Krishnamurthy and BV Natarajan 1967. Heritability of economic characters in sugarcane and its implication in selection. *Indian Sugar* **17**: 153-61.

Singh HN, Singh SB and Sharma S 1978. CoS 770- An outstanding sugarcane variety for Uttar Pradesh. *Indian Sugar Crop Journal* **3-538**: 60-7.

Skinner JC 1966. Use of mixed variety plots to measure gains from selection and effects of self pollination. *ISSCT Sugarcane Breeders Newsletter* **17**: 10-4.

Skinner JC 1971. Selection in sugarcane- A review. *Proc. Int. Soc. Sugarcane Tech.* **14**: 149-62.

Stevenson GC 1965. Genetics and breeding of Sugarcane. *Longman*, London.

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Simultaneous selection of high yielding and stable mid-late maturing sugarcane genotypes of East Coast Zone in India using AMMI Model : A new approach

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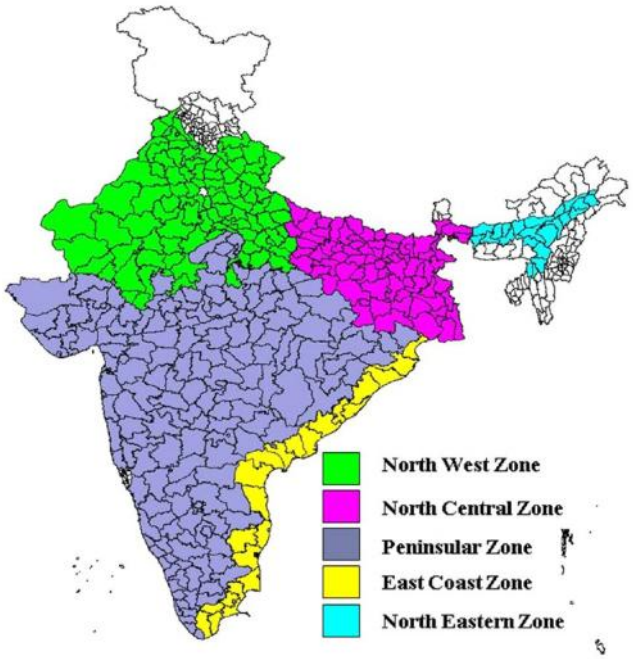
ABSTRACT

Three mid-late entries, 'Co 06031', 'CoC 08339' and 'CoC 09337' and three standards, 'CoV 92102', 'Co 7219' and 'Co 86249', were evaluated during three crop cycle (I and II Plant and Ratoon crop) at five locations in East Coast Zone. Simultaneous selection criterion is used in this study which selects genotypes for both high yield and stability in multi-environmental trials using Additive Main Effects and Multiplicative Interaction (AMMI) model. Results based on index of simultaneous selection, the entry 'Co 06031' was found superior entry as it was at rank one, two and three for sucrose (%), CCS (t/ha and cane yield (t/ha), respectively. Analysis for sugarcane yield (t/ha) revealed that none of the entry was found superior to the best standard 'CoV 92102', which was adjudged best genotype and at the top rank in the trial for CCS (t/ha). Among the entries, 'Co 06031' was the best genotype for CCS (t/ha) as it was placed at the second rank for index value in the trial and recorded the highest value of 12.94 CCS (t/ha). Based on index value of sucrose (%), 'Co 06031' and 'CoC 09337' ranked first and second in the trial. These two entries were also better than the best standard 'CoV 92102'. For sucrose (%), 'Co 06031' was the outstanding genotype as it ranked first for all the characters, index value, sucrose (%) and stability value. 'CoC 09337' was the second best entry because it recorded second best index value and stability value for sucrose (%).

Keywords: Sugarcane yield, AMMI model, Stability, Simultaneous selection, Multi-environment East Coast Zone, AICRP on sugarcane

Sugarcane is highly sensitive to climatic and edaphic factors and therefore location specific selection of varieties is important (Anon, 2014). All India Coordinated Research Project on Sugarcane (AICRP on Sugarcane) under ICAR, New Delhi is playing a pivotal role in development of improved location-specific sugarcane varieties for five agro-climatic zones viz., Peninsular, East Coast, North West, North Central and North East Zones of India (Map 1). During first Workshop on sugarcane research held at the Indian Institute of Sugarcane Research, Lucknow during January 15-18, 1970, it was suggested that under a coordinated variety trial on the basis of performance at the Zonal Trial Centers, the promising genotypes should be selected and tested at all sub-centers and on farmer's holding. The technical programme of plant breeding was formulated for various sugarcane growing areas located in different zones. Since then a large number of improved varieties have been identified through AICRP trials, and some have occupied sizeable area in most parts of the country. Such varieties have contributed in improving the sugarcane productivity.

Although a wide range of techniques to analyze G x E interactions are available, their application to sugarcane is limited in comparison with other field crops (Ramburan, 2012). The majority of studies of G x E interactions (GEI) of sugarcane fall within the empirical category, where the focus was on genotype stability and identification of homogenous environments within breeding programs (Kang and Miller,



Map 1. All India Coordinated Research Project on Sugarcane

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1984; Tai *et al*., 1982). Jackson *et al*. (1995) used ANOVA, cluster analysis and PCA to investigate G x E interactions of three datasets of sugarcane pre-release trials in Australia. Under AICRP on sugarcane, for the first time use of simultaneous selection indices using Additive Main Effects and Multiplicative Interaction (AMMI) model for Advanced Varietal Trial was initiated. AMMI model is a suitable technique to deal with multi-location trials, compared to traditional methods like ANOVA, Principal Component Analysis (PCA) and linear regression. Currently, selection of sugarcane genotypes is based on the performance of cane yield in different locations across the zone and ranking of genotypes is done on the basis of mean data. The analysis and ranking of genotypes based on simultaneous selection of high yielding and stable genotypes give better and reliable picture in identifying a variety for its release in a zone. The present article summarizes the results obtained from Advanced Varietal Trial (mid-late) conducted at five locations in East Coast Zone during 2011-13, using AMMI model and suggests a novel approach for selection of high yielding and stable genotypes in sugarcane.

MATERIALS AND METHODS

Combined analysis of sets of experiments conducted in a randomized complete block design for three crop cycles (two plant crop and one ratoon) over five locations in East Coast Zone (Map 1) was performed for cane yield (t/ha), commercial cane sugar yield CCS (t/ha) and sucrose (%). Stability in performance is one of the most desirable properties of a genotype to be released as a variety for cultivation. In case the variance due to GxE interaction is found significant, one of the various approaches known for measuring the stability of genotypes can be used and the variety may be ranked accordingly (Singh and Chaudhary, 1977). In literature, a large number of stability measures are available (Prabhakaran and Jain, 1994). However, the stability measure alone is of limited use. For a successful breeding of variety testing programme, both stability and yield (or any other trait) must be considered simultaneously. Also integration of stability of performance with yield of genotype through suitable measures will help in appropriate selection of a variety manner. One approach would be to integrate measures of performance and stability as a most informative index (Rao and Prabhakaran, 2005). A brief outline of AMMI and bio-plots procedure is discussed below.

AMMI and simultaneous selection procedure

The AMMI method combines the traditional ANOVA and Principal component analysis (PCA) into a single analysis with both additive and multiplicative parameters (Gauch, 1992). The first part of AMMI uses the normal ANOVA procedures to estimate the genotype and environment main effects. The second part involves the PCA of the interaction residuals (residuals after main effects are removed). The model formulation for AMMI shows its interaction part consisting of summed orthogonal products. Because of this form the interaction lends itself to graphical display in the form of so-called bi-plots (Gabriel, 1971). Here, it is assumed that the first two PCA axes suffice for an adequate description of the GxE interaction. It is evident from earlier sections that the scope of bi-plots is very much limited. The inferences drawn from bi-plots would be valid only when the first two PCAs explain a large portion of interaction variation. In situations, where more than two PCA axes are needed to accumulate considerable portion of GEl variation, what should be the approach for identifying varieties which are high yielding as well as stable. Keeping this in mind, a new family of simultaneous selection indices was proposed by Rao and Prabhakaran (2005), which select varieties for both yield and stability and was applied in the present study. The proposed selection indices (I_i) consists of (i) a yield component, measured as the ratio of the average performance ($\bar{Y}_{i.}$) of the i-th genotype to the overall mean performance of the genotypes under test, and (ii) a stability component, measured as the ratio of stability information ($1/ASTAB_i$) of the i-th genotype to the mean stability information of all the genotypes under test. The simultaneous selection index is given below :

$$I_i = \frac{\bar{Y}_{i.}}{\bar{Y}} + a\,\frac{\dfrac{1}{ASTAB_i}}{\dfrac{1}{T}\sum_{i=1}^{T}\dfrac{1}{ASTAB_i}}$$

Where $ASTAB_i$ is the stability measure of the i-th genotype under AMMI procedure and $\bar{Y}_{i.}$ is mean performance of i-th genotype. ~ is the ratio of the weights given to the stability components *(w_2)* and yield (w_1) with a restriction that $w_1 + w_2 = 1$. The weights considered in the index are, in general, as per the plant breeders' requirement. By considering the values of ~ as 1.0 ($w_1 = w_2 = 0.5$) , 0.66 (w_1=0.6, w_2=0.4), 0.43 (w_1=0.7, w_2=0.3)and 0.25 w_1 = 0.8, w_2 = 0.2), a new family of indices consisting of four indices I_1, I_2, I_3 and I_4 was proposed.

Soil, climate, multi-environment trials and data collection in East Coast Zone

East Coast Zone (ECZ) of AICRP on Sugarcane (Map 1) is an important zone where sugarcane is an important commercial crop (Sinha & Kumar, 2011). It is cultivated in almost all the districts of the zone. The zone occupies an area of 3.92 lakh ha, representing 7.61 per cent of the total sugarcane area in the country. ECZ stretches from the Balasore district of Odisha in the North to the Tirunelveli district in the Tamil Nadu and broadly comprises thirteen districts of Odisha, eleven districts of Andhra Pradesh and twelve districts of Tamil Nadu, besides the Union Territory of Puducherry. The zone has congenial climatic conditions for the growth of sugarcane under irrigated conditions. The highest yields are obtained from this region with more than 110 t/ha in some of the districts of the zone. Nearly 50 % of the net cropped area is irrigated, though widely

distributed between districts in the region (17 to 83 %). Soils and climate in the East Coast Zone are given in Table 1.1 and 1.2.

Multi- location trials and data collection in East Coast Zone

Multi-location advanced varietal trials (AVT) were conducted with three midlate elite sugarcane clones namely 'Co 06031', 'CoC 08339' and 'CoC 09337' and three standards , 'CoV 92102', 'Co 7219' and 'Co 86249' at five different locations, viz., Sugarcane Research Station, Nayagarh (Odisha)**,** Regional Agricultural Research Station, Anakapalle (Andhra Pradesh), Sugarcane Research Station, Vuyyuru (Andhra Pradesh), E.I.D. Sugarcane Research & Development Centre, Nellikuppam (Tamil Nadu) and Sugarcane Research Station, Cuddalore (Tamil Nadu) **– (**Map 2 and 3**).**

AVT was conducted at all the locations of the zone during 2011-12. The same set of clones was evaluated in the following year (2012-13) as Plant II as well as ratoon crop of the clones of AVT (Ratoon). Combination of two years of plant crops (2011-12 and 2012-13) and one ratoon crop during 2012-13 and five locations were treated as 15 environments for stability analysis. At each location, the trial was conducted in randomized block design with four replications of gross plot size 8 rows of 6.0 m with 0.8 m row to row distance and seed rate using 12 buds per meter. Planting of crop was done during the month of December/ January for plant crop. Data on cane yield (t/ha), sugar yield CCS(t/ha) and sucrose (%) were recorded at harvest stage both in AVT (360 days after planting of the crop) and in ratoon crop after 330 days of ratooning (after harvesting of plant crop. The planting and the harvesting were performed manually. Trial of AVT (Mid-late) - Plant I was completely damaged by the Thane cyclone at Cuddalore. For analysis of the data, the data of AVT I were taken as AVT II for cane yield (t/ha), CCS (t/ha) and sucrose (%). AMMI analyses and simultaneous selection indices analyses were performed with the help of SAS 9.3 (SAS Institute, 2002-2010). Other statistical analysis was done using Ms-Excel (2014).

RESULTS AND DISCUSSION

Combination of two years of plant crops (2011-12 and 2012-13) and one ratoon crop during 2012-13 and five locations were considered as 15 environments for AMMI and stability analysis (Table 2.2, 3.2 and 4.2). The significant interactions of genotypes × environments (locations and years combination) suggest that cane yield (t/ha), sugar yield CCS (t/ha) and sucrose (%) of genotypes varied in plant and ratoon crop. Significant differences for genotypes, environments and genotypes x environments interaction indicated the effect of environments in the GE interaction, genetic variability among the entries and possibility of selection for stable genotypes (Table 2.1, 3.1 and 4.1).

AMMI analysis of variance for yield under 15 environments indicated that the effects of genotype, environment and their interaction on cane yield were significant, with the proportion

Table 1.1 Soils and climate in the East Coast Zone

Name of the research station	Latitude	Longitude	Altitude	Soil	pH
Sugarcane Research Station, Panipoila, **Nayagarh** -752 070, Odisha	20^{o} – 54' N	80^{o} – 07' E	4.60 MSL	Sandy loam	6.30-6.60
Regional Agril. Research Station, (ANGR Agril. Univ.), **Anakapalle** -531 001, Andhra Pradesh	18^{o} – 45' N	83^{o} – 01' E	28.82 MSL	Sandy loam	7.2 - 7.4
Sugarcane Research Station, (ANGR Agril. Univ.), **Vuyyuru** -521 165,Krishna, Andhra Pradesh	16^{o} – 50' N	81^{o} – 50' E	33.6 MSL	Black clay	7.5 - 7.7
E.I.D. Parry (India) Ltd., Sugarcane Research & Development Centre, Keel Arungunam Road, **Nellikuppam**- 607 105, Cuddalore, Tamil Nadu	11^{o} – 07' N	78^{o} – 01' E	62.00 MSL	Sandy loam	7.50-7.98
Sugarcane Research Station (TNAU), **Cuddalore** – 607 001, Tamil Nadu	11^{o} – 46' N	79^{o} – 46' E	4.60 MSL	Sandy, sandy loam, clayey loam	7.50-7.98

MSL - Meter above the see level

Table 1.2 Average weather condition in East Coast Zone during 2011-12 and 2012-13

Location	Temperature (^{0}C)		Average Relative Humidity (RH) of Forenoon and Afternoon	Rainfall	No. of rainy days
	Maximum	Minimum	(%)	(mm)	
Nayagarh	33	24	60	1287	79
Annakapalle	33	20	74	1164	56
Vuyyuru	34	19	72	1002	38
Nellikuppam	30	29	75	1102	42
Cuddalore	31	25	80	1508	52

of the total treatment variation of 9.51% for genotype, 50.57 % for the environment and 26.08% for interaction (GxE) (Table 2.2). Similarly for CCS (t/ha), the effects of genotype, environment and their interaction were significant, with the proportion of the total treatment variation of 10.83% for genotype, 49.83% for the environment and 29.90 % for their interaction (Table 3.2). In case of sucrose (%), the effects of genotype, environment and their interaction were significant, with the proportion of the total treatment variation of 18.86 % for genotype, 48.46% for the environment and 29.00 % for their interaction (Table 4.2). Similar results in sugarcane crop were obtained by Silveira *et al.* (2013) who observed that the AMMI analysis of variance of the variable tons of pol per hectare (TPH) across two cuttings and nine environments, 73.36% of the total SS was attributable to environmental effects, 12.01% to genotypic effects and 14.63% to G × E in- teraction effects.

For cane yield (t/ha), CCS (t/ha) and sucrose (%), environment effect was found highly significant which indicated that locations of East Coast Zone are diverse in nature (Table 2.2, 3.3 and 4.2). Mitroviæ *et al.* (2012) also reported a large yield variation explained by environment effect indicating that the environments were diverse, with large differences among environmental means causing most of the variation in sugar yield.

For cane yield (t/ha), CCS (t/ha) and sucrose (%), the significant effect of the G × E interaction (Table 2.2, 3.3 and 4.2) revealed that the genotypes had variable performance in the tested environments of the Zone. Silveira *et al.* (2013) also reported that a change in the av- erage rank of genotypes was verified among the environments, justifying for more refined analysis to increase the efficiency of the selection of cultivars.

Based on the above conclusions, AMMI analysis is more appropriate. In this sense, AMMI analysis represents a potential tool that can be used for in-depth understanding of the factors involved in the manifestation of the G × E interaction. Silveira *et al.* (2013) also indicated that the AMMI method allowed for easy visual identification of superior genotypes for each set of environments. In this study also, a large SS for environments indicated that the environments were diverse with cane yield ranging from 101.60 to 125.46 t/ha for plant crop and 70.53 to 92.28 for ratoon crop (Table 2.2). Similar observations were also noted for CCS (t/ha) parameters. In case of sucrose (%), the variation ranged from 15.82 to 19.03 % for environments. According to Gauch and Zobel (1996), in standard multi-location trials, 80% of the total sum of treatments is due to environment effect and 10% due to GxE. Bissessur *et al.* (2001) also showed that AMMI method was more effective than ANOVA in identifying significant G x E interactions in a study of final stage selection trials in Mauritius. They found that AMMI method was effective at identifying cultivars with broad and specific adaptation and recommended that the technique be routinely used to obtain additional information on clones prior to their commercial cultivation.

Similarly, in East Coast Zone, GxE interaction portion is

Map 2. Regular centres of All India Coordinated Research Project on Sugarcane

Map 3. Voluntary centres of All India Coordinated Research Project on Sugarcane

Table 2.1 Mean performance of sugarcane yield (t/ha) of genotypes of Advance Varietal trials (Mid-late) conducted over fifteen location in East Coast Zone conducted during 2011-12 and 2012-13

Location	Nayagarh			Annakapalle			Vuyyuru			Nellikupam			Cuddalore			Mean
Environ-ment	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	
'Co 06031'	96.78	108.26	77.13	124.50	125.00	98.00	115.71	125.00	91.32	130.67	113.15	78.58	88.83	88.83	82.72	102.96
'CoC 08339'	107.45	109.57	73.68	124.00	127.50	100.00	94.10	110.42	83.68	122.05	115.56	82.68	143.73	143.73	121.36	110.63
'CoC 09337'	96.76	115.73	73.39	90.00	92.50	60.00	117.63	105.21	97.22	119.48	109.51	80.27	99.73	99.73	80.51	95.84
Standard																
'CoV 92102'	111.88	103.48	67.17	107.00	114.25	87.00	101.13	120.14	82.99	122.17	111.01	79.82	116.33	116.33	106.52	103.15
'Co 7219'	94.90	95.94	68.86	112.00	117.50	91.00	102.09	104.17	79.86	134.61	123.63	93.49	91.45	91.45	91.28	99.48
'Co 86249'	101.81	89.76	62.98	92.25	94.00	66.00	115.19	108.34	87.15	123.81	102.73	75.59	88.93	88.93	71.28	91.25
Mean	101.60	103.79	70.53	108.29	111.79	83.67	107.64	112.21	87.04	125.46	112.60	81.74	104.83	104.83	92.28	100.55

Table 2.2 AMMI analysis of cane yield (t/ha) of nine genotypes over fifteen environments in East Coast Zone

Source	DF	SS	MSS	F at 5%	% Contribution to SS	PCA Contribution	PCA Cumulative Contribution
G	5	3361.12	672.22	41.41**	9.51		
E	14	17865.98	1276.14	78.60**	50.57		
GxE	70	9214.72	131.64	8.11**	26.08		
PCA1	18	5493.69	305.21	18.80**	59.62	59.62	59.62
PCA2	16	2480.66	155.04	9.55**	26.92	26.92	86.54
PCA3	14	661.38	47.24	2.91**	7.18	7.18	93.72
PCA4	12	446.47	37.21	2.29**	4.85	4.85	98.56
Residual	10	132.52	0.63				
Average Error	225	3652.92	16.24		10.34		
Total	359	35328.01					

** - Significant at 1 % level of significance

Table 2.3 Ranking of genotypes of Advance Varietal trials (Mid-late) of East Coast Zone according to their (i) mean performance, (ii) stability and (iii) value of simultaneous selection index of genotypes in respect of cane yield (t/ha)

Variety	Estimated value of			Rank based on estimated value of			PI (CI) report based rank
	Index Value	Cane Yield (t/ha) value	Stability value	Index value based rank	Yield (t/ha) based rank	Stability based rank	
'Co 06031'	1.25	102.96	2219.20	3	3	5	2
'CoC 08339'	1.22	110.63	4294.65	4	1	6	3
'CoC 09337'	1.18	95.84	2203.78	5	5	4	1
Standard							
'CoV 92102'	1.35	103.15	1562.18	1	2	2	
'Co 7219'	1.33	99.48	1470.72	2	4	1	
'Co 86249'	1.16	91.25	1985.64	6	6	3	4

very high and significant which capture more than 93.72 % for cane yield (t/ha), 93.47 for CCS (t/ha) and 85.46 % for sucrose (%) by only three significant PCA axis (Table 2.3). It indicated that non-linear component of GxE interaction in sugarcane is very high and routine analysis is not appropriate for screening of genotypes at final stage of selection. Hence it is suggested that AMMI analysis and simultaneous selection of genotypes is more appropriate in sugarcane. In this study, only two to four axis are appropriate for drawing the conclusion. Cornelius (1993) also suggested that the number of multiplicative terms appropriate for a given data set may also be determined by a test of significance. By using principal component analysis, the first interaction axes contain a greater standard percentage, with a decrease in the subsequent axes. Thus, as the number of selected axes increases, the noise percentage also increases, reducing the predictive power of the analysis (Oliveira *et al.,* 2003). In this case we have retained four significant axis in the model for cane yield (t/ha), CCS (t/ha) and sucrose (%).

