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Research Review

Current Horticulture **11**(1): 3–7, January–April 2023

Irrigation, a potential tool for insect pest management in horticultural crops — a review

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ABSTRACT

Irrigation, probably more than any other single factor, has a greater role to enhance the production and productivity of horticultural crops. Different methods of irrigation systems are being followed for various horticultural crops. Apart from soddening the crops, irrigation can also play a pivotal role in insect pest management in so many horticultural crops. A light irrigation minimizes the termite infestation. The drip irrigation in perennial orchard helps maintain lower level of insect pests compared to flood irrigation; whereas drip irrigation maintains the incidence of tomato fruit borer to lower level in field instead of sprinkler irrigation. The paper illustrates this theory by reference to illustrates and discusses the ways in which insect pests menace can be minimized in horticultural crops.

Key Words: Irrigation, Horticultural crops, Insect pests management, Drip irrigation, Sprinkler irrigation

Stupendous efforts have been made to enhance the irrigated area through creation of a large number of surface irrigation projects and through ground water resources in India. Therefore, the irrigated area has increased by almost 250% from 1950-51 (Shankar *et al.*, 2015). Recently, microirrigation is being emphasized to increase the water use efficiency. In microirrigation, water is irrigated through special devices, *viz*. sprinklers, drippers, foggers and additional emitters on surface and subsurface of land. It has a potential role in insect pests management in horticultural crops. When a plant is stressed and weakened because of missing of vital nutrients, it becomes a soft-target for any pests or diseases. If watering for a plant is not appropriate, it can weaken a plant very quickly and the opportunistic pests are already waiting for the opportunity to attack crops (www.naturesseed.com). So, insect pest management thorough irrigation is a unique, distinct and eco-friendly cultural method with potential benefits. Unlike conventional chemical method of pest control which often has problems, such as resistance to pesticides, resurgence of target sucking insects and secondary pest outbreaks, in addition to widespread killing of beneficial non-target organisms (Halder and Rai, 2016; Halder *et al.*, 2015, 2021).

Considering the adverse effects of these synthetic insecticides, this noble cultural method of pest control gives an opportunity to control the pests without no / little cost involvement. However, thorough knowledge of pest bio-ecology and seasonal incidence are paramount in this venture (Halder *et al.*, 2019, 2022). Different methods of irrigation such as surface irrigation; sub-surface irrigation; sprinkler irrigation and drip irrigation are widely used by farmers. The role of these irrigation methods has been reviewed and discussed in the light of insect pest management in horticultural ecosystems.

Irrigation methods in insect pest management

Flood irrigation: Incidence of red spider mites, *Tetranychus urticae* Koch. and *T. cinnabarinus* (Boisduval) on vegetables, *viz.* okra, brinjal, pumpkin, pointed gourd etc. are more in dry months. Frequent irrigations at 4-5 days intervals in clay-loam soils of Varanasi, Uttar Pradesh, India, substantially minimized its incidence in summer season, particularly during May-June (Rai *et al.*, 2014(a). Flooding and water stagnation for 2-3 days kill the over-wintering soil-inhabiting pupal stage of many Lepidopteran, Dipteran and Coleopteran pests of vegetables (Rai *et al.*, 2014(b).

Flooding of fields has been recommended for minimizing the attacks of those pest whose at least one

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or more life-stages are passed in soil. Cutworms [*Agrotisipsilon* (Hufnagel)], army worms [*Spodoptera mauritia* (Boisduval)], red hairy caterpillar [*Amsactaalbistriga* (Fabricius), *A. mooreii* Butler], red pumpkin beetles (*Rhapidopalpa foveicollis* Lucas), cucurbit fruit fly [*Zeugodacus cucurbitae* (Coquillett)], termite [(*Odontotermesobesus* (Rambur)], white grubs [*Holotrichia consanguinea* Blanchard, *Holotrichia serratae* (Fabricius)] are few in the list. Due to flooding, water permeates the soil pores and soil inhabiting stages of insects get killed either due to asphyxiation or emerge out from the soil and finally devoured by the predatory fauna.

The performance of phytophagous insects in tomato (*Lycopersicon esculentum* Linn.) is minimized by water stress, depending on cultivars and other stress level (Inbar *et al.* 2001; Rivelli *et al.* 2013). This is in accordance with the earlier studies on synchronous effects of aphids and water stress on tomato crop growth under controlled conditions (Rivelli *et al.*, 2012). Colella *et al.*, 2014 recorded that incidence and population of phytophagous insects of tomato, *viz*. *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae); *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae); *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae); and leafhoppers (unidentified species) was the maximum in plots where plants obtained the full restoration of crop evapotranspiration and the minimum in plots where crops had not receive any water except during transplanting.

So, water deficit also reduces the insect pest infestation rate under field conditions. Frequent irrigation and optimum soil moistures reduce the phytophagous mite population in horticultural crops (Rai *el al.*, 2014(b). In Chinese cabbage (*Brassica rapa* subsp. *pekinensis*), the mustard aphid population (*Lipaphisery simi* (Kalt.) increased significantly with the number of irrigation from three to six (Dhaliwal and Arora, 2002).

Drip and sprinkler irrigations

Drip and sprinkler irrigations are the improved version of irrigation methods with multiple advantages. Precise and adequate water supply at the root zone made these technologies highly acclaimed around the world. According to Kuhar *et al.* (2010) two drip applications of Chlorantraniliprole drastically reduced the tomatoes ravaged by tomato borer, *Helicoverpa zea* (Boddie), in comparison to that of using repeated foliar applications of insecticides. Taylor (1984) had observed that application of sprinkler irrigation during the larval emergence of cutworm was very effective in reducing infestations compared with pesticide treatment. They concluded that larvae dislodged from the foliage were unable to regain their position on the host plant as they are positively phototactic immediately (up to two days) after emergence.

Sprinkler irrigation on alternate days over the first 3-4 weeks for 5 minutes during dusk, and regular day thereafter, significantly reduced the diamondback moth (DBM), Plutellaxylostella Linn. on cabbage and increased the yield over drip irrigation control plots receiving an equal amount of water. The disruption of flying activity, oviposition, and to some extent wash-off of larvae and adults were from the plant surface seem to be the major causes of the observed effects (Talekar *et al.*, 1986). Sprinkler irrigation presumably drowns and washes away DBM larvae feeding on the leaf surface. Apart from disturbing the adult moths and forces them to fly upon which the water droplets wash them away.

Since, sprinkler irrigation was carried out close to dusk, when the DBM mate and start laying eggs (Harcourt, 1957), there seems a distinct possibility that this treatment disturbs mating and/or oviposition. Crucifer crops with overhead sprinkle irrigation tend to have fewer DBM larvae than drip or furrow-irrigated crops (Gautam *et al.*, 2018). In another study McHugh and Foster (1995) reported that irrigation water was applied to cabbage by Whiz head, Mini head, or Buckner head sprinklers, DBM infestations were reduced by 37.5-63.9% as compared to drip-irrigation. Sprinkler treatments applied between 1500 and 1700 hours continuously, 2000 and 2200 hours continuously, and 2000 and 2330 hours intermittently resulted on an average 53.7, 72.9, and 85.9% reduction in diamondback moth infestation, respectively.

However, the best results were obtained by intermittent daily application of overhead irrigation between 2000 and 2330 hours. In another study on watercress in Hawaii, Tabashnikand Mau (1986) determined that 70% of diamondback moth adult oviposition occurred between the hours of 1700 and 2300. Irrigation during that time was effective in suppressing diamondback moths on watercress by reducing the number of eggs laid per plant. Use of sprinkler irrigation reduced thrips population in chilli and ginger considerably compared to drip and surface irrigation.

The effects of overhead and drip tube irrigation on two spotted spider mite (*Tetranychus urticae* Koch) and its predatorymite (*Phytoseiulus persimilis* Athias-Henriot) populations were investigated on Impulse Orange (*Impatiens wallerana* Hook.f.) by Opit *et al.* (2006). Overhead watering significantly reduced *T. urticae* and *P. persimilis* populations as much as 68 and 1538-fold, respectively, compared to drip irrigation with micro tubes. They also concluded that spider mite infestations and injury may be made by irrigation systems that wet plant foliage. Similar observations were also recorded by Hudson and Beirne (1970); Ranga *et al.* (1990).

Aldryhim and Al-Bukiri, 2003 showed that more infested date palm trees by the red palm weevil *Rhynchophorous ferrugineus* (Olivier), the most serious pest, were detected in plots with flood irrigation compared to drip irrigation. The number of infested trees in these plots represented 89% of the total infested trees. They also concluded that irrigation management and soil moisture are key factors in the dispersion of the red palm weevil infestation and could be used as one of the integrated pest management tools.

However, overhead or sprinkler irrigation wets the plant foliage that could be favorable for plant pathogens and subsequent disease development. Splashing water off the plant foliage often results in the movement of plant pathogens between the plants. Apart from the known benefits of overhead irrigation loss of water to evaporation and chance of disease incidence are greater threats in crop production.

High-pressure water spray

Use of high-pressure water spray to dislodge spider mites, aphids, small caterpillars and other pests from host plants has long been suggested as a "non-chemical" or "organic" method of pest control (Meyer and Stone, 1989). The water pressure (pressure of water coming out of the end of a hose) would be 90-100 pounds per square inch (https://extensionentomology.tamu.edu). Using ones' thumb on the end of the hose to produce a high pressure spray to dislodge the arthropods (insects and mites) from the plants has been widely used practice. Use of these devices would be compatible with biological control programmes to dislodge pests before natural enemies are released. In addition, water or soap water spray treatments may be capable of removing the sugary honey dew secreted by the sucking insects deposited on leaves and other plant parts as black sooty mold, hindering the normal photosynthesis of the plants (Halder *et al.*, 2010; Halder and Rai, 2018).

