ISSN 0250-5193

GUJARAT AGRICULTURAL UNIVERSITIES RESEARCH JOURNAL

S.D.Agricultural University
Sardarkrushinagar

Anand Agricultural University
Anand

Junagadh Agricultural University
Junagadh

Navsari Agricultural University
Navsari

VOLUME : 47 NUMBER : 1

JANUARY, 2022

GAU RES. J. 47 (1)

PATRONS

Dr. R. M. Chauhan
Vice Chancellor
S.D. Agril. University
Sardarkrushinagar

Dr. K. B. Kathiria
Vice Chancellor
Anand Agril. University
Anand

Dr. V.P. Chovatia
Vice Chancellor
Junagadh Agril.University
Junagadh

Dr. Z.P. Patel
Vice Chancellor
Navsari Agril.University
Navsari

ADVISORY BOARD

Dr. C. M. Muralidharan, Director of Research & Dean PGS, S.D.A.U., Sardarkrushinagar

Dr. T. R. Ahlawat, Director of Research & Dean PGS, N.A.U., Navsari

Dr. S. D. Solanki, Principal, C. P. College of Agriculture, S.D.A.U., Sardarkrushinagar

Dr. Y. M. Shukla, Principal, B. A. College of Agriculture, A.A.U., Anand

Dr. C. D. Lakhlani, Principal, College of Agriculture, J.A.U., Junagadh

Dr. R. D. Pandya, Principal, N. M. College of Agriculture, N.A.U., Navsari

Dr. Samit Dutta, Dean, College of Food Processing and Bio Energy, A.A.U., Anand

Dr. P. M. Chauhan, Dean, College of Agril. Engg. & Tech., J.A.U., Junagadh

EDITORIAL BOARD

Dr. C. M. Muralidharan (Editor in Chief)

SDAU, Sardarkrushinagar

Dr. C. K. Patel, Associate Directorate of Research (Farm)
Dr. P. S. Patel, Associate Directorate of Research (Edu.)
Lt. Dr. Simple Jain, Asisstant Professor (Extension Edu.)

AAU, Anand

Dr. S. N. Shah, Associate Director of Research (Agri.)
Dr. D. B. Sisodiya, Associate Professor and Head (Entomology)

JAU, Junagadh

Dr. R. B. Madariya, Director of Research
Dr. A. G. Pansuriya, Associate Research Scientist
Prof. Pinky S. Sharma, Assistant Extension Educationist

NAU, Navsari

Dr. V. R. Nayak, Associate Director of Research (Agri.)
Dr. K. G. Patel, Professor and Head (Soil Sci. & Agri.Chem.)
Dr. R. K. Patel, Associate Professor (Plant Breeding)

Vo. 47
Number 1
January 2022

Gujarat Agricultural Universities Research Journal

Contents

Research Papers

Official Publication of

Gujarat Agricultural Universities, Gujarat State

S.D.Agricultural University
Sardarkrushinagar

Anand Agricultural University
Anand

Junagadh Agricultural University
Junagadh

Navsari Agricultural University
Navsari

GAU Research Journal **47** (1) : 01-11 (January 2022)

Hybrid SARIMA-Facebook Prophet model for prediction and forecasting of the staple food prices in Tanzania

Godfrey Joseph Saqware [1,3*] and Ismail, B.[2]

[1] Department of Statistics, Mangalore University, Karnataka, India.
[2] Department of Statistics, Yenepoya (Deemed to be University), Karnataka, India.
[3] University of Dar es Salaam, Tanzania
Email: [1,3] godjose70@yahoo.com; [2] prof.ismailb@gmail.com

Received: 04th February, 2021 Accepted: 24th February, 2021

ABSTRACT

The country's stable development requires sufficient food production and reserves for its people. However, the global climatic change and other factors, including political instability, resulted in the shortage and volatility of staple food prices. Thus, the best prediction and forecasting models of staple food prices become essential. The advancement of technology gave room for the development of hybrid models. Therefore, in this paper, we develop the SARIMA-Facebook (FB) Prophet model to predict and forecast staple food prices in Tanzania. Based on the Root Mean Squared Error (RMSE) metrics, the proposed hybrid model out performs the SARIMA and other hybrid models in predicting staple food prices. Moreover, the forecasts for the next two years have shown increasing trends in staple food prices. Since most neighbouring countries depend on Tanzania to complement the food crisis in their countries, initiatives should be taken into account to stabilize prices. Finally, the proposed hybrid SARIMA-FB Prophet may be applied to predict and forecast other prices to see the stability of its accuracy. The construction of the theoretical hybrid SARIMA-FB Prophet model may be done in future studies.

Key words : ARIMA,SARIMA-FB Prophet, Staple food, Time series, RMSE.

INTRODUCTION

Global growth in food production has increased from 70 per cent to 110per cent to meet the demand of the rapid population by 2050 is the fundamental debate. The agricultural sector employment in Africa accounts for 65%, and 61% of the rural households depend on agriculture for livelihood in Sub-Saharan Africa. In Tanzania, the future production of staple food crops remains uncertain due to over-dependence on rain-fed, poor agricultural practices, and climate change and variability. Maize experiences higher seasonality compared to rice among staple food crops. The seasonality significantly varies between one market to another. Policymakers should work harder to stabilize the seasonality of food prices and demand to achieve the Sustainable Development Goal of zero hunger by 2030 (Gilbert *et al.*, 2017). The regional markets, rather than global markets, are the source of external pressures on domestic prices. Furthermore, interactions with both external market shocks and domestic weather shocks play a role in how trade policies influence markets. Price transmission and spatial price fluctuations for staple foods vary from one place to another as a factor of distance from the markets. The improved roads and market infrastructures may reduce the price fluctuation between producers and wholesale markets across the country. Moreover, direct price incentives resulting from border protection, government involvement in domestic markets, and border price shocks encourage farmers' supply and price fluctuations–.Climate change potentially makes the communities vulnerable due to decreased agricultural productivity, food insecurity, and water availability".Supporting market linkage and infrastructure and enforcing transparent and non-restrictive food marketing rules would improve market access'.Tanzania experienced various times of food scarcity owing to limited food production. Even though the country has an undeniable food production capacity, the government and development partners must play a more significant role in achieving food self-sufficiency. Based on

[1]Scientist, Department of Statistics, Manglore University, Karnataka
[1]Scientist, Department of Statistics, Yenepoya (Deemed to be University), Karnataka
[2,3]Professor, University of Dar Es Salaam,pandeyhs13@gmail.com

policy, climate, and price changes, the accurate future prediction and forecasting of the staple food prices in Tanzania is becoming important. The Auto regressive Integrated Moving Average (ARIMA) model gains much application in modelling and forecasting the time series data. The ARIMA model has got immerse applications in the fields of business, economics, meteorology, agriculture, health to mention a few. The model still performs well in predicting and forecasting agricultural production. The ARIMA and SARIMA models contribute to the market forecasting prices. In the education sector, enrolment of students has also been predicted using ARIMA and SARIMA models. In the health sector, the ARIMA models have an application in predicting new cases of diseases. Using ARIMA and SARIMA models in energy sector prediction is essential in forecasting energy load and demand. Despite the numerous applications of the Box and Jenkins methodology in recent years, researchers claimed that using single models in time series forecasting is insufficient. The hybrid time series models have caught many researchers' attention and have more excellent performance.

Therefore, this paper is divided into five sections. Section two discusses related literature on hybrid models and proposes a suitable hybrid model for predicting and forecasting staple food prices; Section three describes the material and hybrid methodologies for the study. Section four will discuss the results obtained. Finally, section five will provide a conclusion and recommendations for further studies.

RELATED LITERATURE

Technology and advanced computer knowledge have brought changes in modelling and algorithm development. Several pieces of literature talk about the hybrid time series models. The hybrid ARIMA–ANN model out performs single models in the time series multi-step ahead forecasts with the highest accuracy. The comparison model on the generated values of the observed data showed that the wavelet-SARIMA-ANN model out performed the wavelet-ANN and wavelet-SARIMA models in terms of forecasting accuracy. The comparative performance analysis of the proposed methodology with ARIMA, ETS, the Multilayer Perceptron (MLP), and some existing hybrid ARIMA–ANN models shows that the proposed hybrid model statistically gave optimistic predictions results. The hybrid methodology that integrates empirical mode decomposition (EMD) and the ARIMA model applied to forecast the monthly rice prices in Malaysia has increased the accuracy. Experimental results with real data sets indicate that the combined model can effectively improve forecasting accuracy instead of using models separately. A hybrid model incorporating ensemble empirical mode decomposition (EEMD), ARIMA, and Taylor expansion with a tracking differentiator was proposed. The EEMD decomposes the financial time series into subseries. The ARIMA and Taylor expansion models forecast the linear and non-linear portions. The findings on the real financial time series data revealed that the hybrid model outperforms the benchmark models. The combination of ANN and ARIMA in forecasting the future exchange prices for US Dollar (USD) / Indian Rupees (INR) reveals that the hybrid ANN-ARIMA can closely forecast the foreign exchange rates. A hybridization methodology based on integrating the SARIMA and ANN models to predict the number of inspections indicates that the hybrid SARIMA-ANN model out performs single models. The hybrid SARIMA model that integrates Support Vector Regression (SVR) with Gaussian white noise applied to forecast the future statistical indicators in the aviation industry was proposed. The results of the empirical study suggest that the proposed hybrid SARIMA-SVR increases forecasting accuracy. Furthermore, the hybrid ARIMA–ANN model to forecast electricity prices improved prediction accuracy. Based on the literature review, the proposed hybrid model works better than single models.

Therefore, a hybrid model can effectively improve the forecasting accuracy of the traditional methods using appropriate strategies. In this paper, we will combine ARIMA or SARIMA model and the FB Prophet models and apply the best hybrid model in forecasting the staple food prices in Tanzania. Furthermore, the proposed hybrid model will be compared with the single and hybrid machine learning models.

MATERIALS AND METHODS

3.1 Data specification

This paper considers monthly recorded data of the staple food prices collected from the Ministry of Industry and Trade, the government of the United

Republic of Tanzania. The data covers the time between January 2005 and December 2021. The analysis of the two data sets is important due to climate change, war, outbreaks of pests and diseases, and the global Corona virus pandemic which affects global food production and ultimately hunger. The data was divided in 80% and 20% training and testing sets respectively.

PREDICTION MODELS

3.2.1 Autoregressive Integrated Moving Average Model (ARIMA)

The Auto regressive Moving Average model (AIRMA) is the combination of the Auto regressive (AR) and Moving Average (MA) Models. The auto regressive model predicts the current value based on the previous observations $w_{t-1}, w_{t-2}, \ldots, w_{t-p}$ while the Moving Average model predicts the current value using the residuals of the previous values $\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-p}$

The AR model of order p is given by: -

$$w_t = \psi_1 w_{t-1} + \psi_2 w_{t-2} + \ldots + \psi_p w_{t-p} + \varepsilon_t \quad (1)$$

The model in Eqn. (1) can be re-written as: -

$$w_t - \psi_1 w_{t-1} - \psi_2 w_{t-2} - \ldots - \psi_p w_{t-p} = \varepsilon_t \quad (2)$$

By applying the backward shift operator $B^j w_t = w_{t-j} \;\; j = \{1,2,3,\ldots,\} p$, the model in Eqn. (2) can be re-written as: -

$$\begin{aligned} w_t - \psi_1 B w_t - \psi_2 B^2 w_t - \ldots - \psi_p B^2 w_t &= \varepsilon_t \\ (1 - \psi_1 B - \psi_2 B^2 - \ldots - \psi_p B^2) w_t &= \varepsilon_t \\ \psi(B)\, w_t &= \varepsilon_t \end{aligned} \quad (3)$$

The MA model of order q is given by: -

$$w_t = \varepsilon_t + \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \ldots + \phi_q \varepsilon_{t-q} \quad (4)$$

By applying the backward shift operator $B^j \varepsilon_t = \varepsilon_{t-j} \{j = 1,2,3,\ldots,\} q$, the model in Eqn. (4) can be re-written as: -

$$\begin{aligned} w_t &= \varepsilon_t + \phi_1 B \varepsilon_t + \phi_2 B^2 \varepsilon_t + \ldots + \phi_q B^q \varepsilon_t \\ w_t &= (1 + \phi_1 B + \phi_2 B^2 + \ldots + \phi_q B^q) \varepsilon_t \\ w_t &= \phi(B)\, \varepsilon_t \end{aligned} \quad (6)$$

By applying the backward shift operator $B^j \varepsilon_t = \varepsilon_{t-j} \{j = 1,2,3,\ldots,\} q$, the model in Eqn. (4) can be re-written as: -

$$\begin{aligned} w_t &= \varepsilon_t + \phi_1 B \varepsilon_t + \phi_2 B^2 \varepsilon_t + \ldots + \phi_q B^q \varepsilon_t \\ w_t &= (1 + \phi_1 B + \phi_2 B^2 + \ldots + \phi_q B^q) \varepsilon_t \\ w_t &= \phi(B)\, \varepsilon_t \end{aligned} \quad (6)$$

The *ARMA (p, q)* model is used for forecasting a stationary time series, and it's given in Eqn. (7) below.

$$\begin{aligned} w_t &= \psi_1 w_{t-1} + \psi_2 w_{t-2} + \ldots + \psi_p w_{t-p} + \varepsilon_t \\ &+ \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \ldots + \phi_q \varepsilon_{t-q} \end{aligned} \quad (7)$$

Now, supposed $w_t \square I(d)$ is the stationary series after dth the order of differencing, we say $z_t = (1) - B^d w_t$ and *ARIM(A,d,q)* can be written as: -

$$\begin{aligned} (1-B)^d w_t = z_t &= \psi_1 z_{t-1} + \psi_2 z_{t-2} + \ldots \\ &+ \psi_p z_{t-p} + \varepsilon_t + \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \ldots + \phi_q \varepsilon_{t-q} \end{aligned} \quad (8)$$

We are introducing the backward shift operator as in Eqn. (3 and 6), Eqn. (8) can be written as: -

$$\begin{aligned} [1 - \psi_1 B - \psi_2 B^2 - \ldots - \psi_p B^p][1-B]^d w_t &= \\ [1 + \phi_1 B + \phi_2 B^2 + \ldots + \phi_q B^q] \varepsilon_t & \\ \psi(B)[1-B]^d w_t &= \phi_1(B) \varepsilon_t \end{aligned} \quad (9)$$

The above-postulated model in Eqn. (9) works only when there is no seasonal variation. If the variable contains a seasonal component, then it is called Seasonal ARIMA or SARIMA model.The seasonal ARIMA model incorporates both non-seasonal and seasonal components in a multiplicative model. The *SARIMA* $(p,d,q)*(P,D,Q)_S$ model is given by: -

$$\begin{aligned} \psi(B)\Psi(B^S)(1-B)^d(1-B^S)^D w_t &= \\ \phi(B)\Phi(B^S)\varepsilon_t & \end{aligned} \quad (11)$$

Where, Ψ and ψ are the AR parameters for the seasonal and non-seasonal components, respectively, while Φ are ϕ the MA parameters for the seasonal and non-seasonal components respectively, B is the backward operator, D and d are the differencing terms.

Infitting the ARIMA/SARIMA models, it involves three main stages.

a) Model identification - This stage involves the analysis of autocorrelations, partial autocorrelations, and cross-correlations. To assess if differencing is required, stationarity tests is done.

b) Model estimation and diagnostic tests - The model's appropriateness is determined using diagnostic statistics generated by the estimate. The white noise residuals tests determine whether the residual series has additional information that a more complex model might use.

c) Forecasting - Here we forecast the future values of the time series and generate confidence intervals for these forecasts.

3.2.2 Facebook FB Prophet Model

The FB Prophet is a developed time series prediction model that is both simple and practical without a lot of data preprocessing. The FB Prophet model can fit very quickly and automatically fill in the missing values. Furthermore, the FB Prophet model allows for flexible adjustment of periodicity, making it suited for various applications. The FB Prophet time series forecasting model comprises trend, cyclic, festival, and error items. The model's composition is as follows: -

$$y(t)=g(t)+s(t)+h(t)+e(t) \quad (12)$$

Where, $g(t)$ is the trend function, $s(t)$ is the periodic term function, $h(t)$ is the impacts from the holidays, and the $(e)t$ is the error term.

Where: -

i) The $g(t)$ can either take the form of the logistic growth model or the piece-wise regression model as follows: -

a) For the logistics growth model, $g(t)=\frac{c}{1+e^{(-k(t-m))}}$

C is the saturation value, k is the growth rate, and m is the bias parameter.

b) For the piece-wise regression,

$$y=\begin{cases}\beta_0+\beta_1 x & x\le c\\ \beta_0-\beta_2 c+(\beta_1+\beta_2)x & x>c\end{cases}$$

where c is the trend change point.

ii) The periodic term function $s(t)$ is based on the Fourier series, which results in periodic effects on model flexibility (Harvey & Shephard, 1993). With a conventional Fourier series, the approximate arbitrary smooth seasonal effects is as follows: -

$$s(t)=\sum_{n=1}^{N}\left[a_n\cos\left(\frac{2\pi nt}{P}\right)+b_n\sin\left(\frac{2\pi nt}{P}\right)\right]$$

trepresent periods and P is the regular periodic length of the time series; it can be daily, monthly, or yearly.

iii) The impacts from the holidays, $h(t)=Z(t)\,K_i$; $K_i \sim N(0,\sigma)$ $Z(t)=[I(t\subset D_1),\ldots,I(t\subset D_i),\ldots,I(t\subset D_L)]$ i represents holidays; D represents the collection of past and future holidays; K represents the impact of each holiday on the forecast.

3.2.3 Hybrid SARIMA-FB Prophet Model.

Suppose $\{Y_t,\ t=1,2,3,\ldots,N\}$ which represent linear SARIMA model and $\{FBt\ t=,1,2,3,\ldots,N\}$ which represent non-linear FB Prophet model, as presented in Eqn. (8) below.

$$Y_t=SARIMA_t+FB_t \quad (13)$$

Where S_t and FB_t denotes the linear and non-linear components, respectively. First, the linear part is obtained by fitting the best SARIMA model. Then, the non-linear part is derived from the best fitted linear model, and then we extract the residuals to fit the hybrid SARIMA-FB Prophet model. Finally, the residual of the best model is given in Eqn. (14) below.

$$e_t=Y_t-\hat{SARIMA}_t \quad (14)$$

Then, the extracted SARIMA model for residual with n input nodes is given in Eqn. (15) below.

$$e_t=f(e_{t-1},e_{t-2},\ldots,e_{t-n})+\varepsilon_t \quad (15)$$

Finally, we can find $\hat{}_tY$ (The final forecasted result of the hybrid SARIMA-FB Prophet model) given in Eqn. (16) below.

$$\hat{Y}_t=\hat{SARIMA}_t+\hat{FB}_t \quad (16)$$

3.2.4 Performance Metrics

To determine the best model, Mean Absolute Percentage (MAPE) and the Root Mean Squared Error (RMSE) criterion were applied to measure model prediction accuracy. The MAPE and RMSE measures the differences between actual and predicted values– .Then, Eqn. (17) and (18) are the MAPE and RMSE formulas.

$$MAPE=\frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i-\hat{y}_i}{y_i}\right| \quad (17)$$

$$RMSE=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i-\hat{y}_i\right)^2} \quad (18)$$

Where the y_t is the actual value, $\hat{y}_t$ is the forecasted value, and n is the forecasting horizon.

EMPIRICAL RESULTS AND DISCUSSION

4.1 The plot of the Staple food prices from 2005 to 2021

The prices of beans and rice have increased compared to other staple food. The round potatoes, maize, and sorghum prices are low for all the recording duration. This shows that rice and beans are the most preferred food; thus, their demand increases their prices. Despite the fact that Tanzania has been suffering from a food deficit for decades, a robust agricultural policy is required to stabilize agricultural production and prices '(Mkonda & He, 2017).Institutional and policy-induced factors influence farmers' decisions on which market to sell their primary goods. As a result, there is a lack of motivation to participate in the production and commercialization of agricultural commodities. The factors influence farmers' decisions on which basic food market to buy in Tanzania. Farmers' integration into staple food markets is poor; according to the findings, female-headed households face more challenges' (Kangile *et al..*, 2020). Fig. 1 below shows the staple food prices in Tanzania from 2005 to 2021.

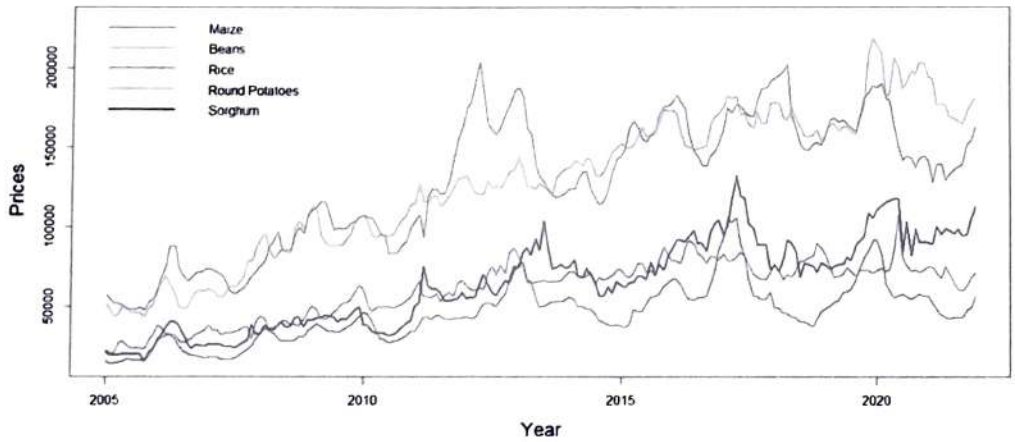


Figure 1: Plot of the Staple Food Prices in Tanzania

4.2 Descriptive Statistics of the Staple food in Tanzania.

Descriptive statistics show that rice and beans have recorded higher prices among the five staples food prices than the rest. Tanzania has a zonal-based production of these crops; rice is produced high in the lake zones and southern part of Tanzania. While beans in the northern and southern regions. Climate change may affect production; thus, if the demand is high, it may lead to shortages and eventually shooting prices. In addition, the global issues in the areas in which oil production is taking place may also increase the staple food prices due to the increase of crude oil per barrel. Table 1 below shows the summary statistics of the staple food prices.