Simultaneous selection criterion proposed by Rao and Prabhakaran (2005) is used in this study which selects genotypes for both high yield and stability in multi-environmental trials using AMMI model by assigning 80 % weight to yield and 20 % to stability value of the genotypes. Such weights were assigned because Hogart (1976) inferred that 75 % of the gains in cane yield in Australia were attributed

to the varietal improvement. Edme *et al*. (2005) estimated that genetic improvement alone contributed 69 % of sugarcane yield.

Simultaneous selection criterion as discussed above has been used for selection of superior genotypes evaluated in Advanced Varietal Trial (Mid-late) of I and II Plant and Ratoon crop in ECZ. Three entries, 'Co 06031', 'CoC 08339' and 'CoC 09337' and three standards, 'CoV 92102', 'Co 7219' and 'Co 86249', were evaluated during three crop cycles (I and II Plant and Ratoon crop) at five locations. The data on cane yield (t/ha), sugar yield CCS(t/ha) and sucrose (%) were subjected to stability analysis by the use of additive main effects and multiplicative interaction (AMMI) criterion and simultaneous selection of high yielding and stable genotypes was done by the use of index value based ranking proposed by Rao and Prabhakaran (2005). Estimated Index value, yield values and stability value of different genotypes for cane yield (t/ha), sugar yield CCS (t/ha) and sucrose (%) along with their ranks are presented in Table 2.3, 3.3 and 4.4.

Results based on index of simultaneous selection of high sugarcane yield (t/ha) and stable genotypes revealed that none of the entry was found superior than the best standards 'CoV 92102' and 'Co 7219'. Both these standards were at rank one and two, respectively in the trial. The entry 'Co 06031' was at rank three. If genotypes are compared based on only yield values, the entry, 'CoC 08339' was found top ranking in the trials with highest cane yield of 110.63 t/ha, but was most unstable entry in the trial. The standard 'CoV 92102' was the best genotype and top ranked in the trial for CCS (t/ha). It recorded high value of 12.80 CCS (t/ha) with lowest stability value of 26.45. In the trial it may be considered as best genotype for CCS (t/ha) followed by the entry, 'Co 06031'. It was placed at the second rank for index value in the trial and recorded highest value of 12.94 CCS (t/ha). Among the entries, it may be considered as the best entry for CCS (t/ha). Based on index value of sucrose (%), 'Co 06031' and 'CoC 09337' were found at rank first and second in the trial. These two entries were also better than the best standard 'CoV 92102' in the trial. For sucrose (%), 'Co 06031' was adjudged as outstanding genotype in the trial because it was at first rank for index value, sucrose (%) and stability value. 'CoC 09337' may be considered as the second best in the trial because it recorded second best value of index value and stability value. Based on above analysis, the entry 'Co 06031' may be considered as good entry as it was at rank one, two and three for sucrose (%), CCS (t/ha) and cane yield (t/ha) respectively.

CONCLUSIONS

A successful evaluation of genotypes for stable performance under varying environmental conditions based on information

Table 3.1 Mean performance of CCS (t/ha) of genotypes of Advance Varietal trials (Mid-late) conducted over fifteen location in East Coast Zone conducted during 2011-12 and 2012-13

Location	Nayagarh			Annakapalle			Vuyyuru			Nellikupam			Cuddalore			Mean
Environ-ment	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoo n	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	
'Co 06031'	9.81	11.00	7.75	16.01	16.95	13.58	13.82	18.50	13.77	15.47	14.45	9.33	11.56	11.56	10.57	12.94
'CoC 08339'	10.85	11.09	7.41	15.01	16.41	13.31	7.59	12.71	9.50	13.05	9.79	7.53	17.97	17.97	15.89	12.41
'CoC 09337'	9.59	11.21	7.21	10.94	12.23	8.08	12.07	14.32	12.37	11.85	11.57	9.82	11.60	11.60	8.74	10.88
Standard																
'CoV 92102'	10.41	10.12	6.44	13.08	17.40	13.69	13.58	16.87	12.39	13.84	12.30	9.48	14.41	14.41	13.65	12.80
'Co 7219'	8.63	9.59	6.93	13.27	15.37	12.02	13.45	14.65	10.94	14.49	14.55	10.61	10.75	10.75	10.93	11.79
'Co 86249'	9.94	8.55	5.95	10.99	11.89	8.50	13.42	14.99	12.06	13.42	10.32	7.13	9.79	9.79	6.80	10.23
Mean	9.87	10.26	6.95	13.22	15.04	11.53	12.32	15.34	11.84	13.69	12.16	8.98	12.68	12.68	11.09	11.84

Table 3.2 AMMI analysis of CCS (t/ha) of nine genotypes over fifteen environments in East Coast Zone

Source	DF	SS	MSS	F at 5%	% Contribution to SS	PCA Contribution	PCA Cumulative Contribution
G	5	89.50	17.90	69.09**	10.83		
E	14	411.96	29.43	113.57**	49.86		
GxE	70	247.00	3.53	13.62**	29.90		
PCA1	18	175.06	9.73	37.54**	70.88	70.88	70.88
PCA2	16	39.71	2.48	9.58**	16.08	16.08	86.95
PCA3	14	16.10	1.15	4.44**	6.52	6.52	93.47
PCA4	12	10.99	0.92	3.54**	4.45	4.45	97.92
Residual	10	0.63	0.06				
Average Error	225	58.30	0.26		7.06		
Total	359	826.17					

** - Significant at 1 % level of significance

Table 3.3 Ranking of genotypes of Advance Varietal trials (Mid-late) of East Coast Zone according to their (i) mean performance, (ii) stability and (iii) value of simultaneous selection index of genotypes in respect of CCS(t/ha)

Variety	Estimated value of			Rank based on estimated value of			PI (CI) report based rank
	Index Value	CCS (t/ha) value	Stability value	Index value based rank	CCS (t/ha) based rank	Stability based rank	
'Co 06031'	1.33	12.94	49.06	2	1	4	2
'CoC 08339'	1.13	12.41	148.47	5	3	6	3
'CoC 09337'	1.20	10.88	40.63	4	5	3	1
Standard							
'CoV 92102'	1.52	12.80	26.45	1	2	1	
'Co 7219'	1.29	11.79	39.83	3	4	2	
'Co 86249'	1.04	10.23	64.14	6	6	5	4

Table 4.1 Mean performance of sucrose (%) of genotypes of Advance Varietal trials (Mid-late) conducted over fifteen location in East Coast Zone conducted during 2011-12 and 2012-13

Location	Nayagarh			Annakapalle			Vuyyuru			Nellikupam			Cuddalore			Mean
Environ-ment	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	Plant I	Plant II	Ratoon	
'Co 06031'	17.95	18.07	17.45	19.00	19.20	19.40	16.67	20.31	20.36	17.13	18.36	17.00	16.55	18.11	18.25	18.25
'CoC 0'8339'	16.72	16.96	17.23	17.80	18.30	19.00	12.16	16.18	16.26	15.68	12.64	13.15	16.08	17.56	18.38	16.27
'CoC 09337'	17.11	17.30	17.08	18.58	19.60	19.00	14.91	18.73	17.47	14.69	15.60	17.47	16.50	16.48	15.82	17.09
Standard																
'CoV 92102'	17.26	17.31	16.35	19.54	21.00	21.80	18.74	19.18	20.37	16.44	16.12	16.98	16.65	17.35	18.51	18.24
'Co 7219'	17.01	17.09	17.19	18.53	18.33	18.60	18.47	19.28	18.80	15.75	17.10	16.47	16.08	16.85	17.05	17.51
'Co 86249'	17.31	17.47	16.50	17.50	17.75	18.80	16.48	18.82	18.84	15.82	14.72	13.86	14.63	15.55	14.38	16.56
Mean	17.23	17.37	16.97	18.49	19.03	19.43	16.24	18.75	18.68	15.92	15.76	15.82	16.08	16.98	17.06	17.32

Table 4.2 AMMI analysis of sucrose (%) of nine genotypes over fifteen environments in East Coast Zone

Source	DF	SS	MSS	F at 5%	% Contribution to SS	PCA Contribution	PCA Cumulative Contribution
G	5	52.17	10.43	276.94**	18.86		
E	14	134.09	9.58	254.22**	48.46		
GxE	70	80.23	1.15	30.42**	29.00		
PCA1	18	42.60	2.37	62.81**	53.10	53.10	53.10
PCA2	16	13.54	0.85	22.46**	16.87	16.87	69.97
PCA3	14	12.43	0.89	23.57**	15.49	15.49	85.46
PCA4	12	8.45	0.70	18.68**	10.53	10.53	95.99
Residual	16	3.22	0.63				
Average Error	225	8.48	0.04		3.06		
Total	359	276.68					

** - Significant at 1 % level of significance 'Co 06031' and 'CoC 09337'

Table 4.3 Ranking of genotypes of Advance Varietal Trials (Mid-late)) of East Coast Zone according to their (i) mean performance, (ii) stability and (iii) value of simultaneous selection index of genotypes in respect of sucrose (%)

Variety	Estimated value of			Rank based on estimated value of			PI (CI) report based rank
	Index Value	Sucrose (%) value	Stability value	Index value based rank	Sucrose (%) based rank	Stability based rank	
'Co 06031'	1.43	18.25	9.24	1	1	1	2
'CoC 08339'	1.03	16.27	37.46	6	6	6	3
'CoC 09337'	1.32	17.09	10.40	2	4	2	1
Standard							
'CoV 92102'	1.29	18.24	14.19	3	2	4	
'Co 7219'	1.23	17.51	15.51	4	3	5	
'Co 86249'	1.20	16.56	14.03	5	5	3	4

on genotype × environment interaction for yield is an essential part of any sugarcane varietal development programme. The selection of sugarcane genotypes is based on the performance of cane yield at different locations across the zone and ranking of genotypes is done on the basis of mean data. The same criterion has been used in AICRP on Sugarcane till 2011-12. A new approach involving simultaneous selection indices using Additive Main Effects and Multiplicative Interaction (AMMI) model for Advanced Varietal Trial (AVT) has been applied for simultaneous selection of high yielding and stable sugarcane genotypes. The approach involves three steps for selection of high yielding and stable genotype in AVT. In the first step, genotypes performing better than the best standards in the trial based on only yield performance are selected. In second step, the selected genotypes are ranked / judged on index values obtained on the basis of both yield and stability. The third step involves the ranking of selected genotypes of step one on the basis of their stability. Genotypes are considered best, high yielding and stable, if their respective ranks were found better than the ranks of best standard or at least one of the standards. If their ranks are inferior to the best standard, then top ranking ones among the tested genotypes are adjudged. Based on the above analysis, the entry Co 06031 may be considered as good entry as it was at rank one, two and three for sucrose (%), CCS (t/ha and cane yield (t/ha) respectively among the entries.

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REFERENCES

Anonymous. 1970. The first workshop on sugarcane research workers, Indian Institute of Sugarcane Research, Lucknow during January 15-18, 1970.

Anonymous. 2014. Principal Investigator's Report (Varietal Improvement Programme), All India Coordinated Research Project on Sugarcane, Sugarcane Breeding Institute, Coimbatore.

Bissessur D, Chong LC, Ramnawaz C and Ramdoyal K. 2001. Analysing G x E interaction in sugar cane using the additive main effects and multiplicative interaction (AMMI) model. *Proceedings of the International Society of Sugar Cane Technologists,* **24 :** 506-11.

Cornelius P L 1993. Statistical tests and retention of terms in the additive and main effect and multiplicative interaction model for cultivars trials. *Crop Science.* **33** : 1186-93.

Edme´ S J Mille J D, Glaz B, Tai Y P and Comstock J C. 2005. Genetic contribution to yield gains in the Florida sugarcane industry across 33 Years. *Crop Science.* **45 :** 92–7.

Gauch H G and Zobel R W. 1996. AMMI analysis of yield trials. In*: Genotype by environment interaction (eds. Kang, M.S., Gauch, H.G.),* **4** : 85–122, CRC Press, Boca Raton, FL, USA.

Gauch H G. 1992. *Statistical analysis of regional yield trials: AMMI analysis of factorial designs.* Elsevier, Amsterdam.

Jackson P, McRae T and Hogarth M. 1995. Selection of sugarcane families across variable environments II. Patterns of response and association with environmental factors. *Field Crops Research* **43 :** 119-30.

Gabriel K R. 1971. The biplot-graphical display ofmatrices with applications to principal component analysis. *Biometrika,* **58** : 453-67.

Hogarth D M, 1976. New varieties lift sugarcane production. *Producers Rev,* **66**(10), 21-2.

Kang M S and Miller J D. 1984. Genotype x environment interactions for cane and sugar yield and their implications in sugarcane breeding. *Crop Science,* **24 :** 435-40.

Mitroviæ B, Mitroviæ B, Stanisavljev D, Tresk S, Stojakoviæ M, Ivanoviæ M, Bekavac G and Rajkoviæ M. 2012. Evaluation of experimental maize hybrids tested in multi-location trials using AMMI and GGE bi-plot analyses. *Turkish Journal of Field Crops,* **17**(1), 35-40.

Oliveira B A, Duarte J B and Pinheiro J B. 2003. Emprego da análise AMMI na avaliação da estabilidade produtiva em soja. *Pesquisa Agropecuária Brasileira,* **38** : 357-64.

Prabhakaran V T and Jain J P. 1994. *Statistical techniques for studying genotype x environment interactions.* South Asian Publishers, New Delhi.

Rao A R and Prabhakaran V T. 2005. Use of AMMI in simultaneous selection of genotypes for yield and stability. *J. Ind. Soc. Ag. Stat.* **59**(1) : 76-2.

Sinha O K and Kumar, R. 2011. Sugarcane production constraints in East Coast Zone and Technologies for improving cane productivity. Paper published in *souvenir released during group meeting of All India Coordinated Research Project on Sugarcane held at Orissa University of Agriculture and Technology, Bhubaneshwar, Orissa. October 17-19, 2011.*

Silveira L C I, Kist V, Paula T O M, Barbosa M.H.P, Peternelli L A and Daros E. 2013. AMMI analysis to evaluate the adaptability and phenotypic stability of sugarcane genotypes, *Sci. Agric,* **70**(1): 27-2.

Singh R K and Chaudhary B D. 1977. *Biometrical methods in quantitative genetics analysis*, Kalyani Publishers, New Delhi.

Tai P Y P, Rice E R, Chew V and Miller JD. 1982. Phenotypic stability analyses of sugarcane cultivar performance tests. *Crop Science,* **22** : 1179-84.

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Forecasting with ARIMA models for area under sugarcane cultivation in India

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ABSTRACT

The importance of sugarcane cultivation coupled with fluctuations in area prompted this study which concludes that the total cropped area can be increased in future, even though a negative impact would be there in the year of 2018-2019. Hence, in that particular period the government will have to support to the sugarcane cultivators to increase the area of cultivation. The projection of ARIMA model shows that sugarcane will play a vital role to improve the sugar and by-products production in the coming period in the country. The analysis shows that the forecasting performance could be increased.

Key words: ARIMA Model, Sugarcane, Area, Forecasting.

Sugarcane is a renewable, natural agricultural resource because it provides sugar besides biofuel, fibre, fertilizer and myriad of byproducts / co-products with ecological sustainability. Sugarcane juice is used for making white sugar, brown sugar (khandhasari), jaggery (Gur) and ethanol. The main by-products of sugar industry are baggase, molasses and press mud. (Saravanan and Parvathi 2010; Patil 2009).

Sugarcane juice has been known for its medicinal value since the vedic period. It originated in New Guinea about 10,000 years ago. (Shanmugam *et al.* 2011). It is of the prime importance among the cash crops grown in our country, (Venkatraman 2008). India is the second largest producing country of sugarcane and cane sugar, after Brazil. (Hari *et al.* 2013). The sugar yield capacity is not only related to the industries' processing capacity but also to the availability of sugarcane. The erratic monsoon and fluctuating price levels are vital factors (Anbazhagan 2010).

The objectives of the study were to suggest appropriate ARIMA model for forecasting area under sugarcane cultivation in India and to make ten years' forecast with appropriate prediction interval.

MATERIALS AND METHODS

The Auto Regressive Integrated Moving Average **(ARIMA)** model is a generalization of an autoregressive moving average (ARMA) model. These models are fitted to time series data either to better understand the data or to predict future points in the series. The existing study applies Box-Jenkins (1970) forecasting model popularly known as ARIMA model. The ARIMA is an extrapolation method, which requires historical time series data of underlying variable generally this ARIMA model was used in macro level data analysis. The model in specific and general forms may be expressed as follows. Let Y_t is a discrete time series variable which takes different values over a period of time. The corresponding AR (p) model of Y_t series, which is the generalizations of autoregressive model, can be expressed as:

$$AR(p): Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \varepsilon t \quad (1)$$

Where, Y_t is the response variables at time t,

$Y_{t-1}, Y_{t-2} \ldots\ldots Y_{t-p}$ is the respective variables at different time with lags $\alpha_0, \alpha_1, \ldots, \alpha_p$ are the coefficients and εt is the error factor. Similarly, the MA (q) model which is again the generalizations of moving average model may be specified as:

$$\text{MA (q): } Y_t = \mu_t + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} + vt \quad (2)$$

Where, μ_t is the constant mean of the series, $\delta_1 \ldots \delta_q$ is the coefficients of the estimated error term, is the error term. Combining both the model is called as ARIMA models, which has general form as:

If Y_t is stationary at level or I (0) or at first difference I (1) determines the order of integration, which is called as ARIMA model. To identify the order of *p* and *q* the ACF and PACF is applied.

Data

For the present study, the data were obtained from secondary sources. Data were collected for the periods of 1970-71 to 2012-13 (43 years) Area (lakh hectares) from source like Cooperative Sugar. For the present study, the statistical tools were employed to assess the growth performance of Sugarcane in India. Since large numbers of data are required for ARIMA model.

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RESULTS AND DISCUSSION

The ARIMA model was formulated after assessing that transforming the variable under forecasting was stationary series. The stationary series was the set of values that varied over time around a constant mean and constant variance. This model was common method to check the stationary and explain in the following figure. Figure 1 reveals in this data used were non-stationary. Again, non-stationary in mean was corrected through first differencing of the data. The area and time variable (Y_t) could now be examined for stationary. The both lines shows increasing trend of area (lakh hectare) cultivation of sugarcane in India.

Since, Y_t was stationary in mean, the next step was to identify the values of p and q. For this, the autocorrelation and partial autocorrelation coefficients (ACF and PACF) of various orders of Y_t were computed and presented in Table 1 and Figure 2**.**

The order of an ARIMA model is usually denoted by the notation ARIMA (p,d,q), where p is the order of the autoregressive part d is the order of the differencing q is the order of the moving-average process.

The ARIMA model were discussed with values differenced once (d=1) and the model which had the minimum normalized Bayesian information criterion (BIC) was chosen. The BIC value to determine the autoregressive order used to estimate the error series. The Estimation of parameters for sugarcane and area was estimated in Best Fitted Model. The various ARIMA models and the corresponding normalized BIC values

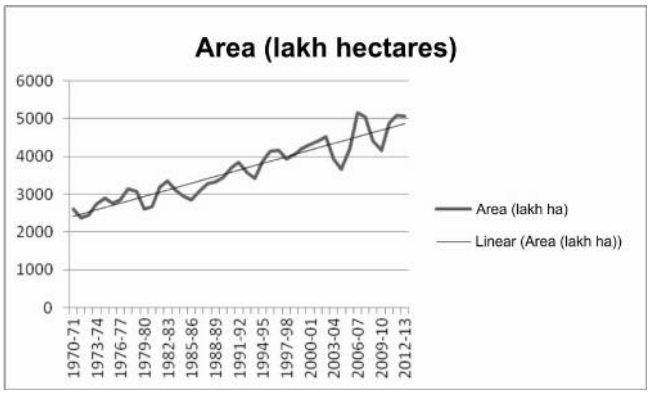

Fig 1. Time Plot of Sugarcane Area (lakh hectares) in India

are given in Table 2. The value of normalized BIC of the chosen ARIMA was 10.970. Estimation of Parameters for Sugarcane, area of Best Fitted Models

Model Estimation

The second step was the estimation of model parameters were estimated using SPSS.20 version to estimate the results and were presented in Table 3 and 4. R^2 value was 0.94. Hence, the most suitable model for Sugarcane cultivation area was ARIMA (2,1,1), as this model had the lowest normalized BIC value, good R^2 and better model fit statics (RMASE and MAPE). In this, justified that the selection of ARIMA (2,1,1) is the best model to represent the data generating process very precisely.