Chemigation

Chemigation is the process of applying an agricultural chemical (pesticides or fertilizers) to the soil or plant surface with an irrigation system by injecting the chemical into the irrigation water (https://hort.purdue.edu). Both the water and pesticides are homogeneously applied, resulting in excellent distribution of the water-pesticide mixture. Pesticides may also be applied when other approaches cannot be used due to humidity, extreme wind, equipment availability *etc.* Depending on the type of agricultural chemical being applied, chemigation may be referred to as herbigation, insectigation, fungigation, fertigation,

Table 1. Effect of different irrigation methods on insect pests management

Irrigation method	Crop(s)	Insect pest(s)	Effects (+ve /- ve) on target pest(s)	Place	References
Flooding followed by water stagnation for 2-3 days	Vegetables	Soil inhabiting stages of Lepidoptera, Coleoptera and Diptera	Negative	Varanasi, Uttar Pradesh	Rai *et al.*, 2014(b)
Sprinkler irrigation	Vegetables	Cutworm	Negative	Londan, U.K.	Taylor, 1984
Sprinkler irrigation	Cabbage	Diamondback moth, *Plutellaxylo stella* Linn.	Negative	Taiwan Ontario, Canada India West Lafayette, U.S.A.	Talekar *et al.*, 1986 Harcourt, 1957 Gautam *et al.*, 2018 McHugh and Foster, 1995
Overhead sprinkler irrigation	Impulse orange (*Impatiens wallerana* Hook. f.)	Two spotted spider mite (*Tetranychus urticae* Koch) and its predatorymite (*Phytoseiuluspers imilis* Athias-Henriot)	Negative	Kansas, U.S.A.	Opit *et al.*, 2006
Flood irrigation	Date palm	Red palm weevil *Rhynchophorous ferrugineus* (Oliver)	Positive		Aldryhim and Al-Bukiri, 2003

etc. Chemigation can be an effective application option for some labeled pesticides if the irrigation system can apply the chemical / water solution uniformly over the target area with the correct water depth.

However, accurate calibration of the irrigation system and the pesticide application rate is most important in this technology. Palumbo (2008) observed that two drip applications of Chlorantraniliprole during stand establishment provided excellent residual control of *Trichoplusiani* (Hübner), *Spodoptera exigua* (Hübner), and *Liriomyza* spp. in romaine lettuce (*Lactuca sativa* Linn. var. *longifolia*), with no significant marketable yield loss. Schuster *et al.* (2009) reported that a single or double drip application of Chlorantraniliprole effectively reduced both leafminer, Liriomyza trifolii (Burgess); and armyworm, *Spodoptera* spp., damage in tomato (*Solanum lycopersicum* L.).

Water management with other management practices

Water management in horicultural crops through irrigations is, in general, compatible with other pest management options, *viz*. physical, mechanical, cultural, biological and chemical pest control methods. In fact, frequent irrigations inflate the moistures / humidity in the crop field which further favour the biological pest control resorted through microbial organisms. Similarly, different physical methods of pest control such as light traps, pheromone traps, colored sticky traps are compatible with water management. However, sometimes, flood irrigation restricts the intercultural operations in the field for few days, depending on soil texture, due to muddy condition of soil. Foliar sprays of pesticides generally do not affect by ground irrigation, however, basal and root zone application of pesticides sometime restricted due to irrigation. Pesticides, particularly organo-phosphates, can move in solution with irrigation water. So, adequate precaution should be taken to prevent this unintended run-off through irrigation water.

CONCLUSION

Obviously, finding of above experiments will enable us to develop a sound Integrated Plant Health Management (IPHM) package and that will help growers to select ways to reduce overall pest load in their field and ensure that the management of pests is compatible with their other crop management inputs. Moreover, it is important that growers should realize that IPHM system is updated from time to time in response to biological changes that occur in their field and new techniques or technologies are introduced as soon as additional relevant information becomes available. Irrigation, the single most crucial factor in increasing horticultural production and productivity, also plays a pivotal role in insect and acarine pests problem. It is evident that at agricultural intensification, irrigation as a central feature can also minimize the impact of natural regulatory mechanisms on insect pest populations.

The examples selected above have been chosen to illustrate rather specifically the influence of irrigation on crop pest problems. The current trends in pest management that mostly emphasize the exploitation of biological and chemical components can also integrate irrigation management as a cultural realistic means of substituting for this crop losses. However, thorough knowledge of bio-ecology the target pest(s) and associated environment are imperative. Identifying the suitable method(s)of irrigation, their time of application, crop phenology, soil texture and its prevalent moisture level in relation to pest biology are the few in the catalogue.

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Research Article

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Time series modeling and forecasting of vegetable production in United Arab Emirates

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ABSTRACT

Crop forecasting is a formidable challenge. The national and state governments need such predictions before harvesting for various policy decisions relating to storage, distribution, pricing, marketing, import-export etc. In this paper, univariate forecasting models such as random walk, linear trend, quadratic trend, exponential trend, S-curve trend, simple exponential smoothing, Holt's linear exponential smoothing and Autoregressive Integrated Moving Average (ARIMA) models are used to predict vegetable production in the United Arab Emirates. For empirical analysis, a set of 9 different vegetable groups have been considered, contingent upon availability of required data. Annual data from 1974-75 to 2018-19 was used to forecast the next five years since 2019. Suitable models were selected based on the lowest RMSE and minimum of AIC criterion. Model diagnostic checking was done through Runs above and below the median, Runs up and down and Ljung-Box tests on ACF and PACF of residual terms. For onions and green shallots linear trend model was selected as the best fit, whereas simple exponential smoothing model was most suitable in cauliflowers and broccoli, pumpkins, squash and gourds and spinach. The optimum model obtained for forecasting carrots and turnips was Holt's linear exponential smoothing model and ARIMA model was the best fit for the rest of vegetable groups.

Key Words: Forecast models, Vegetable production, AIC, ARIMA, ACF, PACF

Several statistical and econometric forecasting models have been developed in the literature that could be used to forecast various issues, including agricultural production, marketing, demand, trade, *etc.* (Hanke and Wichern, 2008). Al-Karablieh and Salman (1999) Verma *et al.* (2015), Kumar *et al.* (2019), Naidu *et al.* (2018) *etc.* are working on various forecasting aspects in agriculture. Fildes and Lusk (1984) advise that forecasters should consider a range of methods and analyze their comparative performance over a random selection of series. Reliable and timely forecasts provide useful and practical advice for effective, foresighted and insightful planning, especially in agriculture, which is full of uncertainties.

Study Area : Food security is at the top of the national agenda in the United Arab Emirates (UAE), but growing crops under the harsh weather conditions of the UAE can be quite a challenge. The landscape of the United Arab Emirates (UAE) is dominated by low-lying, sandy desert. In the country, about 34 per cent of the area is affected by different levels of salinity, where the growth of healthy plants is almost impossible (Qureshi, 2017).

The UAE imports 80 per cent of its food; this is a significant challenge for the country's food security (Sandhya, 2019). To tackle this hurdle, economical production of food has to be approached at a macro level by examining cross-border efficiencies. Sustainable use of natural resources is a crucial evaluation criterion of modern agricultural production systems. Environmentally-controlled agriculture is a significant source of global agricultural production, especially in the UAE where vegetable consumption rates are going up in addition to the boom of the ornamental plants market (Fadel *et al.*, 2014). For the past four decades, UAE's plant holdings had increased 38-fold from 157 ha in 1971 to 5,935 ha in 2018.

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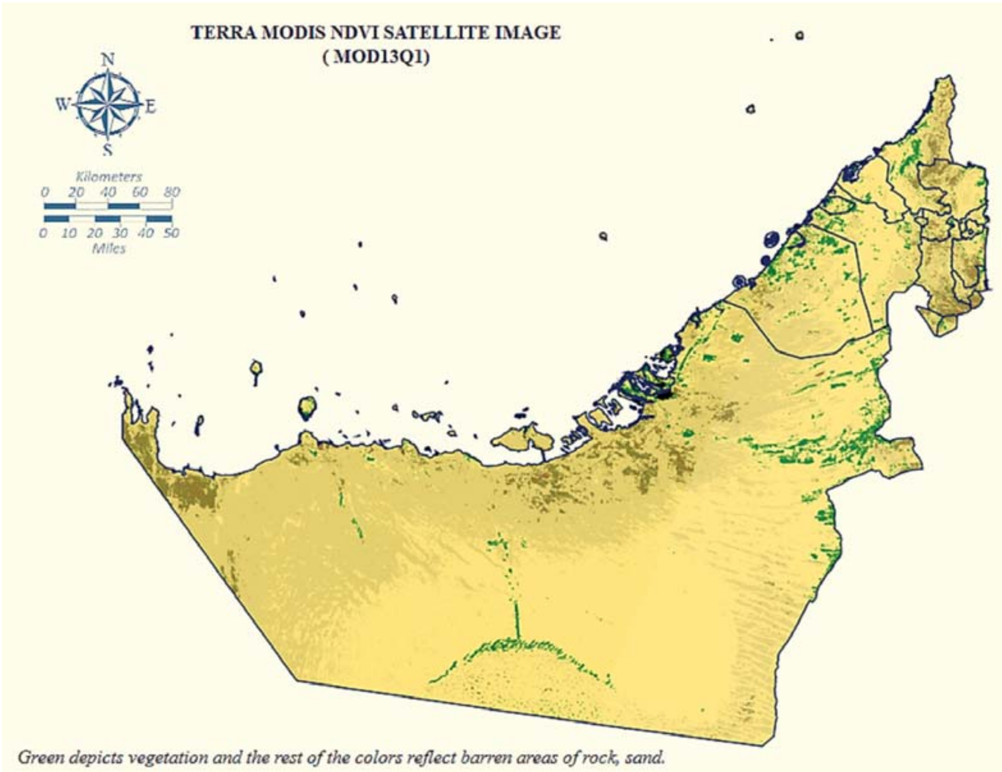

Fig. 1: NDVI image (2019) for the United Arab Emirates

Land classification based on the Normalized Difference Vegetation Index (NDVI) over the UAE is given in Fig. 1. Meanwhile, arable land has expanded by 33-fold from 5530 ha to 1,85,297 ha during the same period. According to the Statistical Book of Abu Dhabi (2019), there are 18,269 greenhouses in Abu Dhabi with 1,415 ha producing vegetables. The smart production of food locally can help alleviate import requirements and as a result, minimize environmental impact in a country that has one of the highest per caput carbon footprints in the world. Duncan (2018) reported high demand for locally-produced fruits and vegetables in UAE supermarkets. Therefore, study was carried out in the United Arab Emirates to find out the trend and forecast the major groups of vegetables using suitable statistical models, which may be useful to the public, researchers, and decision-makers with baseline data.