Table 1 : Summary Statistics

Variables	N	mean	sd	median	min	max	skewess	kurtosis	Q0.25	Q0.75
Maize	204	45663.45	18598.3	44213.7	14298	106166.4	0.645635	0.694675	33415.71	56000.05
Potatoes	204	60733.59	18373.92	66710.85	20950	107448.8	-0.46889	-0.77442	46690.09	73232.55
Rice	204	128696.2	42166.44	136008.3	47654	204025.4	-0.27714	-1.07227	95458.35	163326.7
Beans	204	128399.3	45028.58	132272.4	43557	219078.9	-0.25725	-0.9483	94324	164788.3
Sorghum	204	64789.2	27960.09	66341.97	15801	132964.9	0.078813	-1.04384	39032.93	88872.58

4.3 Evaluation of the performance of the testing data set

The proposed hybrid SARIMA-FB Prophet model has performed better than the single ARIMA/ SARIMA model predicting staple food prices. Moreover, the single FB Prophet model has shown better performance than the proposed hybrid model in predicting beans, round potatoes, and sorghum. In predicting the staple food prices, the hybrid SARIMA-FB Prophet model ranks the numbers 3, 1, 1, 2, and 2 for beans, maize, rice, round potatoes, and sorghum, respectively. On the other hand, the proposed hybrid model ranked poorly only in predicting the maize price. The study that combines linear SARIMA and the non-linear generalized autoregressive conditional heteroscedasticity (GARCH) showed the hybrid SARIMA-GARCH performs better than the SARIMA model in forecasting gold price in India. Furthermore, the sophisticated hybrid models that compare SARIMA, Ensemble Learning Machine (ELM) and the hybrid SARIMA-MLP models in forecasting tourist arrivals to Bali concluded that the hybrid SARIMA-ELM model outperforms the hybrid SARIMA-MLP model. However, the complexity of the time series data proves that no unique model works better for each case. Thus, some developed hybrid models might perform the worst in some time series data. Forecasting financial market dynamics has become a focus of economic research. A hybrid Elman's Recurrent Neural Networks(ERNN) model developed to predict stock prices suggest a Minimal Mean Square Error (MMSE) for the h-step forecasts. Thus, the hybrid developed models prove that the integration of more than one model may result in better accuracy. Table 2 below shows the proposed hybrid model summary against its counterparts.

Table 2 : Proposed model summary

Variable	Model	RMSE	MAE	MAPE	Ranking of RMSE
Beans	FB Prophet	16224.10	13824.22	7.44	1
	SARIMA	31418.28	25847.75	13.39	2
	SARIMA-FB Prophet	31525.54	26278.86	13.66	3
Maize	FB Prophet	17565.67	15935.69	29.63	3
	ARIMA	15524.80	10609.04	16.52	2
	ARIMA-FB Prophet	15384.90	10573.17	16.43	1
Rice	FB Prophet	37831.31	31965.75	22.02	3
	SARIMA	17600.33	15530.32	9.89	2
	SARIMA-FB Prophet	17489.06	15650.63	9.94	1
Round Potatoes	FB Prophet	12637.03	11343.99	15.94	1
	SARIMA	31418.28	25847.75	13.39	3
	SARIMA-FB Prophet	26840.80	25138.17	35.63	2
Sorghum	FB Prophet	15634.96	13695.09	15.49	1
	ARIMA	17600.33	15530.32	9.89	3
	ARIMA-FB Prophet	16188.37	12513.40	12.07	2

4.4 The comparison between the developed hybrid and other machine learning models.

SARIMA-FB Prophet still outperforms single and hybrid machine learning models in terms of RMSE. The ELM model is ranked first in the prediction of beans and round potatoes, while the MLP model is ranked first in the prediction of maize and sorghum. The hybrid SARIMA-MLP model comes out on top in rice price prediction. In predicting the prices of beans, maize, rice, and round potatoes, the suggested hybrid SARIMA-FB Prophet model is ranked 5, 2, 2, 3, and 3, respectively. The model continues to beat other predictive models, although single models can still outperform hybrid models depending on the scenario. However, predicting the prices of staple foods is still difficult since each case uses a different model. Table 3 below shows the summary statistics of the proposed hybrid model against the machine learning models.

Table 3 : Proposed model Vs Machine learning models

Variables	Model	RMSE	MAE	MAPE	Ranking of RMSE
Beans	SARIMA-FB Prophet	31525.54	26278.86	13.66	5
	MLP	27543.08	22194.45	11.54	2
	ELM	27072.25	21018.99	10.81	1
	SARIMA-MLP	30725.68	25345.83	13.14	3
	SARIMA-ELM	31028.07	25422.16	13.15	4
Maize	SARIMA-FB Prophet	15384.90	10573.17	16.43	2
	MLP	13550.12	10395.35	17.84	1
	ELM	16459.24	11749.06	17.58	5
	SARIMA-MLP	15480.27	10591.57	16.53	4
	SARIMA-ELM	15028.45	10419.65	16.60	3
Rice	SARIMA-FB Prophet	17489.06	15650.63	9.94	2
	MLP	22529.09	18395.65	11.14	5
	ELM	21423.02	19486.97	12.66	4
	SARIMA-MLP	17441.12	15635.43	9.99	1
	SARIMA-ELM	18357.03	15692.01	9.69	3
Potatoes	SARIMA-FB Prophet	26840.80	25138.17	35.63	3
	MLP	22380.47	20732.71	29.36	2
	ELM	22826.42	21485.08	30.44	1
	SARIMA-MLP	27247.41	25531.13	36.18	5
	SARIMA-ELM	27057.56	25473.02	36.09	4
Sorghum	SARIMA-FB Prophet	16188.37	12513.40	12.07	3
	MLP	12656.46	9600.99	9.44	1
	ELM	16903.55	12946.46	12.38	5
	SARIMA-MLP	16390.57	12420.54	11.87	4
	SARIMA-ELM	14333.61	10821.17	10.52	2

4.5 The best model forecast of the staple food prices in Tanzania

The forecast of the staples food prices is based on the models' overall comparison performance, as indicated in tables 2 and 3. The next 2 years forecasts from the four staple food prices are shown in Fig. 2, 3, 4, 5, and 6. The forecast from the best models from December, 2021 to December, 2024 shows an increase in prices for staple food prices in Tanzania. The forecast alerts the government and other policymakers to take the initiative to stabilize the prices by combating climate changes and reducing the tax on the equipment and other related production facilities. The ongoing war in the oil-producing countries has already impacted the agricultural sector in different ways, such as increased cost of running production machinery and transportation of the harvest from farm to the consumers. Fig. 2,3,4,5, and 6 below shows the next 2 years' forecasts from the best models for beans, maize, rice, round potatoes, and sorghum.

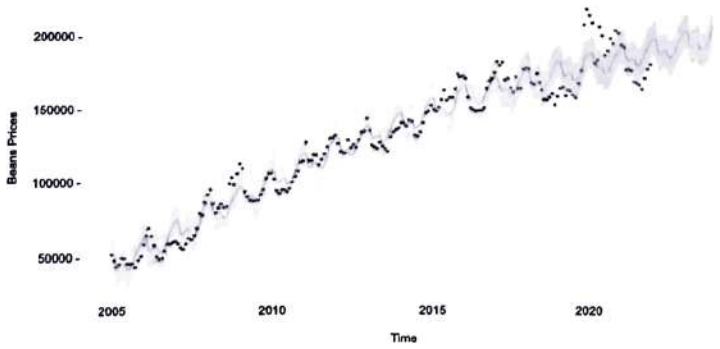


Figure 2 : 2 Years beans prices forecast using FB Prophet model

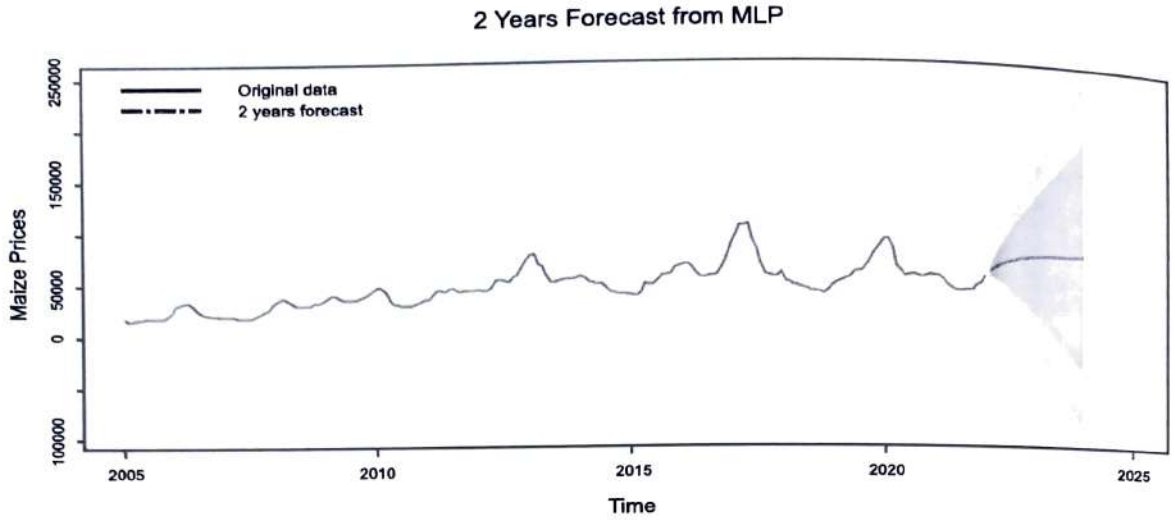


Figure 3 : 2 Year's maize prices forecast using MLP model

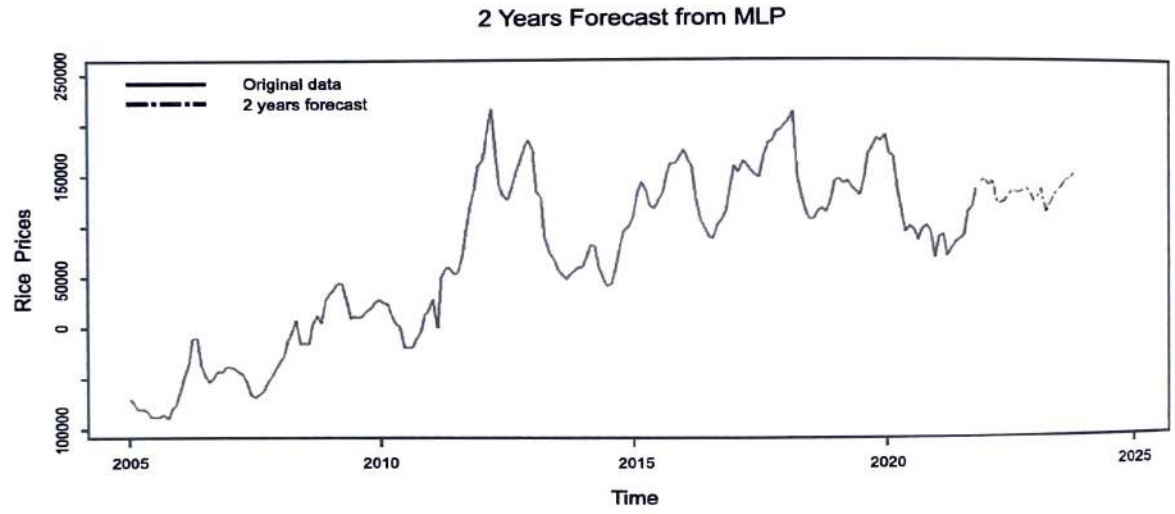


Figure 4 : 2 Year's rice prices forecast using SARIMA-MLP model

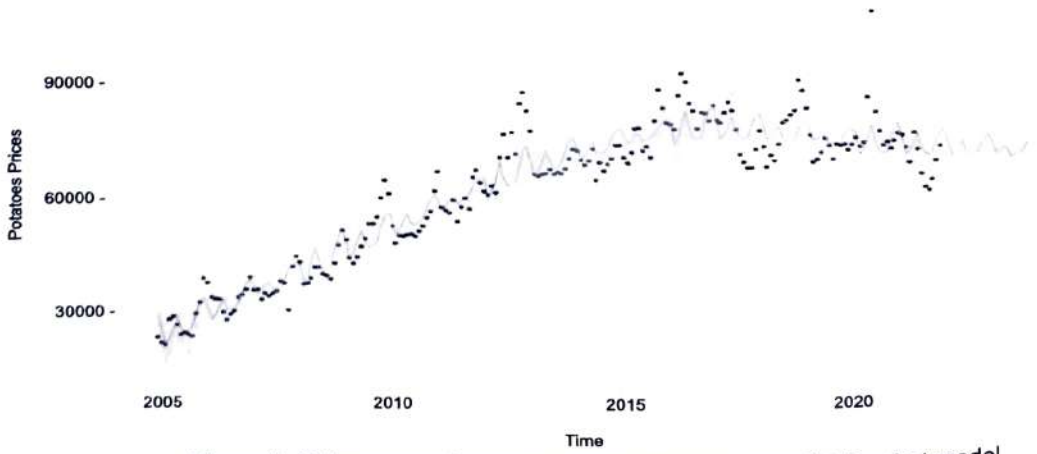


Figure 5 : 2 Years round potatoes prices forecast using FB Prophet model

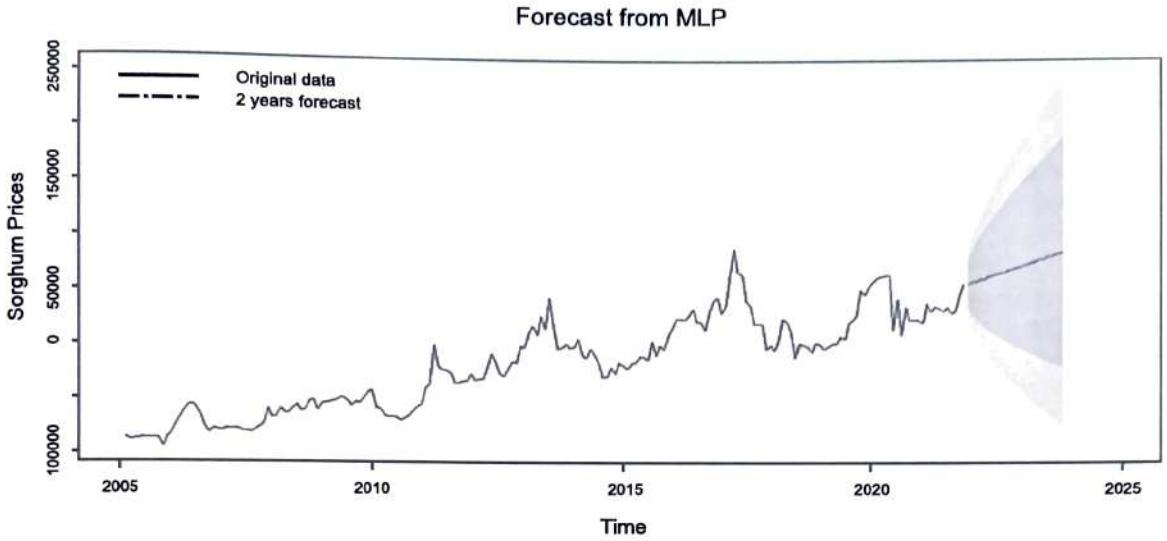


Figure 6: 2 Years sorghum prices forecast using MLP model

CONCLUSION

The hybrid SARIMA-FB Prophet model has shown a more significant performance than the single SARIMA model based on RMSE. The proposed model has shown a convincing performance except in predicting the maize price. Thus, the researchers may use the model to predict the other prices. Compared with a single model, the SARIMA-FB Prophet model can effectively improve a single model's prediction and forecasting accuracy and has more robust applicability. The comparison between the hybrid SARIMA-FB Prophet and machine learning models shows that the model still performs better, although the single ML model performed well in some prediction cases. The next 2 years' forecast of staple food prices using the best selected model shows an increase in prices. Therefore, the private and government planners may formulate more scientific replenishment planning to assure the country's food security and price stability. In this paper, only the hybrid SARIMA-FB Prophet model is developed other hybrid models may be design in the future for further improvement of the prediction and forecasting accuracy.

REFERENCES

Abadan, S., & Shabri, A. (2014). Hybrid empirical mode decomposition-ARIMA for forecasting price of rice. Applied Mathematical Sciences, 8(63), 3133-3143.

Babu, C. N., & Reddy, B. E. (2014). A moving-average filter based hybrid ARIMA-ANN model for forecasting time series data. Applied Soft Computing, 23, 27-38.

Babu, C. N., & Sure, P. (2016). Partitioning and interpolation based hybrid ARIMA-ANN model for time series forecasting. S?dhan?, 41(7), 695-706.

Baffes, J., Kshirsagar, V., & Mitchell, D. (2015). Domestic and external drivers of maize prices in Tanzania. Available at SSRN 2565953.

Borkar, P., & Bodade, V. M. (2017a). Modelling and Forecasting of Tur Production in India Using ARIMA Model. Agriculture Update, 12(2), 252-257.

Borkar, P., & Bodade, V. M. (2017b). Study on Modeling and Forecasting of Tobacco Production in India. International Research Journal of Agricultural Economics and Statistics, 8(2), 281-286.

Boudrioua, M. S. (2019). Modeling and forecasting the Algiers Stock Exchange returns using the Box-Jenkins methodology.

Box, G. (1970). EP and Jenkins, G. M. Time Series Analysis, Holden Day.

Box, G., & Jenkins, G. (1970). Time Series Analysis: Forecasting and ControlV Holden. Day, San Francisco.

Chen, Y. A., Li, R., & Hagedorn, L. S. (2019). Undergraduate international student enrollment forecasting model: An application of time series analysis. Journal of International Students, 9(1), 242-261.

Etuk, E. H., Eleki, A. G., & Sibeate, P. (2016). A Box-Jenkins Model for Monthly Natural Gas

Production in Nigeria. Journal of Multidisciplinary Engineering Science Studies, 2(11), 6.

Hassan, S. A., Abdelaziz, H. H., Ibrahimc, A. H., & Musa, K. S. M. (n.d.). Milk Production-Forecasting In Khartoum State, Sudan.

Hodson, T. O. (2022). Root mean square error (RMSE) or mean absolute error (MAE): When to use them or not. Geoscientific Model Development Discussions, 1-10.

Hussain, J. N., Raheem, S. H., & Enad, M. M. (2021). Use Box-Jenkins strategy for making a time sample to forecasting to Oil prices. Psychology and Education Journal, 58(2), 9943-9951.

Kadigi, I. L., Richardson, J. W., Mutabazi, K. D., Philip, D., Bizimana, J.-C., Mourice, S. K., & Waized, B. (2020). Forecasting yields, prices and net returns for main cereal crops in Tanzania as probability distributions: A multivariate empirical (MVE) approach. Agricultural Systems, 180, 102693.

Kangalawe, R. Y., Mung'ong'o, C. G., Mwakaje, A. G., Kalumanga, E., & Yanda, P. Z. (2017). Climate change and variability impacts on agricultural production and livelihood systems in Western Tanzania. Climate and Development, 9(3), 202-216.

Kangile, R. J., Mgeni, C. P., Mpenda, Z. T., & Sieber, S. (2020). The determinants of farmers' choice of markets for staple food commodities in Dodoma and Morogoro, Tanzania. Agriculture, 10(5), 142.

Karnaboopathy, R., Venkatesan, D., Manikandan, M., Muthukumar, T., Raja, D., & Ramasamy, D. J. (2018). Forecasting Dengue Incidence in Tamil Nadu, India: An Time Series Analysis. Journal of Comprehensive Health, 6(2), 62-66.

Khashei, M., & Bijari, M. (2012). A new class of hybrid models for time series forecasting. Expert Systems with Applications, 39(4), 4344-4357.

Luo, Z., Guo, W., Liu, Q., & Zhang, Z. (2021). A hybrid model for financial time-series forecasting based on mixed methodologies. Expert Systems, 38(2), e12633.

Magrini, E., Balié, J., & Morales-Opazo, C. (2018). Price Signals and Supply Responses for Staple Food Crops in Sub-Saharan Africa. Applied Economic Perspectives and Policy, 40(2), 276-296.

Manikandan, M., Velavan, A., Singh, Z., Purty, A. J., Bazroy, J., & Kannan, S. (2016). Forecasting the trend in cases of Ebola virus disease in west African countries using auto regressive integrated moving average models. Int J Community Med Public Health, 3, 615-618.

Maziku, P. (2019). Variation in Staple Food Prices in Tanzania. African Journal of Applied Research, 5(1), 74-84.

Mbunda, R. (2016). The developmental state and food sovereignty in Tanzania. Agrarian South: Journal of Political Economy, 5(2-3), 265-291.

Mkonda, M. Y., & He, X. (2017). Yields of the major food crops: Implications to food security and policy in Tanzania's semi-arid agro-ecological zone. Sustainability, 9(8), 1490.

Nijbroek, R. P., & Andelman, S. J. (2016). Regional suitability for agricultural intensification: A spatial analysis of the Southern Agricultural Growth Corridor of Tanzania. International Journal of Agricultural Sustainability, 14(2), 231-247.

Panigrahi, S., & Behera, H. S. (2017). A hybrid ETS-ANN model for time series forecasting. Engineering Applications of Artificial Intelligence, 66, 49-59.

Parvez, R., Ali Meerza, S. I., & Hasan Khan Chowdhury, N. (2021). Forecasting student enrollment using time series models and recurrent neural networks.

Pereira, C. M., de Almeida, N. N., & Velloso, M. L. (2015). Fuzzy modeling to forecast an electric load time series. Procedia Computer Science, 55, 395-404.

Priyadarshini, E., Gayathri, G. R., Vidhya, M., Govindarajan, A., & Chakkravarthi, S. (2020). Hybrid forecasting model for non-linear time series. AIP Conference Proceedings, 2277(1), 240005.

Rahman, A. (2017). Modeling of Tea Production in Bangladesh Using Autoregressive Integrated Moving Average (ARIMA) Model. Journal of Applied & Computational Mathematics, 6, 349.

Rajabu, J. K., Mgeni, C. P., Mpenda, Z. T., & Sieber, S. (2020). The Determinants of Farmers' Choice of Markets for Staple Food Commodities in Dodoma and Morogoro, Tanzania. Agriculture, 10(5), 142.