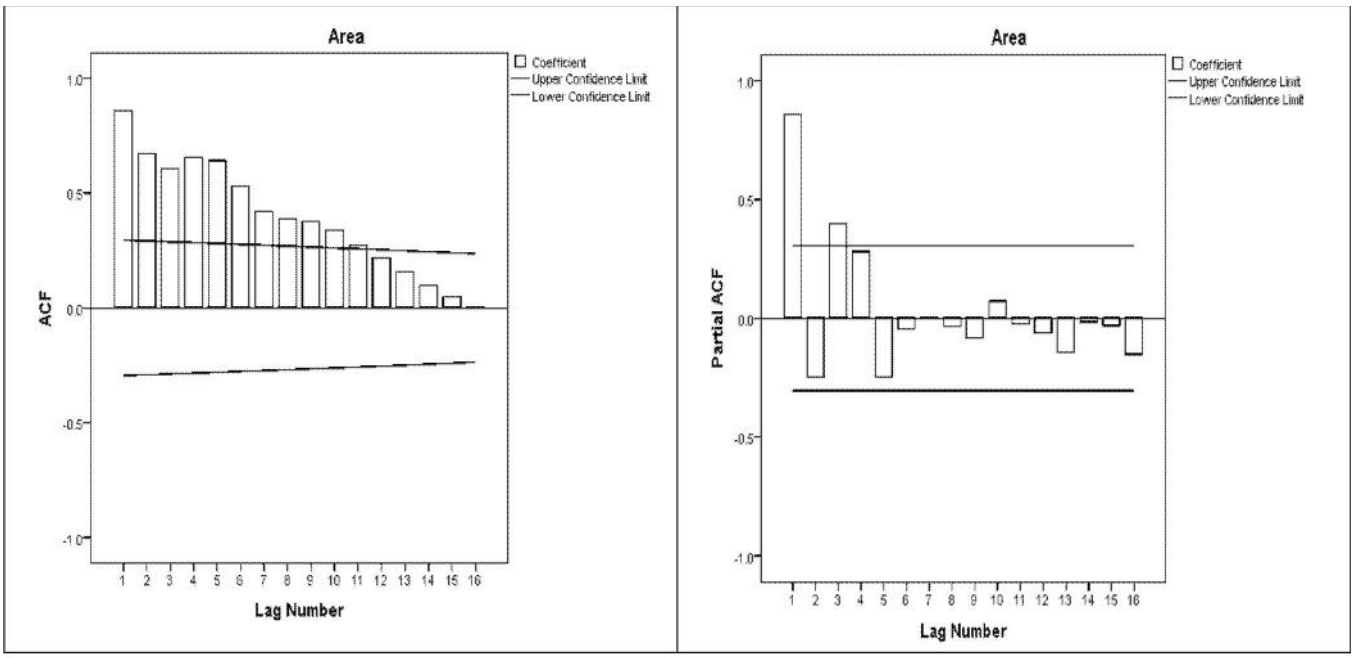

Fig 2. ACF and PACF of differenced data

Table 1 ACF and PACF of Sugarcane Area

Lag	Auto Correlation		Box-Ljung Statistics			Partial Auto Correlation	
	Value	DF	SIG	Value	DIF	Partial Autocorrelation	Std. Error
1	0.859	0.147	33.969	**1**	0.000	0.859	0.152
2	0.673	0.146	55.318	**2**	0.000	-0.246	0.152
3	0.606	0.144	73.111	**3**	0.000	0.398	0.152
4	0.656	0.142	94.483	**4**	0.000	0.280	0.152
5	0.641	0.140	115.418	**5**	0.000	-0.246	0.152
6	0.530	0.138	130.128	**6**	0.000	-0.044	0.152
7	0.420	0.136	139.608	**7**	0.000	0.003	0.152
8	0.388	0.134	147.914	**8**	0.000	-0.035	0.152
9	0.376	0.133	155.950	**9**	0.000	-0.082	0.152
10	0.339	0.131	162.670	**10**	0.000	0.072	0.152
11	0.274	0.129	167.201	**11**	0.000	-0.025	0.152
12	0.219	0.127	170.188	**12**	0.000	-0.063	0.152
13	0.158	0.125	171.793	**13**	0.000	-0.144	0.152
14	0.099	0.122	172.445	**14**	0.000	-0.016	0.152

Table 2 BIC value of ARIMA (p,d,q)

Sl.No	Model Type	BIC Value
1	0,1,0	11.712
2	0,1,1	11.580
3	0,1,2	11.237
4	1,1,1	11.691
5	1,1,2	11.337
6	2,1,0	10.998
7	2,1,1	10.970
8	2,1,2	10.994

Table 3 Estimated ARIMA Model of Sugarcane Area

	Estimate	SE	t	Sig
Constant	40.765	18.754	2.174	.036

Table 4 Estimated ARIMA Model Fit Statistics

Stationary R-squared	R-squared	RMSE	MAPE	Normalized BIC
.664	.944	192.991	3.745	10.970

Diagnostic Checking

In this model proved that the verification was concerned with checking the residuals of the model to see if they contained any systematic pattern which still could be removed to improve the chosen ARIMA, which has been done through examining the autocorrelations and partial autocorrelations of the residuals of various orders. For this purpose, Table 5 shows various autocorrelations up to 10 lags were computed and the same along with their significance tested by Box-Ljung statistic. The results indicated that none of these autocorrelations was significantly different from zero at any reasonable level. The selected ARIMA model was suitable model for forecasting sugarcane area in India.

Forecasts of Sugarcane

The ten year forecast of Sugarcane area was estimated by using the best model of ARIMA is presented in the Table 6. It has predicted that Sugarcane area will increase from 4898 Lak hectares in the year 2013-14 to 5713 in 2022-23 further the predicted area increased to lakh hectares respectively.

Table 5 Residual of ACF and PACF of Sugarcane Area

Lag	ACF		PACF	
	Mean	SE	Mean	SE
1	0.094	0.154	0.094	0.154
2	-0.109	0.155	-0.119	0.154
3	-0.157	0.157	-0.137	0.154
4	0.224	0.161	0.250	0.154
5	-0.165	0.168	-0.275	0.154
6	-0.094	0.172	-0.007	0.154
7	-0.061	0.173	-0.009	0.154
8	0.178	0.174	0.050	0.154
9	-0.276	0.178	-0.285	0.154
10	-0.102	0.188	-0.006	0.154

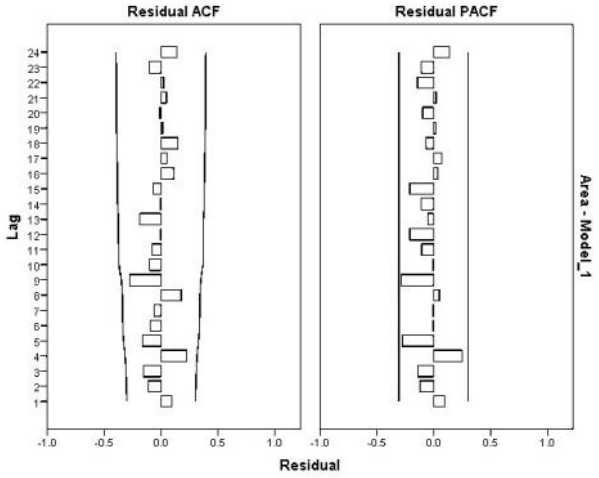

Fig 3. ACF And PACF Plot of Residuals

Table 6 Forecast for the Area of Sugarcane in India (lakh hectares)

SI. No	Year	Predicated	Indices	Percentage	LCL	UCL
1	2013-14	4898	100	9.20	4515	5282
2	2014-15	4909	100.22	9.23	4404	5414
3	2015-16	5129	104.71	9.64	4624	5634
4	2016-17	5333	108.88	10.02	4810	5856
5	2017-18	5366	109.55	10.08	4841	5890
6	2018-19	5318	108.57	9.99	4741	5894
7	2019-20	5356	109.35	10.07	4739	5973
8	2020-21	5507	112.43	10.35	4887	6126
9	2021-22	5653	115.41	10.62	5033	6273
10	2022-23	5713	116.63	10.74	5090	6335
	Total	53182		100		

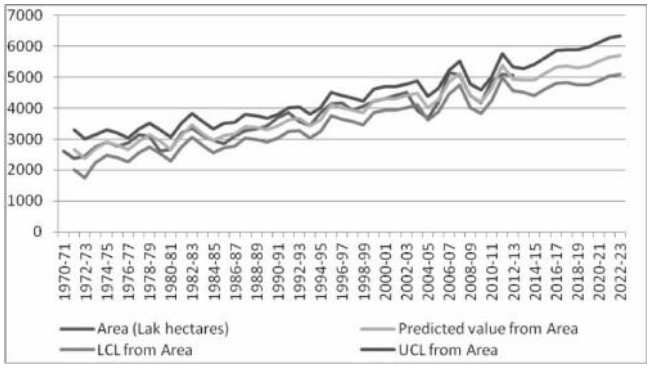

Fig 4. Actual and Estimate of Sugarcane Area

CONCLUSION

The income and employment potentiality of sugar industry in the Indian context is very significant. But it is facing serious fluctuations. "Anything can wait but not agriculture" (Nehru). It is the responsibility of the government to safeguard this industry by assisting technologically, economically, lawfully in the form of fixing remunerative cane price to encourage sugarcane cultivation, and fixing minimum administered prices to sugar which may give at least a nominal profit to the sugar industries. The government must encourage mixing of ethanol with petrol. All these steps make sugar mills more viable and they can pay a fair and remunerative price to the farming community. This may bring stability in both sugarcane and sugar production and miserable growth can be avoided. Saravanan and Parvathi (2010).

As already mentioned above the importance of sugarcane cultivation with some serious fluctuation and hence the study concludes that the total cropped area can be increased in future, even though there is a negative impact would be there in the year of 2018-2019. Hence, in that particular period the government will support to the sugarcane cultivators to increase the area of cultivation. The projection of ARIMA model shows that sugarcane will play a vital role to improve the sugar and by-products production in the coming period in the country. The analysis shows that the forecasting performance could be increased.

REFERENCES

Anbazhagan K. 2010. An Economic analysis of sugar production in Tamil Nadu. Kisan World, 37: 15.

Hari K, Reginold Jebitta S, Sivaraman K.2013. Production and characterization of Sugarcane juice powder, *Journal of Sugarcane Research*, 3(1) 20-34.

Patil VG.2009. Marketing analysis of sugarcane production in Shirpur Tahasil of Dhule District of Maharashtra, *Marketing*, 23-5.

Saravanan K and Parvathi S.2010. The Importance of Sugar Industries in India, Kisan world Vol.37 No.9 pp-38-9.

Shanmugam M ,S Paneerselvam and Manoharan.2011. Sugarcane juice and its health benefits, *Kisan World*, 39: 28.

Venkatraman A L.2008. Sugarcane Productivity, Kisan World, 39: 20-1.

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Relative effects of different organic amendments on *Trichoderma* communities in soils under a sugarcane plant-ratoon agro-ecosystem

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ABSTRACT

Trichoderma spp. are an important component of the agricultural soil microbial community. In the present study we investigated the effect of long term application of six different organic amendments (farmyard manure, vermicompost, sulphitation pressmud, biogas slurry, sugarcane trash & green manure *Sesbania aculeata*), recommended dose of NPK and a control on *Trichoderma* communities under a multi-ratooning organic sugarcane agro-ecosystem. Thirty four *Trichoderma* isolates were established from soil samples collected from different treatments during the 9th ratoon stage. The organic amendments exerted a variable impact on *Trichoderma* population in soils with long term amendment of green manure, sugarcane trash, vermicompost and FYM resulting in significant increase in *Trichoderma* population over control. The growth rates and colony characters of the isolates were assessed and an attempt was made to identify the isolates. *T. harzianum* was observed to be the dominant species (18 isolates). In general, recovery of *T. harzianum* was higher from organically amended soils than NPK and control soils indicating that long term organic soil application may result in selective proliferation of *T. harzianum*. The 34 isolates were assayed for chitinase and cellulase production. Chitinolytic activity was observed in eleven isolates and cellulolytic activity in five isolates. The type of organic amendment applied influenced the distribution of cellulase producing *Trichoderma* isolates which were recovered only from green manure and sugarcane trash applied soils. Two isolates (STr-83 and STr-108) showing high level of activity of both enzymes were identified.

Keywords: *Trichoderma*; Organic farming; Population dynamics; Chitinase; Cellulase

Trichoderma species are an important component of the soil microbial community especially in context of the agricultural eco-system. They are cosmopolitan in nature and can exist as free living soil fungi or as opportunistic avirulent plant symbionts (Harman *et al*. 2004). The importance of this fungus stems from the fact that many members of this genus act as effective antagonists of several plant pathogens in various crops and have also been credited with multifaceted potential like inducing resistance against abiotic and biotic stresses in plants, production of several hydrolytic enzymes and promotion of plant growth (Vinale *et al*. 2008, Harman 2004).

Sugarcane (*Saccharum officinarum*) is an important cash crop of India, cultivated in almost 5.06 hectares land area with an average productivity of 66 tonnes ha-1. It is a long duration, vegetatively propagated crop in which after harvesting of main crop, ratoon crops are taken in successive years. In general, a decline in yield of ratoon crops is observed over successive years and in recent years, organic farming has been explored to counter this problem, with promising results (Singh *et al*. 2007). Organic farming relies primarily on application of organic matter in form of crop residues, green manure or animal manures for meeting the nutritional demands of the crop. Additionally, these organic soil amendments exert a major impact on the soil microbial dynamics and biodiversity (O'Donnell *et al*. 2001). Previous studies have shown that the application of different types of organic amendments results in distinct variations in the soil microbial community structure (Liu and Ristaino 2003, O'Donnell *et al*. 2001). However, even though the long term effects of different organic amendments on total soil microbial biomass, microbial diversity, fluorescent pseudomonas etc. have been investigated previously (Liu and Ristaino 2003); reports on the response of *Trichoderma* communities to long term application of different organic amendments are scanty. Given the agro-ecological importance and multifaceted role of *Trichoderma* as a bioagent and growth promoter; an understanding of the changes in population and community structure of *Trichoderma* as influenced by long term organic matter application is essential to develop strategies for long term sustainable sugarcane production. Since morphology based approaches for characterization and variability studies of *Trichoderma* strains have not yielded conclusive results, sequencing based molecular tools are currently being employed for identification of *Trichoderma* species (Samuels 2006). However, these methods are quite costly and not easily accessible to all researchers and may not be a feasible option

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when dealing with large number of strains. Alternatively, in recent years, several workers have advocated the use of colony characters and growth rates at different temperatures as a low cost and effective method for preliminary identification and characterization of *Trichoderma* strains (Boureghda *et al*. 2008, Samuels *et al*. 2002). Potential to produce diverse hydrolytic enzymes, especially chitinases and cellulases (Vinale *et al*. 2008) has also been exploited by previous workers to study variability in *Trichoderma* populations (Gajera and Vakharia 2010).

Given the above aspects, the present study was undertaken with the objective to evaluate the long term impact of different organic amendments on the population and diversity of *Trichoderma* under an organic sugarcane plant-ratoon cropping system. Cultural and biochemical variability among *Trichoderma* isolates was studied and interactions, if any, with different amendments were assessed.

MATERIALS AND METHODS

Soil sampling

Soil samples were collected during the month of October 2013, from a long term field experiment initiated in 2003 at the research farm of Indian Institute of Sugarcane research, Lucknow, India located at 26°56¹ N, 80°52¹ E and 111 m above mean sea level. The soil of the experimental site is a sandy clay loam, non-calcareous mixed hyper-thermic *udic Ustochrept* (13.3% clay, 24.5% silt and 62.3% sand) of Indo-Gangetic alluvial origin. The experiment comprised of eight treatments viz. soil application of six organic amendment (vermicompost (VC), farmyard manure (FYM), biogas slurry (BS), sugarcane trash (ST), sulphitation press mud (SPM) and intercropped green manure (*Sesbania aculeata*) as well as recommended dose of NPK (150:60:60) and a control (no organic or inorganic fertilizer added). Sugarcane variety 'CoSe 92423' was planted in 2003 and subsequently ratoon crops were taken every year. Organic manures were applied each year @ 10 t ha^{-1} while the green manure *Sesbania* was grown as an intercrop and 2 tonnes of dry matter was added by turning at 45 days after sowing every year. For estimation of *Trichoderma* population, the soil samples were collected from each plot at a depth of 0-15 cm from 5 places during the 9th ratoon. Samples were mixed, bulked, air dried and stored at 4°C for further analysis.

Isolation and enumeration of Trichoderma

Isolation and enumeration of *Trichoderma* sp. from the soil samples was carried out following the soil dilution plate technique using Trichoderma specific medium (TSM) (Elad *et al*. 1981). Briefly, one gram of air dried soil sample was suspended in 9 ml sterile water, shaken well and serial dilutions of 10^{-2} to 10^{-4} were prepared. One ml of each dilution was added to sterile Petri plates and molten cooled TSM was poured in the plates with three replications for each dilution. The plates were incubated at 27±1°C for 7 days and the number of *Trichoderma* colonies appearing in each plate was recorded. Colonies with distinct appearance were isolated for further studies. The isolated strains were purified by single spore culturing and maintained on potato dextrose agar (PDA) slants for further studies. The cfu data on *Trichoderma* was converted to $\log_{10}$ transformed value and analysed statistically using Statistical Package for Social Scientists (SPSS) software (version 10.0) at $P < 0.05$. Mean comparisons were performed using the least significant difference test (LSD).

Characterization of Trichoderma isolates

The colony characters and growth rates of the *Trichoderma* isolates were determined on Potato dextrose agar (PDA) medium following the protocol of Samuels *et al*. (2002). Petri plates (90mm) containing PDA were inoculated, approximately 10 mm from the edge of the dish, with a mycelial disc (5 mm) of the isolate. Inoculated plates were incubated at different temperatures (25°C, 30°C, 35°C, 40°C) with five replications for each isolate at each temperature. The colonies were examined at 24 h intervals and colony radius measured from the edge of the inoculum plug after 72 h at all four temperatures. In colony characters, observations were recorded in cultures grown on PDA at 30°C for (i) formation of yellow conidia (ii) presence of diffusing pigment in agar and (iii) time of first appearance of green conidia. Based on the combined data of growth rates at different temperatures and colony characters of the isolates, an attempt was made to identify the species with the help of previous reports (Boureghda *et al*. 2008, Samuels *et al*. 2002).

Chitinolytic assay of Trichoderma isolates

Chitinolytic activity of the *Trichoderma* isolates was assessed using a chitinase detection medium (Agrawal and Kotasthane 2012). The chitinase detection medium contained (all amounts are per liter) 20 g of moist colloidal chitin, 0.3 gm of $MgSO_4$. $7H_2O$, 3.0 g of $(NH4)_2SO_4$,2.0 g KH_2PO_4, 1 g of citric acid monohydrate, 15 g agar, 0.15 g bromocresol purple and 200 ìl of tween-80. The pH of the medium was adjusted to 4.7 and it was autoclaved at 121° C for 15 min and poured into 90mm Petri plates after sterilization. Poured and solidified plates were inoculated in the centre with a 5 mm diameter plug of *Trichoderma* isolates cut from the edge of a 3-4 days old culture of *Trichoderma*. The inoculated plates were incubated at 27° C with 5 replications for each isolate. On inoculation with chitinase producing *Trichoderma* isolates, the breakdown of chitin into N-acetyl glucosamine occurs causing a shift in pH from acidic to alkaline with a corresponding change in colour of indicator dye (bromocresol purple) from yellow to purple. Inoculated plates were observed at 24 h intervals for formation of purple coloured zone. The diameter and intensity of the purple zone after 7 days was recorded and the isolates were categorized as (i) no chitinase activity (ii) low chitinase activity (iii) high chitinase activity.