MATERIALS AND METHODS

The study was carried out by using time series data from 1974-75 to 2018-19, *i.e.* time series data of 45 years. Forecasting of production for next five years of major vegetable groups: (1) cabbages and other brassicas, (2) carrots and turnips, (3) cauliflowers and broccoli, (4) cucumbers and gherkins, (5) eggplant (aubergines), (6) onions and green shallots, (7) pumpkins, squash and gourds, (8) Spinach and (9) tomatoes. The time-series data were collected from Statistics Division, Food and Agriculture Organization of the United Nations (FAOSTAT) and were analyzed in STATGRAPHICS Centurion 18 software.

Analytical Techniques : The study was tried to fit univariate forecasting models such as random walk, linear trend, quadratic trend, exponential trend, S-curve trend, simple exponential smoothing, Holt's linear exponential smoothing and Autoregressive Integrated Moving Average (ARIMA) models to predict vegetable production. Model diagnostic checking was done through: (1) Runs above and below median (2) Runs up and down and (3) Ljung-Box tests on ACF and PACF of residual terms. Similarly, diagnostic checking can also be done through a minimum of root mean squared error (RMSE) and mean absolute percentage error (MAPE), minimum of Akaike Information Criteria (AIC) and Schwarz Bayesian Criteria (SBC) etc.

Random walk model: It is a non-stationary stochastic time series model also denote as I(1) model. Suppose an is a white noise error term with mean 0 and variance σ^2. Then series Y_n is said to be random walk if

$$Y_n = Y_{n-1} + a_n$$

It means the value of Y (production) at time t is equal to the sum of its value at (n-1) and a random shock.

The above equation can be re-written as

$$Y_n - Y_{n-1} = a_n = \Delta Y_n$$

where, Δ denotes the differencing operator.

Linear trend model

The linear trend is a simple function described as a straight line along with several points of time series value in time series graph and has a typical pattern.

$$Y_n = c + bT_n$$

where c is the constant of production at base period, and b is the coefficient of trend line direction. Method least squares can be applied to find these coefficients.

$$b = \frac{N\sum Y_n T_n - \sum Y_n \sum T_n}{N\sum T_n^2 - \sum (T_n)^2} \text{ and } c = \bar{Y}_n - b\bar{T}_n$$

Non-linear Trend model

In several cases, linear trend was not suitable for time series data. These cases occur when a time series has a different gradient between the beginning phase of the data and the next phase. For these cases, it is better to use a non-linear trend than linear trend. There are several non-linear trends, and in this study, the following models were used:

Quadratic trend $Y_n = c + bT_n + hT_n^2$

Exponential trend $Y_n = cb^{T_n}$

S-curve or Logistic trend $Y_n = \frac{1}{1 + e^{c+bT_n}}$

Non-linear equations can be solved using linearization, Newton Raphson methods etc. see Weisberg (2005).

Exponential smoothing methods

It is a specific kind of moving average technique that is applied to data from time series, used to make a smooth data for projection, or to predict. This method weights preceding observations by diminishing weights exponentially to the prediction of future values.

Simple Exponential Smoothing

It is a process that continually repeats enumeration through the use of the newest data. This approach can be used if trend and seasonal factor do not significantly affect the results. A parameter called the smoothing constant (α) is required to smooth out the data with single exponential smoothing. A convinced weighting is given for each data point, α for the newest data and ($1-\alpha$) for older data etc. The value of α must be 0 to 1. The following is a smoothed-value equation:

$$S_n = \alpha[Y_n + (1-\alpha)Y_{n-1} + (1-\alpha)^2 Y_{n-2} + ...]$$

Forecasting value with single exponential smoothing can be done by substituting this equation:

$$\hat{Y}_{n+1} = \alpha Y_n + (1-\alpha)\hat{Y}_n$$

The initial value S_0 can be calculated from the average of several observations. The first several observations can be chosen to determine S_0.

Double exponential smoothing (Holts)

Holts Method uses different parameters than the one used in the original series. Exponential smoothing prediction can be achieved by using two smoothing constants (with values between 0 and 1) and the following three equations:

$$S_n = \alpha Y_n + (1-\alpha)(S_{n-1} + T_{n-1})$$

$$T_n = \gamma(S_n - S_{n-1}) + (1-\gamma)T_{n-1}$$

$$\hat{Y}_{n+m} = S_n + T_n m$$

The 1st Equation calculates smoothing value S_n from the trend of the previous period T_{n-1} added by the last smoothing value S_{n-1}. Equation 2nd calculates trend value T_n from S_n, S_{n-1} and T_{n-1}. Finally, from equation 3 forward prediction is obtained from trend T_n, multiplied with the amount of next period forecasted m, and added to basic value S_n.

The initial value, *i.e.* S_0 & T_0, can be estimated with the least-squares method is used. The estimation value for S_0 is the intercept value of linear estimation, while T_0 is the slope value.

Autoregressive Integrated Moving Average methodology (ARIMA)

Univariate Box-Jenkins ARIMA forecasts are based only on past values of the variable being forecast. They are not based on any other data series, and uniquely suited to short-term forecasting. The Box-Jenkins procedure for finding a good forecasting model consists of the following three stages. At the identification stage, two graphical devices estimated ACF and estimated PACF are used to measure the statistical relationships within a data series in a somewhat crude way, but helps in giving a feel for the pattern in the available data. These functions act as a guide for choosing one or more ARIMA models that seem to be appropriate. Whatever model is selected from the identification stage, is merely a tentative candidate for the final model. At the estimation stage, one gets precise estimates of the coefficients of the model chosen at the identification stage based on the available data. At the diagnostic checking stage, the residuals are used to test hypothesis about the independence of the random shocks and to help determine if an estimated model is statistically adequate.

This model is generalized model of the non-stationary ARMA model denoted by ARMA (p, q) can be written as:

$$Y_n = \varphi_1 Y_{n-1} + \varphi_2 Y_{n-2} + ... + \varphi_p Y_{n-p} + e_n - \theta_1 e_{n-1} - \theta_2 e_{n-2} - ... - \theta_q e_{n-q}$$

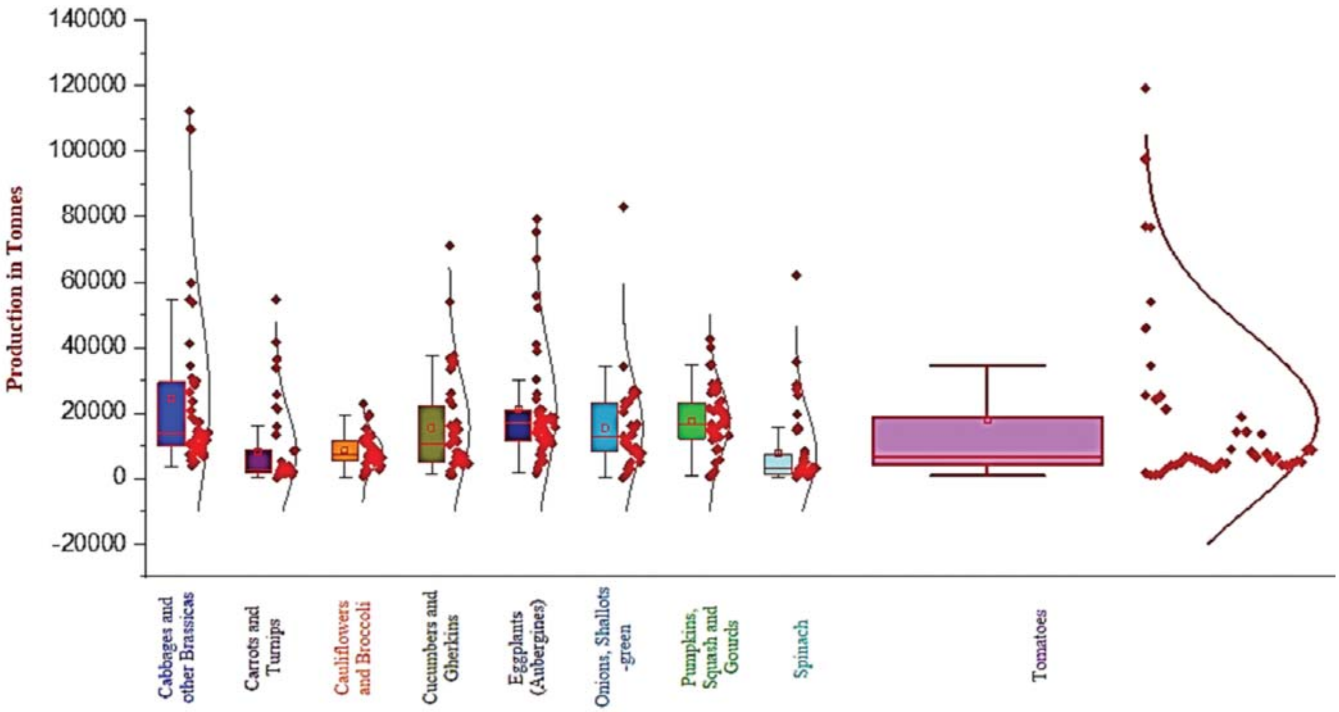

Fig. 2: Box-normal plot of vegetable production in the UAE (1974-75 to 2018-19)

where, Y_n is the original series, for every n, we assume that is independent of $Y_{n-1} + Y_{n-2} + ... + Y_{n-p}$. A time-series $\{Y_n\}$ is said to follow an integrated autoregressive moving average (ARIMA) model if the d^{th} difference $W_n \nabla^d Y_n$ is a stationary ARMA process. If W_n follows an ARMA (p, q) model, we say that $\{Y_n\}$ is an ARIMA (p, p, q) process. Fortunately, for practical purposes, we can usually take d = 1 or at most 2.