Ruiz-Aguilar, J. J., Turias, I. J., & Jiménez-Come, M. J. (2014). Hybrid approaches based on SARIMA and artificial neural networks for inspection time series forecasting. Transportation Research Part E: Logistics and Transportation Review, 67, 1-13.

Shafaei, M., Adamowski, J., Fakheri-Fard, M.,

Dinpashoh, Y., & Adamowski, K. (2016). A wavelet-SARIMA-ANN hybrid model for precipitation forecasting. Journal of Water and Land Development.

Shetty, D. K. (2015). Hybrid SARIMA-GARCH Model for Forecasting Indian Gold Price. 03(08), 7.

Shetty, D. K., & Ismail, B. (2021). Forecasting stock prices using hybrid non-stationary time series model with ERNN. Communications in Statistics-Simulation and Computation, 1-13.

Taylor, S. J., & Letham, B. (2018). Forecasting at scale. The American Statistician, 72(1), 37-45.

Todri, A. (2021). Empirical analysis on the USD/all exchange rate volatility in Albanian market: Preliminary results.

Waciko, K. J., & Ismail, B. (2020). SARIMA-ELM hybrid model versus SARIMA-MLP hybrid model. International Journal of Statistics and Applied Mathematics, 5(2), 01-08.

Wadi, S. A. L., Almasarweh, M., Alsaraireh, A. A., & Aqaba, J. (2018). Predicting closed price time series data using ARIMA Model. Modern Applied Science, 12(11).

Xu, S., Chan, H. K., & Zhang, T. (2019). Forecasting the demand of the aviation industry using hybrid time series SARIMA-SVR approach. Transportation Research Part E: Logistics and Transportation Review, 122, 169-180.

Yonar, H., Yonar, A., Tekindal, M. A., & Tekindal, M. (2020). Modeling and Forecasting for the number of cases of the COVID-19 pandemic with the Curve Estimation Models, the Box-Jenkins and Exponential Smoothing Methods. EJMO, 4(2), 160-165.

Zhang, G. P. (2003). Time series forecasting using a hybrid ARIMA and neural network model. Neurocomputing, 50, 159-175.

GAU Research Journal **47** (1) : 12-21 (January 2022)

Effects of integrated nutrient management on yield attributes and yield of *kharif* sesame (*Sesamum indicum* L.) and its residual effect on succeeding chickpea (*Cicer arietinum* L.) under middle Gujarat condition

G. N. Motaka and A. C. Sadhu

Department of Agronomy, B. A. College of Agriculture,
Anand Agricultural University, Anand (Gujarat), India – 388110
motkagn@yahoo.in

Received: 04th February, 2021 Accepted: 24th February, 2021

ABSTRACT

Field experiment was conducted at College Agronomy Farm, B. A. College of Agriculture, A.A.U., Anand during *kharif* and *rabi* seasons of 2012-13 and 2013-14 to study the integrated nutrient management in *kharif* sesame (*Sesamum indicum* L.) and its residual effect on succeeding chickpea (*Cicer arietinum* L.) under middle Gujarat condition. Fifteen treatment combinations given in *kharif* sesame crop comprised of five nitrogen management treatments i.e. N_1: 100% Recommended dose of nitrogen (RDN) from inorganic fertilizer, N_2: 50% RDN from inorganic fertilizer + 50% RDN from Vermicompost (VC), N_3: 50% RDN from inorganic fertilizer + 50% RDN from Castor cake (CC), N_4: 25% RDN from inorganic fertilizer + 37.5% RDN from VC + 37.5% RDN from CC and N_5: 50% RDN from VC + 50% RDN from CC and three sulphur levels i.e. S_1 (00 kg ha^{-1}), S_2 (20 kg ha^{-1}) and S_3 (40 kg ha^{-1}) were tested in a factorial randomized block design with four replications. The succeeding chickpea (*rabi*) crop was super imposed on the same lay out. The experiment was conducted on the same site during both the years without changing the randomization of treatments.

The various growth and yield attributing characters like periodical plant height, leaf area index (LAI), dry matter production of plant, number of capsules plant^{-1} were significantly affected due to nitrogen management treatments. These attributes were significantly higher in application of 100% RDN from inorganic fertilizers. Whereas, number of branches plant^{-1} and number of seeds capsule^{-1} were significantly higher under the treatment having 50% RDN from inorganic fertilizer + 50% RDN from vermicompost.

The significantly higher seed yield (503 kg ha^{-1}) and stover yield (1192 kg ha^{-1}) were recorded under treatment N_2 (50% RDN from inorganic fertilizer + 50% RDN from vermicompost) in the pooled analysis. The highest net return of Rs. 52,730 ha^{-1} was secured with treatment of 100% RDN from inorganic fertilizer with the maximum B:C ratio of 4.48.

The residual effect of treatment N_5 (50% RDN from vermicompost + 50% RDN from castor cake) gave significantly maximum seed yield (1881 kg ha^{-1}) and haulmyield of (5667 kg ha^{-1}) of chickpea than all other treatments in the pooled analysis. This treatment also gave the highest net realization of Rs. 47,512 ha^{-1} and benefit to cost ratio (3.59) from chickpea crop over residual effect of rest of the nitrogen management treatments in average of two years.

The various growth and yield attributing characters like number of branches plant^{-1}, number of capsules plant^{-1},1000-seeds weight and harvest index of sesame crop were significantly higher under application of 20 kg S ha^{-1}.

Significantly higher seed yield of sesame (493 kg ha^{-1}) in pooled analysis was produced with application of 20 kg S ha^{-1}. The highest net returns of Rs. 49,053 ha^{-1} was incurred by application of 20 kg S ha^{-1} with maximum B:C RATIO value of 3.69 in sesame crop.

Residual effect of 20 kg S ha^{-1} gave significantly higher seed yield (1726 kg ha^{-1}) and the highest haulm yield (5237 kg ha^{-1}) in the pooled analysis and the maximum net return of succeeding chickpea crop.

The highest net return of Rs. 90,113 ha^{-1} was secured with treatment N_2 (50% RDN from inorganic fertilizer + 50% RDN from VC) with B:C ratio value of 3.40. Application of 20 kg S ha^{-1} recorded the highest net realization of Rs. 91,246 ha^{-1} and B:C ratio of 3.47 in sesame-chickpea sequence in average of two years.

Key words : Chickpea, RDN, inorganic fertilizer Vermicompost, Caster cake

Scientist, Department of Agronomy, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat),

INTRODUCTION

Sesame is the oldest oil seed crop cultivated in the world. It is believed that sesame was probably originated in Africa and introduced into India by the earliest human migrants from Africa.

Except for a brief period of satisfaction during 1986-90 wherein country had witnessed near self sufficiency in vegetable oils, in-spite of continuous increase in domestic oilseeds production, only of 50 % the requirement of vegetable oil is met and nearly half is made through import as a huge cost of 9.7 billion US dollars as incurred during 2011-12 (Hegde *et al.*, 2012). Sesame is one of the important oilseeds crops in Indian agriculture. Through the ages, the sesame seeds have been a source of food and oil and seed oil is still the main source of fat used in cooking. Sesame oil has many medicinal values as it is good for respiratory disorders, eye-infections and digestive ailments.

Sesame cultivated on a large area in the states of Maharashtra, Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil nadu, West Bengal, Gujarat, Karnataka, Kerala and Punjab and to a limited extent, in Tripura and Himachal Pradesh. By virtue of its early maturing, sesame fits well into a number of multiple cropping systems either as a catch crop or a sequence crop in *rabi* and pre-*kharif* seasons. India rank first in area, production and export of sesame in the world. Sesame ranks third in terms of total oilseed area and fourth in terms of total oilseed production in India. The average production of sesame in India is very low (274 kg ha^{-1}) (Anonymous, 2012). It is one of the important oilseed crops in Gujarat and mainly grown in marginal land with minimum care. Lack of proper nutrient management is one of the major causes for low yields. Balanced fertilization with NPK was proved beneficial in all the oil seed crops, both under rainfed and irrigated conditions. Integrated use of organic and inorganic fertilizers in a balanced proportion for sustainable production of sesame was therefore emphasized by Deshmukh *et al.* (2002).

Sesame-Chickpea is one of the most prevalent cropping sequences followed in Middle Gujarat. Integrated nutrient management provide the valuable information about the effect of chemical fertilizer alone and in combination with organic manure on the soil fertility and crop productivity under intensive cropping. Integration of inorganic with organic manures will not only sustain the crop production, but also effective in improving soil health and enhancing the nutrient use efficiency. Integrated use of organic manure and chemical fertilizers in sesame helps maintaining stability in crop production, besides improving soil physical conditions (Verma *et al.*, 2012). Higher yield of sesame can be obtained by integrated use of fertilizer along with FYM, vermicompost and Azospirillium (Purushottam, 2005 and Jaishankar and Wahab, 2005). Further combined application of organic and inorganics during kharif season in sesame exerts significant residual effect on succeeding chickpea (Purushottam, 2005).

Irrespective of the crops, sulphur is now rightly called as the fourth essential plant nutrient after N, P and K, but for oilseed crops, it is as important as phosphorus. Presently, its importance is recognized due to its wide spread deficiency in the soil. The beneficial role of sulphur in increasing crop production, particularly in the oilseeds and pulse crops has been reported by several researchers. About 37 per cent soils of the Gujarat are found sulphur efficient. The soils of middle Gujarat are light in texture and mostly in medium and deficient range in S availability; which results in the reduction in yield and quality of the sesame crop. Sulphur is a constituent of three amino acids commonly found in plants viz., cystine, cystenine and methionines, which are essential components of proteins.

Combined application of available organic source along with optimal dose of inorganic fertilizers assure high and sustained productivity in oil seed-legume cropping system due to regulated nutrient supply and reduced losses, beside lowering costs. Such information is lacking for the sesame-chickpea cropping system. The information on the use of organic manures like castor cake, vermicompost and sulphur for sesame crop as well as their effects on sesame-chickpea sequence is scanty. With this background, present investigation was carried out to study the integrated nutrient management in sesame and its residual effect on succeeding chickpea under middle Gujarat condition.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi* season in 2012-13 and 2013-14 at Anand (situated at 22°35' N latitude and 72°55' E longitude with an altitude of 45.1 m above the mean sea level). The chemical test values of soil were 7.40 pH, 0.25 dS/m EC, low in organic carbon (0.33%), low in available nitrogen (N) (195.2 kg ha^{-1}), medium in available phosphorus (32.41 kg ha^{-1}) and low in available sulphur (8.23 mg kg^{-1}). The total rainfall received during the crop growth period was 876 mm in 2012-13 and 1259.6 mm in 2013-14. Fifteen

treatment combinations given in *kharif* sesame crop comprised of five nitrogen management treatments i.e. N_1: 100% RDN (Recommended dose of nitrogen) from inorganic fertilizer, N_2: 50% RDN from inorganic fertilizer + 50% RDN from VC (Vermicompost), N_3: 50% RDN from inorganic fertilizer + 50% RDN from CC(Castor cake), N_4: 25% RDN from inorganic fertilizer + 37.5% RDN from VC + 37.5% RDN from CC and N_5: 50% RDN from VC + 50% RDN from CC and three sulphur levels i.e. S_1 (00 kg ha^{-1}), S_2 (20 kg ha^{-1}) and S_3 (40 kg ha^{-1}) were tested in a factorial randomized block design with four replications. The succeeding chickpea (*rabi*) crop was super imposed on the same lay out. The experiment was conducted on the same site during both the years without changing the randomization of treatments. The recommended dose of fertilizer (RDF) for *kharif* sesame 50: 25: 00 NPK kg ha^{-1}. The organic manures and fertilizers were applied in the experimental plots before sowing as per the treatments. Small furrows were opened manually in each plot keeping the distance of 45 cm between the rows and fertilizers were applied uniformly in the furrows at the time of sowing as basal dose. The nitrogen was applied through urea and phosphorus was applied through diamonium phosphate. Treatment wise vermicompost, castor cake and sulphur were manually incorporated in soil before sowing of the crop as per the treatments.

The plot size for each treatment was 4.5 m × 6.0 m. The pure seeds of sesame variety Gujarat Till-2 were procured from Agricultural Research Station, Anand Agricultural University, Dhandhuka, District Ahmedabad and were used in the experiment. The common seed treatment was given with the fungicide Mancozeb @ 3 g kg^{-1} before sowing. Sowing was done manually in line in the previously opened furrows at 45 cm apart using the seed rate of 2.5 kg ha^{-1} on 14th July in 2012 and 20th July in 2013. The seeds were covered with soil manually for better germination. Chickpea was sown in the same plots as a residual crop after harvesting of sesame. Sowing was done manually in line in the previously opened furrows at 30 cm apart using the seed rate of 60 kg ha^{-1} on 14th October in 2012 and 11th October in 2013. No irrigation was required for sesame crop since it was grown in *kharif* season. Six irrigation were applied to chickpea during crop growth period. Both the crops were kept free from major insect pests and diseases. In order to record various quantitative observations, five plants were randomly selected from each net plot. These plants were suitably labeled for easy demarcation. The observations on the growth and yield contributing characters were recorded from these plants. The gross realization ha^{-1} was worked out on the basis of seed and stover yields of sesame and chickpea for each treatment, considering the prices prevailing in the market. The cost of cultivation ha^{-1} for each treatment was calculated considering the current charges of agricultural operations and market prices of inputs involved. The benefit cost ratio of each treatment was calculated by dividing the gross realization by the cost of cultivation of respective treatments.

RESULT AND DISCUSSIONS

The data pooled analysis is presented and discussed here

3.1 EFFECT OF NITROGEN MANAGEMENT AND SULPHUR LEVELS ON GROWTH ATTRIBUTES OF *KHARIF* SESAME

3.1.1 Effects of nitrogen management (Table-1)

The nitrogen management treatments have significantly influenced the plant height, number of branches $plant^{-1}$, LAI and dry matter production. The plant height of N_1 treatment was at par with N_2only at 60 and 90 DAS, but not at 30 DAS. Significantly higher leaf area index (LAI) was recorded under treatment N_1 (100 % RDN from inorganic fertilizer) than the treatments N_4 and N_5 in the pooled results, but was remained at par with the treatments N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) and N_3 (50 % RDN from inorganic fertilizer + 50 % RDN from castor cake) at 30 DAS and 60 DAS. Significantly higher dry matter production was recorded under the treatment N_1 (100% RDN from inorganic fertilizers) than the treatments N_3, N_4 and N_5 but, remained at par with the treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) at 30 DAS and 60 DAS. Higher dry matter production under application 100 % RDN from inorganic fertilizers can be attributed towards more availability of nitrogen resulting in enhanced vegetative growth and produce higher total dry matter of crop. Similar results were reported by Shashidhara (2007). Significantly higher number of branches $plant^{-1}$was recorded under the treatment N_2 (50% RDN from inorganic fertilizer + 50% RDN from vermicompost), while the treatment N_1 (100% RDN from inorganic fertilizers) was remained at par.

3.1.2 Effects of sulphur levels

Different sulphur levels have varied growth parameters of sesame. (Table-1)

Application of sulphur @ 20 kg ha^{-1} increased important growth characters of sesame over rest of the treatments. The plant height under 20 kg S ha^{-1}

treatment was higher as compared to other sulphur levels during both the years. This was probably due to better availability of sulphur, moisture, space and light. Similar results were observed by Mondal *et al.* (2013). The treatment S_1 (00 kg S ha^{-1}) and S_2 (20 kg S ha^{-1}) produced higher leaf area index at 30 DAS and at 60 DAS than the treatments and S_3 (40 kg S ha^{-1}). The results confirm the finding of Longkumer and Gohain (2012) and Mondal *et al.* (2013). The treatment S_2 (20 kg S ha^{-1}) produced highest values of dry matter production at 30 DAS and at 60 DAS in the pooled analysis. This might be due to the maximum metabolic activity at this level i.e. 20 kg S ha^{-1} resulting increased total dry matter there by seed yield. The results confirm the finding of Mondal *et al.* (2013) and Thentu *et al.* (2014).Application of 20 kg S ha^{-1} recorded significantly higher number of branches $plant^{-1}$than the S_1 and S_3treatment. Increase in number of branches $plant^{-1}$by sulphur application is attributed to the stimulatory effect of sulphur in cell division. This was probably due to more activities of meristematic tissues of the plant producing more number of trifoliate, which ultimately increased total photosynthetic surface area of the plant contributing towards higher production of branches. The results confirm the findings of Chaudhari and Patel (2007), Longkumer and Gohain

Table:1 Growth components of sesame as influenced by various treatments

Treatments	Plant height (cm)			LAI		Dry matter production (g plant-1)		No. of branches plant-1
	At 30 DAS	At 60 DAS	At harvest	At 30 DAS	At 60 DAS	At 30 DAS	At 60 DAS	
Nitrogen management (N)								
N^1: 100% RDN from inorganic fertilizer	56.08	129.16	138.90	2.15	2.58	5.96	15.54	3.51
N^2: 50% RDN from inorganic fertilizer + 50% RDN from vermicompost	52.87	125.27	134.15	2.09	2.50	5.39	14.98	3.57
N^3:50% RDN from inorganic fertilizer + 50 % RDN from castor cake	51.21	123.84	132.95	2.07	2.47	5.16	14.60	3.35
N^4:25% RDN from inorganic fertilizer+37.5% RDN from vermicompost+ 37.5 % RDN from castor cake	49.88	121.34	131.53	2.03	2.44	4.97	14.12	3.18
N^5: 50 % RDN from vermicompost + 50% RDN from castor cake	48.09	117.85	126.75	1.99	2.38	4.72	13.65	3.12
S.Em. ±	0.84	1.75	1.82	0.03	0.03	0.13	0.28	0.05
C.D. at 5 %	2.36	5.00	5.20	0.07	0.10	0.37	0.81	0.14
Sulphur levels (S)								
S^1: 00 kg ha^{-1}	51.63	123.26	133.00	2.07	2.48	5.26	14.56	3.16
S^2: 20 kg ha^{-1}	52.09	123.97	133.48	2.07	2.48	5.33	14.63	3.96
S^3: 40 kg ha^{-1}	51.17	123.19	132.08	2.06	2.46	5.14	14.55	3.31
S.Em. ±	0.64	1.36	1.41	0.02	0.03	0.10	0.22	0.08
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	0.34
Significant Interaction (N × S)	-	-	-	-	-	-	-	--
C.V. %	7.26	6.94	6.71	6.04	6.74	12.05	9.52	7.22

(2012) and Mondal *et al.* (2013).

3.2 EFFECT OF NITROGEN MANAGEMENT AND SULPHUR LEVELS ON YIELD ATTRIBUTES AND YIELD OF *KHARIF* SESAME

3.2.1 Effects of nitrogen management (Table-2)

The treatment N_1 (100% RDN from inorganic fertilizer) produced significantly higher number of capsules plant^{-1} as compared to the treatment N_3, N_4 and N_5, while the treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from VC), remained at par. Application 100 % RDN from inorganic fertilizers attributed towards more availability of nitrogen resulting in enhanced vegetative growth, leading to improved fruiting and thereby more number of capsules plant^{-1}. These results are in close agreement with those reported by Ghosh *et al.* (2013). Significantly higher number of seeds capsule^{-1} were found under treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) followed by treatments N_3 (50 % RDN from inorganic fertilizer + 50 % RDN from castor cake) and N_4 (25 % RDN from inorganic fertilizer + 37.5 % RDN from vermicompost + 37.5 % RDN from castor cake). Application of 50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost enhancedthe uptake of nutrient at flowering and resulted in improvement in the size of the sink to receive the source i.e., increased number of seeds capsule^{-1}. The present findings are in close agreement with those reported by Shashidhara (2007),Jaishankar and Wahab (2005) and Ghosh *et al.* (2013). Higher value of 1000- seeds weight was recorded under the treatment N_2 (50 % RDN from inorganic fertilizer + 50% RDN from vermicompost) followed by treatments N_1 and N_3. Significantly higher seed yield (503 kg ha^{-1}) was recorded under the treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) and it was significantly superior over treatments N_5 (50 % RDN from vermicompost + 50 % RDN from castor cake) and N_4 (25 % RDN from inorganic fertilizer + 37.5 % RDN from vermicompost + 37.5 % RDN from castor cake), but it was remained at par with treatments N_1 (100 % RDN from inorganic fertilizer) and N_3 (50 % RDN from inorganic fertilizer + 50% RDN from castor cake). The treatments N_2, N1 and N_3 gave17.79,15.61 and 9.83 per cent higher seed yield, respectively over treatment N_5. Application of integrated nutrient management with 50% from chemical fertilizer and 50 % from organic i.e. castor cake or vermicompost gave balance nutrition and also provided vital microbes and also increased the availability of both the native and applied nitrogen in the soil and substantially enhance their uptake by the plant. This led to overall improvement in the yield attributing characters like number of capsules plant^{-1}, number of seeds capsule^{-1} and 1000- seeds weight. Vermicompost increases the density of microbes and also provides sufficient energy to remain active. The vermicompost provide the vital macronutrients *viz.*, N, P, K, Ca, Mg and micronutrients such as Fe, Mo, Zn, and Cu etc. and also create salutary soil environmental condition for the crop growth. Above findings are in accordance with those reported by Shaikh *et al.* (2010), Sajadinik *et al.*(2011), Verma *et al.* (2012), Ghosh *et al.* (2013) andVerma *et al.* (2013). The treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) recorded the significantly higher stover yield (1192 kg ha^{-1}) and it was significantly superior to treatments N_5 and N_4, but remained at par with treatments N_1 and N_3. Numerically the significantly higher value of harvest index (30.16 per cent) was recorded under treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) in the pooled analysis, respectively, but treatment N_1 (100 % RDN from inorganic fertilizer) remained at par.