Cellulase production by Trichoderma isolates

The *Trichoderma* isolates were further screened for their cellulase producing potential using the carboxymethyl cellulose plate assay (Bradner *et al*. 1999). A basal medium containing (g L^{-1}): carboxymethyl cellulose 10 g, $NaNO_3$ 6.5 g, K_2HPO_4 6.5 g, yeast extract 0.3 g, KCl 6.5 g, $MgSO_4 \cdot 7H_2O$ 3.0 g and agar 17.5 g, was prepared and sterilized by autoclaving at 121° C for 15 min and poured into 90 mm Petri plates after sterilization. Solidified plates were inoculated in the centre with a 5 mm disc of the *Trichoderma* isolates cut from the edge of a 3-4 day old culture. The inoculated plates were incubated for 7 days at 30°C and the growth of the isolates was measured as the diameter of the colony. A 10 mL aliquot of Congo red dye (1% solution) was then added to each plate. After 30-45 min, the solution was discarded and the cultures were de-stained by washing with 10mL of 1MNaCl for 15-20 min. Cellulase production was indicated by the appearance of a pale halo with orange edges, indicative of areas of hydrolysis. The diameter of the halo zone was measured and the enzymatic index (EI) was calculated as:

EI = diameter of hydrolysis zone/ diameter of colony

RESULTS AND DISCUSSION

Isolation and Enumeration of Trichoderma

The impact of long term application of different organic and synthetic amendments on population of *Trichoderma* under a multi-ratooning sugarcane cropping system was assessed. A total of 34 *Trichoderma* isolates were established from different treatments. The isolates were purified through single spore culture, designated as STr-80 to STr-116 and stored on PDA slants at 4°C for further studies (Table 1). It was observed that different organic amendments exerted considerably variable impact on population of *Trichoderma* in soil as evident by the significant differences observed in *Trichoderma* population across the different treatments. Overall the population ranged from 2.59 to 3.72 $\log_{10}$ cfu g^{-1} air dried soil among the treatments. We observed that application of green manure (*S. aculeata*) supported the highest population (3.72 $\log_{10}$ cfu g^{-1}) of *Trichoderma* in soil and it was significantly superior to all other amendments and control. This was followed by soils with sugarcane trash (3.26 $\log_{10}$ cfu g^{-1}), vermicompost (3.10$\log_{10}$ cfu g^{-1}) and FYM amendments which also showed significantly higher *Trichoderma* population in relation to control (Fig 1). However, *Trichoderma* population did not vary significantly among the remaining two organic

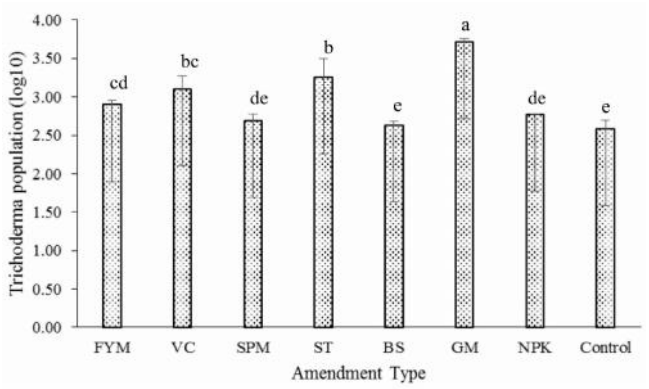

Fig 1. Population of *Trichoderma* in soils under different amendments. Population density expressed as $\log_{10}$ transformed values of colony forming units. Bars with same pattern and different letters denote significant differences ($P<0.05$). Values are means of three replications and error bars represent standard deviation. (FYM= farmyard manure, VC= vermicompost, SPM=sulphitation press mud, ST= sugarcane trash, BS= biogas slurry, GM= green manure)

Table 1 Source and species distribution of *Trichoderma* isolates established from soils under different organic amendments

Amendment type	*Trichoderma* Isolates established	Total *Trichoderma* isolates established (no.)	Isolates identified as Th*	Th isolates (no.)	Recovery of Th isolates (%)
FYM	STr-88, 103, 104, 105	4	STr-88, 103, 104, 105	4	100
Vermicompost	STr-80, 84, 90, 91, 116	5	STr-80, 91	2	40
SPM	STR-92, 93	2	STr-92, 93	2	100
Sugarcane trash	STr-81, 82, 83, 85	4	STr-81, 82, 85	3	60
Biogas Slurry	STr-113, 114, 115	3	STr-113	1	33.3
Green Manure	STr-94, 95, 96, 97, 98, 99, 100, 101, 108, 109, 110	11	STr-94, 95, 96, 98, 108	5	45.5
NPK	STr-102, 107, 111, 112	4	STr-107	1	25
Control	STr-89	1	-	-	-

*Th= *T. harzianum*

amendments (SPM & biogas slurry), NPK and control soils. Previous studies have documented the widely varying effects of different organic amendments on soil microbial diversity, total microbial biomass, bacterial population etc. (Liu and Ristaino 2003, Liu *et al*. 2008). However, there are very few and generally contrasting reports on impact of organic amendments on population of *Trichoderma*. While Bulluck *et al*. (2002) had reported that organically managed soils (amended with cotton gin trash, yard waste or cattle manure) tended to have higher population of *Trichoderma* as compared to conventionally managed soils; Liu *et al*. (2008) observed higher population in soils from conventionally managed fields than organic fields. Our results also revealed that while soils with green manure, sugarcane trash, vermicompost and FYM application had significantly higher population of *Trichoderma* compared to control and NPK applied soils; the population in SPM & biogas slurry applied soils did not vary significantly in relation to NPK and control soils. These findings imply that changes in *Trichoderma* population in relation to organic matter application, are largely governed by the nature and type of organic matter applied and even though all organic amendments may result in increased total soil biodiversity and biomass they may not necessarily impact population of *Trichoderma*.

Characterization of Trichoderma Isolates

In growth rate studies, the results did not reveal considerable difference in growth rates among isolates at 25°C and 30°C. At both these temperatures, majority of the isolates exhibited good growth of >50 mm after 72 h on PDA (Table 2). For most isolates, growth was similar or higher at 30°C as compared to 25°C with only eight isolates showing a slight decline in growth with increase in temperature from 25°C to 30°C. However, growth of all isolates declined considerably at 35°C and they failed to grow at 40°C, with the exception of isolate STr-83 which exhibited growth of 75.0 mm at 35°C and 39.3 mm at 40°C. Among the remaining 33 isolates, at 35°C, highest growth recorded was 47.3 mm (STr-94) after 72 h on PDA. At this temperature three isolates exhibited growth of >40 mm, 11 in range of 30-39.9 mm, six between 20-29.9 mm, nine isolates less than 20 mm while four isolates did not grow at all. It was observed that the optimum growth temperature was in the range of 25-30°C for 33 isolates and between 30-35°C for STr-83 (Table 2).

In colony characters, diffusing pigment in agar was observed in 25 out of the 34 isolates (Table 3). The colour of the diffusing pigment varied from bright fluorescent yellow in case of STr-83 to varying shades of dull yellow, orange or brown among the remaining isolates. In 19 of the 34 isolates, formation of yellow conidia was observed with conidial colour change occurring from initial white to yellow to green conidia (Table 3). In majority of the isolates (26 no.) green conidia were observed within 72 h after incubation in cultures grown on PDA at 30°C while in six isolates green conidia were observed between 72-96 h and at > 96 h in two isolates (Table 3).

Colony characters and growth rates of isolates, especially at 35°C and 40°C, have been successfully used by several workers to distinguish between species of *Trichoderma* (Boureghda *et al*. 2008, Samuels *et al*. 2002). Growth between 20 to 35 mm at 35°C on PDA after 72 h is reported in only a few species of *Trichoderma* which includes the biocontrol species *T. harzianum*, *T. virens* and *T. asperellum* while 35-55 mm growth at 35°C is observed only in *T. harzianum* and the species belonging to section *longibrachiatum*. The production of yellow/ orange diffusing pigment in media along with >20

Table 2 Growth of 34 *Trichoderma* isolates at different temperatures after 72 h on PDA

Growth after 72 h on PDA	Isolate No.			
	25^0C	30^0C	35^0C	40^0C
> 60 mm	STr-80, 82, 83, 85, 88, 91, 94, 99, 107, 114, 116	STr-80, 82, 83, 85, 88, 91, 94, 95, 96, 98, 107, 110, 115, 116	STr-83	----
50-59.9 mm	STr- 81, 84, 93, 95, 96, 98, 100, 103, 104, 105, 108, 109, 110, 112, 113, 115	STr-89, 93, 97, 99, 103, 104, 105, 108, 113, 114	----	----
40-49.9 mm	STr- 89, 90, 92, 97, 101	STr-81, 84, 90, 92, 100, 101, 109, 112	STr-91, 93, 94	----
30-39.9 mm	STr-102, 111	STr-102	STr-80, 82, 85, 88, 92, 95, 96, 97, 103, 107, 108	STr-83
20-29.9 mm	----	STr-111	STr-81, 90, 98, 104, 105, 113	----
0.1 to <20mm	----	----	STr-84, 89, 100, 101, 102, 111, 114, 115, 116	----
No growth	----	----	STr-99, 109, 110, 112	Remaining 33 isolates

Table 3 Colony characters of 34 *Trichoderma* isolates on PDA at 30°C

Character	No. of isolates	Isolates
Diffusing pigment in agar:	25	STr-80, 81, 82, 83, 85, 88, 91, 92, 93, 94, 95, 96, 98, 102, 103,104,105, 107, 108, 110, 111, 112, 113, 114, 116
Presence of yellow conidia	19	STr-80, 81, 82, 83, 85, 88, 92, 93, 94, 95, 96, 98, 102, 103, 107, 108, 111, 112, 113
Time for first appearance of green conidia:		
• *48-72 h*	26	STr-80, 81, 82, 83, 85, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 101, 103, 104, 105, 107, 108, 113, 115, 116
• *72-96 h*	6	STr-100, 109, 110, 111, 112, 114
• *> 96 h*	2	STr-84, 102

mm growth at 35°C is observed only in *T. harzianum* and *T. virens* strains while formation of yellow conidia is generally restricted to strains of *T. harzianum* alone. Bright yellow pigmentation in media and the ability to grow at 40°C is restricted to strains belonging to species grouped under section *longibrachiatum* (Boureghda *et al*. 2008, Samuels *et al*. 2002). Using the data on colony characters and growth rates of the 34 isolates in our study, we tentatively identified 18 *Trichoderma* isolates showing growth of >20 mm at 35°C along with production of yellow/orange diffusing pigment in agar and yellow conidia as *T. harzianum* (Table 1). Similarly, isolate STr-83 (produced bright yellow pigment, >55 mm growth at 35°C and was able to grow at 40°C) was grouped under section *longibrachiatum*.

It is evident from the results that *T. harzianum* was the major *Trichoderma* species recovered (18 out of 34 isolates) from soils (Table 1). The high recovery of *T. harzianum* from soils, especially in warmer climates, has been reported previously (Kubicek *et al*. 2003). We also observed that the recovery percent of *T. harzianum* was generally higher from organically amended soils (33%-100% of total *Trichoderma* isolates established) than NPK applied and control soils (Table 1). In particular, *T. harzianum* population in soils amended with FYM, VC and sugarcane trash accounted for 60-100% of the total isolates established. These findings indicate that application of organic amendments may favour selective proliferation of *T. harzianum* as compared to other *Trichoderma* species. *T. harzianum* is one of the most explored and commercialized species of *Trichoderma*, mainly due to its multifaceted activities which includes biological control of several pathogen and growth promotion (Harman *et al*. 2004, Vinale *et al.* 2008). Previous studies on application of different organic amendments in a sugarcane plant-ratoon cropping system had reported higher plant and ratoon cane yield in organically amended soils than control soils (Singh *et al*. 2007). Given the multi-faceted potential of *T. harzianum*, enhanced population of this species under organically amended soils may be a factor contributing towards the improvement in yield.

Chitinolytic Assay of Trichoderma Isolates

The chitinase producing potential varied considerably among the *Trichoderma* isolates with only 11 out of the 34 isolates showing chitinase production (Table 4). Even amongst these 11 isolates, the diameter of the purple zone ranged from

Table 4 Chitinase and Cellulase production by *Trichoderma* isolates.

Organic amendment	Chitinase Production				Cellulase Production	
	Isolate No.	Activity	Purple Zone Diameter (mm)[a]	Colour Intensity	Activity	EI[b]
Farmyard manure	STr-88	Low	14.2	Light purple	Nil	-
	STr-105	Low	25.0	Light purple	Nil	-
Vermicompost	STr-91	Low	11.4	Light purple	Nil	-
	STr-116	Low	15.6	Light purple	Nil	-
Pressmud	STr-92	High	72.6	Dark purple	Nil	-
Sugarcane trash	STr-81	Nil	-	-	Present	1.69
	STr-83	High	89.4	Dark purple	Present	1.80
	STr-85	Low	56.0	Light purple	Present	1.54
Biogas slurry	STr-114	High	72.2	Dark purple	Nil	-
Green Manure	STr-96	High	88.6	Dark purple	Present	1.14
	STr-108	High	88.8	Dark purple	Present	1.91
NPK	STr-111	Low	53.0	Light Purple	Nil	-

[a]Values are mean of 5 replications; [b]Enzymatic Index

11.4 mm (STr-91) to 89.4 mm (STr-83) after 7 days incubation. The five isolates (STr-83, 92, 96, 108 & 114) which gave a rapid response, as evident by the formation of a dark purple zone of >70 mm diameter within 7 days of incubation, were grouped under high chitinase activity group. Six isolates (STr-85, 88, 91, 105, 111 & 116) showed low activity with formation of light purple zone of diameter <56 mm at 7 days while remaining 23 isolates in which no colour change was observed, were categorized under no chitinase activity group. Our results are in accordance with previous studies reporting that the chitinase producing potential of *Trichoderma* varies considerably among different strains (Agrawal and Kotasthane 2012, Gajeria and Vakharia 2010). Among the 11 chitinase producing isolates, seven belonged to *T. harzianum* and one to sect. *longibrachiatum* (STr-83). There was no relation between the type of organic amendment applied and recovery of chitinase producing isolates, with representative isolates from all six organic amendments comprised of both chitinase producing as well as non-producing strains. The production of chitinase enzyme is attributed to be a major factor determining the mycoparasitic activity and biocontrol potential of *Trichoderma* strains, and in case of sugarcane, previous studies have reported the involvement of *Trichoderma* chitinolytic enzymes in the suppression of *Colletotrichum falcatum* Went, the causal agent of red rot disease of sugarcane (Viswanathan *et al*. 2003).

Cellulolytic activity of Trichoderma Isolates

Among the 34 *Trichoderma* isolates screened for cellulolytic activity, formation of halo zone, indicating CMC degradation, was observed in only five isolates (Table 4). The EI of the five cellulase producing isolates varied from 1.14 (STr-96) to 1.91 (STr-108). With the exception of STr-83, which had been identified as a member of sect. *longibrachiatum*, the remaining four cellulase producing isolates belonged to *T. harzianum*. Interestingly, all five cellulase producing strains were isolated from two treatments only *viz*., green manure (two isolates) and sugarcane trash amendments (three isolates). Strains of *T. harzianum* as well as the species *T. reesei* and *T. longibrachiatum* which belong to sect. *longibrachiatum* are reported to be highly effective cellulase producing microbes (Benoliel *et al*. 2013). The recovery of cellulase producing *Trichoderma* isolates only from sugarcane trash (3 isolates) and green manure (2 isolates) incorporated soils may be due to the fact that, in contrast to FYM, VC, BS and SPM treatments; both sugarcane trash and green manure serve as a rich source of cellulose and their repeated soil application over several years may have favoured selective proliferation of cellulolytic *Trichoderma* isolates resulting in recovery of cellulase producers from these soils. Apart from various industrial applications, microbes with cellulolytic activity play an important role in the ecosystem by recycling cellulose. Sugarcane, in particular, produces large quantities of dry leaves (trash) annually. In studies carried out by Yadav *et al*. (2009) it was reported that trash mulching along with inoculation of a biocontrol strain of *T. viride* in sugarcane ratoon crop was more effective than trash mulching alone in increasing soil organic matter and nutrient status. However, it can be expected that the use of *Trichoderma* strains with already established high cellulase producing potential, as identified in our study, in place of a biocontrol strain may result in even higher levels of trash degradation and improved soil health.

CONCLUSION

Overall, the findings suggest that changes in *Trichoderma* population in response to long term organic matter application is largely governed by the nature and type of organic matter applied. We found green manure (*S. aculeata*) application most conducive for proliferation of *Trichoderma* while SPM and BS did not have any impact on total *Trichoderma* population. Distribution of strains having different enzymatic potential was also influenced by the type of organic matter applied especially in case of cellulase producing strains which were restricted only to the soils receiving repeated cellulose based organic matter. However, within the existing *Trichoderma* population, long term application of all six organic amendments resulted in selective proliferation of *T. harzianum*. Four *Trichoderma* isolates (STr-83, 85, 96 & 108) showed production of both chitinase and cellulase enzymes in the plate assays with isolates STr-83 and STr-108 showing high level of activity of both these enzymes. These isolates can be explored further for their application in biocontrol of sugarcane diseases and trash recycling.

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REFERENCES

Agrawal T and Kotasthane A S. 2012. Chitinolytic assay of indigenous *Trichoderma* isolates collected from different geographical locations of Chattisgarh in central India. *Springer Plus* **1**: 73.

Benoliel B, Torres F A G, de Moraes L M P. 2013. A novel promising *Trichoderma harzianum* strain for the production of a cellulolytic complex using sugarcane bagasse in natura. *Springer Plus* **2**: 656 doi:10.1186/2193-1801-2-656.

Boureghda H, Bouznad Z and Decock C. 2008. Cultural and Molecular characterizations of some isolates of *Trichoderma* spp. *Arab Journal of Plant Protection* **26**: 75-80.

Bradner J R, Gillings M and Nevalainen K M H. 1999. Qualitative assessment of hydrolytic activities in Antarctic microfungi grown at diûerent temperatures on solid media. *World Journal of Microbiology and Biotechnology* **15**: 131–32.

Bulluck L R, Brosius M, Evanylo G K and Ristaino J B. 2002. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology* **19**: 147–60.

Elad Y, Chet I and Henis Y. 1981. A selective medium for improving quantitative isolation of *Trichoderma* species from soil. *Phytopathology* **9**: 59-7

Gajera H P and Vakharia D N. 2010. Molecular and biochemical characterization of *Trichoderma* isolates inhibiting a phytopathogenic fungi *Aspergillus niger* Van Tieghem. *Physiological and Molecular Plant Pathology* **74**: 274-82.

Harman G E, Howell C R, Viterbo A, Chet I and Lorito M. 2004. Trichoderma species—opportunistic, avirulent plant symbionts. *Nature Reviews Microbiology* **2**: 43–56.

Kubicek C P, Bisset J, Druzhinia I, Kullnig-Gradinger C M and Szakacs G. 2003. Genetic and metabolic diversity of *Trichoderma*: a case study on South East Asian isolates. *Fungal Genetics and Biology* **38**: 310-19.

Liu B, Glenn D and Buckley K. 2008. *Trichoderma* communities in soils from organic, sustainable and conventional farms and their relation with southern blight of tomato. *Soil Biology and Biochemistry* **40**: 1124-36.

Liu B and Ristaino J B. 2003. Microbial community structure in soils from organic and conventional agro-ecosystems. *Phytopathology* **96**: S53.

O'Donnell A G, Seasman S, Macrae A, Waite I and Davies J T. 2001. Plants and fertilizers as drivers of change in microbial community structure. *Plant and Soil* **232**: 135-45.

Samuels G J. 2006. *Trichoderma*: Systematics, the sexual stage and ecology. *Phytopathology* **96**: 196-206.

Samuels G J, Dodd S L, Gams W, Castlebury L A and Petrini O. 2002. *Trichoderma* species associated with the green mold epidemic of commercially grown *Agaricus bisporus*. *Mycologia* **94**:146-70.

Singh K P, Suman A, Singh P N and Lal M. 2007. Yield and soil nutrient balance of a sugarcane plant-ratoon system with conventional and organic nutrient management in sub-tropical India. *Nutrient Cycling Agroecosystems* **79**: 209-19.

Vinale F, Sivasithamparam K, Ghisalberti E L, Marra R, Woo S L and Lorito M. 2008. *Trichoderma*-plant –pathogen interactions. *Soil Biology and Biochemistry* **40**: 1-10.

Viswanathan R, Ramesh Sundar A and Premkumari S M. 2003. Mycolytic effects of extracellular enzymes of antagonistic microbes to *Colletotrichum falcatum*, red rot pathogen of sugarcane. *World Journal of Microbiology and Biotechnology* **19**: 953-59.

Yadav R L, Shukla S K, Suman A and Singh P N. 2009 *Trichoderma* inoculation and trash management effects on soil microbial biomass, soil respiration, nutrient uptake and yield of ratoon sugarcane under subtropiccal conditions. *Biology and Fertililty of Soils* **45**: 461-68.

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Site-specific nutrients management for targeted yield in sugarcane

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ABSTRACT

A field experiment on site-specific nutrient management for targeted yield in sugarcane was conducted after buffering the nutrient heterogeneity of experimental site after harvest of uniformity trial. Outcome of the experiment revealed that the grids with same available nitrogen (173.6 kg N/ha) grid 38 and grid 54 recorded 53.5 t/ha and 97.0 t/ha respectively and grid 39 and grid 59 though have almost same nitrogen content but produced a yield with a massive difference of 41.6 t/ha and 163.8 t/ha respectively. Thus, the concept again revealed that the inherent fertility of the soil i.e., organic fraction of the soil in proper proportion with inorganic fraction helps to restore the native fertility and keeps the available nutrients in their higher range and the system keeps fit itself to respond and utilize the externally applied sources of nutrients for crop uptake. Hence, soils being living and dynamic in nature they tend to change with the time. Therefore, well manured and managed soils do have high amounts of available nutrients and little application of external source of nutrients helps to overcome the variations that exists within the field and yields uniformly in the long run.

Key words: SSNM, Sugarcane, Target yield, Nutrients

Indian sugar industry is under mounting pressure to minimize off-farm losses of nutrients and reduce its overall costs of production. Site specific management of production zones within field on cluster basis coupled with target yield approach may further enhance the nutrient use efficiency and helps to sustain yield level of crops on the whole field basis.

It sometimes look tedious to work out the fertilizers for each zone / cluster zones but helps to save lot of fertilizers by avoiding over application in areas where the nutrient availability suffices the crop demand and suggests to apply the nutrients as per the crop demand to get uniform yields over the field.

Thus, the concept of nutrient management on target yield basis helps to re-distribute the fertilizer application within the field on zonal basis and there by avoids/eliminates the possibility under or over application of fertilizers besides saving. Johnson *et al*. (2003) are of the opinion that site-specific management (SSM) can potentially improve both economic and ecological outcome in agriculture. Effective SSM requires strong and temporally consistent relationships among identified management zones; underlying soil physical, chemical and biological parameters and crop yields. With the intension to test the potentiality of sugarcane to targeted feeding of nutrients present investigation was taken up.