Diagnostics checking

Models that are estimated are acceptable only when the residuals are random. For this purpose, several alternative models that may be appropriate were to be fitted. The ACF and PACF of the residuals of these models are then estimated. If the plot of these ACF and PACF exhibit a non-significant pattern, then the corresponding model is valid and can be considered for forecasting. Three standard tests to test the randomness of residuals based on ACF and PACF are: (1) Runs above and below median (2) Runs up and down and (3) Ljung-Box tests. See Box and Jenkins (2008).

To measure the adequacy of the fitted model, RMSE and AIC values are utilized, and it can be computed as follows:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum e_n^2} \quad \mathrm{AIC} = 2\ln(\mathrm{RMSE}) + \frac{2k}{N}$$

where, *k* is the number of estimated model parameters.

RESULTS AND DISCUSSION

Descriptive statistics

The data indicated that there is no stability in the production of all vegetable crops/(variables) over the period. The production of certain variables indicates increasing trends, although non-linear in many cases, with some showing declining trends and others having mixed data (Fig. 4). In time-series language we can say most of the variables are non-stationary in nature and this is reflected in descriptive statistics (Table 1). The descriptive statistics demonstrates the range, minimum, maximum and average values along with other statistical properties. Tomatoes have highest production significantly. It may be attributed to favorable government policies to encourage the production of tomatoes, high acceptance of modern agricultural practices such as hydroponics, greenhouse cultivation etc. Vegetable production shows a subtle pattern as the standard deviation (Std. Dev.) value is too high for all variables. The coefficient of variation (CV) is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from each other. It is calculated as the ratio of the standard deviation to mean. The coefficient of variation is lesser for Pumpkins, Squash & Gourds, *i.e.* 58 per cent and higher for Tomatoes, *i.e.* 152 per cent, which means that the production of these series is less and more dispersed from the mean values.

Table 1. Descriptive statistics for vegetable production in the UAE (1974-75 to 2018-19)

Variable	Range	Minimum	Maximum	Mean	Std. Dev.	CV	Skewness	Kurtosis
Cabbages and other Brassicas	108383	3836	112219	24541.84	26455.492	107.798	2.309	5.056
Carrots and turnips	54471	129	54600	8136.71	12314.763	151.348	2.294	4.931
Cauliflowers and broccoli	22355	452	22807	8548.98	4841.855	56.637	.825	.948
Cucumbers and gherkins	70218	1132	71350	15419.89	15078.885	97.789	1.770	3.511
Eggplants (aubergines)	77758	1638	79396	21350.87	18220.429	85.338	1.919	3.315
Onions and green shallots	83021	90	83111	15412.71	13559.401	87.975	2.895	13.380
Pumpkins, squash and gourds	42037	589	42626	17544.82	10179.228	58.018	.349	.029
Spinach	61571	406	61977	7931.13	11867.568	149.633	2.808	9.410
Tomatoes	1152720	4700	1157420	170434.82	260048.89	152.580	2.444	5.660

Table 2. Comparison of different time series models based on selection criteria

Variable	Selection Criteria	Forecast Models							
		Random walk	Linear trend	Quadratic trend	Exponential trend	S-curve trend	Simple exponential smoothing	Holt's linear exp. smoothing	ARIMA
Cabbages and other Brassicas	RMSE	13.949	26.728	22.523	27.989	27.419	13.949	14.252	12.472
	AIC	5.271	6.660	6.362	6.753	6.711	5.315	5.403	5.225
Carrots and turnips	RMSE	6.326	8.813	5.900	7.844	12.682	5.626	4.940	4.962
	AIC	3.689	4.441	3.683	4.208	5.169	3.499	3.284	3.293
Cauliflowers and broccoli	RMSE	3.508	4.848	3.324	5.299	4.405	3.383	3.422	3.412
	AIC	2.510	3.246	2.536	3.424	3.054	2.482	2.549	2.499
Cucumbers and gherkins	RMSE	9.136	11.023	10.564	10.781	14.778	9.063	9.115	8.272
	AIC	4.424	4.889	4.848	4.844	5.475	4.453	4.509	4.404
Eggplants	RMSE	9.408	10.382	15.562	19.577	17.939	9.408	11.989	7.769
	AIC	4.483	4.725	5.623	6.038	5.863	4.528	5.057	4.278
Onions and green shallots	RMSE	12.553	10.760	10.818	12.814	12.164	11.492	11.160	11.210
	AIC	5.060	4.840	4.896	5.190	5.086	4.928	4.914	4.922
Pumpkins, squash and gourds	RMSE	5.931	8.532	6.452	11.519	8.172	5.716	5.857	5.758
	AIC	3.560	4.377	3.862	4.977	4.290	3.531	3.624	3.546
Spinach	RMSE	12.148	12.001	10.594	12.770	12.528	10.563	10.691	10.685
	AIC	4.994	5.059	4.854	5.183	5.145	4.759	4.828	4.782
Tomatoes	RMSE	131.635	260.619	224.928	279.754	272.257	131.637	168.109	125.626
	AIC	9.760	11.215	10.965	11.357	11.302	9.805	10.338	9.756

Table 3. Model summary and forecast values of vegetable production in the UAE

Selected model summary					Forecast values (tonnes) 2019	2020	2021	2022	2023
Cabbages and other Brassicas									
ARIMA(2,1,2)									
Parameter	Estimate	SE	t	P-value					
AR(1)	0.101	0.141	0.719	0.476	13071	9787	10059	12106	12146
AR(2)	-0.615	0.145	-4.248	0.000					
MA(1)	-0.098	0.070	-1.385	0.174					
MA(2)	-1.004	0.035	-28.823	0.000					
Carrots and turnips									
Holt's linear exp. smoothing					52420	56869	61318	65766	70215
alpha = 0.1276 and beta = 0.9999									
Cauliflowers and broccoli									
Simple exponential smoothing					6312	6312	6312	6312	6312
alpha = 0.7194									
Cucumbers and gherkins									
ARIMA(2,1,2)									
Parameter	Estimate	SE	T	P-value					
AR(1)	0.359	0.111	3.226	0.003	57833	51949	62656	72077	65303
AR(2)	-0.948	0.098	-9.715	0.000					
MA(1)	0.669	0.092	7.275	0.000					
MA(2)	-0.920	0.075	-12.340	0.000					
Eggplants									
ARIMA(2,1,2)									
Parameter	Estimate	SE	T	P-value					
AR(1)	0.476	0.138	3.455	0.001	27079	29406	26807	24182	24481
AR(2)	-0.596	0.141	-4.223	0.000					
MA(1)	0.103	0.040	2.581	0.014					
MA(2)	-0.961	0.038	-25.267	0.000					
Onions and green shallots									
Linear trend = 0.686041 + 0.64029 t									
Parameter	Estimate	SE	t	P-value					
Constant	0.686	3.262	0.210	0.834	30139	30780	31420	32060	32701
Slope	0.640	0.124	5.184	0.000					
Pumpkins, Squash and Gourds									
Simple exponential smoothing					20712	20712	20712	20712	20712
alpha = 0.7448									
Spinach									
Simple exponential smoothing					3142	3142	3142	3142	3142
with alpha = 0.3617									
Tomatoes									
ARIMA(1,0,1)									
Parameter	Estimate	SE	t	P-value					
AR(1)	0.864	0.085	10.200	0.000	66944	57841	49976	43180	37308
MA(1)	-0.299	0.156	-1.916	0.062					

Fig. 2 is the box plot of variables that is the structured way to show the distribution of data based on a five-number summary (minimum, first quartile (Q1), median, third quartile (Q3), and maximum) which provides idea on the variability or dispersion of data.

Identification and estimation of model

The results of fitting different models to the data are compared (Table 2). The model with the lowest value of RMSE and AIC was selected and used to generate the forecast values. The summary of the chosen model is given (Table 3).

It is noteworthy that variable 6 (onions & green shallots) trails in an incremental linear fashion and linear trend model has been selected as the best fit. This model assumes that the best forecast for future best-fit forecasting model data is given by the linear regression line fit to all previous data. Simple exponential smoothing with alpha values 0.7194, 0.7448