3.2.2 Effects of sulphur levels (Table-2)

Significantly higher number of capsules plant^{-1} was recorded under treatment S_2 (20 kg S ha^{-1}) than treatments S_3 (40 kg S ha^{-1}) and S_1 (00 kg S ha^{-1}). Increase in number of capsules plant^{-1} with treatment 20 kg S ha^{-1} was probably due to stimulatory effect of sulphur on tillering through cytokines synthesis and rapid conversion of synthesized carbohydrates into protein, consequent to increase in the number and size of growing cells, resulting into more number of branches thereby increase in number of capsules plant^{-1}. These results are in accordance with those reported by Mathew *et al.* (2011),Longkumer and Gohain (2012),Mondal *et al.* (2013) and Verma *et al.* (2014).The differences in number of seeds capsules^{-1} due to sulphur levels were not found significant. The highest number of seeds capsules^{-1} was recorded under the treatment S_2 (20 kg S ha^{-1}) as compared to treatments S_1 (00 kg S ha^{-1}) and S_3 (40 kg S ha^{-1}). Significantly higher values of 1000- seeds weight were recorded under treatment S_2 (20 kg S ha^{-1}) than treatments S_1 (00 kg S ha^{-1}) and S_3 (40 kg S ha^{-1}). These findings are in close agreement with those reported by Patel *et al.* (2009), Mathew *et al.* (2011), Longkumer and Gohain (2012), Mondal *et al.* (2013) and Verma *et al.* (2014). Significantly the higher seed yield (493 kg ha^{-1}) was recorded under treatment S_2 (20 kg S ha^{-1}) over treatment S_1 (00 kg S ha^{-1}) and remained at par with treatment S_3 (40 kg S ha^{-1}) and the increase was by 10.78 and 6.25 per cent, respectively. Similarly, decline in yield at 40 kg S ha^{-1} might be ascribed to greater increase in sulphur

Table: 2 Yield components of sesame and succeeding chickpea as influenced by various treatments

Treatments	Sesame						Chickpea	
	Number of capsules plant^{-1}	Number of seeds capsule^{-1}	1000-seeds weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Nitrogen management (N)								
N^1: 100% RDN from inorganic fertilizer	32.79	39.54	3.10	494	1170	29.68	1422	4289
N^2: 50% RDN from inorganic fertilizer + 50% RDN from vermicompost	31.83	47.75	3.15	503	1192	30.16	1674	5052
N^3:50% RDN from inorganic fertilizer + 50% RDN from castor cake	30.50	45.46	3.08	469	1148	28.93	1615	4908
N^4:25% RDN from inorganic fertilizer + 37.5 % RDN from vermicompost + 37.5 % RDN from castor cake	29.00	43.13	3.04	443	1118	28.27	1726	5200
N^5: 50 % RDN from vermicompost + 50 % RDN from castor cake	27.21	41.21	3.03	427	1104	27.90	1881	5667
S.Em. ±	0.50	0.84	0.04	13	24	0.40	30	81
C.D. at 5 %	1.44	2.36	NS	37	67	1.10	81	230
Sulphur levels (S)								
S^1: 00 kg ha^{-1}	29.43	42.90	3.01	445	1126	28.42	1607	4863
S^2: 20 kg ha^{-1}	31.33	44.38	3.19	493	1178	29.59	1726	5237
S^3: 40 kg ha^{-1}	30.05	42.98	3.06	464	1140	28.95	1652	4974
S.Em. ±	0.39	0.65	0.04	10	19	0.30	22	59
C.D. at 5 %	1.10	NS	0.10	30	NS	0.90	59	178
Significant Interaction (N × S)	-	-	-	-	-	-	-	-
C.V. %	8.15	9.32	6.85	10.27	10.21	6.81	8.70	8.71

uptake. The increase in seed yield with application of sulphur might be due to the maximum metabolic activity at this level i.e. 20 kg S ha^{-1} resulting increased total dry matter there by seed yield. They might be increase in nitrate reductase activity and chlorophyll content due to sulphur application due to the availability of sulphur in the plant medium that help in producing sulphur containing amino acid. As a result, synthesis of nitrate reductase enzyme increased and it enhanced the reduction of NO_3 - to reduced N ultimately resulting in higher accumulation of sugar there by increased total dry matter and seed yield of sesame.These findings are in close agreement with those reported by Chaudhari and Patel (2007), Patel *et al.* (2009), Mathew *et al.* (2011), Longkumer and Gohain (2012),Mondal*et al.* (2013),Thentu*et al.* (2014) and Verma*et al.* (2014). Higher value of stover yield (1170 kg ha^{-1}) was recorded under treatment S_2 (20 kg S ha^{-1}). This increase might be due to that sulphur made the plants more efficient in photosynthetic activity and thereby enhancing carbohydrate metabolism in the plant and increased dry matter production. Finally the beneficial effects of all attributes were reflected on stover yield. Other result for increasing in stover yield might be due to maximum utilization of nutrient, water, solar radiation and increase metabolic activity produced maximum stover yield. Similar results were observed by Bhosale *et al.* (2011), Mathew *et al.* (2011), Longkumer and Gohain (2012) and Mondal *et al.* (2013). Significantly higher harvest index (29.59 per cent) was recorded under treatment S_2 (20 kg S ha^{-1}) than other treatments and significantly lower harvest index (28.42 per cent) was recorded under the treatment S_1 (00 kg S ha^{-1}).

3.3 RESIDUAL EFFECTS ON SUCCEEDING CHICKPEA

3.3.1 Residual effect on seed and haulm yields (Table2)

3.3.1.1 Residual effect of nitrogen management

It was observed that the increase in seeds yield of chickpea under treatment N_5 (50 % RDN from vermicompost + 50 % RDN from castor cake) by 8.98 percent over treatment N_4, 16.47 per cent over N_3, 12.36 per cent over $N_2$and 32.27 per cent over N_1.

Likewise, the increase in haulm yield of chickpea was maximum with (N_5) (50 % RDN from vermicompost + 50 % RDN from castor cake) and the increase was 8.98 per cent over treatment N_4, it was 15.46 per cent over treatment N_3, it was 12.17 per cent over treatment N_2 and it was 32.12 per cent over treatment N_1.

These results were ascribed to higher C: N ratio at initial stage of the crop under organic manure treatments. Organic manure is an essential ingredient of the balance dose of fertilizer, which has directly influenced the plant growth and development of crop canopy through better utilization of photosynthesis. Moreover, at later stages of growth, more photosynthets are diverted and accumulated in the pod, which led to maximum seed and haulm yield. Further, residual macro and micro elements available through organic treatments provided better soil environment and physical condition for better root development, plant growth and yield. These findings are similar to those of Thiruppathi*et al.* (2001), Purushottam(2005), Jat and Ahlawat (2006), Malligawada (2010), and Ghoshe*t al.* (2013).

3.3.1.2 Residual effect of sulphur levels

Significantly higher seed and haulm yields were recorded under treatment S_2(20 kg S ha^{-1}) and the increase was 7.40 and 7.69 per cent respectively over treatment S_1 (00 kg S ha^{-1}). Moreover, increase under treatment S_2 was might be ascribed to comparatively more addition of nitrogen also left over residual phosphorus applied to sesame which enhanced the available nitrogen and phosphorus in the soil after harvest of sesame. Therefore improved nutrient status of the soil might have increased the yield attributes of chickpea crop. Similar results were also reported by Srinivasrao *et al.* (2010).

3.4 ECONOMICS (Table 3)

3.4.1 Economics of sesame

3.4.1.1 Effect of nitrogen management

The highest net return of Rs. 52,730 ha^{-1} was secured from treatment N_1 (100 % RDN from inorganic fertilizers) with the maximum B:C RATIO of 4.48. The treatments $N_3$and N_2 also recorded higher net return of Rs. 46,967 ha^{-1} and Rs. 49,830 ha^{-1} with B:C RATIO of 3.68 and 3.59, respectively. Similar results were also reported by Deshmukh *et al.* (2002),Jaishankar and Wahab (2005) and Tripathy and Bastia (2012).

3.4.1.2 Effect of sulphur levels

The highest net returns of Rs. 49,053 ha^{-1} was incurred by treatment S_2 (20 kg S ha^{-1}), with maximum B:C RATIO value of 3.69. Similar results were also reported by Wadile *et al.* (2005), Mathew *et al.* (2011),De *et al.* (2013) and Verma *et al.* (2014).

3.4.2 Economics of chickpea

3.4.2.1 Effect of nitrogen management

Application of treatment (N_5) (50 % RDN from vermicompost + 50% RDN from castor cake) to preceding sesame gave highest net realization (Rs.

Table : 3 Economics of sesame, succeeding chickpea and sesame-chickpea cropping sequence as influenced by various treatments

Treatments	Economics of sesame				Economics of succeeding chickpea				Economics of sesame-chickpea cropping sequence			
	Gross realization Rs. ha-1	Cost of cultivation Rs. ha-1	Net realization Rs. ha-1	B:C ratio	Gross realization Rs. ha-1	Cost of cultivation Rs. ha-1	Net realization Rs. ha-1	B:C ratio	Gross realization Rs. ha-1	Cost of cultivation Rs. ha-1	Net realization Rs. ha-1	B:C ratio
Nitrogen management (N)												
N^1: 100% RDN from inorganic fertilizer	67919	15189	52730	4.47	49756	18337	31419	2.71	117675	33526	84149	3.51
N^2: 50% RDN from inorganic fertilizer + 50% RDN from VC	69069	19234	49830	3.59	58620	18337	40283	3.20	127690	37577	90113	3.40
N^3:50% RDN from inorganic fertilizer + 50 % RDN from CC	64523	17555	46967	3.68	56674	18337	38337	3.09	121198	35893	85305	3.38
N^4:25% RDN from inorganic fertilizer + 37.5% RDN from VC + 37.5 % RDN from CC	60908	20005	40903	3.05	60393	18337	42056	3.29	12130	13834	28295	93.16
N^5: 50 % RDN from VC + 50% RDN from CC	58769	21607	37162	2.72	65849	18337	47512	3.59	124618	39945	84673	3.12
Sulphur levels (S)												
S^1: 00 kg ha^{-1}	61251	17765	43486	3.45	56394	18337	38057	3.08	117645	36102	81543	3.26
S^2: 20 kg ha^{-1}	67772	18719	49053	3.62	60530	18337	42193	3.30	128302	37057	91246	3.46
S^3: 40 kg ha^{-1}	63690	19673	44016	3.24	57852	18337	39515	3.15	121541	38011	83531	3.20

47,512 ha^{-1}) and B:C RATIO (3.59) from succeeding chickpea crop over rest of the nitrogen management treatments given in preceding sesame crop in average of two years. Similar results were also reported by Gudadhe *et al.* (2011) and Ghosh*et al.* (2013).

3.4.2.2 Residual effect of sulphur levels

Treatment S_2 (20 kg S ha^{-1}) recorded the maximum net realization Rs. 42,193ha^{-1}with maximum B:C RATIO of 3.30 in average of two years. The lowest monetary net return (Rs. 38,057 ha^{-1}) and B:C RATIO (3.08) was obtained under treatment S_1(00 kg S ha^{-1}) Similar results were also reported by Srinivasrao *et al.* (2010).

3.4.3 Economics of sesame-chickpea crop sequence (Table-3)

3.4.3.1 Effect of nitrogen management

The highest net return of Rs. 90,113 ha^{-1} was secured with treatment N_2 (50 % RDN from inorganic fertilizer + 50 % RDN from vermicompost) followed by treatment N_3 (50 % RDN from inorganic fertilizer + 50 % RDN from castor cake) in average of two years. The highest B:C RATIO of 3.51 was secured from sesame-chickpea sequence with the treatment N_1 (100 % RDN from inorganic fertilizer), followed by 3.40 with treatment N_2 in average of two years.

3.4.3.2 Effect of sulphur levels

The highest net realization of Rs. 91,246 ha^{-1} in average of two years) was recorded under treatment S_2(20 kg S ha^{-1}) with the B:C RATIO values of 3.47 in average of two years.

CONCLUSION

From the results of two years experimentation, it can be concluded that application of 50 % RDN (25 kg ha^{-1}) from inorganic fertilizer + 50 % RDN (25 kg ha^{-1}) from vermicompost and 20 kg S ha^{-1} applied to sesame crop produced higher yield and net realization of sesame-chickpea cropping sequence, followed by application of 50 % RDN (25 kg ha^{-1}) from inorganic fertilizer + 50 % RDN (25 kg ha^{-1}) from castor cake and 20 kg S ha^{-1} under middle Gujarat condition.

REFERENCES

Anonymous, (2012). Sesame seed output may decline 25 %. Available from http://www.business-standard.com/ article/ markets/ sesame.

Bhosale, N.D., Dabhi, B.M., Gaikwad, U.P. and Chavan, A.B. (2011). Growth, yield and quality parameters of sesame influenced by different levels of potash and sulphur. *International Journal of Forestry and Crop Improvement*, **2**(2): 1212-123.

Chaudhari , S.R. and Patel, D.B. (2007). Response of sesame to different levels of phosphorus and sulphur under north Gujarat agro climatic conditions. *GAU Research Journal*, 32(1&2): 31-33.

De, P.S., Bhale, V.M. and Khadse, V.A. (2013). Quality and economics of summer sesame (*Sesamumindicum* L.) as influenced by irrigation and nutrient levels. *International Journal of Bio-resource and Stress Management*, **4**(2): 369-371.

Deshmukh, M.R., Jain, H.C., Duhoon, S.S. and Goswami, U. (2002).Integrated nutrient management in sesame for kymore plateau zone of Madhya Pradesh. *Journal of Oilseeds Research*, **19**(1): 73-75.

Ghosh, A.K., Duary, B. and Ghosh, D.C. (2013). Nutrient management in summer sesame and its residual effect on succeeding *kharif* black gram. *International Journal of Bio-resource and Stress Management*, 4(4):541-546.

Gudadhe, N.N., Khang, V.T., Thete, N.M., Lambade, B.M. and Jibhkate, S.B. (2011). Studies on organic and inorganic sources of nutrient application in cotton-chickpea cropping sequence. *Omonrice*, **18**: 121-128.

Hegde, D.M., SudhakarBabu, S.N., Rana, D.S., Vyas, A.K. (2012). Agronomic research on oil seed in india: An overview. *Indian Journal of Agronomy*, 57 (3rd IAC Special issue), 58-63.

Jaishankar, S. and Wahab, K. (2005). Effect of integrated nutrient management on the growth, yield components and yield of sesame. *Sesame and Safflower Newsletter*-20: 48-50.

Jat, R.S. and Ahlawat, I.P.S. (2006). Direct and residual effect of VC, bio fertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *Journal of Sustainable Agriculture*, 28(1): 51-54.

Jaishankar, S. and Wahab, K. (2005). Effect of integrated nutrient management on the growth, yield components and yield of sesame. *Sesame and Safflower Newsletter*-**20**: 48-50.

Longkumer, I.T. and Gohain, T. (2012). Effect of sulphur and calcium on growth and yield of sesame under rain fed condition of Nagaland. *Annales Plant Soil Research*, **14**(1): 58-60.

Malligawada, L.H. (2010). Studies on the effect of in-situ soil moisture conservation and nutrient management practices on the productivity of sesame and sorghum in sequence cropping system. *19th World Congress of Soil Science, Soil Solutions for a Changing World, 1 -6, August, 2010, Brisbane, Australia.*

Mathew, J., George, S. and Indira, M. (2011). Effect of sulphur and boron on the performance of sesame (*Sesamumindicum* L.) in Onattukara sandy soil of Kerala, India. *Indian journal of Agricultural Science*, **47(3)**: 214-219.

Mondal, M M A., Badruddin, M.B., Malek, M.A., Hossain, M.B. and Puteh, A.B. (2013). Optomization of sulphur requirement to sesame (*Sesamumindicum* L.) genotypes using tracer techniques. *Bagnladesh Journal of Botany*, **41**(10): 7-13.

Patel, P.N., Patel, P.G. and Patel, B.T. (2009). Response of sesame varieties to different levels of nitrogen and sulphur in loamy sand soils of north Gujarat. *GAU Research Journal*, **34**(2): 150-151.

Purushottam, G. (2005). Integrated nutrient management in sesame (*Sesamumindicum* L.) and its residual effect on succeeding chickpea (CicerarietinumL.). M.Sc. (Agri.) Thesis, *University of Agricultural Sciences, Dharwad.*

Sajadinik, R., Yadavi, A., Balouchi, H.R. and Farajee, H. (2011). Effect of chemical (urea), organic (VC) and biological (nitroxin) fertilizers on quantity and quality yield of sesame (*Sesamumindicum* L.). *Journal of Agricultural Science*, **12**(2): 87-101.

Shashidhara, G.C. (2007). Effect of planting methods and nutrient management practices on growth and yield of sesame (*Sesamumindicum* L.) under rain fed situation. M.Sc. (Agri.) *Thesis, University of Agricultural Sciences, Dharwad.*

Shaikh, A.A., Desai, M.M., Kamble, R.S. and Tambe, A.D. (2010). Yield of summer sesame (*Sesamumindicum* L.) as influence by integrated nutrient management. *International Journal of Agricultural Science*, **6**(1): 144-146.

Srinivasarao, Ch., Masood, A., Venkateswarlu, S., Rupa, T.R., Singh, K.K., Sumanta, K. and Prasad, J.V.N.S. (2010). Direct and residual effects of integrated sulphur fertilization in maize (Zea mays)-chickpea (Cicerarietinum) cropping system on typicustochrept. *Indian journal of Agronomy*, **55**(4): 259-263.

Thentu, T.L., Nawlakhe, S.M., Mankar, D.D., Shrinivasrao, M. and Gauri, V.B. (2014). Growth, yield and quality of summer sesame as influenced by the fertilizer and sulphur levels. *Journal of Soils and Crops*, **24**(1): 143-147.

Thiruppathi, M., Thammathan, K., Ganapathy, M.,Prakash, M., Imayavaramban, V. (2001). Nutrient uptake and quality characters of sesame (*Sesamumindicum* L.) as influenced by micro nutrient, bio fertilizer and phyto hormones. *Sesame and Safflower Newsletter*, **16**: 195.

Tripathy, S. and Bastia, D. K. (2012). Irrigation and nutrient management for yield augmentation of summer sesame (*Sesamumindicum* L.). *Journal of Crop and Weed*, **2**: 54-58.

Verma, S, Saxena, R. and Singh, H. (2012). Integrated nutrient management in sesame (*Sesamumindicum* L.). *Journal of Life Science*, 9(4A): 576-579.

Verma, S., Singh, H. and Saxena,R. (2013). Relative performance of sesame (*Sesamumindicum* L.) under organic, inorganic and integrated nutrient management. *The Indian Journal of Agricultural Sciences*, 83(2): 78-83.

Verma, R.K., Yadav, S.S., Puniya, M.M., Yadav, L.R., Yadav, B.L. and Shivran, A.C. (2014). Effect of phosphorus and sulphur fertilization on growth and yield of sesame (*Sesamumindicum* L.) under loamy sand soils of Rajasthan. *Annales of Agriculture Research*, 35(1): 65-70.

Wadile, S.C., Patil, S.S., Jadhav, M.G., Chaudhari, G.B., Bahale, T.M., Surywanshi, R.T. and Rajput, S.D. (2005). Effect of sulphur application through different sources on seed yield and oil content in sesame (*Sesamumindicum* L.). *Sesame and Safflower Newsletter*, 20: 148.

GAU Research Journal **47** (1) : 22-29 (January 2022)

Development and Standardization of *Carica papaya* Powder Incorporated Food Products

Dr. D. Vijayarani[1], A.Jeevarathinam[2], R. Agnes Bejats[3]

[1] Department of Home Science, V.V. Vanniaperumal College for Women, Virudhunagar- 626001. TamilNadu, India.
vijayarani@vvvcollege.org
[2] Department of Home Science, V.V. Vanniaperumal College for Women, Virudhunagar- 626 001. Tamil Nadu,India.
[3] M.Sc. Food Processing and Quality Control, V.V.Vanniaperumal College for Women, Virudhunagar – 626 001. Tamil Nadu, India.

Received: 04th February, 2021 Accepted: 24th February, 2021

ABSTRACT

The present study was carried out during the academic year 2020-2021 in the Food Processing and Quality Control Lab in the Department of Home Science at V. V. Vanniaperumal College for Women, Virudhunagar, Tamil Nadu. Antioxidant is a substance that delays, prevents or removes oxidative damage and improve the immune power. Papaya consumption improves the immune power of the human being and decreases the antioxidant deficiency. Papaya has very poor keeping quality. Drying is a solution offered to overcome the post-harvest losses and improves the shelf-life. The research revealed that the raw and ripen papaya powders prepared by using cabinet dryer contained 50% and 66.6% of antioxidant activity respectively. The raw and ripen papaya powders prepared by using freeze dryer contained 69% and 87% of antioxidant activity respectively. It is concluded that the ripen papaya powder prepared by using freeze dryer contained more antioxidant activity. Even though the antioxidant activity is higher in the papaya powder prepared by using freeze drying but output of the papaya powder was low yield. So, it is concluded from the study that the ripen papaya powder prepared by using cabinet drying can be utilized for developing new food products. The selected *Carica papaya* powder was incorporated into the biscuit, milk shakes and milk kova at 2%, 4% and 6% level by using replacement method.

Key words: antioxidant elements, phytochemical test, freeze and cabinet dryer, nutritional content, milk kova.

INTRODUCTION

Antioxidants are called "Free- radical scavengers" which improve the immune power and decrease the risk of diseases. Foods rich in antioxidants play an important role in reducing the oxidative stress. Antioxidants through our diet play an important role in helping for the neutralization of excess free radicals. In 21st century, demand for intake of antioxidant food or dietary antioxidant has been increasing with the hope of keeping our body healthy and free from diseases. (Benzie, 2003) Antioxidant deficiency diseases are the major public health issues in the world. Oxidative stress is the main cause for the development of chronic and degenerative ailments such as cancer, arthritis, aging, autoimmune disorders and cardiovascular. Papaya is a common man's fruit with a high nutritive value available at a reasonable price. It contains more vitamins and minerals. The low calories content (32 Kcal / 100 g of ripe fruit) makes a favorite fruit of obese people who are into weight reducing regime. Papayas also contain high levels of antioxidants such as carotenes, vitamin C and flavonoids, which helps to reduce the risk of antioxidant deficiency. It improves the antioxidant defense in elderly patients even without any overt antioxidant deficiency state at the dose of 9 g/day orally. (NIH 1997) They also promote the health of the cardiovascular system and also provide protection against colon cancer. (Arvind *et al.*, 2003) During fiscal year 2020, the volume of papaya production in India amounted to over six million metric tons. (SRD, 2020) Papaya has very poor keeping quality. Drying is a solution offered to overcome the post-harvest losses and improves the shelf life through storage. (Kaleem *et al.*, 2006,)

[1] Scientist, Department of Home Science, V.V. Vanniaperumal College for Women, Virudhunagar, TamilNadu, India.
[2] Professor, Department of Home Science, V.V. Vanniaperumal College for Women, Virudhunagar, Tamil Nadu,India.
[3] Professor, M.Sc. Food Processing and Quality Control, V.V. Vanniaperumal College for Women, Virudhunagar, Tamil Nadu, India.