MATERIAL AND METHODS

The experiment was conducted in research farm of NSSK, Krishna Nagar, the experimental area consist of one acre area and was divided into 30 equal sized grids of 10 m x 10 m size. Ridges and furrows were opened at 120 cm apart, soil samples were drawn and planting of sugarcane with two eye budded setts. As a buffer crop to minimize inherent nutrient heterogeneity a common crop of sugarcane was grown without application of any fertilizers and organic manures. Periodic observations on growth and yield parameters were recorded. The crop was harvested and subsequently the cultural operations were carried out to raise a good ratoon crop, for the ratoon crop treatment plot was applied with basal applications at 5t/ha vermicompost to each plot and entire quantity of phosphorus through single super phosphate as per the target yield requirement for each plot was calculated and applied. Nitrogen and potassium requirement for each plot was calculated and the quantity to be applied for each plot was divided into 6 equal parts and was applied at monthly intervals from 90 days after ratooning upto 240 days after ratooning. Crop was raised under standard crop husbandry practices by varying only the quantity of fertilizer nutrients. The fertilizers were applied on the basis of nutrient requirement of the crop based on target yield (250 t/ha). The fertilizers required for each plot was calculated using the formulae based on the soil available nutrient status.

$$FD = NR/CF \times 100 \times T - CS / CF \times STV$$

where,

FD = Fertilizer N or P_2O_5 or K_2O (kg/ha)

NR = Nutrient requirement of N or P_2O_5 or K_2O (kg/t)

CF = Contribution from fertilizers N or P_2O_5 or K_2O (%)

CS = Contribution from soil N or P_2O_5 or K_2O (%)

STV = Soil test value of N or P x 2.29 or K x 1.21 (kg/ha).

Total uptake of nutrients in treated plot (kg/ha)

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$$NR = \frac{\text{Total uptake of nutrients in treated plot } (kg/ha)}{\text{Economic Yield } (q/ha)}$$

$$\%CS = \frac{\text{Total uptake in control plot}}{\text{STV for control plot}} \times 100$$

$$\%CF = \frac{(\text{Total uptake in treated plot}) - (\text{STV of soil})}{\text{Fertilizer dose applied}} \times 100$$

$$\text{Nutrient supplied through soil } (NSS) = STV \times \frac{CS}{100}$$

Table 1 Correlation of yield with initial available soil nutrients status for site Specific nutrients management (SSNM) and target yield in ratoon crop

	Initial soil nutrient status (kg/ha) Vs. Yield (t/ha)				
Plots	Yield (t/ha)	N	P_2O_5	K_2O	OC (%)
31	83.2	207.2	18.3	383.6	0.60
32	75.2	184.8	55.0	341.6	0.72
33	61.4	190.4	36.6	308.0	0.42
34	49.5	218.4	45.8	330.4	0.66
35	75.2	190.4	49.5	322.0	1.20
36	110.9	201.6	27.5	366.8	1.10
37	118.8	179.2	33.0	358.4	0.69
38	53.5	173.6	36.6	344.4	0.39
39	41.6	190.4	55.0	333.2	0.96
40	44.1	184.8	58.6	305.2	0.54
41	53.5	179.2	51.3	322.0	0.45
42	103.0	190.4	33.0	324.8	0.45
43	95.0	196.0	31.1	336.0	0.36
44	77.2	201.6	38.5	366.8	0.84
45	81.2	218.4	45.8	375.2	0.30
46	73.3	212.8	55.0	361.2	1.32
47	87.1	207.2	51.3	361.2	1.20
48	95.0	190.4	56.8	372.4	1.05
49	77.7	207.2	53.1	366.8	1.32
50	79.2	212.8	55.0	358.4	1.32
51	87.1	201.6	49.5	364.0	1.77
52	59.4	190.4	34.8	355.6	1.02
53	79.2	184.8	33.0	330.4	1.50
54	97.0	173.6	44.0	322.0	1.14
55	93.1	190.4	47.6	302.4	1.41
56	67.3	196.0	56.8	336.0	1.26
57	95.0	212.8	55.0	364.0	1.44
58	103.0	201.6	36.6	296.8	1.08
59	163.8	196.0	45.8	361.2	1.56
60	81.2	184.8	51.3	366.8	1.44
SD (σ)	24.77	12.65	10.50	24.11	0.42
Correlation (r values)		0.06	-0.27	0.26	0.34
SEm±	4.52	2.31	1.92	4.40	0.08

Observation on various growth and yield, quality parameters of sugarcane was made as per the standard methodology and Spectral reflectance of the crop canopy was measured with the help of hand held multi band Spectro-radiometer (Optomech Engineers Pvt. Ltd. Model 041) and NDVI was calculated by following formula.

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where,

NIR and R are the reflectance in the Near Infrared and Red regions, respectively.

RESULTS AND DISCUSSION

Soil available phosphorus and potassium were in their highest available range, as a result the external application of

Table 2 Correlation of yield with nitrogen, phosphorus and potassium uptake by the crop for SSNM and target yield in ratoon crop

	Nutrient uptake (kg/ha) Vs. Yield (t/ha)			
Plots	Yield	N	P	K
31	83.2	589	8.8	465
32	75.2	569	7.9	438
33	61.4	552	7.2	440
34	49.5	463	6.8	412
35	75.2	572	8.2	449
36	110.9	610	10.3	495
37	118.8	635	12.2	624
38	53.5	480	7.3	433
39	41.6	450	6.8	422
40	44.1	480	7.4	425
41	53.5	492	7.8	428
42	103.0	596	9.8	500
43	95.0	589	8.9	488
44	77.2	582	8.2	446
45	81.2	595	9.6	486
46	73.3	570	7.6	435
47	87.1	585	10.2	489
48	95.0	600	11.6	598
49	77.7	590	8.8	463
50	79.2	586	10.0	453
51	87.1	580	9.6	500
52	59.4	546	7.8	460
53	79.2	575	9.6	449
54	97.0	590	9.6	545
55	93.1	583	8.8	532
56	67.3	563	8.2	481
57	95.0	588	8.9	549
58	103.0	605	10.6	512
59	163.8	665	13.3	648
60	81.2	583	8.8	500
SD (σ)	24.77	49.22	1.56	59.40
Correlation (r values)		0.89	0.90	0.86
SEm±	4.52	8.99	0.29	10.85

Table 3 Correlation of yield with NDVI values for site specific nutrients management (SSNM) and target yield in ratoon crop

Plots	Yield (t/ha) Vs. NDVI					
	Yield (t/ha)	6 month	8 month	10 month	12 month	At harvest
31	83.2	0.33	0.35	0.32	0.32	0.32
32	75.2	0.27	0.30	0.22	0.19	0.21
33	61.4	0.27	0.28	0.38	0.31	0.38
34	49.5	0.31	0.33	0.35	0.31	0.33
35	75.2	0.30	0.33	0.33	0.30	0.32
36	110.9	0.33	0.32	0.28	0.26	0.25
37	118.8	0.36	0.38	0.38	0.30	0.24
38	53.5	0.27	0.31	0.36	0.30	0.32
39	41.6	0.36	0.37	0.39	0.32	0.32
40	44.1	0.42	0.38	0.38	0.33	0.33
41	53.5	0.25	0.32	0.35	0.30	0.29
42	103.0	0.27	0.35	0.50	0.43	0.36
43	95.0	0.39	0.35	0.34	0.33	0.33
44	77.2	0.35	0.36	0.36	0.35	0.35
45	81.2	0.42	0.38	0.28	0.28	0.28
46	73.3	0.33	0.36	0.36	0.33	0.30
47	87.1	0.31	0.34	0.35	0.30	0.29
48	95.0	0.33	0.35	0.35	0.30	0.25
49	77.7	0.38	0.33	0.29	0.29	0.29
50	79.2	0.38	0.37	0.36	0.34	0.33
51	87.1	0.37	0.37	0.36	0.36	0.35
52	59.4	0.39	0.37	0.36	0.31	0.25
53	79.2	0.42	0.40	0.36	0.31	0.28
54	97.0	0.33	0.35	0.35	0.31	0.31
55	93.1	0.36	0.35	0.31	0.28	0.26
56	67.3	0.28	0.30	0.33	0.33	0.33
57	95.0	0.33	0.34	0.36	0.35	0.35
58	103.0	0.30	0.33	0.35	0.32	0.32
59	163.8	0.28	0.30	0.24	0.24	0.24
60	81.2	0.35	0.36	0.42	0.36	0.29
SD (σ)	24.77	0.05	0.03	0.05	0.04	0.04
Correlation (r values)		-0.09	-0.08	-0.26	-0.16	-0.35
SEm±	4.52	0.01	0.01	0.01	0.01	0.01

these nutrients to match the target yields did not influence much on the yield and indicates that these nutrients are to be essentially added to the soils to maintain their available form in higher availability range. Data on initial soil assessment for nutrient status indicated that initial soil nutrients status of the grids before ratoon crop showed wide range of variations with available nitrogen (173.6 – 218.4) 44.8 kg/ha, phosphorus (18.3 – 58.6) 40.3 kg P_2O_5 /ha and potassium with a variability range of (296.8 – 383.6) 86.8 kg K_2O/ha. The grids also showed deviation of nutrients distribution. The highest deviation was recorded in potassium (σ = 24.11) followed by nitrogen (σ = 12.65) and the lowest deviation was recorded in phosphorus distribution (σ = 10.50). The grids recorded cane yields as low as 41.6 t/ha to as high as 163.8 t ha^{-1} with a range of 122.2 t/ha. The deviation of cane yield (σ = 24.77) was noticed among the grids. The grids recording higher cane yields also recorded higher nutrients uptake, similarly the grids recording low cane yields recorded lower nutrients uptake. The highest standard deviation was recorded with potassium uptake (σ = 59.40) followed by nitrogen uptake (σ = 49.22). SPAD readings recorded at different intervals of crop growth period had positive correlation to yield at 10 and 12 months and at harvest, whereas, negative correlation was recorded at 6 and 8 month crop. The grids recorded highest standard deviation (σ = 4.40) at harvest and the lowest was recorded at 10 month (σ = 2.64). Crop yield was positively correlated to all the growth and yield parameters except for cane girth (-0.04). Number of tillers per millable canes was strongly correlated with age of the crop (0.62 at 150 days to 0.78 at harvest). The lowest positive correlation with yield of 0.14 was recorded in weight of five canes. The phosphorus uptake had lowest deviation with value σ = 1.56.

The range of phosphorus and potassium availability when compared before and after the uniformity trial, the nutrients

Table 4 Correlation of yield with SPAD readings for SSNM and target yield in ratoon crop

Plots	Yield (t/ha) Vs. SPAD values					
	Yield (t/ha)	6 month	8 month	10 month	12 month	At harvest
31	83.2	35.3	37.4	36.8	34.3	32.7
32	75.2	35.8	38.1	35.5	34.6	31.4
33	61.4	33.9	36.4	33.2	29.9	26.5
34	49.5	36.6	38.8	37.9	36.8	30.6
35	75.2	30.8	31.9	34.6	31.6	25.9
36	110.9	34.7	36.8	36.9	33.6	33.3
37	118.8	36.6	36.9	35.9	35.8	33.4
38	53.5	32.2	33.8	34.6	30.9	26.3
39	41.6	31.6	36.6	35.8	34.9	31.3
40	44.1	30.3	33.6	36.1	30.8	26.4
41	53.5	34.8	35.9	34.9	34.6	31.9
42	103.0	33.9	40.6	42.0	39.9	37.3
43	95.0	35.6	37.9	37.6	34.3	31.3
44	77.2	30.0	34.9	39.9	39.6	37.0
45	81.2	32.3	33.2	34.0	33.9	32.6
46	73.3	30.9	33.0	34.6	33.8	31.5
47	87.1	31.8	32.9	32.8	32.9	32.9
48	95.0	31.3	36.3	38.9	35.8	31.3
49	77.7	30.8	33.6	36.3	33.8	30.2
50	79.2	38.0	38.0	42.6	41.8	40.1
51	87.1	36.5	38.5	38.3	38.5	38.5
52	59.4	30.0	36.0	32.8	28.9	25.0
53	79.2	29.9	30.3	34.6	32.9	27.8
54	97.0	30.0	34.6	34.1	33.8	29.5
55	93.1	30.4	34.4	33.9	33.2	30.4
56	67.3	32.3	33.2	38.6	36.5	36.3
57	95.0	36.3	37.5	38.9	37.8	35.0
58	103.0	28.8	30.9	33.4	33.6	27.1
59	163.8	28.9	30.6	33.8	32.8	23.2
60	81.2	25.6	30.6	32.8	28.9	22.9
SD (σ)	24.77	2.98	2.75	2.64	3.11	4.40
Correlation (r values)		-0.05	-0.12	0.03	0.16	0.02
SEm±	4.52	0.54	0.50	0.48	0.57	0.80

availability range reduced to 5 kg phosphorus and 100 kg potassium per hectare from the grids. Hence, external source of varied application was found to be essential to maintain the soil fertility uniformly to get uniform yields. Nitrogen on the other hand being highly mobile element, the range of available nitrogen before uniformity trial (105 kg /ha) was reduced to 44.8 kg/haafter the uniformity trial indicated that initial higher available nutrient status can contribute considerably to the crop growth and development. Hence, fertilization based on target yield approach is of vital importance in maintaining the uniform soil fertility with saving in fertilizer cost and sustained yields through management of better agronomic practices like timely planting, maintaining plant population etc it confirms the results of Bundy and Andraski (2004).

The grids with same available nitrogen (173.6 kg N/ha) grid 38 and grid 54 recorded 53.5 t/ha and 97.0 t/ha respectively and grid 39 and grid 59 though have almost same nitrogen content but produced a yield with a massive difference of 41.6 t/ha and 163.8 t/ha respectively. Although in these two cases nitrogen from external source (urea) applied was same but the yield difference was due to the variation in growth and yield components like number of clumps, number of tillers and number of millable canes, cane weight, cane girth, higher the number. Higher is the yield under similar fertility conditions. The results of Michael Flowers *et al.* (2004) also confirm these findings.

Quality parameters were positively correlated to yield except for juice per cent (-0.07) and CCS (-0.01) which were negatively correlated. However, the strong positive correlation among quality parameters tested was recorded with purity of juice (0.16). The standard deviation values for quality parameters varied in the range of 0.31 (recovery %) to 2.88 (juice %).

Table 5 Correlation of yield with growth and yield attributes for SSNM and target yield in ratoon crop

Plots	Yield (t/ha) Vs. Growth and Yield Parameters							
	Yield (t/ha)	Clumps	Tillers at 150 days	NMC at 180 days	NMC at 240 days	NMC at harvest	Girth (mm)	Wt. of 5 canes (kg)
31	83.2	15207	109946	97850	90250	86655	22.38	5.57
32	75.2	12916	77496	74396	72300	70688	22.48	5.39
33	61.4	12916	89378	85800	80455	77385	21.24	4.98
34	49.5	12499	67744	66390	64648	60738	27.32	6.12
35	75.2	13124	112866	101579	97600	94395	22.16	4.02
36	110.9	15624	124992	109990	105750	103755	24.38	6.25
37	118.8	14791	138739	124865	115855	113856	23.14	4.77
38	53.5	10208	66760	64757	62600	60398	22.96	3.30
39	41.6	11458	72300	65795	63735	60635	24.25	3.27
40	44.1	9374	53900	52850	50650	49968	26.53	4.45
41	53.5	13124	88849	82630	74608	70608	25.48	4.03
42	103.0	15624	135772	119480	115295	110299	22.61	3.81
43	95.0	15624	130929	115225	110635	108453	27.91	7.10
44	77.2	15624	141709	123285	95435	93455	26.79	6.53
45	81.2	14374	121604	108300	96336	96633	29.42	7.42
46	73.3	12500	81750	76845	74395	73954	28.55	7.28
47	87.1	14374	114992	102342	95380	93850	25.82	5.65
48	95.0	14374	123185	105959	102645	100546	25.24	4.40
49	77.7	16249	144941	121750	111475	104175	31.15	8.69
50	79.2	13749	105730	94099	86295	85926	28.73	7.11
51	87.1	15624	128273	111650	96178	92768	27.66	6.99
52	59.4	14582	100907	92835	86954	84965	29.69	7.93
53	79.2	13957	103002	95795	93903	90933	26.38	6.53
54	97.0	14037	112835	100423	97455	95745	24.08	5.22
55	93.1	16041	179341	126955	110955	105951	25.40	5.84
56	67.3	18957	120945	110450	98465	94865	28.51	6.65
57	95.0	16874	121661	110850	104860	100486	28.31	7.11
58	103.0	18540	140533	123755	116455	110655	25.27	5.82
59	163.8	16041	122553	109215	106210	105900	26.8	5.71
60	81.2	16041	143085	123610	112553	105253	25.18	5.80
SD (σ)	24.77	3390.21	28293.96	20612.48	17945.46	17291.05	2.56	1.38
Correlation (r values)		**0.27**	**0.62**	**0.67**	**0.75**	**0.78**	**-0.04**	**0.14**
SEm±	4.52	618.96	5165.75	3763.31	3276.38	3156.90	0.47	0.25

The concept again reveals that the inherent fertility of the soil *i.e.*, organic fraction of the soil in proper proportion with inorganic fraction helps to restore the native fertility and keeps the available nutrients in their higher range and the system keeps fit itself to respond and utilize the externally applied sources of nutrients for crop uptake. Hence, soils being living and dynamic in nature they tend to change with the time. Therefore well manured and managed soils do have high amounts of available nutrients and little application of external source of nutrients helps to overcome the variations that exist within the field and yields uniformly in the long run.

CONCLUSION

Site specific nutrients management proved to be the best tool. This could be practiced through the criteria like yield based management zones, categorizing the soils based on initial soil nutrients status, as soil clusters, which enhances the nutrients use efficiency and avoids under or over application

Table 6 Correlation of yield with quality parameters for SSNM and target yield in ratoon crop

Plots	Yield (t/ha) Vs. Quality Parameters (%)							
	Yield	Juice	Bagasse	Brix	Pol	Purity	Recov	CCS
31	83.2	47.96	52.04	21.38	18.68	82.39	11.89	12.46
32	75.2	50.85	49.15	21.44	17.95	83.93	11.93	12.59
33	61.4	53.88	46.12	21.63	18.69	82.69	11.96	12.63
34	49.5	55.88	44.32	21.56	18.39	86.39	11.75	12.79
35	75.2	50.69	49.31	22.68	19.58	84.39	12.75	13.95
36	110.9	49.36	50.64	22.18	19.23	82.36	12.51	13.69
37	118.8	54.36	45.64	21.54	18.49	85.34	11.92	12.96
38	53.5	50.59	49.41	21.43	18.34	82.66	11.82	12.55
39	41.6	53.39	46.61	22.23	19.65	80.96	12.46	13.96
40	44.1	53.39	46.61	22.26	18.98	81.31	12.51	13.78
41	53.5	56.36	43.64	22.29	19.21	82.42	12.53	13.95
42	103.0	60.64	39.36	22.38	18.96	83.24	12.45	13.13
43	95.0	58.68	41.32	22.31	16.98	82.33	12.36	12.99
44	77.2	49.34	50.66	21.53	17.76	81.67	11.88	12.68
45	81.2	55.51	44.49	21.48	17.59	82.73	11.84	12.92
46	73.3	50.69	49.31	21.34	16.98	82.86	11.86	12.68
47	87.1	56.88	43.12	21.39	17.69	84.43	11.75	12.57
48	95.0	50.22	49.78	21.45	17.58	84.35	11.85	12.98
49	77.7	52.57	47.43	21.64	18.23	82.35	11.95	12.79
50	79.2	52.59	47.41	22.18	18.69	83.63	12.45	13.21
51	87.1	54.45	45.55	21.54	17.95	86.15	11.85	12.88
52	59.4	53.22	46.78	22.00	19.69	84.33	12.15	13.29
53	79.2	54.86	45.14	21.48	18.86	82.09	11.99	13.16
54	97.0	54.39	45.61	22.16	19.33	83.37	12.43	13.27
55	93.1	54.46	45.54	22.14	19.33	84.49	12.47	13.75
56	67.3	55.85	44.15	21.80	18.75	85.29	11.94	13.12
57	95.0	53.94	46.06	21.45	18.97	85.16	11.79	12.98
58	103.0	54.39	45.61	21.54	18.56	82.73	11.74	12.89
59	163.8	50.26	49.74	22.24	19.52	83.16	12.35	13.54
60	81.2	54.71	45.29	21.51	18.89	82.92	11.98	12.93
SD (σ)	24.77	2.88	2.87	0.39	0.75	1.38	0.31	0.45
Correlation (r values)		-0.07	0.06	0.06	0.01	0.16	0.04	-0.01
SEm±	4.52	0.53	0.52	0.07	0.14	0.25	0.06	0.08

of fertilizers. This also helps to maintain uniform and sustained yield levels in the long run.

REFERENCES

Michael Flowers, Randall Weisz, Ronnie Heiniger, Deanna Osmond and Carlcrozier, 2004, In season optimization and site specific nitrogen management for soft red winter wheat. *Agron. J.*, 96: 124-34.

Bundy L G and Andraski T W. 2004. Diagnostic Tests for site-specific nitrogen recommendations for winter wheat. *Agron. J.*, 96: 608-14.

Johnson C K, Mortensen D A, Weinhold B J, Shanahan J F and Doron J W. 2003. Site-Specific management zones based on soil electrical conductivity in a semiarid cropping system. *Agron. J.*, 95 : 303-15.