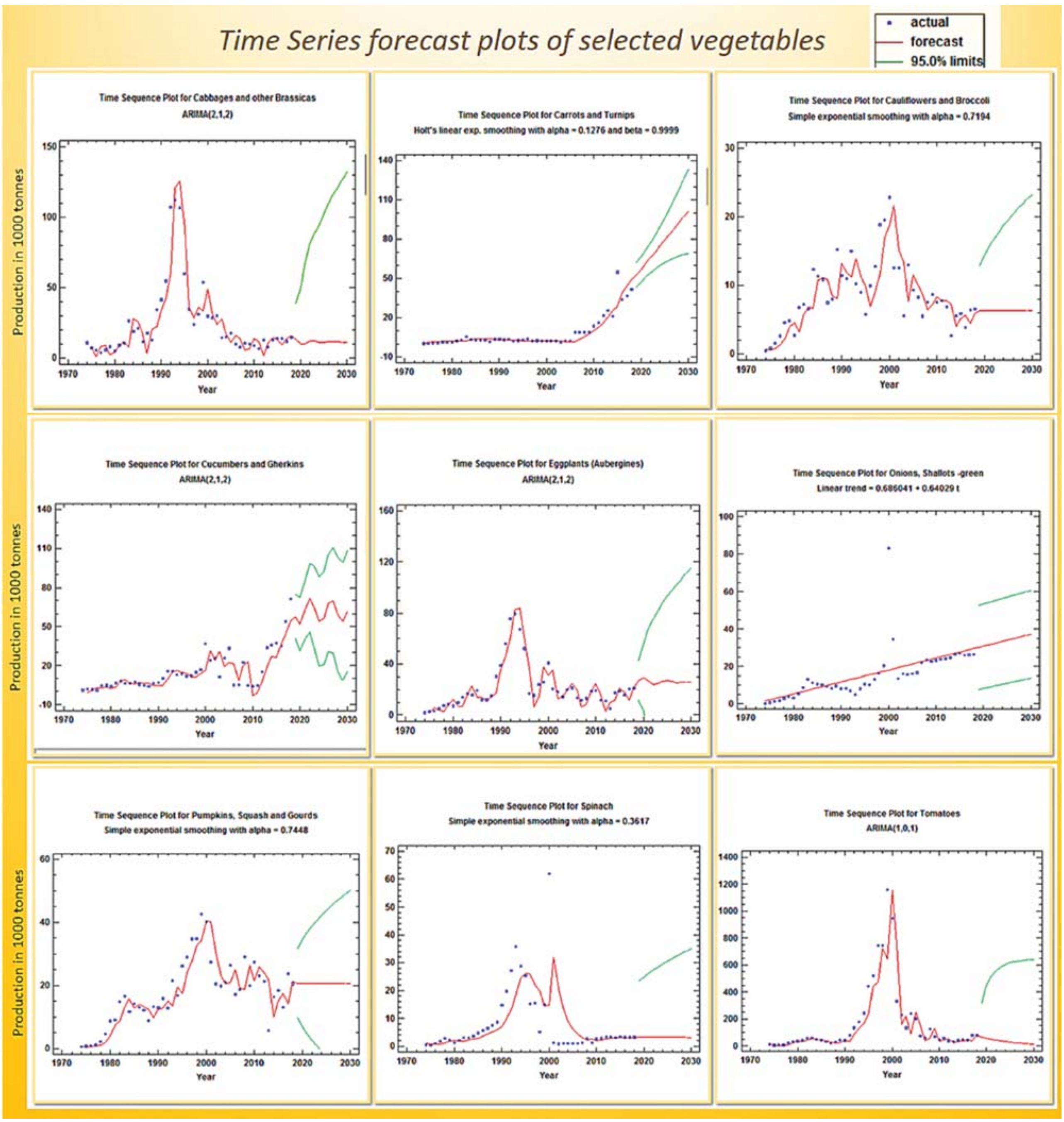

Fig. 3: Time series forecast plots for vegetable production data in the UAE

and 0.3617 fitted best for 3rd variable (cauliflowers and broccoli), 7th variable (pumpkins, squash and gourds) and 8th variable (spinach) respectively. This model assumes future data forecast, is given an exponentially weighted average of all previous data value. Whereas, the forecast model selected for 2nd variable (carrots and turnips) was Holt's linear exponential smoothing with alpha = 0.1276 and beta = 0.9999 and this model assumes that the best forecast for future data is given by a linear trend estimated by exponentially. In the case of the first variable, i.e. cabbages & other brassicas, model ARIMA (2, 1, 2) has been selected with the standard deviation of the input white noise equals12.6221. Similarly ARIMA (2, 1, 2) also found best fit for variable 4 and 5 (Cucumbers, gherkins and eggplants) with the standard deviation of the input white noise equals to 8.29 and 7.80 respectively. Finally, for the final variable (tomatoes), ARIMA (1, 0, 1) was found to be the best fit with a standard deviation of the input white noise equals to 125.626. The ARIMA model assumes that the best forecast for future data is given by a parametric model relating the most recent data values and previous noise.

Diagnostic checking

The plots of residual normal probability analysis, ACF and PACF are given in the Annexure.

Three tests mentioned in the methods and materials have been run to determine whether or not the residuals form a random sequence of numbers. A series of random numbers is often called white noise since it contains equal contributions at many frequencies. The pooled results indicate that in case of variable 2, 6 and 8, the residuals are not wholly random and that the selected model does not capture all of the structure in the data. In contrast, for rest of the variable, the tests suggest we cannot reject the hypothesis that the series is random at the 95.0% or higher confidence level. Hence in this, forecast value is spoken as a point value without declaring any confidence interval.

Forecasting

The five-year point forecast value obtained by estimating the selected model are reported in Table 3. It is interesting to note that in the case of variables 3, 7 & 8, the chosen models provided a single value forecast for all the forecast years and the forecast value depends solely on the recent production values. Various forecast values with changing trends are seen for the remaining variables and noticeable in figure 3.

CONCLUSIONS

Time series models were found as adequate for forecasting major vegetables of the UAE. Other researchers, people in business, policy-makers, food producers and many more in the supply chain can use these selected models for information, resource planning and decision-making on vegetable production. The time series modelling for each significant food crop production was appropriate. Based on the forecast trend report, it can be concluded that an increase in production can be expected for carrots, turnips, onions and green shallots. In contrast, almost stagnant output of cabbages and other brassicas, cauliflowers and broccoli, eggplant, pumpkins, squash, gourds and spinach can be expected. It is observed that the production of cucumbers and gherkins is in an undulating pattern. Tomato production shows a declining trend. Also, at the same time, the Box-Jenkins ARIMA model gives a good representation of short-time forecasting. Thus, methodology will encourage other researchers working in the area of vegetable production to develop more efficient and better-grounded forecasting models and techniques.

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Inheritance for ToLCV and EB resistance in tomato using *S. habrochaites* and *S. pimpinellifolium*

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ABSTRACT

Two accessions of wild species of tomato, *viz*. EC-520060 *(Solanum habrochaites)* and EC-521080 *(Solanum pimpinellifolium)* have been utilized for introgression of ToLCV and EB resistant gene into 12 susceptible cultivars bearing good yield traits. Most of the crosses of EC-520060 exhibited 13 (resistant): 3 (susceptible) genetic ratio but 'Flora Dade × EC-520060' expressed 3:1 genetic ratio. The crosses of EC-521080 have diverse genetic ratio of 1:2:1, 3:1 and 1:3. In result of inheritance of EB, the crosses of EC-520060 revealed 3:1 genetic ratio, and the crosses of EC-521080 represented 1:3, 1:2:1 and 3:1 genetic ratio. The crosses of EC-520060 and EC-521080 showed additive, dominance × dominance and additive × additive genetic models for both ToLCV and EB diseases. The inheritance among crosses and genetics of variables can be utilized for improvement of resistant tomato.

Key Words: Tomato, Interspecific crosses, Resistance, ToLCV, EB, Genetics

Tomato leaf curl virus (ToLCV) and early blight (EB) are responsible for complete yield loss (Singh *et al.*, 2010, 2014a,b, 2015a, 2017; Kumar and Kumar, 2018; Subhasmita *et al.*, 2021). Limited resistant source had been identified in cultivated tomato against ToLCV and EB (Singh *et al.*, 2014a,b, 2015a,b, 2017, 2018; Adhikari *et al.*, 2017; Kumar and Kumar, 2018). Wild accessions had been utilized to develop new ToLCV and EB resistant breeding lines and hybrids due to presence of maximum level of resistance or complex genetics of resistance in wild species or wild derivatives (Singh *et al.*, 2017, 2018, 2019; Subhasmita *et al.*, 2021).

Earlier, three wild species had been utilized for identification of six tomato leaf curl virus resistant genes (Kumar and Kumar, 2018; Singh *et al.*, 2019). The utilization of DNA markers may be more appropriate (Singh *et al.*, 2010, 2015a). Many accessions of wild species had been used in ToLCV and EB resistant breeding programmes (Singh *et al.*, 2013, 2014a,b, 2015a,b 2017, 2018; Subhasmita *et al.*, 2021). Thus, new sources of ToLCV and EB resistance is needed to know the gene action using wild species for improvement in tomato.

MATERIALS AND METHODS

A total five crosses were developed by using a resistant accession 'EC-520060' (Table 1). While, twelve crosses developed by using another resistant accession 'EC-521080' were used (Table 1). The seeds of these 17 crosses were sown in field to produce F_1 hybrids. The 17 F_1 hybrids were selfed to produce F_2. The seeds of 17 F_2 were sown in field. All the individual plant of each F_2 population were selfed and seeds harvested by single plant selection method to produce F_3. The seeds of only five similar crosses of F_3 of each accession 'EC-520060' and 'EC-521080' were sown in field and transplanted for raising the population. Seeds of each generation F_1, F_2 and F_3 along with P_1 and P_2 were saved and divided into two sections for testing in field and glasshouse conditions. In field condition, the experiments were designed during most favourable season (September-March) for pathogens of ToLCV and EB, respectively. In glasshouse, it was tested in two sections for ToLCV and EB on the same time.

Thirty plants of each parent and F_1 were planted in three replications (10 plants in each). Two hundred forty plants of each F_2 were transplanted in field in three replications (80 plants in each) but some plants could not survive. The survived plants were in the ranges of 208 (Hissar Anmol × EC-520060) to 135 (Flora Dade × EC-521080) of (Table 1). Ten plants of each F_3 progeny (developed by single fruits of each separate plant of $5F_2$s of EC-520060 and $5F_2$s of EC-521080

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through SSD methods) were transplanted. The susceptible tomato variety Punjab Chhuhara was also transplanted after every 10 rows between the plant population of parents, F_1, F_2 and F_3 generation. Spread of the vector population was allowed by avoiding spray for whitefly control.

A total fifteen seedlings of each parent and F_1s as well as 60 seedlings of each F_2 were transplanted in earthen pots, and kept in three replications, and divided into two sections with similar strength of plants on the same time. For ToLCV incidence, each tomato seedling covered by insect-proof cages and inserts 15-20 viruliferous whiteflies for 48 hr. Plants were examined on weekly intervals till 12 weeks for looking ToLCV symptom and followed same procedure of Singh *et al.* (2015a). For EB appearance, pure culture of virulent A. solani used potato dextrose broth (PDB) and uniformly sprayed on tomato seedlings for looking EB symptom as earlier used by Singh *et al.* (2017). The inoculated plants were maintained in glasshouse at 28 ± 2°C for symptom development.