Drying can discharge approximately 80-90% of water from the fresh products and drying also prevents the growth of microorganisms and reduces the rate of chemical reaction spoilage. (Lau & Taip, 2011) Hence the study is undertaken to improve the immune power of human being which is the need of the hour. Keeping the health benefits and functional benefits of the papaya, the antioxidant rich papaya powder incorporated food products improve the immune power of the people in an economical way.

MATERIALS AND METHODS

1.1 a Preparation of the raw and ripen *carica papaya* powders by using cabinet drying

The raw and ripen papayas free from damages were collected and washed under the running water. Then the skin was removed gently using a peeler after weighing. Then it was cut half using a teaspoon the seeds were scooped and taken out and cut into pieces. After cutting, the raw papayas were weighed and spread over trays and placed into the cabinet dryer (which was indigenously designed by BIOTRONICS, Madurai) at 95°C for 20 hours. The dried papayas were collected and ground in a suitable grinding for 15 sec and sieved. After this process raw and ripen papaya fine powders were stored in a container.

1.1 b Preparation of the raw and ripen papaya powders by using freeze drying

The raw and ripen papayas free from damages were collected and washed under the running water. Then the skin was removed gently using a peeler after weighing. Then it was cut in to half. Using a teaspoon the seeds were scooped and taken out and then the pulp was cut into pieces. After cutting the raw papayas were weighed and ground by blender and placed the papaya juices inside the Freeze Dryer (FD) which was indigenously designed by Kamaraj Engineering College, Virudhunagar, with total pressure and the temperature inside the vaccum chamber of -0.102mbar and -53°C respectively. Then the extraction was carried out by placing extracted papaya juices into a 50ml falcon tube, which were prefrozen in a -70°C freezer overnight. The samples were placed in the FD until pure crystalline ice formed and turned into a powder like product. (Mustapa & Ahmad 2019) For FD, 10g of the extracted papaya juices was placed in each falcon tube and processed for 3 days.

1.2 Comparison of the antioxidant activity of raw and ripen papaya powders prepared by cabinet and freeze drying

DPPH free radical scavenging assay was measured for Carica powder prepared by cabinet and freeze drying methods. DPPH solution was added to 3ml of ethanol and the absorbance was noted at 520 nm. A different level volume of test sample (0.5, 1, 1.5,2 and 2.5ml) was made up to 3ml with ethanol.3ml of DPPH solution was added to each of the above test tube. All the test tubes were incubated at room temperature in dark for 30 minutes. (Eugehio *et al.*, 2012) Absorbance was taken at 520 nm in colorimeter after 30 minutes and percentage of inhibition was calculated by using the formula,

$$\% \text{ Antioxidant} = \frac{Ac - At \times 100}{Ac - As}$$

1.3 Phytochemical screening of the *Carica papaya* powder

The phytochemical tests were also performed in the distilled water extracts of the *Carica papaya* powder. They were carried out using standard qualitative methods as described by Raaman, 2006.. The qualitative phytochemical activity of *Carica papaya* powder was carried out to detect the various constituents such as saponin, sugar, tannins, alkaloids, phenols and quinone.

2.3.1. Test for Saponins:

Foam Test:

2 ml of extract was treated with 2 ml of distilled water shaken vigorously for 2 minutes and adding of 1 ml of olive oil to the foam. Stable foam indicates the presence of saponin.

2.3.2. Test for Reducing Sugars:

Benedict's test :

1 ml of extract was treated with 1 drops of Benedict's reagent and allow to boil for 2 minutes in water bath. Appearance of green colour indicates the presence of reducing sugar.

2.3.3. Test for Tannins:

Ferric Chloride Test:

1 ml of extract was treated with 2 ml of 5 % Ferric chloride solution. Appearance of dark blue or greenish black colour indicates the presence of tannin.

2.3.4. Test for Alkaloids:

Mayer's Test:

2 ml of extract was treated with 1ml of Mayer's reagent (Potassium Mercuric Iodide). Formation of a

yellow colour precipitate indicates the presence of alkaloids.

2, 3.5.Test for Phenols:

Lead Acetate Test:

3 ml of extract was treated with 1ml of 10% lead acetate solution. Appearance of white precipitate indicates the presence of phenol.

2.3.6.Test for Quinone

1 ml of the extract was added to 1 ml concentrated sulphuric acid. Formation of red color indicates the presence of quinones

1.4 Development of the selected *Carica papaya* powder incorporated biscuit, milkshake and milkkova

The selected *Carica* powder was incorporated into biscuit, milkshake and milk kova by using replacement method in the proportions of 2%, 4% and 6%.

1.4.1 Preparation of the selected *Carica papaya* powder incorporated biscuit

The procedure for the preparation of the selected papaya powder incorporated biscuit is described in the flow chart 1.

Sieved all the dry ingredients

↓

Mixed all the dry ingredients (Wheat flour, selected papaya powder, palm sugar and baking powder)

↓

Added the butter and made it into dough and rest it for 30 minutes

↓

Divided the dough into separate balls and rolled it

↓

Cut into various shapes using biscuits mould and baked at 110◦C for 20 minutes.

Flow chart 1 : Preparation of the selected *Carica papaya* powder incorporated biscuit

1.2.2 Preparation of the selected *Carica papaya* powder incorporated milkshake

The procedure for the preparation of the selected papaya powder incorporated milk shake is described in the flow chart 2.

Mixed all the Ingredients (milk, palm sugar, fresh cream, ice cubes and selected papaya powder)

↓

Blended it

↓

Stored in refrigerator

Flow chart 2 : Preparation of the selected *Carica papaya* powder incorporated milk shake

1.4.3 Preparation of the selected carica papaya powder incorporated milk kova

The procedure for the preparation of the selected papaya powder incorporated milk kova is described in the flow chart 3.

↓

Boiled the milk

↓

Added the sugar, cardamom andselected papaya powder

↓

Added ghee and served it hot

Flow chart 3 : Preparation of the selected *carica papaya* powder incorporated milk kova

2.5.4 Preference of the selected *carica papaya* powder incorporated food products by the consumers

Ranking is a test which is used to determine how several samples differ on the basis of a single characteristic. A control need not be identified. All the samples with code numbers were given to panelists. They were asked to rank all the samples according to the intensity of the specific characteristic. In consumer analysis, the panelists were asked to rank the coded samples according to their preference. The selected *Carica papaya* powder incorporated food products such as biscuit, milkshake and milk kova were given to the consumers to rank their preference for the overall acceptability of the products.

1.5 Sensory evaluation of the selected *carica papaya* powder incorporated biscuit, milk shake and milk kova

When the quality of the food product is assessed by means of human sensory organs, the evaluation is said to be sensory or subjective or organoleptic. (Shrilakshmi, 2018) The developed products were assessed by eight panel members. The panelists were asked to determine the sensory attributes on the basis of 5 point hedonic scale and they scored on the basis of sensory qualities such as colour, flavor, consistency, taste and over all acceptability. The overall acceptability was evaluated by the means core of all the attributes.

2.7 Nutritional analysis of the *Carica papaya* powder, control milk kova and the selected *Carica papaya* powder incorporated milk kova

Nutritional analysis of the selected *Carica papaya* powder, control milk kova and the selected *Carica papaya* powder in corporated milk kova was carried out for the detection of various constituents such as potassium, phosphorus, magnesium, vitamin C, vitamin A, iron, calcium and carbohydrate by using standard procedures (AOAC,2012).

2.8 Cost analysis of the selected papaya powder incorporated milk kova

The cost analysis was done considering the raw materials, labor cost and electricity used for the research. The cost was calculated for 100 g of the developed products.

RESULTS AND DISCUSSION

3.1 Comparison of the weight of the dried papaya powder prepared by using cabinet and freeze drying

De hydration is the best method in order to increase the shelfli feoffruits. The *Carica papaya* powder was prepared by using cabinet and freeze drying methods.

Table 1 : Comparison of the weight of the dried papaya powder prepared by using cabinet and freeze drying

S.No	Fruit Powder	Drying Method	Papaya pulp weight (g)	Papaya powder weight (g)
1	Ripen papaya	Cabinet dryer	100g	16.2%
2	Raw papaya	Cabinet dryer	100g	16.2%
3	Ripen papaya	Freeze dryer	100g	4.2%
4	Raw papaya	Freeze dryer	100g	4.2%

Table 1 shows the weight of the papaya powder prepared from raw and ripened papaya by using freeze and cabinet dryers. The research revealed that the 100g of raw and ripen papayas dried under the cabinet dryer contained 16.2% of powder but the 100g of raw and ripen papayas dried under the freeze dryer contained 4.2% of powder. So the weight of papaya powder prepared by using cabinet dryer got more weight than the freeze dryer.

3.1 Comparison of the antioxidant activity of the raw and ripen papaya powders by using cabinet and freeze dryers

The antioxidant activity of the raw and ripened *Carica papaya* powder prepared by cabinet and freeze dryers was determined and the results are presented in table2.

Table 2: Comparison of the antioxidant activity of the raw and ripen papaya powders by using cabinet and freeze dryer

S.No	Name of the Sample	Drying method	Antioxidant activity
1	Ripen papaya powder	Cabinet dryer	66.6%
2	Raw papaya powder	Cabinet dryer	50%
3	Ripen papaya powder	Freeze dryer	87%
4	Raw papaya powder	Freeze dryer	69%

The research revealed that the raw and ripen papaya powders prepared by using cabinet dryer contained 50% and 66.6% of antioxidant activity respectively. The raw and ripen papaya powders prepared by using freeze dryer contained 69% and 87% of antioxidant activity respectively. It is concluded that the ripen papaya powder prepared by freeze drying contained more antioxidant activity. Even though the antioxidant is higher in the papaya powder prepared by using freeze drying but output of the papaya powder was low in yield. So, it is concluded from the study that the ripen papaya powder prepared by using cabinet drying can be utilized for developing new food products.

3.3 Phytochemical screening of the selected *Carica papaya* powder

The phytochemical active compounds of the selected *Carica papaya* powder were qualitatively analyzed and the results are presented in table 3

Table 3: Qualitative analysis of Phytochemicals in the selected *Carica papaya* powder

S.No.	Name of the test	Presence or absence in the selected papaya powder
1	Tannin	+
2	Phenol	+
3	Reducing sugar	+
4	Quinones	-
5	Saponins	+
6	Alkaloids	+

The phytochemical tests were performed in the distilled water extracts of the selected *Carica papaya* powder. The phytochemicals like saponin, alkaloid, tannin, reducing sugar and phenol were present in *Carica papaya* powder. The result to obtained was similar to the result of the research done. (Akshata, 2017)

3.4 Sensory evaluation of the selected *Carica papaya* powder incorporated food product

3.4.1 Sensory evaluation of the selected *Carica papaya* powder incorporated biscuit

Table 4 shows the mean score of colour, flavour, taste, consistency and overall acceptability of the *Carica papaya* powder incorporated biscuit.

Table 4: Sensory evaluation of the selected carica papaya powder incorporated biscuit

S.No	Sensory Attributes	Control	Experimental		
			Sample A	Sample B	Sample C
1	Colour	4.2±0.5	3.8±0.5	4.9±0.2	3.7±0.7
2	Flavour	4.5±0.4	3.6±0.7	4.7±0.4	3.7±0.6
3	Taste	4.6±0.4	3.7±0.4	4.6±0.3	3.5±0.6
4	Consistency	4.8± 0.2	4.0± 0.2	4.8± 0.5	3.5± 0.2
5	Overall acceptability	4.5±0.3	3.9±0.3	4.7±0.4	3.4±0.4

It was found that 4% of the selected *Carica papaya* powder incorporated biscuit was excellent in the overall acceptability and the mean score was 4.7. But in the 2% and 6% powder incorporated biscuit mean scores were 3.9 and 3.4 respectively. Out of the three various formulations, 4% *Carica papaya* powder incorporated biscuit scored the best in quality attributes like appearance, colour, texture, flavor and taste.

3.4.2 Sensory evaluation of the selected *Carica papaya* powder incorporated milkshake

Table 5 shows the mean score of colour, flavour, taste, consistency and overall acceptability of the *Carica papaya* powder incorporated milk shake.

Table 5: Sensory evaluation of the selected *Carica papaya* powder incorporated milk shake

S.No	Sensory Attributes	Control	Experimental		
			Sample A	Sample B	Sample C
1	Colour	4.4±0.3	3.8±0.5	4.9±0.2	3.5±0.5
2	Flavour	4.0±0.5	3.8±0.7	4.7±0.4	3.7±0.6
3	Taste	4.4±0.3	3.7±0.5	4.8±0.4	3.9±0.4
4	Consistency	4.5± 0.3	4.0± 0.3	4.8± 0.2	3.6± 0.3
5	Overall acceptability	4.1±0.3	3.9±0.3	4.8±0.4	3.5±0.4

It was found that 4% *Carica papaya* powder incorporated milkshake was excellent in the overall acceptability and the mean score was 4.8. But in the 2% and 6% *Carica papaya* powder incorporated milkshake mean scores were 3.9 and 3.5 respectively. Out of the three various formulations, 4% *Carica papaya* powder incorporated milkshake scored the best in quality attributes like colour, consistency , flavour, taste and overall acceptability.

3.4.3 Sensory evaluation of the selected *Carica papaya* powder incorporated milk kova

Table 6 shows the mean score of colour, flavour, taste, consistency and overall acceptability of the *Carica papaya* powder incorporated milk kova.

Table 6: Sensory evaluation of the selected *Carica papaya* powder incorporated milk kova

S.No	Sensory Attributes	Control	Experimental		
			Sample A	Sample B	Sample C
1	Colour	4.3±0.5	4.0±0.5	4.6±0.3	3.7±0.7
2	Flavour	4.5±0.4	3.8±0.5	4.7±0.4	3.8±0.7
3	Taste	4.4±0.4	4.1±0.3	4.8±0.2	3.5±0.6
4	Consistency	4.8± 0.2	4.2± 0.5	4.9± 0.2	3.3± 0.4
5	Overall acceptability	4.5±0.3	4.1±0.2	4.9±0.2	3.4±0.4C

It was found that 4% *Carica papaya* powder incorporated milk kova was excellent in the overall acceptability and the mean score was 4.9. But in the 2% and 6% *Carica papaya* powder incorporated milk kova mean scores were 4.1 and 3.4 respectively. Out of the three various formulations, 4% *Carica papaya* powder incorporated milk kova scored the best in quality attributes like colour, consistency, flavor, taste and overall acceptability.

3.4.4 Preference of the selected *Carica papaya* powder incorporated food products by the consumers

Figure 1 shows the preference of *Carica papaya* powder incorporated food products by the consumers

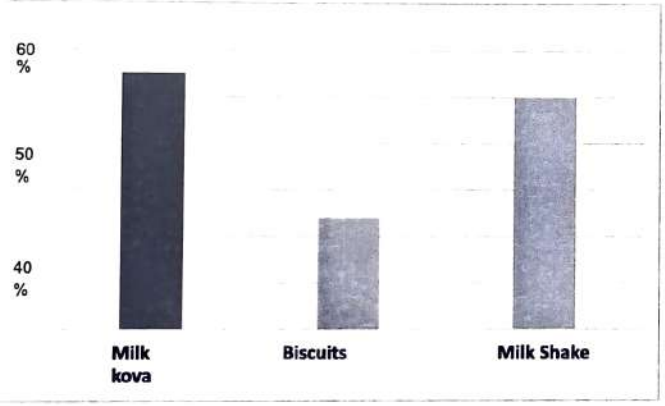


Figure 1: preference of *Carica papaya* powder incorporated food products by the consumers

The prepared products were subjected to ranking test in order to find out the preference of the selected *Carica papaya* powder incorporated food products by the consumers. Then the most preferred food product was used for biochemical and cost analysis. It was found that milk kova was preferred by 55% of the consumers. The selected *Carica papaya* powder incorporated biscuits and milk shake were preferred by 24% and 21% respectively.

3.4 Nutritional analysis of the selected *Carica papaya* powder and the selected *carica papaya* powder incorporated food product

3.5.1 Nutrient analysis of the selected *Carica papaya* powder

The nutrient content of the selected *Carica papaya* powder was analysed and the results are given below in table 7.

Table 7: Nutritive value of the selected *Carica papaya* powder

S.No	Nutrients	Nutritive value of the selected *Carica papaya* powder
1	Phosphorus (mg)	2.3
2	Iron (mg)	0.14
3	Potassium (mg)	17.3
4	Magnesium (mg)	33
5	Calcium (mg)	20
6	Vitamin C (mg)	15
7	Vitamin A (IU)	13
8	Fiber (%)	1.0
9	Carbohydrate (g)	9.8

The nutrient content of the selected *Carica papaya* powder is reported as 2.3mg of phosphorus, 0.14mg of iron, 17.3mg of potassium, 33mg of magnesium, 20mg of calcium, 15mg of vitamin C, 13 IU of vitamin A, 1.0% of fibre and 9.8g of carbohydrate

4.5.2 Nutrient analysis of the control milk kova and the selected *Carica papaya* powder incorporated milk kova

The potassium content of control milk kova and the selected *Carica papaya* powder incorporated milk kova was 22.7mg and 23.6mg respectively. The magnesium content of control milk kova and the selected *Carica papaya* powder incorporated milk kova was 14.3mg and 15mg respectively. The calcium content of control milk kova and the selected *Carica papaya* powder incorporated milk kova was13.8mg and15.5mg respectively. The vitamin A content of control milk kova and the selected *Carica papaya* powder incorporated milk kova was 3.4IU and 5.7 IU respectively. The crude fiber content of control milk kova and the selected *Carica papaya* powder incorporated milk kova was 1.0% and1.2% respectively. Hence, the incorporation of the papaya powder increased the nutritive value of the milk kova. Figure 2 shows the nutrient content of the control milk kova and the selected *Carica papaya* powder incorporated milk kova

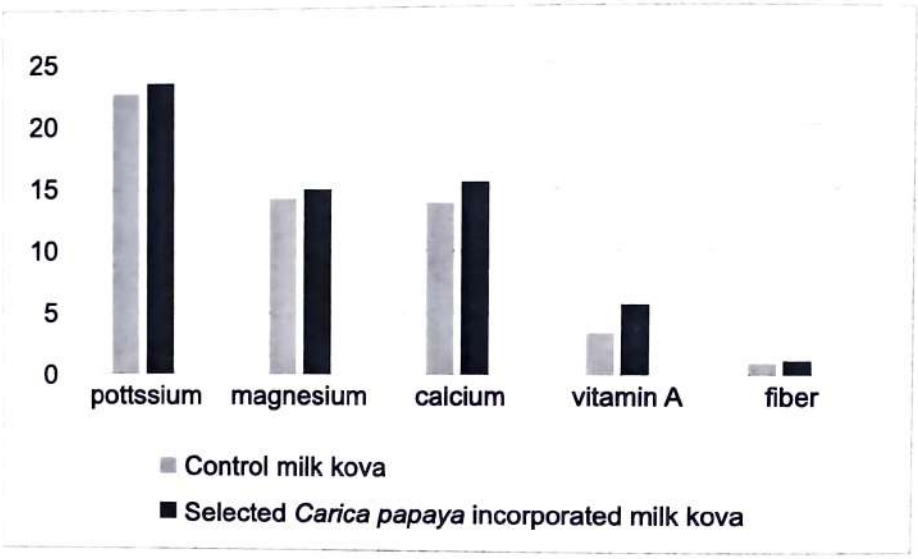


Figure 2: Nutrient analysis of the control milk kova and the selected *Carica papaya* powder incorporated milk kova

3.4 Cost analysis of the selected papaya powder incorporated food product

The cost calculated for the 100 gm of the *Carica papaya* powder incorporated milk kova was Rs.18.75.

CONCLUSION

Carica papaya is rich in antioxidant elements. Human being needs more antioxidant elements in order to combat various deficiencies related to it. Since papaya has low shelf life, drying is the best solution and it decreases the global malnutrition due to its excessive availability. The research revealed that the ripen *Carica papaya* powder by using freeze dryer method contained 87% antioxidant activity. Hence, it is concluded that the ripen *Carica papaya* powder obtained through freeze dryer method has more antioxidant element. Even though the antioxidant is higher in the papaya powder prepared by using freeze drying but output of the papaya powder was low in yield. So, the ripen papaya powder prepared by using cabinet drying can be utilized for developing new food products economically. It was found that 4% of the selected *Carica papaya* powder incorporated milk kova was excellent in the overall acceptability and the mean score was 4.9 and preferred by 55% of the consumers. So, it is concluded from the study that the ripen papaya powder prepared by using cabinet drying can be utilized for developing new food products which pave way for improving the health of the people.

REFERENCE

Aravind G., Bhowmik D., Duraivel S., and Harish G. (2013) Traditional and medicinal uses of Carica papaya. *J Med Plants Stud* 1,7–15.

Benzie, I. F. F.(2003)Comp. Biochem. Physiol. *A Mol. Integr. Physiol, 136,113–126.*

Srilakshmi B. (2018).Food Science, *New Age Iternational (P) Ltd., Pblishers,* Vol.7, PP.309-310,317.

Eugenio J., Garcia T., Luiza C., Oldoni S., Martiasde A., Alessandra R., Alessandro D. L., Rosa, H. and Miranda, G. (2012). Antioxidant activity by DPPH assay of potential solutions to be applied on bleached teeth, *Braz. Dent. J.* 23 (1) :22-27.

Kaleem, A., Nazir, H., Pervaiz, S., Iqtedar, M., Abeullah,R.,Aftab,M., and Naz,S.(2016) , Investigation of the effect of temperature on vitamin C in fresh and packed fruits juices. *FUUAST journal of biology,* 6 (1), 117- 120.

Lau,F.F., & Taip, F.S .(2011).Effects of deferent operating parameters in papaya halwa drying, Pertanika *Journal of science and technology, 19*(2),389-396.

Mustapa, N.A.H.,& Ahmad, S.R(2019). Effects of Various Drying Methods on the Vitamin C Level of Papaya Locally Grown in Brunei Darussalam. Pertanika, *Jiurnal of Science & Technology,* 27 (1).

National Institutes of Health .(1997). Carotenoid analyses of U.S. foods, Food Composition Laboratory.