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Factory-level R&D initiatives for improved sugarcane borer management: Issues and strategies

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ABSTRACT

In India, the biotic constraints affecting cane productivity and sugar recovery include insect pests, mainly sugarcane borers. The dynamic research knowledge being continuously generated by public/private R&D institutions on eco-friendly pest management options require to be locally fine-tuned to match with the local pest severity variations in space and time at sugar factory level, by complimentary R&D initiatives, so to reliably optimize the promising pest control inputs. This paper is focused on the practical scope to improve borers management at factory level, both based on literature survey as well as from the outcome of recent factory-level project methodologies adopted uniformly among several factories under an R&D network supported by Sugar Development Fund (SDF) to optimize the releases of a heat tolerant strain of *Trichogramma chilonis* for biocontrol of the internode borer in South India. Based on the experiences gained and results obtained from these two major R&D initiatives, a model set of specific recommendations for factory level initiatives are illustrated towards enhancing the impact potential of biocontrol and pheromone trapping as key components of sustainable pest management. The operational strategy visualized is that a voluntary pool of pest management R&D experts could be established, so to be able to advise/assist either individual factories or a regional network of interested factories to access scientifically sound guidance in field methodologies, possibly also with annual one-day pest management refresher training to enable individual sugar factories to empower their own R&D teams in conducting suitable on-farm assessments/ trials towards understanding local borer severity variations and in making informed local decisions for optimizing the release regimes and/or doses of *Trichogramma*, besides the selective use of pheromone trapping to minimize the local borer levels.

Keywords: Sugarcane borers, Factory-level R & D, Bio control, *Trichogramma*

The main thrusts of sugar industry in India for maximization of cane productivity include improved crop production-protection technologies as means of enhancing the sugar recovery and borers are an important and often variable source of loss in cane productivity at factory level. The borers affecting sugarcane in India include the early shoot borer (ESB)- *Chilo infuscatellus* Snellen, inter node borer (INB)- C*hilo sacchariphagus indicus* (Kapur), top shoot borer (TSB)- *Scirpophaga excerptalis* Walker, stalk borer (STB)- *Chilo auricilius* Dudgeon, root borer (RTB)- *Emmalocera depressella* Swinhoe, pink borer (PNB) *Sesamia inferens* Walk., green borer (GRB)- *Raphimetopus ablutellus* Zell., Gurdaspur borer(GSB)-*Acigona steniellus* (Hampson) and Plassey borer (PLB)-*Chilo tumidicostalis* (Hampson) (David *et al*. 1986), especially the internode borer (*Chilo sacchariphagus indicus*), (Eswaramoorthy 1983). Among them, ESB, INB, TSB and STB occur more widely and/or more severely (Sithanantham *et al.* 2013; Sithanantham and Geetha 2014). Globally including India, the use of *Trichogramma* release for augmentative bio control of borers is common, more as an inevitable option, due to alternative methods being apparently not so effective/economical/ adoptable (Sithanantham *et al.* 2013). While the target sugarcane borer genera and species may differ, and also the Trichogramma species chosen to be locally mass produced and released to control them may also vary, but the system is the same, namely choice of locally adapted strain, mass rearing of the factitious host insect (like *Corcyra, Sitotroga*) and releasing them repeatedly (inundatively) within the crop season (Sithanantham, 2014). In Tamilnadu, Kalyanasundaram *et al.* (1993) and Manisegaran (2004) confirmed the benefit to cane yield and/or sugar recovery from Trichogramma releases in Tamilnadu. More recently, factory-level on-farm trials around Coimbatore by Geetha *et al*.(2009) showed that both six releases (fortnightly) and 24 releases (weekly) of Trichogramma for INB control provided cost: benefit ratios of 1:13 and 1:11 respectively, the increase in cane yield being 12 and 22%,and respective increase in sugar recovery (CCS) by 3.0 and13.5%, over no release plots. Both Geetha *et al.* (2009) and Geetha (2010b) have demonstrated unambiguously the economic benefit of inundative releases of *Trichogramma chilonis* against INB in South India. Sithanantham *et al.* (2009) surveyed the scenario of INB bio control among several sugar factories in Tamil Nadu and Andhra Pradesh and found wide

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variations in the adopted doses/ numbers of releases of Trichogramma for ESB and INB.

Researchers of the Indian Council of Agricultural Research (ICAR) have recently developed heat tolerant (HT) strains of *Trichogramma chilonis* and *T. japonicum* which make it possible to use this bioagent even in hotter periods up to about 40°C, and several field trials across India by ICAR network scientists having shown very promising results against different borers, especially INB and STB (Sithanantham *et al*.2014). Pheromone-based trap systems can be used for monitoring and/or mass trapping of the adult (moth) stage of the borers (David *et al.* 1985; Easwaramoorthy *et al*. 2003). The scope for selecting effective sex pheromone lure dispensers for improving the trap catches of adult males of the sugarcane borers had been pointed out by Mukunthan (1988). Past studies on pheromone trapping of INB had focused mainly on distance between traps, vertical positioning of the trap and trap design comparisons (Nandagopal *et al*. 2004). Scope exists to combine the releases of the biocontrol agent (*Trichogramma*) and pheromone traps deployment for improved impact in IPM of sugar cane borers in South India (Sithanantham and Kandasamy 2011). Geetha (2010a) have also indicated that these two technologies are compatible and possibly also complementary in impacting on sugarcane borer control. It is possible to visualize that in case of mass trapping sugarcane borer egg numbers will decrease per unit area, which could indirectly also enhance the egg parasitism rate by the released Trichogramma adults due to narrow ratio between host and parasitoid in unit habitat, besides the direct impact of reduced larval numbers infesting the cane. Alternatively, pheromone trap monitoring of borer adults can guide in timing/dose adjustments for Trichogramma releases, based on the relative catches and the timing of peaks.

MATERIALS AND METHODS

The materials and methods for the future model are summarized herein:

Network R&D for optimizing INB biocontrol in South India

Tthis section illustrate the field methodologies recommended by experts panel (pool) and adopted uniformly among several factories under an R&D network supported by Sugar Development Fund (SDF) to optimize the releases of a heat tolerant strain of *Trichogramma chilonis* for biocontrol of the internode borer in South India, which are already given in detail by Thamaraichelvi *et al*.(2012, 2013) and Sithanantham *et al*.(2012, 2013). The overall initial strategy was to release *T.chilonis* @1cc/release/acre and compare three release regimes-releases (alternate weeks during 5-7 month age),12 releases(alternate weeks during 5-10 month age) and 24 (weekly during 5-10 month age) for their impact on per cane weight and sugar recovery (CCS). The participating factory personnel were oriented in a planning-cum-methodology workshop about field trials to be taken up in each factory in two zones each involving four fields (plots) of about 5 acres. The overall strategy was to release Tricho cards @1cc/release/acre and compare three release regimes-releases(alternate weeks during 5-7 month age),12 releases (alternate weeks during 5-10 month age) and 24(weekly during 5-10 month age) for their impact on per cane weight and sugar recovery (CCS). The production and supply of the required Tricho cards was from the same mother culture which was periodically upgraded by for all releases in all the 12 factories to ensure uniformity in the quality and quantity of Trichogramma released. The methodology along with results from the R&D network across three states (among 12 sugar factories) in South India are being illustrated as basis for our vision for factory level R&D model for improving borer management as a component of multi-dimensional improvement in sustainable enhancement of cane productivity and sugar recovery.

2.2. Need to understand the local borer severity levels in optimizing their biocontrol:

The impact potential of inundative releases of *Trichogramma* for sugarcane borer biocontrol is mostly can be influenced by locational/seasonal severity levels of the target borers (Sithanantham *et. al*., 2013). Such model of sugar factory-linked R&D has recently also been adopted in improving the impact of releases of *T.chilonis* and *T.japonicum* against three borers (*C. auricilius, C. sacchariphagus* and *S. excerptalis*) in Indonesia (Goebel *et al.* 2013). Illustrated below are the methodologies proposed to capture the variations in borer severity based on the above two collaborative R&D programs.

Variability in incidence levels of borers among six different sugar factories

The most basic data base for strategising the local borer control at factory level is reliable data on the level of damage/ loss caused by the common borers locally. The extent of variability between factories in INB incidence levels among five sugar factories in South India during two years under the R & D network project of SDF is illustrated below (Fig 1). This study has enabled distinguishing the year to year variation in five factories for local INB incidence levels.

Seasonal variation in relative abundance of two borers within one factory area

The scope of capturing the variations in seasonal incidence could be illustrated from the results of monthly pheromone trap monitoring of the two borers-ESB and INB- undertaken under the network R & D project in one factory by Thamaraichelvi and Sithanantham (2014) (Fig.2), indicating Jul-Dec to be more abundant period for both the borers than Jan-Jun period.

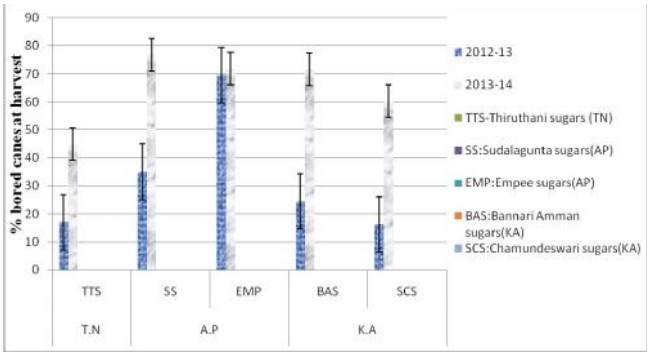


Fig 1. Variation in INB infestation levels in five factories during 2012-14

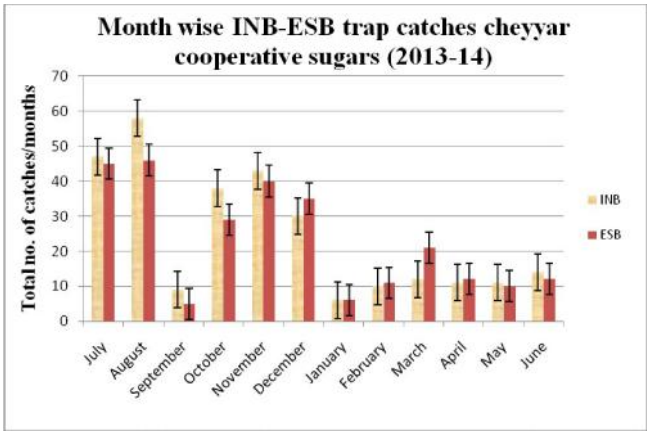


Fig 2. Monthly trap catches of two borers in Cheyyar co operative sugar factory area, 2013-14

In addition by knowing the seasonal flutuations in their abundance, it was classified that the adults of both the borers were available in all months, indicating scope for year-round breeding.

FACTORY-LEVEL R&D MODEL TO IMPROVE BORER BIOCONTROL IMPACT

The following details are based on the fore going justifications for and the availability of standardized methodologies to reliably determine the severity of borer damage and / or their adult abundance in pheromone traps.

Vision for-factory level R&D to include pest management impact

Sithanantham (2006) had already pointed out that while public research institutions can only provide generic recommendations for INB biocontrol with Trichogramma releases there is need and scope for factory-level baseline R&D studies on local borer incidence variations, so to optimize the Trichogramma release regimes for cost-effective INB control and so contribute to enhancing the local sugar recovery. The major thrust of the present paper is to propose a useful and adoptable model set of initiatives and linkages for implementing such factory-level R&D as means of reliably capturing the local variations in borer incidence severity levels and to suitably link up for optimizing the Trichogramma release regimes as well as use of pheromone traps as supplementary tool towards maximizing the impact on borer control at factory-level, so contributing to multi-dimensional improvement in sustainability of cane productivity.

The visualized linkages and thrust initiatives for pest management focus R&D at factory level

The proposed linkages with experts and client factories are illustrated in the diagram below (Fig 3). It is envisioned that relevant R&D experts either working with or retired from different institutions such as ICAR (Indian Institute of Sugarcane Research, Lucknow and Sugarcane breeding Institute, Coimbatore), SAUs, (State Agricultural Universities), Sugar Directorate R&D centers and other private/academic R&D centers, besides National Sugar Institute, Kanpur could be availed from pools (consortia) through approved and standard norms for extending their expertise/experience in planning/training/advisory inputs. These can cater to two types of R&D needs –for individual factories on specific need basis or for a network of factories with common/shared needs. It is visualized that the common methodologies for the four main tasks, namely assessing borer severity variations and for impact of Trichogramma in different release regimes, the releasing of heat tolerant Trichogramma strains as well as the use of pheromone traps could be vetted/standardized by the expert panels within these pools and availed on standard terms for use/training for the factory R&D teams.

Functional scenario of integrating pest management in factory-level R&D

It is visualized that the three priority activities for borer biocontrol, namely Tricho release optimization, linking weather factors to predict borer severity and pheromone trap monitoring(in 4-6 zones), may require part-time seasonal inputs approximating 3, 3 and 4 man weeks respectively per year. Out of total of 56 man weeks per year, this would be about 14% share of the human resource, while the remaining 48 man weeks could cater for the main activities (about 86% share of time). For supporting/motivating the factory management towards decision in favour of such inclusion of pest management related activities, it may be justified to assume, based on the outcomes of many locational/regional field trails on *Trichogramma* impacts so far summarized/ published, it would be reasonable to assume that pest management related initiatives could contribute to about 20-30 percent share in cane yield increase, with about 10-20percent share in sugar recovery, at local factory level. This visualized scenario is illustrated in Fig 4 below:

Experts Pool assistance to train/guide factory-level staff in field methodologies

As already indicated, the experts' pool could be approached to cater to the related information /training needs for pest

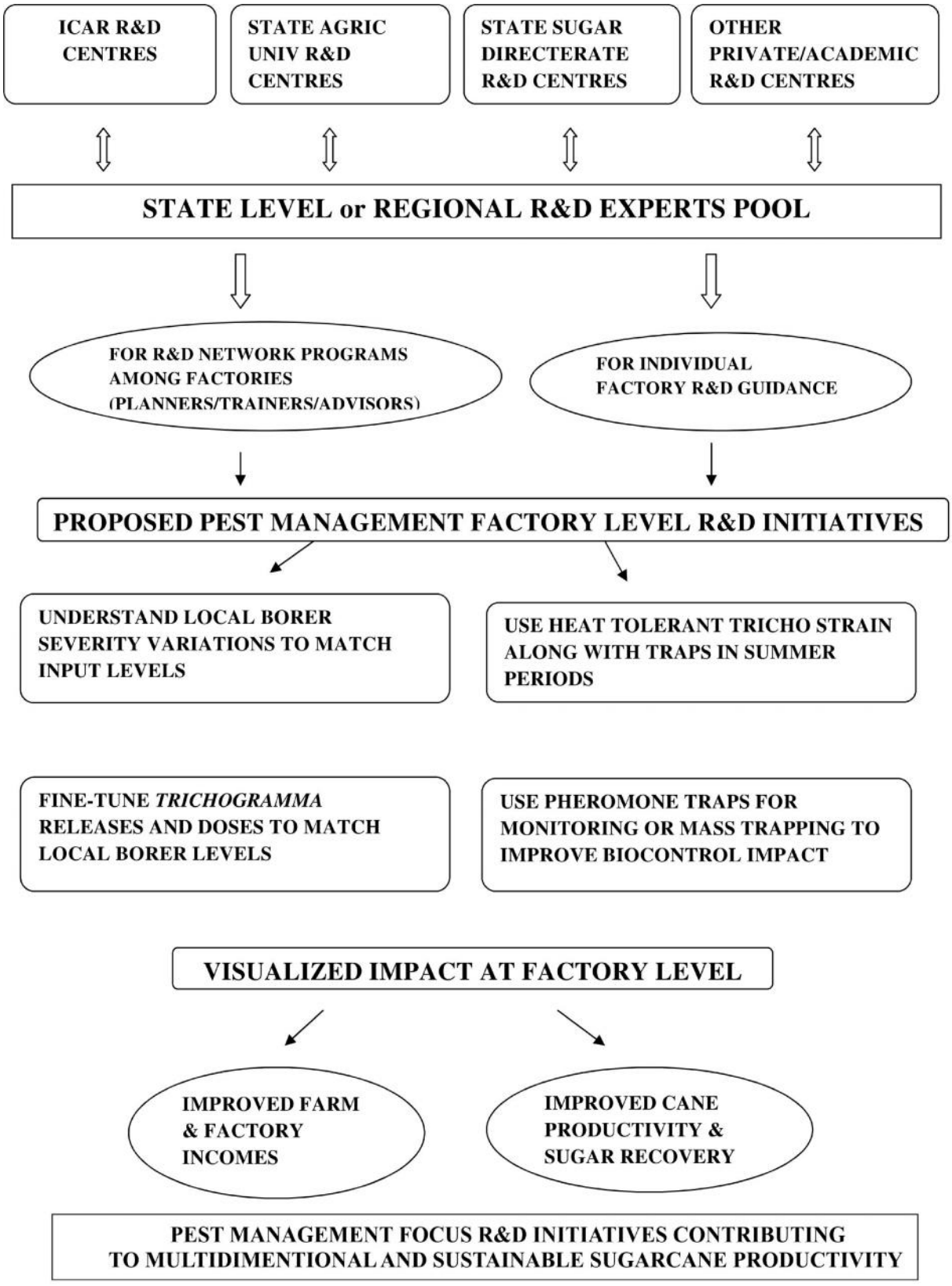


Fig 3. Proposed model for factory level R&D to improve impact of sugarcane

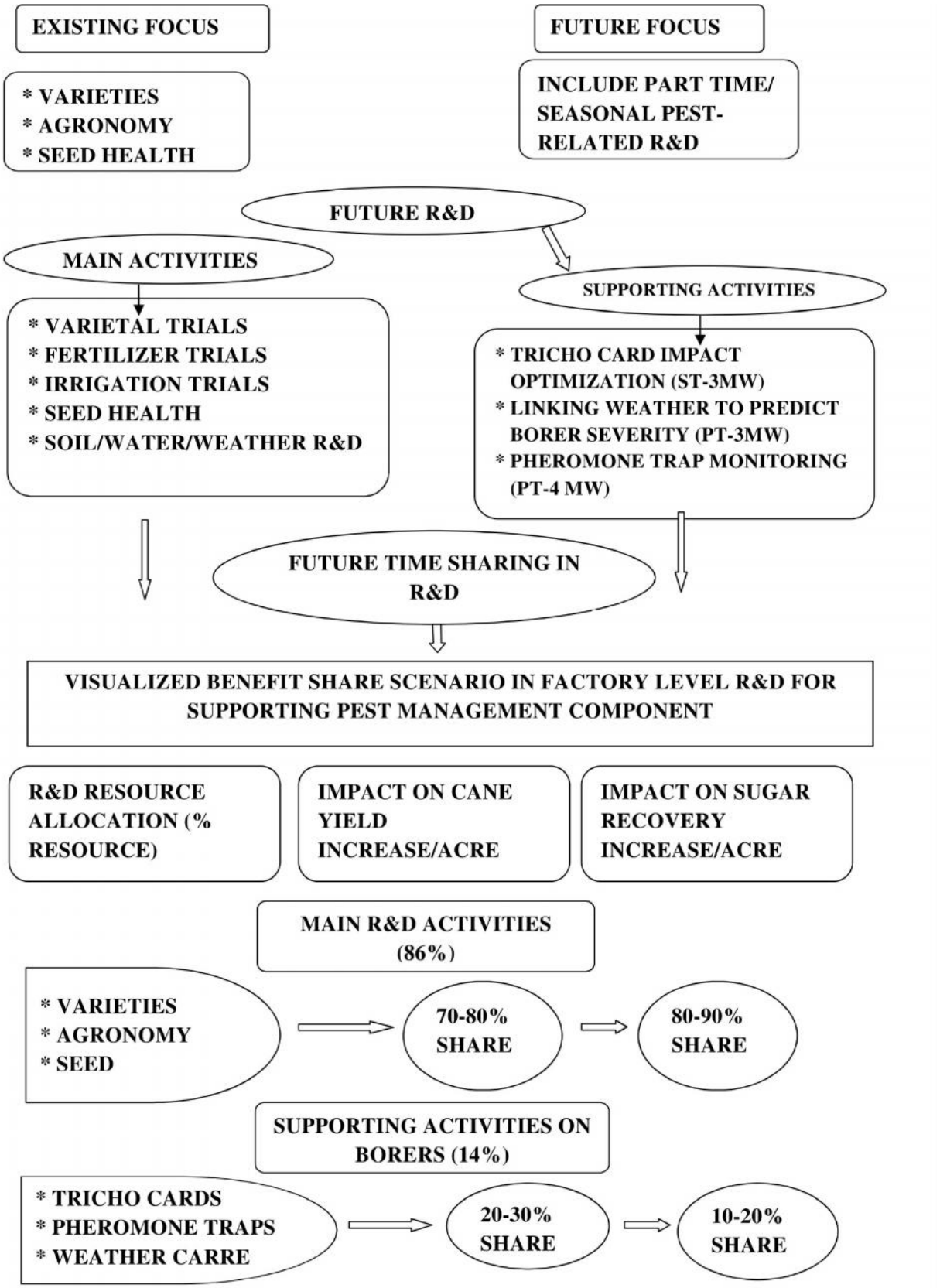


Fig 4 Visualized benefit scenario in factory level R&D with pest management component

management, on either individual factory basis or in a network of interested and willing factories within a region/state. Much of the information for the pest management R&D can be secured from electronic means, whereas a maximum need may be an annual one-day training/refresher workshop. Organizations like ICAR institutions/SAUs /State Sugar Directorate R&D may be able to co-ordinate/host such one day workshop.

Special focus on pheromone traps system for monitoring/mass trapping

As already mentioned, pheromone trap deployment for monitoring the target borer adults can help in fine-tuning the timing and/or dose of *Trichogramma*, mass trapping could contribute to reducing the egg density per unit area of crop, which may have a direct effect in reducing the borer inoculum/ damage levels, besides also enhancing the impact of the *Trichogramma* releases by narrowing the ratio between the parasitoids released and host eggs per unit area. Realizing the importance of motivating the use of pheromone traps at farm level, recently initiated joint R&D efforts between Sun Agro Biotech Research Centre and Padmaa Devi Sugar Mills have shown the scope to replace the presently laborious water-basin traps with waterless alternative trap designs, without any major cost differences. The ongoing R&D also seeks to improve the pheromone lure dispenser type/loading towards increasing the field life of the pheromone lures in the traps.