The observations were recorded on plant height (PH), number of fruits / plant (NOFPP), fruit set per cent (FS%), average fruit weight (AFW) and fruit yield / plant (FYPP) in kilogram. The observation on disease incidence of ToLCV was recorded 15 days and 30 days after transplanting in glasshouse and field conditions, respectively. The disease incidence of EB was recorded 7 and 30 days after transplanting in glasshouse and field condition, respectively.

The disease was scored on a 0-5 scale for both ToLCV and EB incidence, where 0=0%-5% (highly resistant), 1=5.1%-12.0% (resistant), 2=12.1%-25.0% (moderately resistant), 3=25.1%-50.0% (moderately susceptible), 4=50.1%-75.0% (susceptible), and 5=75.1%-100% (highly susceptible). The per cent disease incidence (PDI) was calculated by using formula of Singh *et al.* (2015a, 2017).

$$\text{PDI} = \frac{\text{Score of individual plant} \times 100}{\text{No. of plant samples} \times \text{maximum rating scale}}$$

Genetic analysis

The chi-square analysis was studied for PDI of ToLCV and EB by using all the population of F_2 generation developed by 'EC-520060' and 'EC-521080'. Chi-square was calculated by following formula:

$$\chi^2 = \Sigma(O-E)^2 / E$$

where 'O' is observed frequency in each category; 'E' is the expected frequency in corresponding category.

For generation mean analysis (GMA) only five similar crosses of each parent 'EC-520060' and 'EC-521080' were used. In order to find differences among parents (P_1 and P_2) vs. F_1, F_2: F_3 the data obtained for each character (PDI of ToLCV and EB, PH, NOFPP, FS%, AFW and FYPP) were analysed by five parameter models (m, d, h, i and l) on the basis of previously used formula of Singh *et al.* (2015a).

RESULTS AND DISCUSSION

All female parents were susceptible to highly susceptible, while both male parents (EC-520060 and EC-521080) were highly resistant to ToLCV and EB diseases. All the cultivars were scored on '4-5' scale but two wild accessions, EC-520060 and EC-521080, were scored on '0-1' scale for both ToLCV and EB diseases during field and artificial screening. Resistance capacity in both wild accessions EC-520060 and EC-521080 were due to the background of *S. habrochaites* and *S. pimpinellifolium* (Singh *et al.*, 2010, 2012, 2015a, 2017, 2018, 2019; Subhasmita *et al.*, 2021). Total five and twelve crosses were developed by using the accessions, 'EC-520060' and 'EC-521080', respectively. These crosses were segregated to F_1:F_2:F_3 generations.

Mendelian inheritance for ToLCV and EB

Five F_1 crosses of EC-520060 were expressed highly resistant to ToLCV and EB diseases (Table 1). Total number of resistant plants were in the range of 100-160 for ToLCV. However, four F_2 were categorized into resistant (including highly resistant, resistant and moderately resistant): susceptible (including susceptible, moderately susceptible and highly susceptible) plants and showed 13 (resistant): 3 (susceptible) genetic ratio. While, one F_2 (Flora Dade × EC-520060) expressed 3 (resistant): 1 (susceptible) genetic ratio with chi-square value 0.144 and probability range 0.50-0.75 (Table 1). The inhibitory gene action and monogenic dominant gene action were reported by Singh *et al.* (2018). However, numbers of resistant plants were obtained in the range of 100-160 for EB. All the F_2s were expressed 3 resistant (highly resistant, resistant and moderately resistant): 1 susceptible (susceptible, moderately susceptible and highly susceptible) genetic ratio (Table 1) with chi-square value along with the probability range was 0.267 (0.50-0.75) to 1.297 (0.25-0.50). The crosses of EC-520060 *(S. habrochaites)* were expressed in 3:1 genetic ratio and monogenic dominant gene action for EB. The monogenic dominant gene effect for EB resistant has also been reported by Singh *et al.* (2017).

Among crosses of EC-521080 *(S. pimpinellifolium)*, all the F_1 were resistant to ToLCV and EB diseases (Table 1). In F_2 crosses, infected plants were categorized into highly resistant, moderately resistant and susceptible in the range of 30-160, 0-100 and 30-160, respectively. A total six F_2 were segregated in a 1:2:1 genetic ratio as resistant (including highly resistant): moderately resistant (including resistant and moderately resistant): susceptible (including susceptible,

Table 1. Performance of F_1s and F_2 populations of *S. lycopersicum* × *S. habrochaites* 'EC-520060' and *S. lycopersicum* × *S. pimpinellifolium* 'EC-521080' and χ^2 value for ToLCV and EB reaction

Character	F_2 populations									
	P_1 (HS)	P_2 (HR)	F_1	HR =0	R+MR =1+2	MS+S+HS =3+4+5	Genetic ratio	Degrees of freedom	Chi-square (χ^2)	Probability range
Tomato leaf curl virus (ToLCV)	Punjab Chhuhara	EC-520060	HR	140	0	40	13:3	1	1.425	0.10-0.25
	Pusa Ruby	EC-520060	HR	134	0	34	13:3	1	0.244	0.50-0.75
	Hissar Anmol	EC-520060	HR	160	0	48	13:3	1	0.410	0.50-0.75
	Hissar Arun	EC-520060	HR	120	0	34	13:3	1	1.123	0.25-0.50
	Flora Dade	EC-520060	HR	113	0	35	3:1	1	0.144	0.50-0.75
	Punjab Chhuhara	EC-521080	R	49	84	53	1:2:1	2	1.914	0.25-0.50
	Pusa Ruby	EC-521080	R	44	78	42	1:2:1	2	0.439	0.50-0.75
	Flora Dade	EC-521080	R	30	69	36	1:2:1	2	0.610	0.25-0.50
	Vaibhaw	EC-521080	R	36	88	38	1:2:1	2	1.259	0.25-0.50
	Arka Vikash	EC-521080	R	39	71	44	1:2:1	2	1.260	0.25-0.50
	Hissar Arun	EC-521080	R	51	93	53	1:2:1	2	0.655	0.25-0.50
	Kashi Vishesh	EC-521080	R	124	0	43	3:1	1	0.050	0.75-0.90
	TLBR-3	EC-521080	R	142	0	51	3:1	1	0.209	0.50-0.75
	IIHR-2200	EC-521080	R	121	0	54	3:1	1	3.202	0.05-0.10
	Hissar Anmol	EC-521080	R	129	0	59	3:1	1	4.085	0.25-0.50
	Meghalaya Local	EC-521080	R	48	0	136	1:3	1	0.116	0.75-0.90
	Sikkim Local	EC-521080	R	41	0	103	1:3	1	0.926	0.25-0.50
Early blight (EB)	Punjab Chhuhara	EC-520060	HR	132	0	48	3:1	1	0.267	0.50-0.75
	Pusa Ruby	EC-520060	HR	123	0	45	3:1	1	0.286	0.50-0.75
	Hissar Anmol	EC-520060	HR	151	0	57	3:1	1	0.641	0.25-0.50
	Hissar Arun	EC-520060	HR	119	0	35	3:1	1	0.424	0.50-0.75
	Flora Dade	EC-520060	HR	117	0	31	3:1	1	1.297	0.25-0.50
	Punjab Chhuhara	EC-521080	R	42	95	48	1:2:1	2	0.524	0.75-0.90
	Pusa Ruby	EC-521080	R	42	0	122	1:3	1	0.036	0.75-0.90
	Flora Dade	EC-521080	R	34	69	32	1:2:1	2	0.126	0.75-0.90
	Vaibhaw	EC-521080	R	37	86	39	1:2:1	2	0.556	0.25-0.50
	Arka Vikash	EC-521080	R	119	0	35	3:1	1	0.424	0.50-0.75
	Hissar Arun	EC-521080	R	39	111	48	1:2:1	2	4.457	0.10-0.25
	Kashi Vishesh	EC-521080	R	34	94	39	1:2:1	2	2.608	0.05-0.10
	TLBR-3	EC-521080	R	48	99	46	1:2:1	2	0.171	0.75-0.90
	IIHR-2200	EC-521080	R	134	0	41	3:1	1	0.231	0.50-0.75
	Hissar Anmol	EC-521080	R	42	97	49	1:2:1	2	0.713	0.25-0.50
	Meghalaya Local	EC-521080	R	48	89	47	1:2:1	2	0.203	0.50-0.75
	Sikkim Local	EC-521080	R	33	77	34	1:2:1	2	0.486	0.50-0.75

HR= Highly resistant; R= resistant; MR= moderately resistant; MS= moderately susceptible; S= susceptible; HS= highly Susceptible moderately susceptible and highly susceptible). While, four F_2 expressed 3 (resistant): 1 (susceptible) genetic ratio and remaining two F_2 (Meghalaya Local × EC-521080 and Sikkim Local × EC-521080) were segregated as 1 (resistant): 3 (susceptible) with the chi-square value 0.1159 and 0.9259 and probability range 0.75-0.90 and 0.25-0.50 (Table 1).

In case of EB, F_2s infected plants in range of 30-140, 0-120 and 30-140 as highly resistant, moderately resistant and susceptible, respectively. One F_2 (Pusa Ruby × EC-521080) was segregated into 1 resistant (highly resistant, resistant and moderately resistant): 3 susceptible (susceptible, moderately susceptible and highly susceptible) genetic ratio with the 0.0325 and 0.75-0.90 chi-square value and probability range (Table 1). Nine F_2 were categorized into three categories of resistant (including highly resistant): moderately resistant (including resistant and moderately resistant): susceptible (including susceptible, moderately susceptible and highly susceptible) plants and segregated as 1:2:1 genetic ratio along with chi-square value and probability range were 0.1259 (0.75-0.90) to 2.6083 (0.05-0.10).