Official Methods of Analysis of AOAC INTERNATIONAL. (2012) 19th Ed., AOAC INTERNATIONAL, Gaithersburg, MD, USA

Akshata P. (2017). Antidiarrheal activity and phytochemical analysis of carica papaya extract. *Journal of pharmacological science and research ,9[7]: 1151 – 1155.*

Raaman, N. (2006). *Phytochemical Techniques*: New India Publishing Agency.

Statista Research Department, (2020). Production volume of papaya in India FY 2015-2020 Oct 21,2020.

GAU Research Journal **47** (1) : 30-37 (January 2022)

Antifungal Activities of some Essential oil against selected Post-harvest Pathogens

[1]Fatima Siddiqua, [2]Sushmita Paul, [3]Nabanita Baruah, [4]Piyush Kumar Mishra and [5]Kumananda Tayung*

[1&2]Department of Botany, Gauhati University, Assam, India
[3]Department of Bioengineering and Technology, Gauhati University, Assam, India
[4&5]Department of Botany, Bholanath College, Dhubri, Assam, India
*Corresponding Author Email address: kumanand@gauhati.ac.in

Received: 04th February, 2022 Accepted: 24th March, 2022

ABSTRACT

Plant pathogens are causing serious destruction of post harvest vegetables during storage and transport. Though, easy availability, immediate effects and cost-effectiveness are the reasons for which the synthetic pesticides and preservative chemicals are being frequently used world wide but reports of food poisoning and environmental degradation are also being associated with such acts. Therefore, scientists are searching for some alternatives that should be cheap, effective and environment friendly. In the present investigation, antimicrobial activity of 12 aromatic plant's essential oils was examined against two post harvest plant pathogens namely *Geotrichum sp.* and *Mucor sp.* by following agar cup diffusion method. The investigation reveals that *Elettaria cardamomum, Murraya koenigii, Curcuma zedoaria* and *Pandanus amaryllifolius* were most effective essential oil and their killing time revealed that they can kill the pathogens effectively within 24 hours. Therefore, these essential oils can be used to preserve vegetables after harvesting effectively.

Key words : Moulds, Post-harvest, Preservatives, Terpenoids, Volatile.

INTRODUCTION

Horticultural crops and vegetables faces trouble during post-harvest storage and in post-harvest decay, microorganisms play a major role for rotting of horticultural crops and vegetables (Kumar and Iqbal, 2020). These microorganisms mainly include bacteria, yeast and moulds. Fungal and bacterial infections cause around 50% losses to the post-harvest crops (Magro *et al.*, 2006), again moulds colonizes foods and synthesizes a number of enzymes causing economic losses. But fungi causes the most destruction of vegetable and fruit crops by causing numerous plant diseases and economic losses due to favorable environmental conditions like water activity, PH, temperature, atmosphere, time etc. Magan and Aldred (2007) documented *Aspergillus sp.*, *Fusarium sp. Alternaria sp.* and *Penicillium sp.* as the most prevalent fungal genera which causes loss in quantity and quality of fruit and vegetable production. As microorganisms are omni present in our environment and they can easily reach and grow in foods anytime during their harvesting from agricultural field to packaging and transporting to commercial market areas. As there is increasing concerns about the harmful side effects of pesticides and increasing cost of development of new synthetic preservatives, there is a need for alternative methods to control disease occurrence. There is also an increasing case of fungicide resistance (Bradshaw *et al.*, 2021). Therefore scientists are constantly searching for safer alternatives to effectively control the post harvest pathogens which should be eco-friendly and also increase the shelf life of vegetables and food products (Sadgrove *et al.*, 2013). Many researchers have been investigating the utilization of plant products, plant extracts, essential oils etc. with antifungal land anti-bacterial, anti-viral activity as effective natural preservatives (Gigantra and Darmayasa, 2019). Crude extracts of leaf, stem, flower, fruit, bark, root etc are used for treatment of various human diseases from a long period of time. Similarly, essential oils have recently got a great interest as a natural antimicrobial agent against

[1&2]Scientist, Department of Botany, Gauhati University, Assam, India and Ph.D. Scholar, Department of Botany, Gauhati University, Assam, India
[3]Professor, Department of Bioengineering and Technology, Gauhati University, Assam, India
[4&5]Professor, Department of Botany, Bholanath College, Dhubri, Assam, India

human and plant pathogenic bacteria (Herman *et al.*, 2019). Essential oils have antimicrobial property because they consist monoterpenes, sesquiterpenes as primary terpenoids and secondary terpenoids like diterpenes which can effectively kill or slow growth of yeasts, moulds and bacteria (Chorianopoulos *et al.*, 2008). They are volatile metabolites which are extracted from stem, leaf and roots of plants through steam or hydro distillation method which produces a fragrant mixture of compounds (Thierry *et al.*, 2012). Assam is regarded as a great zone for medicinal plants which are used extensively by local peoples in treating various diseases. The local people use there plants in the form of decoction, extracts etc in a regular basis to cure their diseases. As the medicinal plants are regularly being studied for their antimicrobial activity against human pathogens but there still few studies have been done to explore their effectivity against post harvest plant pathogens. Therefore, in this study we have collected some medicinal plants used by local people of Assam and tried to find the antimicrobial activity of the essential oil extracted from the collected plant specimens against some post harvest plant pathogens.

MATERIAL AND METHODS

The present investigation was conducted in the Mycology and Plant Pathology laboratory, Department of Botany, Guwahati University, Gopinath Bordoloi Nagar, Guwahati, Assam.

1. COLLECTION OF PLANT MATERIAL

The samples were collected from Grahampur area of Kokrajhar district of Assam and Garigaon area of Kamrup district of Assam by a field visit. The plants were identified by consulting Herbaria of Botany Department of Gauhati University. The plants with fresh leaves were collected and packed in separate polythene bags and were carried to the laboratory. A total of 12 plant specimens were collected and the plants were identified as *Curcuma zedoaria, Glycosmis pentaphylla,Pandanus amaryllifolius, Paederia foetida, Murraya koenigii, Ageratum conyzoides, Elettaria cardamomum, Mansoa alliacea, Murraya paniculata, Zanthoxylum rhetsa, Hibiscus acetosella* and *Eryngium foetidum.*

2. EXTRACTION OF CRUDE OIL

The leaves of the selected plants were separated and chopped into small pieces. The materials were then put in Clevenger's apparatus and 300ml of distilled water were added to it. The apparatus was kept in heating mantle and temperature was set at 50°C and the solution was heated for 4 hours. After heating for specific time period, the oil was obtained through hydro-distillation process and collected in air tight container. The oil extract was concentrated by passing through magnesium chloride to obtain essential oil in pure form (100)

The essential oils so obtained were kept in refrigerator at 4°C for further study.

3. COLLECTION OF POST HARVEST PLANT PATHOGEN

Infected vegetables were collected from Pamohi market of Garchuk, Guwahati and they were brought to the laboratory in polythene bags. Then pathogens were isolated from the infected vegetable parts by inoculating the surface sterilized disease part into Potato Dextrose Agar medium and incubated for 3-5 days at 35°C. Fungal hyphae growing out of the inoculated fragments were transferred to freshly prepared PDA slants. Identification of the pathogens was carried out by morphological traits and microscopic observation of the spores.

4. ANTIMICROBIAL EVALUATION

The oil extracts were evaluated for antimicrobial activity by following agar cup diffusion method. The fungal pathogen was cultured in freshly prepared Potato Dextrose Broth. The preparations of media were done as per manufacturer's instruction. The fungal pathogens were inoculated on PDA plates by the help of sterile cotton swabs. Agar cups were prepared by scooping out the medium with a sterile cork borer (7mm in diameter). Each cup was then loaded with 0.5ml of crude oil extracts. The fungal pathogen was incubated at 35°C for 24 hours. The plates were observed for zone of inhibition. The inhibition zones so formed were measured in millimeter with the help of an SI 100mm ruler.

5. STATISTICAL ANALYSIS

Three replicas were taken for standard deviation and followed the standard deviation method to get the accurate measurement.

6. KILLING TIME DETERMINATION

Killing time was determined for the essential oil which shows highest activity against a particular pathogen. For this experiment 5 ml of broth culture was prepared and the pathogen inoculated into it and incubated for 24 hours. Generally the experiment was carried out for 12 hours duration. 12 sets of test tubes were taken where 1µl of broth culture was added. Then 6 test tubes were taken as control and in another 6 test tubes 1µl of essential oil

was added. Then the test tubes were incubated and after 2 hours a set of test tube having a control and a test tube containing essential oil were taken. With the help of cotton swab the broth cultures were inoculated on two Petri plates containing PDA media by striking method and it was incubated for 24 hours.

Table 1: List of diseased plant materials and types of plant pathogens isolated

Sl. no.	Name of vegetables	Name of pathogen isolated
1.	Squash	*Geotrichum candidum*
2.	Pointed guard	*Geotrichum candidum*
3.	Tomato	*Geotrichum candidum*
4.	Bitter gourd	*Geotrichum candidum, Aspergillus sp.*
5.	Sponge gourd	*Geotrichum candidum, Mucor sp.*
6.	Teasle gourd	*Geotrichum candidum, Aspergillus sp.*
7.	Brinjal (eggplant)	*Aspergillus sp.*
8.	Capsicum	*Aspergillus sp.*
9.	Cucumber	*Geotrichum candidum*
10.	Cabbage	*Geotrichum candidum, Mucor sp.*
11.	Pumpkin	*Geotrichum candidum*

Similarly one set of control and essential oil containing broth cultures were inoculated on Petri plates after every 2 hours and incubated. Then 24 hours of incubation of all the sets of Petri plates were evaluated. The set of Petri plates where the essential oil inhibited the growth of the pathogen by reducing the CFU at maximum amount in comparison to the control plate was determined as the killing time of the essential oil against the particular pathogen.

RESULTS

The 12 medicinal plants collected for the study were listed below in Table-2 along with their uses.

Table 2: List of essential oil bearing plants selected for antimicrobial study

Sl. no.	Plant name	Family	Activity	Sources
1.	*Ageratum conyzoides* L.	Asteraceae	Antifungal, antibacterial activity	Kambooj and Saluja, 2008
2.	*Curcuma zedoaria* Rosc.	Zingiberaceae	Antimicrobial activity	Kaushik and Jalalpur, 2011
3.	*Elettaria cardamomum* (L.) Maton	Zingiberaceae	Antimicrobial activity	Souissi et al., 2020
4.	*Eryngium foetidum* L.	Apiaceae	Food preservatives	Homer et al., 2007
5.	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	Antimicrobial activity	Taib et al., 2022
6.	*Hibiscus acetosella* Welw. ex Hiern	Malvaceae	Antimicrobial activity	Srivastava et al., 2019
7.	*Murraya koenigii* (L.) Spreng	Rutaceae	Antimicrobial activity	Gahlawat et al., 2014
8.	*Mansoa alliaceae* (Lam) A.H. Gentry	Bignoniaceae	Fungicidal activity	Rajanna and Vinod, 2021
9.	*Pandanus amaryllifolius* Roxb.	Pandanaceae	Food preservatives	Bhuyan and Sonowal, 2021
10.	*Murraya paniculata* (L.) Jacq.	Rutaceae	Fungicidal activity	Khatoon et al., 2017
11.	*Paederia foetida* L.	Rubiacea	Can kill food borne pathogens	Bardhan et al., 2010
12.	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	Antimicrobial activity	Aziz et al., 2022

Among the 12 medicinal plants, from preliminary assay it is seen that essential oil of all the medicinal plants except *Paederia foetida* and *Ageratum conyzoides* showed antimicrobial activity against both the pathogen or inhibited at least one pathogen (Table 3).

Table 3 : Preliminary assay of essential oils against plant pathogens by agar cup diffusion method

Name of Essential oil	Plant Pathogens	
	Mucor sp.	G. candidum
Pandanus amaryllifolius	+	+
Paederia foetida	--	--
Elettaria cardamomum	+	+
Murraya koenigii	+	+
Ageratum conyzoides	--	--
Monsoa alliacea	+	+
Curcuma zedoaria	+	+
Glycosmis pentaphylla	+	--
Murraya paniculata	+	--
Zanthozylum rhetsa	+	+
Eryngium foetidum	+	+
Hibiscus acetocella	+	--

"+" sign indicates presence of activity, "--"sign indicates absence of activity

In secondary screening, both *Murraya koenigii* and *Elettaria cardamomum* showed highest zone of activity of 24± 0.76mm and 24± 1.00mm respectively against *G. candidum*. Similarly, *Curcuma zedoaria* showed 20± 0.50mm of zone of inhibition against *Mucor sp.*, *Pandanus amaryllifolius* showed 19± 0.24mm of zone of inhibition against *G. candidum* and *Glycosmis pentaphylla* showed 19± 0.51mm of zone of inhibition against *Mucor sp.* (Table 4). After the secondary screening, most effective essential oils were selected for determining the exact time of killing of the particular pathogen.

TABLE 4 : Zone of inhibition of Essential oils against pathogens by agar cup diffusion Method

Name of Essential oil	Plant Pathogens	
	Zone of inhibition (mm)	
	Mucor sp.	G. candidum
Pandanus amaryllifolius	12± 1.00	19± 0.24
Elettaria cardamomum	12± 1.52	24± 1.00
Murraya koenigii	13± 1.32	24± 0.76
Monsoa alliacea	18± 1.00	--
Curcuma zedoaria	20± 0.50	10± 1.00
Glycosmis pentaphylla	19± 0.51	--
Murraya paniculata	18± 1.00	--
Zanthozylum rhetsa	18± 0.52	--
Hibiscus acetocella	12± 0.25	--
Eryngium foetidum	17± 0.65	10± 0.93

n = 3; ± = Standard deviation;--Sign indicates no significant zone of inhibition (less than 10mm)

The killing time was determined for the essential oil of *Murraya koenigii* against *Geotrichum candidum* and 6 hours was noted as the killing time of essential oil of *Murraya koenigii* against *Geotrichum candidum* (Fig.1). The killing for the essential oil of *Pandanus amaryllifolius* against *Geotrichum candidum* was 6 hours. Similarly, the killing time for essential oil of *Glycosmis pentaphylla* against *Mucor sp.* was 6 hours, the killing time of essential oil of *Curcuma zedoaria* against *Mucor sp.* was 10 hours and the killing time for the essential oil of *Elettaria cardamomum* against *Geotrichum candidum* was observed as 10 hours.

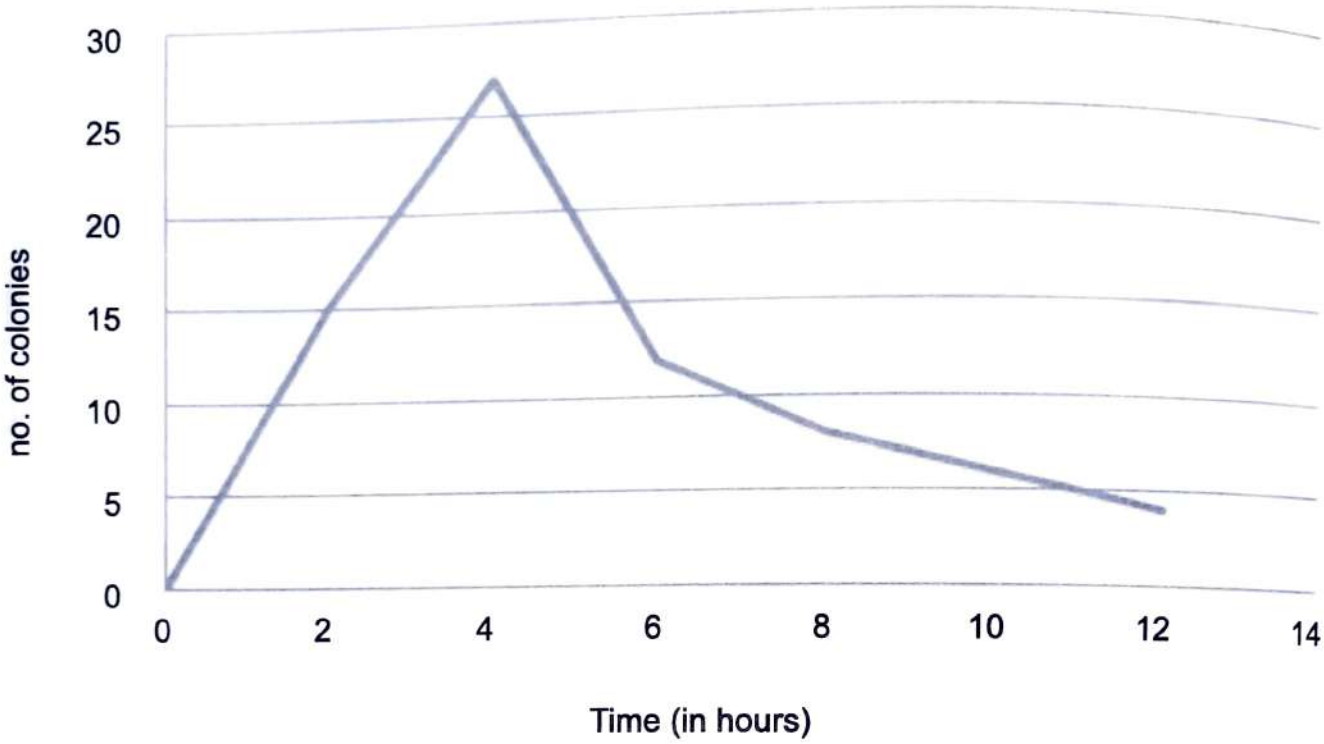


Figure 1: Graph depicting killing time of *Pandanus amaryllifolius* against *Geotrichum candidum*.

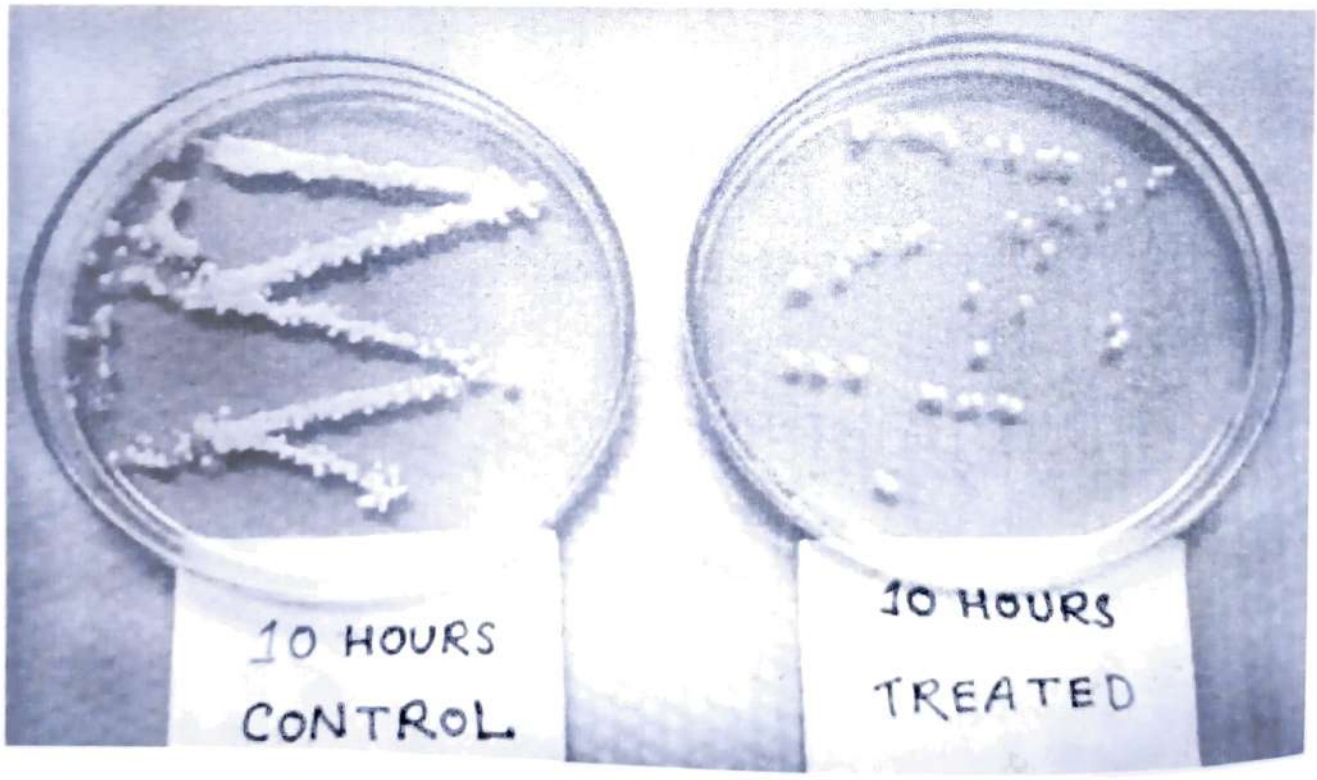


Photo plate: Photograph showing killing time of essential oil of *Curcuma zedoaria* against *Mucor sp.*

DISCUSSION

The post harvest plant pathogens are becoming an alarming factor in most of the developing countries because most of the food scarcity in those countries occurs due to post harvest food spoilage as reported by Kana *et al.*, 2012. The substantial economic losses of vegetables and fruits due to pest infestation and diseases occurred during storage and marketing crosses 50% of total productions in the developing countries. Vegetables and fresh fruits are generally get destroyed by fungal pathogens which cause a great economic loss of the farmers and suppliers (Sommer, 1985).Some fungal pathogens like *Mucor sp.*and *Geotrichum candidum* were collected for our study which causes various fruit and vegetable diseases. *Mucor sp.* causes mucor rot of pear and apple; mucor rot of strawberry; soft rot of tomato etc. (Udhave, 2011). *G. candidum* were reported causing sour rot of tomato (Sajad *et al.*, 2017); creamy rot of *Musa paradisiacal*; black spot of *Citrus reticulate*, brown spots of *Carica papaya*; milky rot of vegetables like cabbage, bottle gourd etc. Fungi produce mycotoxins which causes serious health problems to consumers. Food product industries use various synthetic chemical preservatives to prevent the growth of unwanted pathogens which produces toxic and carcinogenic compounds in food materials (Farag *et al.*, 1989). Some fungicides that are used for controlling post-harvest diseases have recently come under threat of posing a potential oncogenic risk (Barnard *et al.*, 1997). Essential oils show a wide range of antifungal activity against various plant pathogens. Moreover, they are also recognized as safe substances by Human health services to be used as antibacterial additives in food substances and they can be applied in rational quantities to improve food quality and safety and also not causing any nutritional losses to vegetable and food products (Stefanaskis *et al.*, 2013, Kumar and Iqbal, 2020). In our current study, essential oils were extracted from twelve aromatic medicinal plants used as ethno-medicine by ethnic communities which are namely *Curcuma zedoaria, Mansoa alliacea, Elettaria cardamomum, Murraya koenigii, Pandanus amaryllifolius, Paederia foetida, Ageratum conyzoides, Glycosmis pentaphylla, Murraya paniculata, Zanthoxylum rhetsa, Hibiscus acetosella* and *Eryngium foetidum.* The essential oils of all the collected plants were obtained by using hydro-distillation method and agar cup diffusion assay was done to check their antimicrobial activity against the post-harvest plant pathogens. The assay showed that essential oil of *Pandanus amaryllifolius* was effective against plant pathogens like *Mucor sp.* and *G. candidum*. Likewise, the essential oil of *Eryngium foetidum* was effective against *Mucor sp., G. candidum* and similar results were obtained by Lingaraju *et al* (2016) against plant pathogens. The essential oil of *Mansoa alliaceae, Glycosmis pentaphylla* and *Hibiscus acetocella* showed activity against *Mucor sp.* The essential oil of *Elettaria cardamomum, Curcuma zedoaria* and *Murraya koenigii* showed activity against *Mucor sp.* and *G. candidum.* From the study we can conclude that the selected essential oil showed 100% activity against *Mucor sp.* and 50% activity against *Geotrichum candidum.* It has been seen that various species of *Hibiscus* showed antimicrobial activity against fungal pathogens. But no significant work has been documented for *Hibiscus acetocella*, so this essential oil can be studied further for its detailed activity.