Technical /methodological aspects of factory-level R&D to be taken up include

Baseline data on local seasonal/locational severity variations: The R&D teams of individual interested factories could be trained in simple methodologies to record the following types of variations in borer (example-INB) severity at factory level:

Extent of borer damage variations between different planting months: To focus on fortnightly sampling for INB incidence levels among major planting months for each factory; assess the incidence on cane basis and on internode basis, it is suggested to sample from plots measuring 5row x12ft @ 3-4 plots/acre; sample one field each in each zone (4-6 zones per factory).The losses in cane weight and juice yield/quality linked to borer incidence could be collected by one cane assistant per zone from SMT samples from each harvested field. Such study to be initially done for 2 years. It can be repeated after 5-6 years, as per needs.

Pattern of INB attack builds up during different crop ages: Under this methodology, the node position of borer damage from the bottom, to be used to estimate the age of the internodes @ 8per 2 months into 5-6,7-8,9-10 and 11-12 month age of crop and the percent internodes infested during each two month periods and also cumulatively for the entire duration (5-12 months). Correlations between borer levels to lead to prediction formulae using data over 2-3 years and 4-6 zones for plant vs. ratoon crops among the common cane varieties grown. The time in recording the node basis INB data may be 2 hours per field with one assistant per zone per day per harvesting month. The number of fields in each zone to be locally decided, as well as the months in which these data are to be collected, such study needs to be initially done for 2 years. It may be repeated after 5-6 years, as per needs.

Correlation of borer severity levels with weather factor variations: In each sugar factory, the weather data locally collected daily could be worked into weekly means/totals and correlations attempted for each weather parameter (like maximum temperature) for different weeks (about 4-6 weeks) ahead of the week in which the borer damage severity level(%) is recorded. The prediction formulae for borer levels based on strength of correlation could be worked out. This may permit local level short term prediction of impending borer severity. This initiative requires just one part-time R&D staff time on weekly basis, which would be affordable in most factories.

Field methodology to optimize the biocontrol input intensity at factory level

The R&D networking model and the methodologies adopted for impact assessment, besides the sampling strategy followed have been as described in details by Sithanantham *et al*. (2014). The interested future R&D networks or individual sugar factories may suitably revisit the numbers of releases to be compared as well, as the dose rates of 1cc. versus 2 cc, as per their collective needs. The impact assessments made on the internode borer incidence levels (Fig 5) on the cane yields (Fig 6) as well as sugar recovery (Fig 7) were illustrated.

Impact on internode borer incidence: This methodology was adopting the individual factory level assessment of borer damage on cane basis at harvest and then combining the results among factories according to the states, wherein the overall direct positive effect of *Trichogramma* (cards) release on INB damage was evident compared to 'No release' treatment, with differences being statistically significant in five sugar factories. In Tamilnadu, the overall percent canes bored by INB without any Tricho release (T1) was about 44, while for 6, 12 and 24 releases (T2, T3, T4 respectively), the percent reduction in INB infested canes was by 25.0, 59.0 and 75.0, respectively. (Fig.6). In A.P., the overall percent canes in no release (T1) plots was about 42, while the respective release regions (T2, T3 and T4) recorded percent reduction in INB incidence by 2.4, 26.2 and 42.9 for the three release regimes about 41, 31 and 24. The extent of reduction in INB incidence on cane basis was found to be generally related to on the numbers of releases made (T2=6 releases; T3 =12 releases; T4 =24 releases), which confirmed the consistent beneficial effect of the *Trichogramma* releases. These trials have helped the participating factories to themselves decide on the locally profitable/beneficial numbers of Tricho releases to be made,

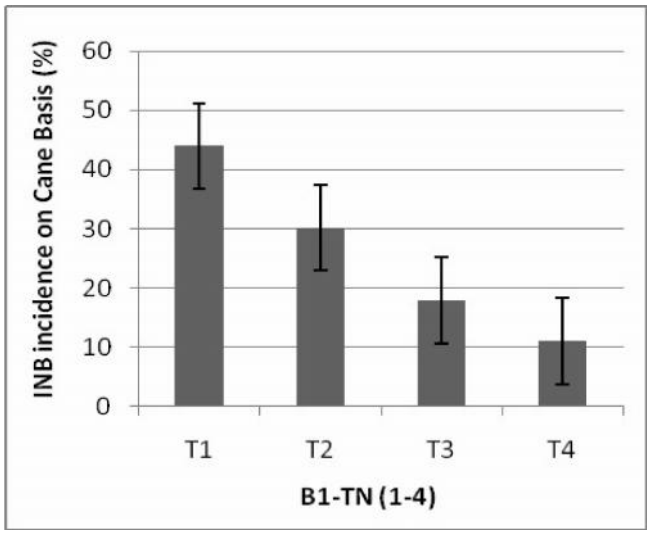
based on local INB incidence level variations.

Effect on cane productivity: This methodology was to combine the individual factory analysis of data for each state and the state-wise summary showed that in Tamil Nadu, the overall per acre yield in no release treatment (T1) was 41.3 tonnes, which increased by 3.3, 4.6 and 6.5 tonnes/acre compared to 44.6, 45.07 and 47.9 for T2, T3 and T4 respectively (Fig 7). For Andhra Pradesh, the respective per acre cane yield was 21.4, for no release (T1) with increase by to1.7, 2.5 and 2.9 tonnes/acre for the three Tricho release treatments (T2, T3, T4).

These results confirm that overall there is good scope for cane yield increase at farm level, as well as increase in farmers' incomes, at different intensities of Tricho release. Such local validation of benefits could be carried out at factory level among the major zones and planting months.

Local borer severity levels on biocontrol impact: In the R&D network project under SDF, when we compared as three categories of INB severity levels/ (low, medium,high) sampling from two individual factories each, showed that the relative yield benefit (worked out at Rs.2000/ton) per acre (as illustrated in Fig 8), was good at lower INB level,but did not show benefit beyond 12 release, whereas at medium or high incidence levels, the benefits were evident at all release regimes (6,12 and 24 releases). This methodology was simply adopting the individual factory assessments and then regrouping the data from the factories according to their borer intensity levels and taking representative sample factories to derive an average for each severity category.

Impact on sugar recovery: The overall trend was that the weighted **CCS** % of the juice (linked to % canes with INB damage), was mostly enhanced due to the Tricho card release treatments. In Tamil Nadu, against **CCS** % of 10.35 for no release plots (T1), the Tricho card release and plots (T2, T3, and T4) recorded **CCS** % values of 10.50, 10.58 and 10.72, respectively (Fig 9.). In Andhra Pradesh, the respective overall



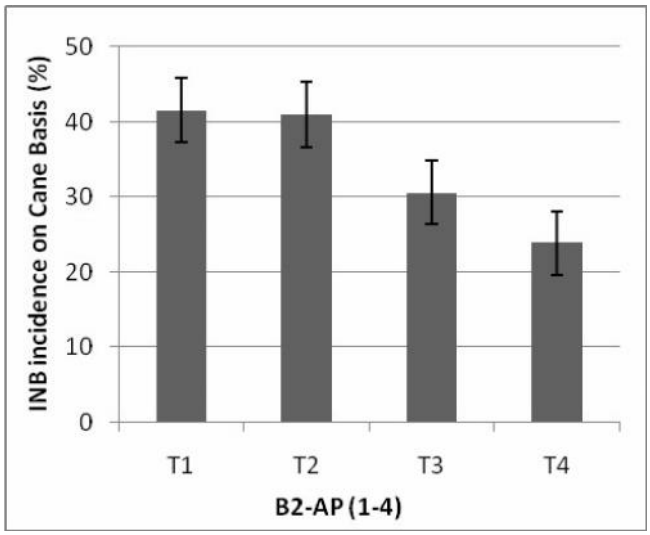
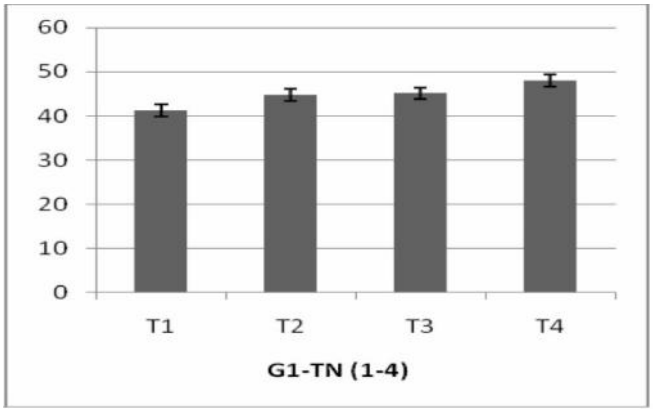


Fig 5 & 6 Overall percent INB infested canes in TN and AP for four Tricho release treatments



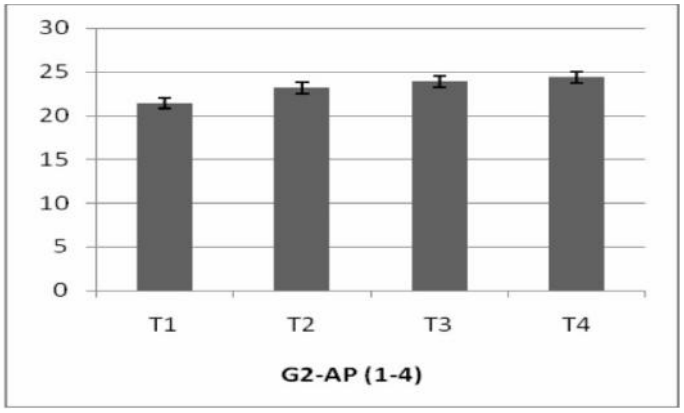


Fig 7 Overall estimated cane yield/acre in TN and AP for Tricho release treatments (T1-T4).

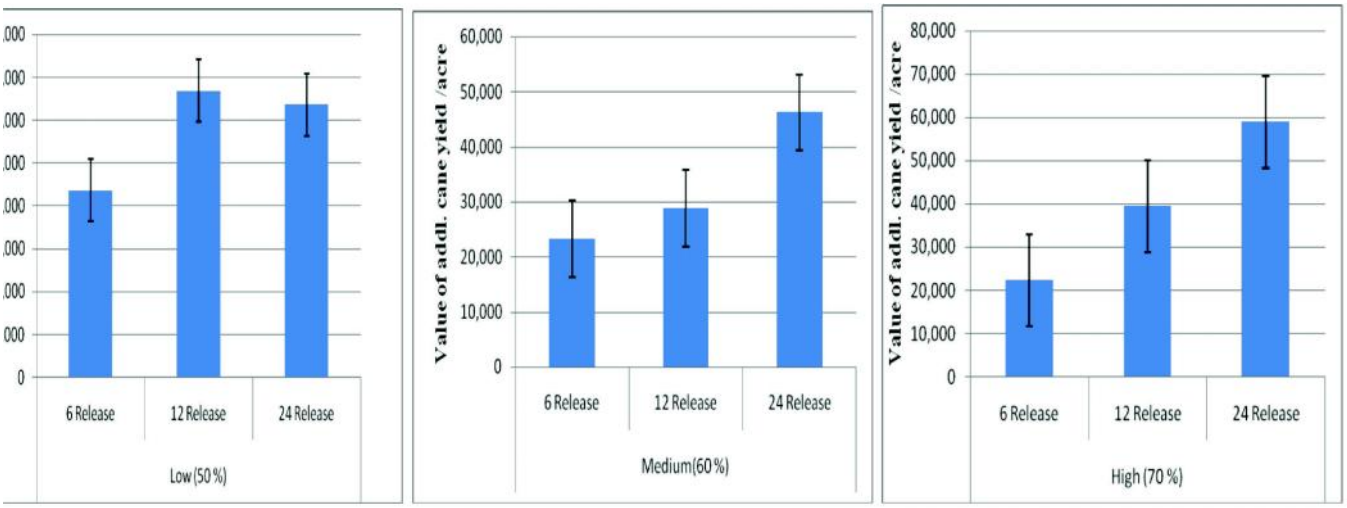


Fig 8 Relative value of cane yeild increase due to Tricho releases in three INB severity categaries

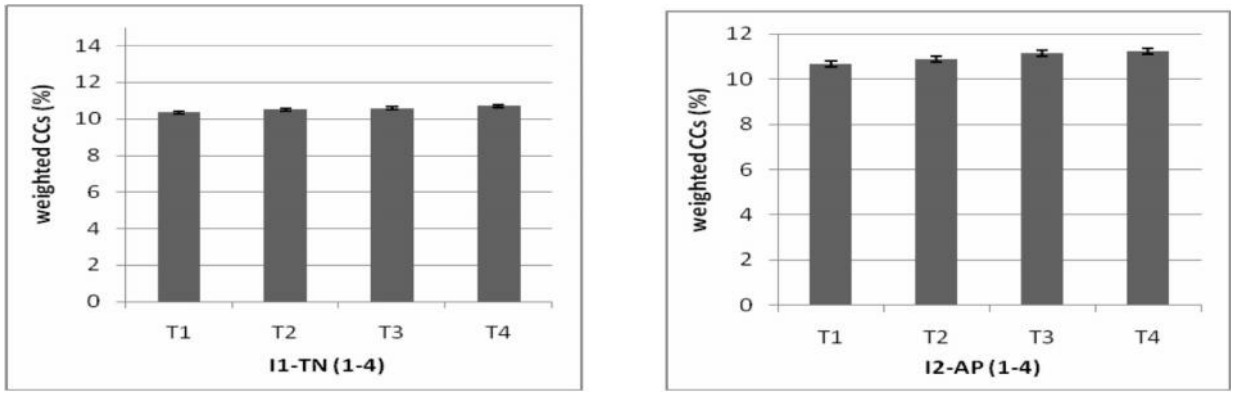


Fig 9 Overall weighted sugar recovery (CCS %) in TN and AP for four Tricho treatments

CCS % value for the four treatments was 10.65, versus 10.90, 11.16 and 11.22.

Use of pheromone trap system for monitoring or mass trapping: The scope for use of pheromone traps at individual factory level for borer levels monitoring is illustrated below (Fig 10).

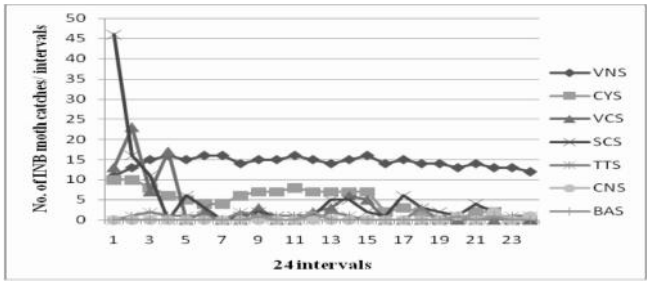


Fig 10. Weekly pattern of INB moth catches in seven factories, Jul-Sep, 2013

The scope for using the traps for mass trapping also needs to be explored. To promote farmer adoption of trapping technology, there is need for replacing water-based traps for sugarcane borers with waterless (sticky) traps appears promising, as illustrated from recent exploratory trials at Padmaa Devi Sugars Mills (Fig-11). It is hoped that more user friendly adapted pheromone trap optimize will become available soon for wide-scale adaption at factory level.

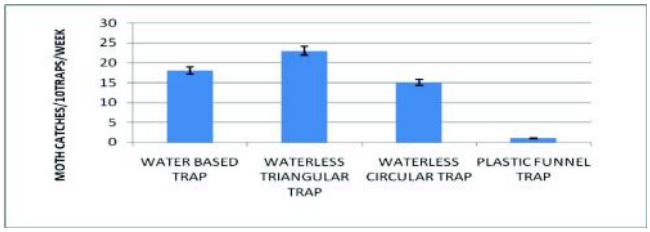


Fig 11. Relative borer moth catches in water-based versus waterless trap designs, 2014.

CONCLUSIONS

- Biocontrol of sugarcane borers with *Trichogramma* is a well- proven technology for improving cane productivity and requires factory level R&D to optimize the impact.
- Optimizing this technology at factory level should be

based on capturing the local variations in the severity levels of the borers within the existing R&D framework.

- The available pool of expertise from different sources and the recent successful factory R&D network experience can adequately guide in adopting such a model.
- Such dynamic re-focus in factory level R&D structure and function can be sustainably adopted with the existing human resources and minimal extra funding support.
- The scope for and potential benefit from such re-focusing the factory level R&D is illustrated from the factory level R&D network and such other initiatives.
- The factory managements should consider this reliable window of opportunity for the factory level R&D on pest management to additionally impact as part of the multidimensional approach to sustainably improve cane productivity and sugar recovery.

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REFERENCES

Anonymous. 2009. Annual Report AICRP on Biological Control of Crop Pests and Weeds. 2008-09 pp. 66-102, Project Directorate of Biological Control, Bellary Road, Bangalore 560024, India.

Bindra O S, Varma G C and Nasib Chand. 1973. Field recovery of *Trichogramma australicum* Girault. (Taiwan strain) and *Tetrastichus israeli* Mani and Kurian (Thailand strain) and their value in controlling *Bissetia steniella* (Hampson). *Indian Journal of Plant Protection* **1**: 16-18.

Brar K S and Shenhmar M, Bakhetia D R C, Doomra S, Sharma D K, Duhra M S and Singla M L. 1996. Bioefficacy of *Trichogramma chilonis* Ishii (Hymenoptera, Trichogrammatidae) for the control of Chilo auricilius Dudgeon on sugarcane in Punjab. *Plant Protection Bulletin Faridabad*. 48(1-4), 9-10.

Brar K S, Singh D, Shenhmar M and Singh J. 2001. Demonstration of effectiveness of *Trichogramma chilonis* Ishii for the control of *Chilo auricilius* Dudgeon on sugarcane in Punjab. *Symposium Biological Based Pest Management for Quality Crop Protection, In the Current Millennium,* PAU, Ludhiana, 18-19 July, 2001. pp. 160-61.

David H, Nesbitt B F, Easwaramoorthy S and Nandagopal V. 1985. Application of sex pheromones in sugarcane in pest management. *Proceeding of Indian Academy Science* (Anim. Sci.), 94: 333-39.

David H, Easwaramoorthy S and Jayanthi R. (eds.) 1986.Sugarcane Entomology in India. Sugarcane Breeding Institute, Coimbatore, India.564pp.

David H, Sithanantham S and Velayutham B. 1979. Some aspects of losses due to internode borer in sugarcane in Tamil Nadu. *Proceedings of Deccan Sugar Technologists Association*.29:27-40.

Easwaramoorthy S. 1983. Estimation of damage and losses caused by sugarcane pests. p5-18. In

M Balasubramanian and A R Solayappan (eds.) Sugarcane Pest Management in India.Tamilnadu Cooperative Sugar Federation, Chennai, and India.77pp.

Easwaramoorthy S, Mukunthan N and Singaravelu B. 2003. Sex pheromones in the management of sugarcane internode borer, *Chilo sacchariphagus indicus* (Kapur). *Proc. SISSTA.* Annual Convention: 49-52.

Geetha N. 2009. Effect of timing, increase in frequency of release and dose of *Trichogramma chilonis* Ishii for the management of the internode borer, *Chilo sacchariphagus indicus* (Kapur), in sugarcane. *Pest Managt.Eco. Zool.*, 17(1): 17-23.

Geetha N. 2010a.Compatibility of pheromones and *Trichogramma chilonis* Ishii for the management of inter node borer *Chilo sacchriphagus indicus* (Kapur) in Sugarcane. *J. Insect. Sci.* 23(3):301-07.

Geetha N. 2010b. Management of inter node borer *Chilo sacchariphagus indicus* (Kapur) by *Trichogramma chionis* Ishii: Appraisal of weekly releases at increased doses. *Indian J. Entomol.*, 72(2):155-69.

Geetha N, Shekinah E D and Rakkiyappan P. 2009. Comparative impact of release frequency of *Trichogramma chilonis* Ishii against *Chilo sacchariphagus indicus* (Kapur) in sugarcane. *J. Biol. Control*, 23: 343-51.

Goebel Francois-Regis, Etik Achadian Peter Mc Guire. 2013. Economic impact of sugarcane moth borers in Indonesia. Proc. *Int. Soc. Sugar Cane Technol*: 28.

Kalyanasundaram M, Justin C G L, Swamiappan M, Sundarababu P C and Jayaraj S. 1993. Efficacy of *Trichogramma chilonis* against sugarcane internode borer, *Chilo sacchariphagus indicus. Indian Journal of Plant Protection*. 21 (2):119-21.

Kamalakara rao C. 1980. Biological control of sugarcane shoot and internode borers in the factory are of the Jeypore Sugar Company., Chagallu, West Godhavari district, Andhra Pradesh. p37-38.

Kandasamy R and Sithanantham S. 2012. Model initiatives for factory-level prioritization among eco-friendly sugarcane borer control methods. p275-278. *In Proceeding of International Symposium on New Paradigms in Sugarcane Research*, 15-18 October, Coimbatore, India.

Kandasamy R, Sithanantham S, Manikandan K R and Judy S. 2013. Factory-level study of internode borer incidence and juice quality losses towards optimum biocontrol and enhanced sugar recovery. In Proceeding of 72nd Annual conventional, The Sugar Technologists' Association of India, (26-28 September, 2013), *STAI*, Lucknow, p497-512.