Remaining two F_2s (Arka Vikash × EC-521080 and IIHR-2200 × EC-521080) were expressed 3 (resistant): 1 (susceptible) genetic ratio along with the chi-square value 0.1159 and 0.9259 and probability range 0.50-0.75 and 0.50-0.75, respectively (Table 1). The crosses of 'EC-521080 *(S. pimpinellifolium)*' indicated partial dominant gene effects, monogenic dominant gene effects and monogenic recessive gene effects for both ToLCV and EB diseases (Singh *et al.*, 2017, 2018; Oladokun *et al.*, 2022).

Generation mean analysis

Among the crosses of EC-520060, all the crosses showed 'additive (m+d)' genetic models for resistant to ToLCV and EB, while a population 'Hissar Arun × EC-520060' showed 'additive and 'dominance × dominance (m+d+l)' for the resistant to EB (Table 2). Earlier, 'additive' and 'dominant' gene action for ToLCV and EB were also reported by Singh *et al.* (2015b, 2017, 2018, 2019) in the population of *S. habrochaites*.

For PH, Punjab Chhuhara × EC-520060, Pusa Ruby × EC-520060 and Hissar Anmol × EC-520060 exhibited dominance genetic models (m+h), while, the Hissar Arun × EC-520060 and Flora Dade × EC-520060 showed dominance × dominance (m+l) and dominant (m+l) and dominance × dominance (m+h+l) genetic models. The dominant genetic characters of plant height may be possible due to the luxurious plant growth habit of *S. habrochaites* (Singh *et al.*, 2014a,b, 2018, 2019). For NOFPP, the crosses of Punjab Chhuhara × EC-520060, Pusa Ruby × EC-520060 and Hissar Anmol × EC-520060 showed dominant and additive × additive (m+h+i) inheritance models while, crosses Hissar Arun × EC-520060 and Flora Dade × EC-520060 indicated additive × additive and dominant × dominant (m+i+l) inheritance models.

For FS%, Punjab Chhuhara × EC-520060 and Pusa Ruby × EC-520060 showed dominant (m+h) gene effects. The crosses Hissar Anmol × EC-520060 and Hissar Arun × EC-520060 exhibited dominance and additive × additive (m+h+i) genetic models, and Flora Dade × EC-520060 was indicated dominance × dominance genetic models (m+l). For AFW, only Hissar Arun × EC-520060 exhibited additive and additive × additive genetic model (m+d+i) but remaining four crosses showed additive genetic model (m+d). Two crosses, Hissar Anmol × EC-520060 and Hissar Arun × EC-520060 exhibited additive (m+d) and dominance (m+h) genetic effects and remaining crosses showed additive and dominant × dominant (m+d+l) inheritance model for FYPP (Table 2).

The number of fruits, fruit set per cent, fruit weight and fruit yield per plant of the crosses showed 'dominant' and 'additive' genetic models, while the crosses of 'Hissar Anmol × EC-520060', 'Hissar Arun × EC-520060', and 'Flora Dade × EC-520060' indicated either 'additive' or 'dominant' inheritance models for these traits. This may be due to the presence of either *S. habrochaites* in pedigree background of 'Hissar Anmol', 'Hissar Arun' and 'Flora Dade' or presence of any other close pedigree of wild species (Zdravkovic *et al.*, 2011; Singh *et al.*, 2014a, b, 2018).

The data indicated that population of Pusa Ruby × EC-521080 for ToLCV, EB, AFW and FYPP, the population of Flora Dade × EC-521080 for ToLCV and EB, and population of Hissar Arun × EC-521080 for AFW showed additive (m+d) genetic models (Table 2). The population of Pusa Ruby × EC-521080 exhibited additive × additive and dominant × dominant genetic models (m+i+l) for NOFPP; dominance and additive × additive genetic models (m+h+i) for FS%; additive (m+d) genetic effects for ToLCV, EB, AFW and FYPP; and dominance (m+h) and dominant × dominant (m+h+l) genetic model for PH and NOFPP. Whereas, population Hissar Anmol × EC-521080 exhibited additive and dominant × dominant genetic models (m+d+l) for ToLCV and FYPP; additive and additive × additive genetic models (m+d+i) for EB and AFW; and dominance and dominant × dominant (m+h+l) genetic model for PH, NOFPP and FS%.

The population of Hissar Arun × EC-521080 displayed additive and dominant × dominant genetic models (m+d+l) for ToLCV; additive and additive × additive genetic models (m+d+i) for EB and FYPP; dominance and dominant × dominant (m+h+l) genetic model for NOFPP. The population of Flora Dade × EC-

Table 2. Genetic effects of 5 parameters in 5 populations developed by *S. habrochaites* 'EC-520060' and *S. pimpinellifolium* 'EC-521080' for ToLCV and EB.

Generation	PDI (ToLCV)	PDI (EB)	PH	NOFPP	FS%	AFW	FYPP
Punjab Chhuhara × EC-520060	m+d	m+d	m+h	m+h+i	m+h	m+d	m+d+l
Pusa Ruby × EC-520060	m+d	m+d	m+h	m+h+i	m+h	m+d	m+d+l
Hissar Anmol × EC-520060	m+d	m+d	m+h	m+h+i	m+h+i	m+d	m+d
Hissar Arun × EC-520060	m+d	m+d+l	m+l	m+i+l	m+h+i	m+d+i	m+i
Flora Dade × EC-520060	m+d	m+d	m+h+l	m+i+l	m+l	m+d	m+d+l
Punjab Chhuhara × EC-521080	m+d+l	m+d+i	m+h+l	m+h+l	m+h+l	m+d+i	m+d+l
Pusa Ruby × EC-521080	m+d	m+d	m+h	m+i+l	m+h+i	m+d	m+d
Hissar Anmol × EC-521080	m+d+i	m+d+l	m+h+l	m+h+l	m+h+i	m+d+i	m+d+l
Hissar Arun × EC-521080	m+d+l	m+d+i	m+h	m+h+l	m+h	m+d	m+d+i
Flora Dade × EC-521080	m+d	m+d	m+h+i	m+i+l	m+h+l	m+d+l	m+i

m=Mean effect, d=pooled additive effects, h=pooled dominance effect, i=pooled additive × additive epistatic effects and l=pooled dominance × dominance epistatic effects, PDI=Percent Disease Incidence, ToLCV=tomato leaf curl virus; EB=early blight; PH= plant height; NOFPP= number of fruits per plant; FS%= fruit set percent; AFW= average fruit weight; FYPP= fruit yield per plant

521080 exhibited additive genetic models (m+d) for ToLCV and EB; dominance and additive × additive genetic models (m+h+i) for PH; additive × additive and dominant × dominant genetic models (m+i+l) for NOFPP; dominance and dominant × dominant (m+h+l) genetic model for FS%; additive and dominant × dominant genetic models (m+d+l) for AFW; and additive × additive genetic models (m+i) for FYPP (Table 2).

All the crosses of 'EC-521080' had shown additive (m+d), dominant × dominant genetic models (m+d+l) and additive × additive genetic models (m+d+i) for ToLCV and EB resistance due to presence of S. pimpinellifolium background (Singh *et al.*, 2017, 2018). Among the yield traits, all crosses showed either additive, dominant × dominant and additive × additive gene effect for AFW and FYPP or represented dominant, additive × additive and dominant × dominant genetic effects for PH, NOFPP and FS%. Earlier, many reports have been published for genetics of yield traits by using *S. pimpinellifolium* or any other background of tomato (Zdravkovic *et al.*, 2011; Singh *et al.*, 2018).

CONCLUSION

It was concluded that crosses of 'EC-520060' exhibited inhibitory gene action and monogenic dominant gene action, while crosses of 'EC-521080' showed partial dominant, monogenic dominant and monogenic recessive for both ToLCV and EB resistance. The accessions of *S. habrochaites* had a strong and fix genetic architecture in resistant breeding programmes but accessions of *S. pimpinellifolium* would be given flexible results of genetics in resistance breeding of tomato.

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Introduction of potato *(Solanum tuberosum)* in hot arid region of north-western Rajasthan

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ABSTRACT

The experiment was conducted at ICAR-CIAH, Bikaner, (Rajasthan) to assess the performance of potato *(Solanum tuberosum)* cultivars in hot arid region during 2015-16 and 2016-17. Potato cultivars Kufri Khyati, Kufri Garima, Kufri Chipsona4, Kufri Pukhraj, Kufri Frysona, Kufri Surya and Kufri Jyoti, were grown under sprinkler and drip irrigation system with recommended management practices. Under sprinkler irrigation, Kufri Chipsona 4 gave highest yield (534.8 q/ha), followed by Kufri Frysona (479.7 q/ha) and Kufri Jyoti (465.1 q/ha), Kufri Garima (430.9 q/ha), Kufri Surya (398.6 q/ha) and Kufri Khyati (387.6 q/ha), while minimum yield was observed in Kufri Pukhraj (338.9 q/ha). In drip irrigation, Kufri Frysona gave highest yield (435.37 q/ha), followed by Kufri Chipsona4 (428.67 q/ha), Kufri Garima (374.45 q/ha) and Kufri Jyoti (344.58 q/ha) Kufri Pukhraj (203.99 q/ ha). The tuber yield of all varieties was also classified into large (>75 g), medium (25-75 g) and small (<25 g) categories under both irrigation systems. On an average, >71.40% tubers were under large-sized category. Similarly, dry matter content was highest (22.22%) in Kufri Frysona and minimum in Kufri Khayati (15.09%) at 90 days of harvesting. The appearance of the tuber though varies with variety but it was very shining golden yellowish and was better than its recommended areas of Indo-gangetic plains. Based on tuber yield, size of tubers, dry matter content and appearance of tubers; it is recommended that Kufri Chipsona 4 and Kufri Frysona are suitable for processing types, while Kufri Garima and Kufri Jyoti as table types for cultivation under sprinkler system in hot arid region of Rajasthan.