REFERENCES

Aziz F., Rahman F.I., Huque S., Ether S.A., Hasan C.M. and Ahsan M., 2022. *Zanthoxylum rhetsa* (Roxb.) DC: A systematic review on traditional uses, phytochemistry, and pharmacology. *Journal of Pharmacy & Pharmacognosy Research*, 10 (1): 52-72.

Barnard M., Padgitt M. and Uri N.D., 1997. Pesticides use and its measurement. *International Journal Pest Control*, 39:161–164.

Bardhan P., Faruque A.S.G., Naheed A. and David A.S., 2010. Decreasing Shigellosis-related Deaths without *Shigella spp.*-specific Interventions, Asia. *Emerging Infectious Disease*, 16: 1718–1723.

Bhuyan B. and Sonowal R., 2021. An overview of *Pandanus maryllifolius* Roxb. ex Lindl. and its potential impact on health. *Current Trends in Pharmaceutical Research*, 8(1): 138-157.

Bradshaw M.J., Bartholomew H.P., Hendricks D., Maust A. and Jurick W.M., 2021. An analysis of post harvest fungal pathogens revealed temporal-spatial and host pathogen associations with fungicide resistant-related mutations. *Phytopathology*, 111:1942-1951.

Chorianopoulos N.G., Giaouris E.D., Skandamis P.N., Haroutounian S.A. and Nychas G.J.E,

2008. Disinfectant test against monoculture and mixed-culture biofilms composed of technological, spoilage and pathogenic bacteria: Bactericidal effect of essential oil and hydrosol of *Satureja thymbra* and comparison with standard acid-base sanitizers. *Journal of Applied Microbiology*, 104:1586–1599.

Farag R.S., Daw Z.Y., Hewedi F.M. and El-Baroty G.S.A., 1989. Antimicrobial Activity of Some Egyptian Spice Essential Oils. *Journal of Food Protection*, 52(9): 665-667.

Gahlawat D.K., Jakhar S. and Dahiya P., 2014. *Murraya koenigii* (L.)Spreng: an ethnobotanical, phytochemical and pharmacological review. *Journal of Pharmacognosy and Phytochemistry*, 3(3): 109-119.

Sudigra S.K., Ginantra K. and Darmayasa I.B.G., 2019. Antifungal activity of leaf extracts of *Mansoa alliacea* against *Colletotrichum acutatum* the cause of anthracnose disease on chili pepper. 6th International Conference on Sustainable Agriculture, Food and Energy, *IOP Conf. Series: Earth and Environmental Science*, 347(1): 012058.

Hatab S., Althanaiso R., Holley R., Rodas-Gonzalez A. and Narvaez-Bravo C., 2016. Survival and reduction of shiga toxin-producing *Escherechia coli* in a fresh cold-pressed juice treated with antimicrobial plant extracts. *Journal of Food Science*, 81: 1987-1995.

Herman R.A., Ayepa E., Shittu S., Fometu S.S. and Wang J., 2019. Essential oils and their applications -A mini review. *Advances in Nutrition & Food Science*, 4(4): 1-13.

Homer S., Baccus-Taylor G. and Akingbala J., 2007. Antibacterial Efficacy of *Eryngium foetidum* (Culantro) against Selected Food-borne Pathogens, 27th West Indies Agricultural Economics Conference, Belize, 179-192.

Kana H.A., Aliyu I.A. and Chammang H.B., 2012. Review on neglected and underutilized root and tuber crops as food security in achieving the millennium development goals in Nigeria. *Journal of Agriculture and Veterinary Science*, 4: 27-33.

Khatoon A., Mohapatra S. and Satapathy K.B., 2017. Botanicals to Control Post-harvest Decay of Potato (*Solanum tuberosum* L.) Tubers in Odisha. India. *International Journal of Pharmaceutical Sciences Review and Research*, 42(1): 117-121.

Kamboj A. and Saluja A.K., 2008. *Ageratum conyzoides* L.: A review on its phytochemical and pharmacological profile. *International Journal of Green Pharmacy*, 59-68.

Kumar V. and Iqbal N., 2020. Post-harvest and disease management of horticultural crop: A brief review. *Plant Archives*, 20 (2): 2054-2058.

Kaushik M.L. and Jalalpure S.S., 2011. Effect of *Curcuma zedoaria* Rosc root extracts on behavioral and radiology changes in arthritic rats. *Journalof Advanced Pharmaceutical Technology& Research*, 2(3):170-176.

Lingaraju D.P., Sudarshana M.S., Mahendra C., and Rao P., 2016. Phytochemical screening and Antimicrobial activity of leaf extracts of *Eryngium foetidum* L. (Apiaceae). *Indo American Journal of Pharmaceutical Research*, 6(2): 4340-4344.

Magan N. and Aldred D., 2007. Post-harvest control strategies: minimizing mycotoxins in the food chain. *International Journal of Food Microbiology*, 119: 131–139.

Magro A., Carolino M., Bastos M. and Mexia A., 2006. Efficacy of plant extracts against stored products fungi. *Revistal beroamericana de Micología*, 23, 176–178.

Rajanna L. and Vinod N., 2021. Antimicrobial activity of leaf extracts of *Mansoa alliacea* (Lam.)A. H. Gentry. *Bulletin of Environment, Pharmacology and Life Sciences*, 10(12): 106-113.

Sadgrove N. and Jones G.L., 2013. Antimicrobial activity of essential oils and solvent extracts from *Zieria* species (Rutaceae). *Natural Product Communications*, 8:741–745.

Sajad U.N., Raja W.H., Kumawat K.L., Mir J.I., Sharma O.C., Singh D.B. and Sheikh M.A., 2017. Post Harvest Diseases of Temperate Fruits and their Management Strategies-A Review. *International Journal of Pure and Applied Bioscience*, 5(3): 885-898.

Sommer N.F., 1985. Strategies for control of post-harvest disease of selected commodities. In: Post-harvest Technology of Horticultural Crops. University of California Press: 83-98.

Souissi M., Azelmat J., Chaieb K. and Grenier D., 2020. Antibacterial and anti-inflammatory activities of cardamom (*Elettaria cardamomum*) extracts: Potential therapeutic

benefits for periodontal infections. *Anaerobe*, 61: 102089.

Stefanakis M.K., Touloupakis E., Anastasopoulos E., Ghanotakis D.,Katerinopoulos H.E., and Makridis P., 2013. Antibacterial activity of essential oils from plants of the genus *Origanum*. *Food Control*, 34: 539–546.

Taib M., Hassan N., Mohdkamal N.M. and KhinSoe M., 2022. Bioautography, combination effects and photo-activated enzymatic restriction inhibition activity of antimicrobial alkaloids from *Glycosmis Pentaphylla* (Retz.) DC. *Malaysian Journal of Science*, 41(3): 1-9.

Thierry R., Sandra C. and Wilma D.P., 2012. Essential Oils and Other Plant Extracts as Food Preservatives, in Progress in Food Preservation. John Wiley & Sons, Ltd: New York, USA: 539-579.

Udhave B.N., 2011. Survey of market storage diseases of some important fruits of Osmannabad District (M.S.) India. *Science Research Reporter*, 1(2): 88 – 91.

GAU Research Journal **47** (1) : 38-41 (January 2022)

Morphological and anatomical characteristics of Leaf and Stem anatomy in *Garcinia mangostana* L.

C. PRIYA[1*] AND N. HARI[2]

Department of Botany, C M S College Kottayam (Autonomous), Kottayam, Kerala-686001, India.

Received: 04th February, 2022

Accepted: 24th March, 2022

ABSTRACT

Garcinia mangostana has been widely used to treat abdominal pain, diarrhoea, dysentery, infected wound, suppuration, and chronic ulcer. The observation on cellular level morpho-anatomy is a major aid for the authentication of the species. Because of this, the present study was carried out for the morphological and anatomical exploration of the leaf and stem of *Garcinia mangostana* L. (Family: Clusiaceae), popularly known as Queen of fruits. In morphological evaluation, it was observed that the leaves are opposite, shortly petiolate, thickly coriaceous, ovate-oblong, simple with entire margin, base acute to obtuse, apex acuminate, glabrous, pinnately nerved with a prominent midrib, evenly spaced lateral nerves and green in colour. Stem is cylindrical in shape and brownish-green in appearance. Microscopic evaluation revealed the presence of thick cuticle, uniseriate epidermis, and rubiaceous stomata. The leaf tissues include druses and calcium oxalate crystals. It is concluded that these characteristics are important for the identification of the studied species used in drugs.

Key words : *Garcinia mangostana*, Morphology, Anatomy, Leaf, Petiole and Stem

INTRODUCTION

Morphology and anatomy are the classical source of data used in plant taxonomy and are useful in solving problems of relationships. The internal characters are as valuable as the external characters because of the frequent persistence of the vascular supply of lost organs after all external evidence of the organs has disappeared (Eames 1961).

Plant systematics deals with the description, naming, classification, identification, and determination of relationships among plants by using data from many disciplines such as morphology, anatomy, molecular biology, ecology, etc. The majority of the plants have evidence according to morphological features; however, for accurate classification, information from diverse sources must be utilized. Anatomical features have played a very important role in determining phylogenetic relationships. *Garcinia mangostana* L., (Mangosteen) which is popularly known as "Queen of fruits" belongs to the family Clusiaceae. It has been widely used to treat abdominal pain, diarrhoea, dysentery, infected wound, suppuration, and chronic ulcer. The genus *Garcinia* was named to honour the Dutch army doctor and naturalist Laurentius Garcin, who studied these plant specimens of mangosteen (Garcin and Zollmah 1733). The family occupies 6 genera and up to 26 species in Kerala (Sasidharan, 2006).Many species are cultivated for edible fruits and medicinal purposes.

Thus, this study aimed to perform the morphological and anatomical characteristics in the leaf and stem of Mangosteen for the authentication of the species.

MATERIALS AND METHODS

G. mangostana leaf and stem samples were collected from Aymanam (9° 36'32.5" N 76° 29' 40.9"E) of the Kottayam district of Kerala. The herbarium specimen of Mangosteen was deposited at the Department of Botany, C M S College Kottayam, Kerala (Voucher no: CMS 3119). The healthy plants were selected and the mature leaves from the fifth and sixth nodes were taken for the anatomical studies (Plate 1-A.). The leaf sections were made at a position approximately halfway between the base and apex, from one side of the

[1]Scientist, Department of Botany, C M S College Kottayam (Autonomous), Kottayam, Kerala, India. and Ph.D. Scholar, Department of Botany, C M S College Kottayam (Autonomous), Kottayam, Kerala, India.

lamina and the stem was studied by collecting the tertiary branches. The transverse section (TS), transverse longitudinal (TLS), and radial longitudinal section (RLS) were stained with Safranin. The slides were analyzed by a trinocular compound microscope (model no.10093409) and photographs were made by using the camera Nikon Coolpix 4500.

RESULTS AND DISCUSSION

Morphological characteristics

The leaf and stem morphological characteristics were observed. The leaflet is dark green coloured, having an opposite decussate arrangement, round base, acuminate apex and margin are entire. The leaf shape varies greatly from oblong to elliptic. The leaves are petiolate with a swollen base and with a brownish-green cylindrical stem.

Anatomical characteristics

a) Anatomy of leaf

Leaf anatomical characteristics of Mangosteen were observed and illustrated in Plates 1 (A-D). The cuticle is thick on the adaxial surface of the species. The epidermal cells are uniseriate (Priya and Hari, 2018). The ground tissue showed the presence of numerous druses, starch grains, and secretory cavities. The secretary cavities are lined with epithelial cells similar to features that were reported in leaves of dicotyledonous plants (Amanda *et.al.*, 2013; Dickison,2000). The vascular elements are arranged as patches and are plate-like in appearance. The phloem cells are arc-shaped and overarch the xylem bands. The entire vascular elements were covered with sclerenchymatous cells. The xylem elements are compactly packed and are with narrow medullary rays.

The thickness of the cuticle and the uniseriate epidermis are the important characteristics of Clusiaceae (Metcalfe and Chalk, 1950). The massive palisade cells were present in Mangosteen. Then round spongy parenchyma cells appeared as networks with airspace and are highly chlorophyllated.

The vascular zone with a cowry-like appearance (Plates 1-B). In the leaf lamella, transfusion tracheids were seen and the vascular structure is interrupted with a unilacunar leaf trace and is on the opposite sides.

The leaf contains highly pigmented polygonal-irregular shaped epidermal cells. The stomatal unit showed the elongated stomatal pore, which contains two subsidiary cells and is parallel to the guard cells (Pate.1- B, C & D).

The outer surface showing ridges and furrows stomata were rubiaceous and with an average length of 15.2 µm and width of 3.2 µm. The most common stomatal type in *Garcinia* is parasitic (Pathirana and Herat, 2004).

b) Anatomy of Petiole

The trichomes were absent in the epidermis. The epidermal cells were somewhat elevated and dome-shaped (Plate 1-E & F). The cross-section of the petiole shows a semi-circular stele. The anatomical characteristics showed a thick cuticle with a uniseriate epidermis (Vigi and Hari, 2020). The ground tissue was prominently dispersed with numerous starch grains and druses.

The siphonous incurved vascular strand with a wide distinct gap. The gap consisted of interfascicular round parenchyma cells (Plate 1-E & F). (Rutuja *et al.*, 2017) reported a similar nature of vascular strand in species of *Garcinia*.

The stele consisted of unlayered endodermis. The xylem and phloem were somewhat equal and the species showed the radially arranged vessels. The xylem rays are short and very narrow.

c) Anatomy of stem

The stem was circular in cross sectional view. The epidermis was covered with a thick cuticle. Cortex was thick, multi-layered and parenchymatous. A large number of tannin cells occurred in both cortex and pith. Sclerids and Calcium oxalate crystals were also present in the cortex and pith (Plate 1-G, H & I). Xylem and phloem were in the form of continuous rings.

The radial longitudinal section (RLS) showed the vessels and tracheids; vessels with spiral and annular thickenings; consists of fiber tracheids, axial and ray-parenchyma cells (Plate.1-J). The transverse longitudinal section (TLS) of wood showed alternate intra vascular pitting, the sieve tube with compound sieve plate, companion cells, sclereids, phloem parenchyma, septate and nonseptate phloem fibres. The depositions were found in the sieve elements. Medullary ray was uniseriate. Perforation plates were simple and derived from fusiform initials (Plate.1-K).

CONCLUSION

It is concluded from the present study that morphological and anatomical characteristics play

an important role in the authentication of the species and also the identification of drugs. Anatomical evaluation is one of the cost-effective methods for the correct identification of the source of the material.

Acknowledgement

The authors thank CMS College Kottayam, Kerala for providing the required facilities to carry out this research work and Kerala forest Department, Biodiversity board & Govt. of Kerala for granting permission to collect specimens from Western Ghats of Kerala.

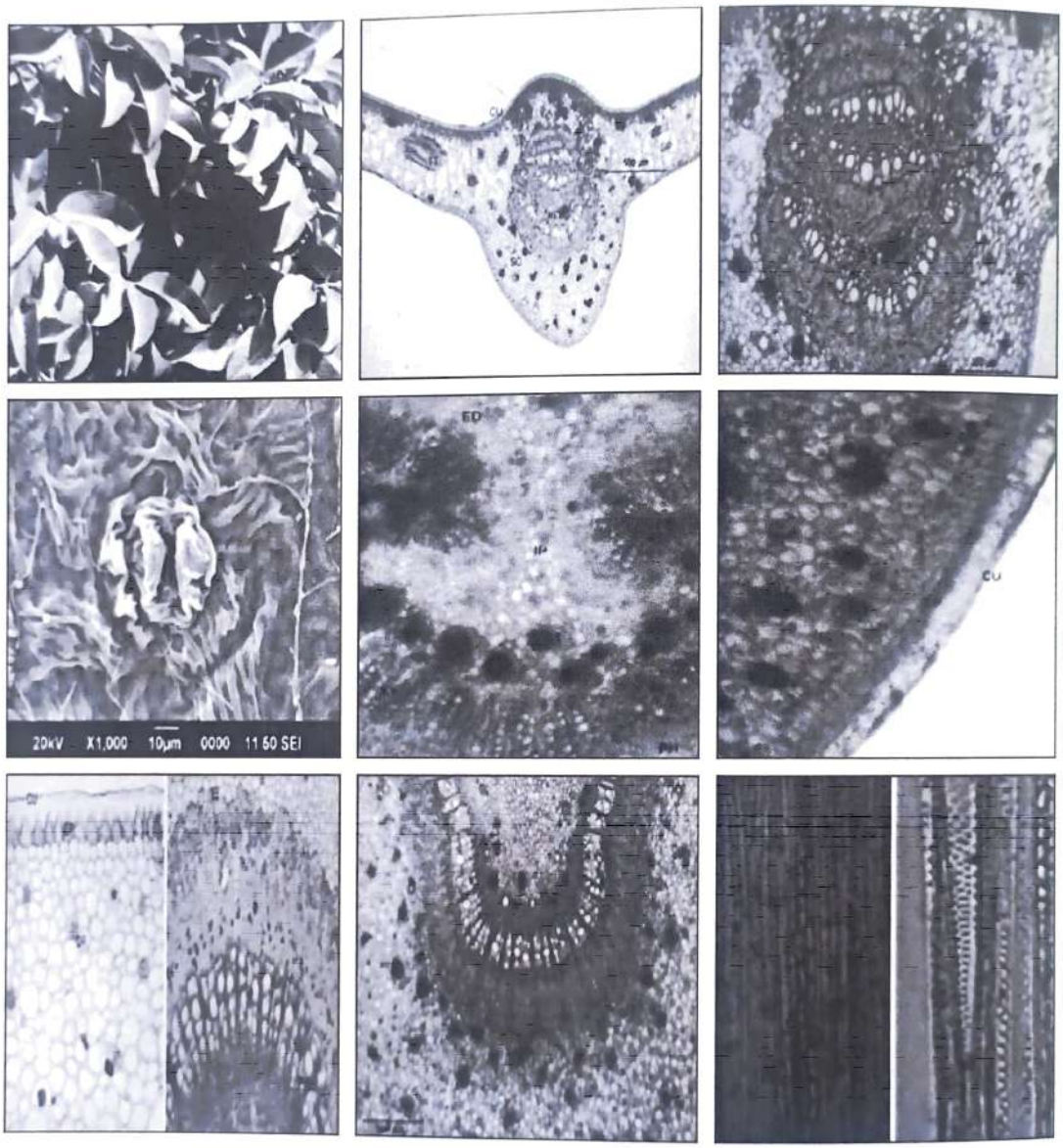


Plate.1- Anatomical characteristics of Leaf (B,C & D) , Petiole (E & F) and Stem (G,H,I ,J & K).

EP-epidermal cell, CU-cuticle, SC-secretory cavities, XY-xylem, PH-phloem, DR-druses, SG-starch grains, TE-tracheary elements, IP- Interfascicular parenchyma and ED- Endodermis.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

Amanda, A. C.; Fabricio, J. P.; Marcio, P. P; , Felipe, F. C.and Evaristo, M. C. , Breno, R. S. (2013). Anatomy of Stems, leaves, roots and the

embryo of Garcinia brasiliensis Mart. Clusiaceae. *Revista de Ciências Agrarias - Amazon Journal of Agricultural and Environmental Sciences*.5: 23-29.

Dickison, C. W.(2000).Integrative Plant anatomy. Academic Press.pp. 40-43.

Eames, A. J. (1961). Morphology of the Angiosperms. The Maple Press company, McGraw Hill Book, New York.

Garcin, L. and Zollman, P. H. (1733). "III. The settling of a new genus of plants, called after the Malayans, Mangostans; by Laurentius Garcin, M. D. and F. R. S. Translated from the French by Mr. Zollman, F. R. S.," *Philosophical Transactions of the Royal Society of London*, 38(431):232–242.

Metcalfe, C.R., and Chalk, L.(1950). Anatomy of the dicotyledons, vol.1. Clarendon Press, London. pp.170-179.

Pathirana, P. S. and Herat, T.R. (2004). "Comparative vegetative anatomical study of the genus Garcinia L. (Clusiaceae /Guttiferae) in Srilanka". *Ceylon Journal of science*. 32:39-66.

Priya, C. and Hari, N.(2018)."A study on leaf and petiole anatomy of endemic and vulnerable species of *Garcinia*. *Journal of Emerging Technology & Innovative Research* 5(12):509–512.

Rutuja, S. P., Janarthanam, M. K., and Krishnan, S. (2017)."Taxonomic identity and occurrence *Garcinia spicata* and *Garcinia talbotii* (Clusiaceae) in peninsular India". *Rheedia*. 27(2):143 151.

Sasidharan, N. (2006). Biodiversity Documentation for Kerala. Flowering plants. Kerala Forest Research Institute. Peechi, Kerala, India. p.6.