Manikandan K R, Sithanantham S, Kandasamy R, Sanjaiyan K P and Judy S. 2013a. Biocontrol potential of heat tolerant strain of *Trichogramma chilonis* on sugarcane early shoot borer (*Chilo infuscatullus* snell). 4thBiopesticide International Conference BIOCICON, 2013 at St. Xavier's College, Palayamkottai, Tamilnadu.p.210.

Manikandan, K.R., Sithanantham, S., Prasad, A.R., Jyothi, K.N., Prasuna, A.L., Kandasamy, R., Thirumurthy, K. and Judy, S. 2013b. Comparing two pheromone lures for trap catches of sugarcane internode borer adults.*Hexapoda*.20:14-17.

Manikandan, K.R., Sithanantham, S., ThamaraiChelvi, C. and Judy, S. 2013c. Stakeholder perception assessment on local importance of three sugarcane borers and adoption potential some borer control methods in South India (p.25-26). International Conference on Insect Science ICSI, 2013.University of Agricultural Sciences, GKVK, Bangalore, Karnataka.

Manisegaran, S. 2004. Revalidation of *Trichogramma chilonis* for the control of internode borer, *Chilo sacchariphagus indicus* in sugarcane. *Indian Journal of Entomology*. 66 (1):24-26.

Mishra, B.K., Nayak, N., Das, P.K., Mohapatra, S.S. and Jena, B.C. 1997. Biological control of sugarcane borers through Trichogramma chilonis Ishii in Nayagarh district of Orissa. Indian Sugar 46, 797-98.

Misra, M.P., Pawar. A.D. and Srivastava, U.L. 1987. Biocontrol of sugarcane moth borers by releasing *Trichogramma* parasites at Harinagar, West Champaran, Bihar. *Indian Journal of Plant Protection*14: 89-91.

Mukunthan, N. 1988. Scope of pheromone technology in sugarcane pest management. p. 337-346. In Biocontrol Technology for Sugarcane Pest Management. *Sugarcane Breeding Institute*. Coimbatore.

Nandagopal V, Anand Prakash, Jagadiswari Rao, Yadav, J S and Prasad A R. 2004. Present status of pheromone research in India. p. 35-54 *Pheromone Principle and Practices***,** AZRA and CRRI, Cuttack.

Patil S B, Khot R S and Kambar N S. 1996. Biocontrol of Early shoot borer of sugarcane *Chilo infuscatellus* (Snell.). In.: *Proceedings of the 58th Annual Convention of the Sugar Technologists' Association of India, 14-16th September, 1996*. p13-15.

Shenhmar M, Brar K S, Bakhetia D R C and Singh J. 1998a. Tricho capsules, a new technique for release of the egg parasitoids-Trichogrammatids. *Insect Environment*, 4, 95.

Singh S, Shenhmar M and Brar K S. 2006. Evaluation of the egg parasitoid *Trichogramma japonicum* Ashmead for the management of Sugarcane top borer, *Scirpophaga excerptalis* Walker. *Journal of Insect Science* **19** (special issue): 37-42.

Sithanantham S.1977. Emerging trends in pest management for sugarcane in Tamil Nadu. *SISSTA Sugar Journal*, 4: 5-7.

Sithanantham S. 1983. Perspectives in sugarcane pest management in India. p1-4. *In:* Balasubramanian, M. and Solayappan A R (eds.) Sugarcane Pest Management in India.Tamilnadu Cooperative Sugar Federation, Chennai, India.77pp.

Sithanantham S. 2006. Towards enhancing the adoption of biological pest control technologies in sugarcane: case study of borers in South India. *SISSTA Sugar Journal.* 73-76.

Sithanantham S and Kandasamy R. 2011. Assessing the adoption potential of eco-safe control methods for sugarcane borers: model study of the local perception scenario at factory level. *Sugar Journal - 41st Annual Convention of SISSTA*. 95-105.

Sithanantham S and Navarajan Paul A V. 1978.Biocontrol of sugarcane borers in India with *Trichogramma:* in retrospect and prospect. *Pestology*, 2: 11-20.

Sithanantham S and Solayappan A R (eds.) 1980.Biological control of sugarcane Pests in India. Tamil Nadu Cooperative Sugar Federation, Chennai.84pp.

Sithanantham S and Geetha N. 2014. Biological control of sugarcane borers with *Trichogramma*. In Proceeding of National Symposium on emerging trends in Eco-friendly Insect Pest Management, Tamil Nadu Agricultural university, Coimbatore (in press).

Sithanantham S, Geetha N, Baitha A and Jalali S K. 2013. Utility of Trichogramma for Biocontrol of Sugarcane borers. p271-300 in S. Sithanantham, Chandish R. Ballal, S.K. Jalali and N. Bhaktavatsalam (Eds). Biological control of Insects pests using egg parasitoids, Springer publishers London.

Sithanantham S, Kandasamy R and Naidu N V. 2009. *Trichogramma* release for biocontrol of sugarcane borers (p77-83): The adoption scenario and way forward in Tamil Nadu and Andhra Pradesh.

Sithanantham S, Muthusamy S and Durai R. 1973. Experiments on the inundative release of *Trichogramma australicum* Gir, in the biological control of sugarcane stem borer, *Chiloindicus* (Kapur). *Madras Agric. J.* 60: 457-61.

Sithanantham S, Thamaraichelvi C, Manikandan K R and Judy S. 2014. Enhancing cane productivity by optimizing borer biocontrol: model and scope of factory-level R&D network in South India (p.41-53): Proceedings on All India Seminar on Sustainable Sugarcane Development and Emerging Technology Tools for Higher Sugarcane Productivity, STAI & SISSTA. March 1, 2014, Puducherry.

Sithanantham S.1985. Utilisation of Trichogrammatid parasites-problems and prospects with special reference to India. Paper presented at the ICAR National Biological control workshop, Coimbatore, 13-16 September, 1985

Sithanantham S, Geetha N and Baitha A. 2012. Recent research progress and future thrusts to improve Augmentative biocontrol impact on sugarcane borer in India. pp 277. *In Proceeding of the International Symposium on new paradigms in Sugarcane Research*, Sugarcane Breeding Institute, Coimbatore, India.

Sithanantham S. 2014. Biological control of sugarcane borers with *Trichogramma*. National Symposium on Emerging Trends in Eco-friendly Insect Pest Management. Coimbatore, p26. (Eds.,), M.R.Srinivasan., N Ganapathy., M.Suganthy., K.Bhuvaneswari., R.Vishnupriya., S.Kuttalam and K.Ramaraju (January 22-24, 2014).

Solayappan A R and Jothkumar S.1983. Factory based pest management with emphasis on biocontrol.p56-70. In M. Balasubramanian and A.R. Solayappan (eds.). Sugarcane Pest Management in India. Tamilnadu Cooperative Sugar Federation, Chennai, India.77pp.

ThamaraiChelvi C and Sithanantham S. 2014. Networking to minimize losses in sugarcane yield and sugar recovery by promoting biological pest control technology for internode borer in South India. *Annual progress report 2013-2014*. Directorate of Science, Chennai. pp- 1-42.

Thamaraichelvi C, Sithanantham S, Manikandan K R and Judy S. 2013. Sugarcane internode borer biocontrol, R&D network model (p.205). 4thBiopesticide International Conference BIOCICON, 2013 at St. Xavier's College, Palayamkottai, Tamil Nadu.

Thamaraichelvi C, Sithanantham S, Dhanasekaran S, Manikandan K R and Judy S. 2012. R&D networking with factories to optimize

heat tolerant strain *Trichogramma chilonis* for sugarcane internode borer control in South India. p.376. In Proceeding of International Symposium on New Paradigms in Sugarcane Research, 15-18 October, 2012, Coimbatore, India.

Varadhrajan G. 1976. The scope and prospects in the utilization of *Trichogramma australicum* for the control of internode borer, *Chilo sacchariphagus indicus*. In Tamil Nadu. *Madras Agricultural Journal*.64:561.

Yalawar S, Pradeep S, Ajith kumar M A, Hosamani V and Rampure S. 2010. Performance of egg parasitoid, *Trichogramma chilonis* against sugarcane internode borer, *Chilo sacchariphagus indicus* (Kapur) *Karnataka J. Agric. Sci.*, 23(1): *142-43*

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Factory-level R&D to optimize *Trichogramma* releases for sugarcane internode borer biocontrol: The model and results from sugar mills in Karanataka

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ABSTRACT

The internode borer *Chilo sacchariphagus indicus* being the most destructive pest on sugarcane in South India. Biological control of internode borer using Trichogrammatid egg parasitoids is a globally adopted practice. In the present study, heat tolerant strain of *Trichogramma chilonis* Ishii was released in three different doses in Chemundeeeswari sugar mill, Bannari amman sugar factory, NSL sugar factory and Vijayanagar sugar factory in Karnataka for control of internode borer of sugarcane. There was overall reduction in the internode borer incidence and increase in sugar yield and recovery recorded in all the four sugar mills in Karnataka.

Key words: Sugarcane, Internode borer, Heat tolerant strain, *Trichogramma chilonis*, Cane yield, Sugar recovery

The potential for biological control of internoder borer (INB) through inundative (weekly) releases of *Trichogramma chilonis* was pointed out from early field experiments in Tamilnadu (Sithanantham *et al.* 1973), followed by impact validations with 6-10 releases per season (Varadharajan 1976; Solayappan 1980),which provided impetus to establishing/ strengthening *Trichogramma* mass production units, with *Trichogramma* releases under factory-based programs (Solayappan and Joth Kumar 1983). Later Kalyanasundaram *et al.* (1993) and Manisegaran (2004) confirmed the benefit to cane yield and/or sugar recovery from *Trichogramma* releases in Tamilnadu. More recently, factory-level on-farm trials around Coimbatore by Geetha *et al*. (2009) showed that both six releases (fortnightly) and 24 releases (weekly) of *Trichogramma* for INB control provided cost: benefit ratios of 1:13 and 1:11 respectively, the increase in cane yield being 12 and 22%, and respective increase in sugar recovery (CCS) by 3.0 and13.5%, over no release plots.

Sithanantham (2006) pointed out that while public research institutions can only provide generic recommendations for INB biocontrol with *Trichogramma* releases there is need and scope for factory-level studies to optimize the release regimes for cost-effective INB control and so also contribute to enhancing the local sugar recovery. Sithanantham *et.al.* (2009) have surveyed the adoption scenario of *Trichogramma* for INB control across several sugar factories in Tamilnadu and Andhra Pradesh and found wide variation in availing local information the dose/timing of *Trichogramma* releases. The present R&D network initiative in South India was supported by Sugar Development Fund of Government of India, was undertaken to primarily fine-tune the dosage/ timing for *Trichogramma* release, based on the local INB severity towards adopting more cost-effective biocontrol of INB, by adopting uniform methodology of release and impact assessment, and data collected by trained R&D teams from each factory.

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MATERIALS AND METHODS

Network model and common methodology

The network model involved R&D teams from 4 sugar factories located in Karnataka. The participating factory personnel were oriented about the field trials to be taken up in each factory in involving eight fields of about 5 acres each. The strategy was to release *Trichogramma chilonis* @1cc/ release/acre and compare three release regimes-6 releases (alternate weeks during 5-7 month age), 12 releases (alternate weeks during 5-10 month age) and 24 releases (weekly during 5-10 month age) and assess their impact on the borer incidence, cane yield and sugar recovery (CCS). The production and supply of the required Tricho cards of the Heat tolerant strain of *T. Chilonis* with culture obtained from (National Bureau of Agricultural Important Insect, NBAII, at Bangalore). The mass production and dispatch was handled by courier at Sun Agro Biotech Research Centre, Chennai, so to ensure uniformity in the quality and quantity of *Trichogramma* released.

Selection and lay out of on- farm trial plots

To minimise the variations, fields with comparable crop management practices and soil characteristics were chosen. To effectively compare the three release regimes of *Trichogramma* (6, 12 and 24 releases per crop season), each of the four fields (5 acres area each) chosen in two locations in each factory, was divided into four treatments (1 acre each) for imposing the 3 release regimes plus one no release control treatment.

Trichogramma release and sampling plots

For each of the Tricho release plots T2, T3 and T4 there were eight release points for the Tricho cards. This was adopted

to ensure adequate adult dispersal space for maximum *Trichogramma* adults impact on parasitism of INB eggs.There were four sampling sub-plots located in four quarters of the treatment plot (1 acre). The size of the sampling sub-plots was five adjacent rows of 12 feet each**.**

Impact assessment

Cane basis INB incidence: In each sample plot, 50 millable canes were chosen at random and after examining each cane individually, the number of canes showing INB damage (based on bore-holes) and those without INB damage (healthy canes) were recorded. The percent cane damaged by INB was thus estimated (as also adopted by Geetha *et al*. 2009).

Per acre cane yield: In each treatment field, the yield was recorded from the harvested canes on arrival at the yard and estimated for one acre area basis.

Sugar recovery: The commercial cane sugar content (CCS %) was estimated in the same SMT samples in which brix were estimated, as per procedure adopted by Geetha *et al.* (2009), based on standard protocols from the juice quality parameters (CCS%, pol, purity). The reduction in CCS% between healthy canes versus INB-infested cane was arrived at as potential loss and the weighted CCS% was based on per cent cane basis incidence (worked out for mixed canes).

RESULTS AND DISCUSSION

The result of Analysis of Variance (ANOVA) from Chamundeeeswari sugar mill is summarized in Table 1.

Table 1 ANOVA

Parameters	Year1 (CD :P=0.05)	Year 2 (CD :P=0.05)
Borer(INB)cane basis %	NA	3.68*
Cane yield/acre	NA	3.49*
CCS %	NA	NS

NS=Not significant; *-significant; **- highly significant; NA-Not ApplicableCD: Critical difference (LSD)

The data collected were only for year 2 and showed that the borer (INB) incidence differences were significant among the treatments (T1-T4). A similar trend was observed for cane yield. In case of sugar recovery (CCS %), the differences were not significant. The borer (INB) incidence (on cane basis) was found to decrease from 'No release' (T1) treatment significantly. Overall reduction in borer INB incidence (cane basis) was about 18 percent for 6 releases (T2), 23 percent for 12 releases (T3), and 35 percent for 24 releases (T4). The yield increase for 6, 12, and 24 releases (T2, T3 and T4) was about 11, 15 and 29 tons/ acre, respectively. The sugar recovery (CCS %) adjusted to INB incidence was found to increase significantly from 10.5% CCS in no release plots to 11.1,11.5 and 11.8% for 6,12,and 24 releases.

The ANOVA from *Bannari Amman Sugars Ltd* is summarized in Table 2.

Table 2 ANOVA for main variables

Parameters	Year1(CD :P=0.05)	Year 2 (CD :P=0.05)	Pooled Analysis (CD:P=0.05)
Borer (INB)-cane basis %	9.97*	2.79*	3.03**
Cane yield/acre	2.94*	0.76*	2.12**
CCS %	NS	NA	NS

NS=Not significant; *-significant; **- highly significant; NA-Not ApplicableCD: Critical difference (LSD)

The data collected for two years showed that the borer (INB) incidence differences were significant among the treatments (T1-T4). A similar trend was observed for cane yield. In case of sugar recovery (CCS %), the data were available only for year1 and the differences were not significant. The borer (INB) incidence (on cane basis) was found to decrease gradually from 'No release' (T1) treatment in both Year 1 and Year 2. The overall pattern was similar when pooled for both years. Overall reduction in borer INB incidence (cane basis) was about 13 percent for 6 releases (T2), 29 percent for 12 releases (T3), and 49 percent for 24 releases (T4). The sugar recovery (CCS %) adjusted to INB incidence was found to not differ significantly among the treatments in Year 1. The CCS% was 9.7, 9.9, 10.0 and 9.7 respectively; however, the values being not significantly different among the treatments indicate no reliable effect. The sugar recovery (CCS %) adjusted to INB incidence was found to not differ significantly among the treatments in Year 1. The CCS% was 9.7, 9.9, 10.0 and 9.7 respectively; however, the values being not significantly different among the treatments indicate no reliable effect.

The ANOVA from NSL Sugar Factory, Alland, Gulbarga is summarized in Table 3.

Table 3 ANOVA for main variables

Parameters	Year1 (CD :P=0.05)	Year 2 (CD :P=0.05)
Borer(INB)-cane basis %	NS	NA
Cane yield/acre	NS	NA
CCS %	NS	NA

NS=Not significant; *-significant; **- highly significant; NA-Not Applicable CD: Critical difference (LSD)

The INB incidence differences were not significant. A similar trend was seen for cane yield and sugar recovery (CCS %). The borer (INB) incidence (on cane basis) was found to decrease only non-significantly from 'No release' (T1) treatment. Overall reduction in borer INB incidence (cane basis) was about 5 percent for 6 releases (T2), 7 percent for 12 release (T3), and 15 percent for 24 release (T4). The overall yield increase for 6, 12, and 24 releases (T2,T3 and T4) was non-significant, about 4, 2 and 2 tons/ acre, respectively. The

sugar recovery (CCS %) equivalent to INB incidence was 10.1, 10.2, 10.2 and 10.4 respectively and did not differ significantly.

The ANOVA of Vijayanagar Sugar Factory Ltd, Vijayanagar, Hubli is summarized in Table 4.

Table 4 ANOVA (Analysis of Variance) for main variables

Parameters	Year1 (CD :P=0.05)	Year 2 (CD :P=0.05)	Pooled Analysis (CD:P=0.05)
INB-cane basis %	NS	4.35*	9.72*
Cane yield/acre	NS	1.32*	1.38**
CCS %	NA	-NA	NA

NS=Not significant; *-significant; **- highly significant; NA-Not Applicable CD: Critical difference (LSD)

The data for year1 was limited to one replication, hence combined with 4 replications for year 2 in pooled analysis. It showed that the INB incidence differences were significant among the treatments (T1-T4). A similar trend was observed for cane yield. In case of sugar recovery (CCS %), the data not available for both years. The borer (INB) incidence (on cane basis) was found to decrease from 'No release' (T1) treatment in both Year 1 and Year 2. The overall pattern was similar when pooled for both years. Overall reduction in borer INB incidence (cane basis) was about 24, percent for 6 releases, 41 percent for 12 releases (T3), and 52percent for 24 releases (T4). The cane yield (tons/acre) was found to increase with the release regimes, in both Year 1 and Year 2. The yield increase for 6, 12, and 24 releases (T2,T3 and T4) was about 3,5 and 7 tons/ acre, respectively.

CONCLUSION

Specific local recommendations for the Chamunndeeswari sugar factory

- Encourage local farmers to adopt 6 or 12 releases of tricho cards for INB control. *Recommending more releases (upto 24 as in here) is possible in case the INB severity is high.*
- Timing of release to be more during 5-10 months and negligible during 11-12 months.

Specific local recommendations Bannariamman sugar factory

- Encourage local farmers to adopt 6 or 12 releases of tricho cards for INB control. *Recommending more releases (upto 24 as in here) is possible in case the INB severity is high.*
- Timing of tricho card release to be more during 7-8 months and the rest during 5-6 or 9-10 months, based on the local age-wise INB incidence pattern below..

Specific local recommendations for NSL Sugar factory

- Encourage local farmers to adopt 6 or 12 releases of tricho cards for INB control.
- Timing of release to be more during 5-6 months and the rest during 7-10 months.

Specific local recommendations for Vijayanagar sugar factory

- Encourage local farmers to adopt 6 or 12 releases of tricho cards for INB control. *Recommending more releases (upto 24 as in here) is possible in case the INB severity is high.*
- Timing of Tricho card release to be more during 5 to 10 months age, since negligible in 11-12 months.

This study is perhaps the first of such kind in India, pinpointing specific crop ages for different harvesting months, so to selectively target increased *Trichogramma* doses. Such refinements based on the local variation in INB incidence at different crop ages would indeed be very useful local information for targeting the *Trichogramma* release program suitably.

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REFERENCES

David H. Easwaramoorthy S. and Jayanthi R. (eds.) 1986. Sugarcane Entomology in India. Sugarcane Breeding Institute, Coimbatore, India.564pp.

Easwaramoorthy S.1983. Estimation of damage and losses caused by sugarcane pests.p5-18.In M.Balasubramanian and AR Solayappan (eds.) Sugarcane Pest Management in India. Tamilnadu Cooperative Sugar Federation, Chennai, and India.77pp).

Geetha, N, E D Shekinah and P Rakkiyappan. 2009. Comparative impact of release frequency of *Trichogramma chilonis* Ishii: Against *Chilo sacchariphagus indicus* (Kapur) in sugarcane. J. Biol. Control, **23**: 343-51.

Kalyanasundaram M , Justin C G L, Swamiappan M, Sundarra babu P C and Jayaraj S. 1993. Efficacy of *Trichogramma Chilonis* against sugarcane internode borer, *Chilo sacchariphagus indicus.* Indian Journal of Plant Protection. **21**(2):119-21.

Sithanantham S.2006.Towards enhancing the adoption of biological pest control technologies in sugarcane: case study of borers in South India. SISSTA Sugar Journal.73-6.

Sithanantham S, Kandasamy R and Naidu N V. 2009. Trichogramma release for biocontrol of sugarcane borers: The adoption scenario and way forward in Tamil Nadu and Andhra Pradesh. P77-3.

Solayappan A R. 1980. Mass production of *Trichogramma* for release in factory area. pp. 29-35. In: Sithanantham, S. and Solayappan, A.R. (eds.), Biological Control of Sugarcane Pests in India. Parasite Breeding Centre, Madaranthagam Co operative Sugar Mills Limited, Chengalpattu, 603001, Tamilnadu, India.

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