Vigi, G. M. and Hari, N.(2020)."Morpho-anatomical study of leaf and stem of *Sapindus trifoliatus* L., as a taxonomical identification tool. *Life science international research journal* 7(1):39-45.

GAU Research Journal **47** (1) : 42-47 (January 2022)

Development of Tractor Mounted Inter Row Shielded Herbicide Sprayer for Weed Control in Wide Row Crops

BABASAHEB S. GHOLAP[1], GHANSHYAM TIWARI[2]

Department of Farm Machinery & Power Engineering
College of Technology and Engineering
Maharana Pratap University of Agriculture and Technology, Udaipur – 313 001 (Rajasthan)

Received: 04th February, 2022 Accepted: 24th March, 2022

ABSTRACT

A six-row tractor mounted inter row shielded herbicide sprayer was developed for weeds control in wide row crops. The different components of the developed sprayer were main frame, chemical tank, spray pump, pressure gauge, control assembly, boom, spray shields, hose pipes, nozzles and power transmission unit. The performance of developed shielded sprayer was evaluated in the field to study the effect of operating pressure (100, 200, 300 and 400 kPa) on volume median diameter (VMD), droplet density (DD) and uniformity coefficient (UC) at different forward speeds (2, 3 & 4 km/h) and different wind velocities (5, 6 and 7 km/h). From the results, it was found that operating pressure had significant effect on volume median diameter, droplet density and uniformity coefficient for all combination of wind velocities and forward speeds.

Key words : Volume median diameter, droplet density, uniformity coefficient.

INTRODUCTION

Weeds compete with crop for moisture, nutrients and sunlight and can have a detrimental impact on crop yields and quality, if uncontrolled. Weeds alone can cause a loss up to 37 per cent of total agricultural production in India (Gharde *et al.*, 2018). Herbicides are chemicals, designed to kill/control the weeds. Herbicide based weed control system may be both biologically efficacious and economically effective (Tewari *et al.*, 2018). For successful use of herbicides, their application must be accurate and uniform. Manually operated knapsack sprayer, knapsack power sprayer, solar powered knapsack sprayer, trolley power sprayer, tractor power sprayer and tractor mounted boom sprayer are used for application of herbicides (Tewari *et al.*, 2018). Tractor operated boom sprayer are commonly used for higher coverage and speedy operation, but they tend to leads a common problem known as "spray drift"spraying with boom sprayer for weed control has major issues such as drift, environmental pollution, health effect of operator and damage to the adjacent crops. Further application of this type sprayer is limited to the selective application of herbicide only. To tackle these issues a six-row tractor mounted inter row shielded herbicide sprayer was developed to control weeds in wide row crops. The performance of developed sprayer was evaluated in the field to study the effect of operating pressure at different combinations of forward speed and wind velocity on volume median diameter, droplet density and uniformity coefficient. The droplet size for effective application of herbicides is 250-350 µm for medium spray and 350-450 µm for coarse spray. The droplet densities for pre-emergence and post emergence herbicide application are 20-30 and 30-40 drops/cm^2, respectively (Anonymous, 2011).

Scientist, Department of Farm Machinery & Power Engineering College of Technology and Engineering Maharana Pratap University of Agriculture and Technology, Udaipur

MATERIALS AND METHODS

A six-row tractor mounted inter row shielded herbicide sprayer was developed and fabricated at Agricultural Research and Development Foundation (ARDF) of M/s. American Spring and Pressing Works Private Limited (ASPEE), Thane District of Maharashtra State (Fig.1). The different components of the developed sprayer were main frame, chemical tank, spray pump, pressure gauge, control assembly, boom, spray shields, hose pipes,

nozzles and power transmission unit. The brief specification of the different components used for fabrication of the developed sprayer is given in Table 1.

Table : 1 specification of components used for fabrication of the sprayer

S. N.	Sprayer parts	Specifications
1.	Main frame	Material: MS angles, Size: 75×45×5, 70×65×5, 80×70×5 mm, L×B: 1580×680 mm.
2.	Chemical tank	Material: Roto-mold plastic, Capacity: 400 l with agitator 20-40 l/min.
3.	Spray pump	Horizontal triplex pump (HTP), RPM: 950, Output: 50 l/min. Max. pressure: 28 kg/cm2, HP required:5.
4.	Pressure gauge	Make: ASPEE, Pressure range: 0-7 kg/cm2.
5.	Control assembly	Material: Brass, Seven on-off control valve (6 for shields & 1 for back flow) with pressure regulator and suck back valve.
6.	Boom	MS square pipe, Size: 50×50×3 mm, Length: 4500 mm.
7.	Spray shields	6 Nos. Material: 1 mm Aluminium sheet.
8.	Hose pipes	Make: ASPEE Duratek, Material: HDPE, Size: 10 mm ?, Working pressure: 50 kgf/cm2.
9.	Nozzles	6 Nos. Flat fan nozzle, Discharge 800 ml/min., Spray angle, 80°.
10.	Power transmission unit	PTO shaft (L:300, Dia.:30 mm), V belts (A30, 8 mm) & pulley (Two, 175 & 100?)

Development of six row tractor mounted inter row shielded herbicide sprayer

Main frame

Main frame was the part to which all other parts of the sprayer were attached. Main frame was fabricated to accommodate herbicide tank, boom, pump and other accessories of the sprayer. The overall length and width of the frame was 1580 mm and 698 mm, respectively. The height of the main frame was 1205 mm. The provision to mount the control panel and three-point hitches were also provided on the main frame.

Chemical tank

The roto-mould plastic chemical tank of ASPEE having tank capacity of 400 Ltr. was used to accommodate in the main frame of the sprayer. The tank was mounted on the main frame and bolted with two T type nut and bolts to the main frame. Usually, agitation flow should be 5 to 10 percent of the tank capacity (Sharma and Mukesh, 2013). Therefore, for 400 litre capacity of chemical tank the agitation flow was kept 20-40 litre/min.

Spray pump

The horizontal triplex pump (HTP) of discharge capacity of 50 lpm was used in the sprayer. The filter was also provided in between the outlet of chemical tank and inlet of pump to remove any foreign material in chemical with the help of transparent plastic pipe.

Control assembly

The control assembly consisted of seven on-off valves, pressure regulator and suck-back valve was fitted at front left-hand side of sprayer. It facilitated in spraying any section of the shield. Six on/off valves were provided for nozzles inside the shields and one for agitation assembly. Pressure regulator of the pressure range 0-7 kg/cm^2 was also provided for regulating the spray pressure of the sprayer.

Boom

The boom was fabricated from Mild Steel (MS) square pipe of size 50×50×3 mm. Spray shields were mounted on the boom with help of shield mounting assembly. The boom size in terms of length was established based on field capacity, speed and time using the expression given by Mathews (1992) thus;

$$L = \frac{A}{S \times T}$$

Where, A = Area to be covered, ha; S = Spraying speed, km/h; T = Time taken to cover an area, h; L = Length of boom

Spray shields

Spray shields (6 Nos.) were developed locally using 2 mm aluminum sheet (Fig. 1). Spray pattern of the nozzle was taken into consideration for developing the shield, so that edges of the shield do not touches and affects the spray pattern of nozzle (Nimkar, 2013). Rubber sheet of appropriate size was riveted to the shield so that shield should not damage with

obstacles in the field.

Spray shields were mounted on shield assembly. Shield assembly consisted of clamps (2 for each shield) fabricated from 3 mm Mild Steel sheets, upper and lower pipes (one each for each shield), and shield brackets. The lower pipe was able to close fit inside the upper pipe and holes were made into both the pipes for height adjustment by nut and bolts.

Spray hoses

ASPEE Duratek high density polyethylene spray hoses of 10 mm Φ with working pressure of 50 kgf/cm^2 were used to carry spray chemical from control assembly to nozzles inside the shields.

Nozzle

The flat fan nozzle (one for each shield) was used as it is most commonly used nozzle for herbicide application (Bainer *et al.*, 1987). The position of the nozzle was kept in the center of the shield and care was taken so that the spray pattern of nozzle should not touch the edge of the shield. The material used for the nozzles was brass as it has less wear than plastic nozzles.

Power transmission

The power to operate the spray pump was taken from the power take off (PTO) shaft of the tractor. PTO shaft operated the pedestal pulley which further operated HTP pump through V belts and pulley arrangement (Gholap *et. al.*, 2014).

Experimental set up for field operation of the sprayer

Fig. 1 View of the developed shielded sprayer

The sprayer was mounted on the tractor and tank was filled with blue indigo dye mixed with the water (Gholap and Mathur, 2013). The sample glossy paper were placed in the field under each shield/nozzle for each experiment and collected for analysis in the laboratory. For analysis of VMD, DD and UC image analyzer with microscope (Fig. 2) was used. The sample glossy papers collected in different experiments were placed under the microscope. The microscope processed the glossy paper and directly gave Volume Median Diameter (VMD), Number Median Diameter (NMD) and Droplet Density (DD). Ratio of VMD and NMD gave uniformity coefficient (UC).

Fig. 2 Image analyzer for analysis of droplet spectrum

The operating pressure was adjusted through the control panel of the sprayer. The forward speed of sprayer was adjusted by changing the tractor travel speed through accerator pedal. A view of shielded sprayer in field operation for chilly crop is shown in Fig. 3.

Fig. 3 Field operation of devloped shielded sprayer for chilly Data analysis

The data obtained in different experiments were stored in microsoft (MS) excel and statistical analysis was carried out. The data were analyzed using CRD statistical software package (Gholap *et. al.*, 2012).

RESULTS AND DISCUSSION

Effect of spraying pressure on volume median diameter (VMD) at different wind velocities and forward speeds

The volume median diameter of sprayer varied from 139 µm to 445 µm. The smallest volume median diameter of 139 µm was found at operating pressure of 400 kPa, forward speed of 4 km/h and wind velocity of 7 km/h. The largest VMD of 445 µm was found at operating pressure of 100 kPa, forward speed of 2 km/h and wind velocity of 5 km/h. It is evident from Fig. 4 that volume median diameter decreased as spraying pressure increased for all combinations of wind velocities and forward speeds.

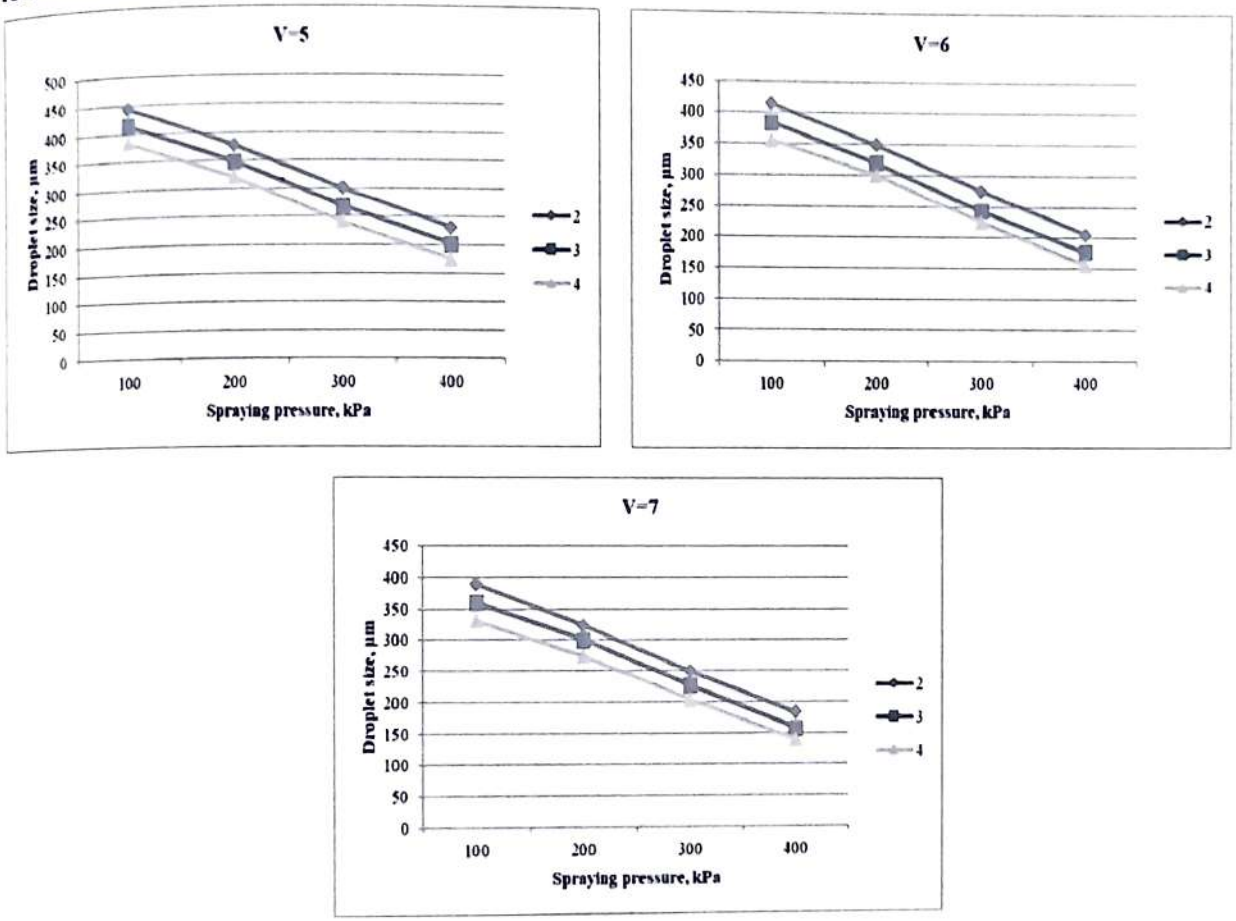


Fig. 4 Effect of spraying pressure on volume median diameter at different wind velocities and at different forward speeds

Effect of spraying pressure on droplet density (DD) at different wind velocities and forward speeds

The droplet density of sprayer varied from 32 to 42 No./cm^2. The smallest droplet density was found at operating pressure of 100 kPa, forward speed of 2 km/h and wind velocity of 5 km/h. The largest droplet density was found at operating pressure of 400 kPa, forward speed of 4 km/h and wind velocity of 7 km/h. It is evident from Fig. 5 that droplet density increased as spraying pressure increased for all combinations of wind velocities and forward speeds.

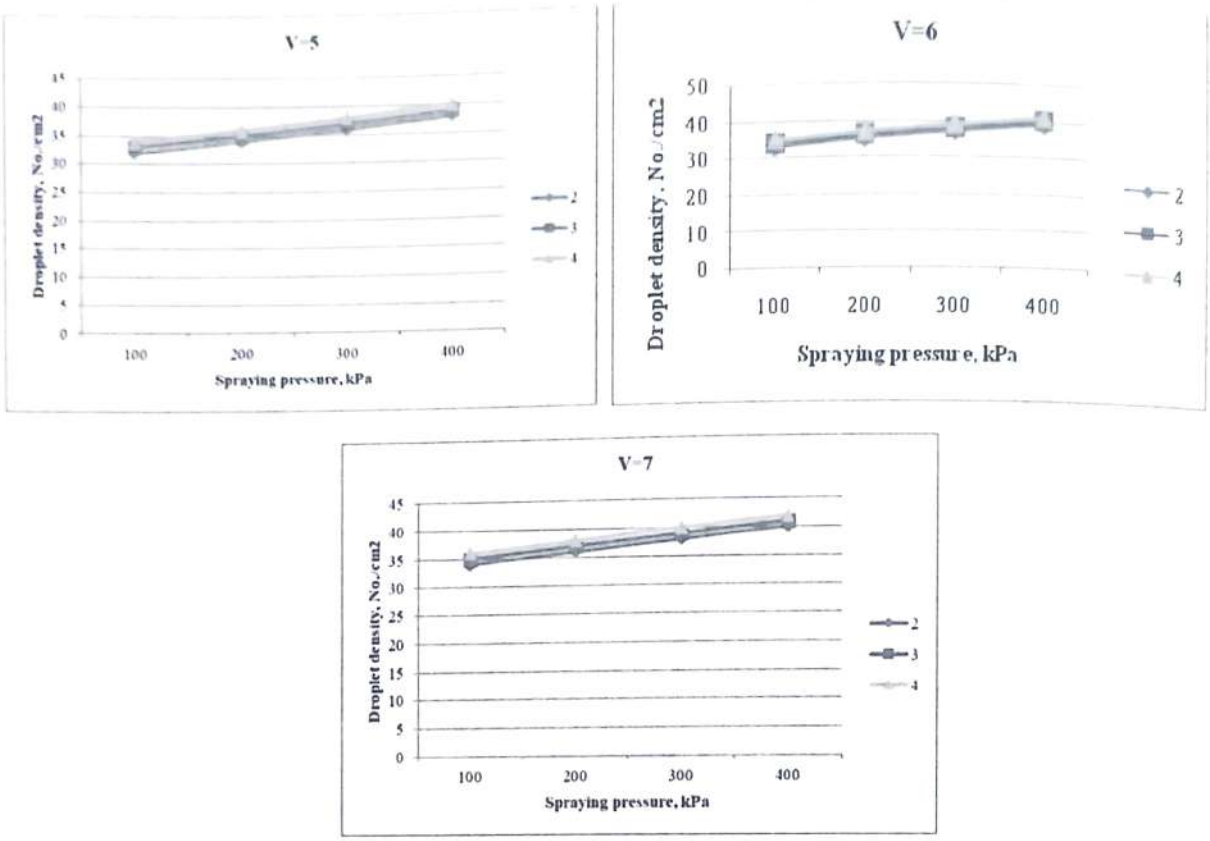
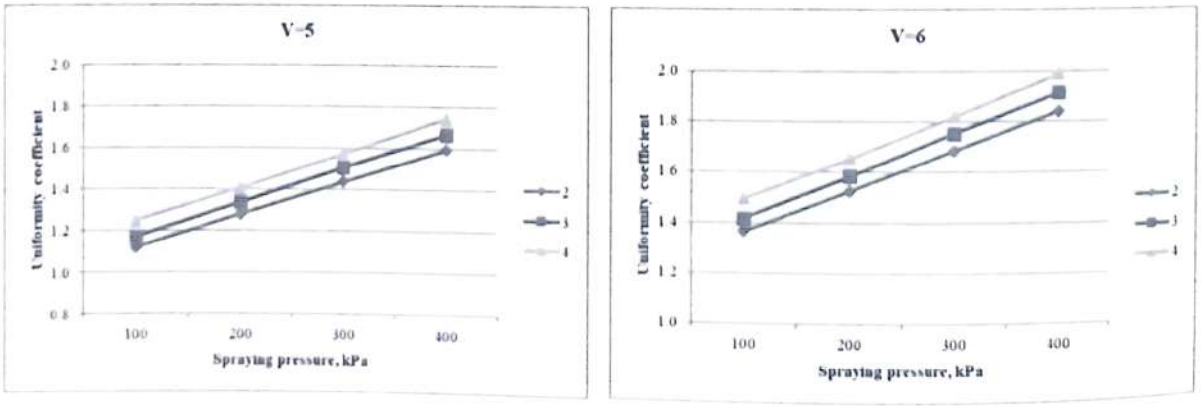


Fig. 5 Effect of spraying pressure on droplet density at different wind velocities and at different forward speeds

Effect of spraying pressure on uniformity coefficient (DD) at different wind velocities and forward speeds

The uniformity coefficient of sprayer varied from 0.95 to 1.15. The smallest uniformity coefficient was at operating pressure of 100 kPa and forward speed of 2 km/h. The largest uniformity coefficient was at operating pressure of 300 kPa and forward speed of 4 km/h. Fig. 6 slows that uniformity coefficient in-creased as spraying pressure in-creased for all combinations of wind velocities and forward speeds.



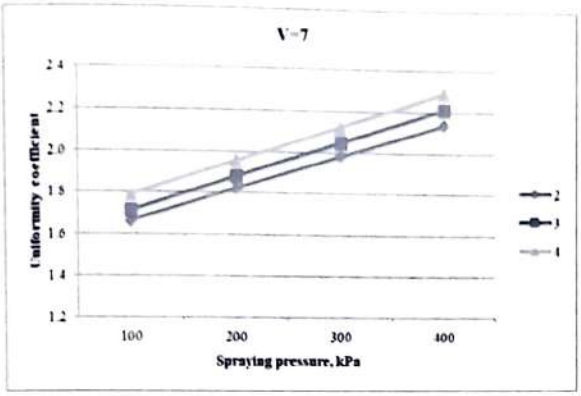


Fig. 6 Effect of spraying pressure on uniformity coefficient at different wind velocities and at different forward speeds

CONCLUSIONS

From the results, it was found that operating pressure had significant effect on volume median diameter, droplet density and uniformity coefficient for all combination of wind velocities and forward speeds. The volume median diameter, droplet density and uniformity coefficient of sprayer varied from 139 µm to 445 µm, 32 to 42 No./cm^2 and 0.95 to 1.15, respectively.

REFERENCES

Anonymous. 2011. Spray application basics. Vegetable Industry Development Program, Horticulture Australia, Government of Australia.

Bainer, R., Kepner, R.A., Barger, E.L. 1963. Principles of farm machinery. Wiley, NY.

Gharde, Y., Singh, P.K., Dubey, R.P. and Gupta, P.K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. Crop Protection 107: 12–18

Gholap, B., Mathur R. 2013. Field evaluation of tractor operated boom sprayer for cotton crop. International Journal of Agricultural Engineering. 6 (2): 372-374.

Gholap, B., Mathur, R. and Dhande, K.G. 2012. Laboratory performance evaluation of 12 m tractor mounted boom sprayer for cotton crop. International Journal of Agricultural Engineering. 5 (1): 31-36.

Gholap, B. Mathur, R. Jadhav, P. and Gonjari, V.V. 2014. Development and performance evaluation of tractor mounted boom sprayer for cotton crop. Green Farming. 5 (5): 211-214.

Nimkar, A. S. 2013. Design and evaluation of protective shield for spray drift in hydraulic boom sprayer. Unpublished M. E. thesis submitted to MPUAT, Udaipur.

Sharma, D. N. and Mukesh, S. 2013. Farm Machinery Design - Principles and problems. Third revision. Jain Brothers, New Delhi. pp. 216-219.

Tewari, V.K. and Chethan, C.R. 2018. Mechanization in weed management – A review. Pp. 215-237 In: Fifty Years of Weed Science Research in India. Indian Society of Weeds Science, Jabalpur.