Key Words: Agronomic-use efficiency (AUE), Net returns, Tuber yield, Hot arid region

Potato (*Solanum tuberosum* L.) plays a vital role in food security the world over. Considering more or less stagnant cultivable land and impending food insecurity threat in our country, increasing productivity and bringing additional area under potato cultivation is the need of the hour. Besides, tuber crops are used for food, medicines and raw materials for starch-based industries (Neducnchezhiyan *et al.*, 2022). The domestic demand of potato alone will be around 125 million tonnes (Paul *et al.* 2022). The main reasons of non-adoption of potato in hot arid region are; sandy soils with poor fertility and subjected to wind erosion, very low (average of about 213 mm/annum) and erratic rainfall, extremes of temperature and frost during winter, poor water resource, lack of situation specific knowledge about scientific cultivation of potato etc. Though, metrological database and ICAR-CPRI, Shimla, simulation models have indicated that western Rajasthan has good potential for potato cultivation. Therefore, there is a need to venture non-traditional areas like hot arid zone under potato cultivation through better scientific management.

MATERIALS AND METHODS

The experiment was conducted at Experimental Farm of ICAR-CIAH, Bikaner (Rajasthan) in collaboration with ICAR-CPRI, Shimla (Himachal Pradesh) to assess the performance of potato cultivars for processing as well as for table purpose, during 2015-16 and 2016-17. The surface soil samples taken before planting of potato crop were analyzed for their physico-chemical properties employing standard analytical techniques. The soil of experimental field was sandy in texture with low organic carbon (0.1%), pH (7.70), available N (90 kg/ha), available P (11.5 kg/ ha) and available K (297.4 kg/ha). The climatic parameters were also recorded. The experiment was laid out in factorial randomized block design and

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replicated six times. The analysis of variance was done based on pooled data.

The healthy seeds of seven potato cultivars, *viz.* Kufri Khyati, Kufri Garima, Kufri Chipsona4, Kufri Pukhraj, Kufri Frysona, Kufri Surya and Kufri Jyoti, were procured from ICAR-CPRI, Shimla. Well sprouted potato seed tubers were planted in second week of November during both years under sprinkler and drip irrigation systems with recommended package of practices. One-third of N was applied through neem, coated urea and DAP in side-band along with a uniform dose of 80 kg P_2O_5 through di-ammonium phosphate and 100 kg / ha K_2O through muriate of potash during planting time, while one-third of N was applied through neem-coated urea 35 days after planting, *i.e.* at the time of earthing up and the remaining one-third N through neem-coated urea 50 days after planting, *i.e.* at the time of bulking stage.

The haulms were cut at 100 days and harvesting of tubers was done 15 days later. Irrigation was applied through on line drippers and low height sprinklers at weekly intervals before crop enters into wilting stage. The observation on plant height, number of branches / plant and number of compound leaves / plant at 45 and 75 days were recorded. The yield and yield-attributing characters of tubers were recorded after harvesting, while dry-matter content was recorded at 90 days. Tubers after final harvesting were also classified into, large, medium and small-sizes of tubers. The economics of potato cultivation was recorded based on prevailing rates of inputs and output in local market.

RESULTS AND DISCUSSION

The plant height, number of branches / plant and number of compound leaves / plant for all varieties grown under sprinkler and drip system was recorded at 45 and 75 days after planting. The data indicated that as days of planting advances from 45 to 75 days, vegetative growth increased irrespective of variety. There was wide variation in mean plant height of potato varieties under sprinkler and drip irrigation. The mean plant height at 75 days after planting under sprinkler was 60.38 cm, while it was only 43.46 cm under drip irrigation. Meanwhile, number of branches and number of compound leaves / plant were slightly higher under drip system compared to sprinkler system of irrigation. Thereby, dwarf and bushy plant growth were observed in drip and sprinkler systems,

Maximum plant height (80.80) was recorded 75 days after planting in Kufri Chipsona 4, followed by Kufri Frysona (67.60 cm), Kufri Surya (60.00 cm), Kufri Khyati (58.40 cm), Kufari Pukhraj (57.06 cm), while minmum in Kufri Garima (43.00 cm) under sprinkler system. Similarly, under drip system also maximum plant height (61.58 cm), was recorded 75 days after planting in Kufri Chipsona4, followed by Kufri Frysona (55.29 cm), Kufri Surya (46.58 cm), Kufri Jyoti (42.21 cm), Kufari Pukhraj (35.94 cm), Kufri Khyati (32.32 cm), and minmum in Kufri Garima (30.32 cm). Kufri Chipsona 4 was vigorous type, while Kufri Garima was comparatively dwarf type. However, number of branches and number of compound leaves / plant did not follow the same trend, which is obvious that these variations are due to their genetic nature.

The mean tuber yield / plant was 11.74q / ha irrespective of cultivars, though tuber yield / plant varied significantly, highest tubers / plant being in Kufri Chipsona 4 (14.57), followed by Kufri Frysona (13.45), Kufri Jyoti (12.13) lowest (Table 1) in Kufri Pukhraj (8.74). More than 62 g of tubers were obtained in all cultivars except Kufti Khyati (57.64 g). The main reason of higher number of tuber in microirrigation was the capacity of a genotype to use / absorb more nutrients per unit from soil, *i.e.* ability of root system of a genotype to acquire more nutrients from soil. The highest weight of tubers was recorded in Kufri Garima (72.42 g), followed by Kufri Pukhraj (67.87 g), Kufri Jyoti (67.12 g) and Kufri Chipsona 4 (64.23 g). The highest length of tuber was recorded in Kufri Pukhraj (4.44 cm), followed by Kufri Surya (4.43 cm), Kufri Frysona (4.37 cm) and Kufri Chipsona 4 (4.35 cm). The significantly lowest length of tubers was recorded in Kufri Jyoti (3.52 cm). Maximum tuber width (3.55 cm) was recorded in Kufri Chipsona4, followed by Kufri Pukhraj (3.35 cm) and Kufri Surya (2.32 cm).

Difference in tuber yield obtained under micro sprinkler and drip irrigation systems was higher than furrow irrigation. The higher yield in micro sprinkler and drip irrigation systems might be due to that frequent watering resulted into higher water potential, minimizing fluctuation in soil moisture in effective root zone, which holds promise to increase crop yield. Better crop performance under micro sprinkler could be attributed to minimum influence of frost, white fly and nutrient leaching; besides micro sprinkler irrigation might have created better microclimate, which facilitated better photosynthesis, root aeration and plant growth. Further, during tuberization (in December) minimum temperature was as low as 5-12°C for few days. Micro sprinkler irrigation system might have protected the crop from adverse effect of low temperature by sprinkling water droplets on leaves which, helped in better growth, early maturity and higher yield as compared to traditional method.

The tuber yield was classified into three grades, *viz*. small- sized tubers (< 25 g), medium -sized tubers (25-75 g) and large- sized tubers (> 75 g). For better understanding, grading was done both for 1000 tubers

Table 1. Grade-wise tuber yield of potato varieties under sprinkler and drip irrigation systems

Variety	Sprinkler system						Drip system					
	Yield (q/ha)			No. of tubers (000)			Yield (q/ha)			No. of tubers (000)		
	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)	Small (<25 g)	Medium (25-75 g)	Large (>75 g)
Kufri Khyati	21.3 (5.50)*	68.0 (17.54)	298.3 (76.96)	194 (28.84)	124 (18.37)	355 (52.78)	25.39 (7.62)	82.19 (24.66)	225.76 (67.73)	107 (22.24)	118 (24.44)	257 (53.41)
Kufri Garima	27.8 (6.45)	75.2 (17.45)	327.9 (76.10)	158 (26.55)	147 (24.71)	290 (48.74)	16.70 (5.15)	102.76 (31.67)	204.99 (63.18)	128 (24.59)	185 (35.58)	207 (39.83)
Kufri Chipsona 4	34.2 (6.40)	93.3 (17.45)	407.2 (76.15)	156 (18.74)	144 (17.33)	532 (63.93)	45.18 (10.54)	74.31 (17.34)	309.17 (72.12)	240 (55.60)	118 (27.39)	250 (57.82)
Kufri Pukhraj	26.8 (7.90)	82.5 (24.35)	229.6 (67.75)	126 (25.29)	132 (26.46)	241 (48.25)	11.78 (5.78)	65.28 (32.00)	126.92 (62.22)	66 (18.16)	142 (39.17)	155 (42.66)
Kufri Frysona	35.4 (7.38)	146.1 (30.46)	298.2 (62.16)	186 (24.16)	228 (29.68)	355 (46.16)	15.18 (3.49)	72.07 (16.55)	348.12 (79.96)	161 (26.53)	141 (23.24)	305 (50.26)
Kufri Surya	27.9 (7.00)	112.3 (28.17)	258.4 (64.83)	180 (28.24)	177 (27.78)	280 (43.99)	5.41 (1.59)	92.63 (27.16)	243.02 (71.25)	31 (8.07)	127 (32.76)	230 (59.17)
Kufri Jyoti	25.4 (5.46)	86.9 (18.69)	352.8 (75.86)	141 (20.31)	145 (20.86)	408 (58.83)	16.23 (4.70)	116.60 (33.78)	212.35 (61.52)	91 (19.60)	175 (37.96)	196 (42.44)
Mean	28.4	94.9	310.3	154.1	157.3	381	19.41	86.55	238.62	117.6	143.82	228.48
SEm (±)	1.47	5.87	16.53	7.54	7.88	19.78	0.92	4.38	11.83	5.92	7.13	11.49
CD (p=0.05)	4.68	17.78	49.47	23	24	57	2.91	12.98	35.79	17.65	21.57	34.27

*Values in parentheses are in percentage

Table 2. Yield and yield-attributing characters of potato varieties under sprinkler and drip irrigation systems

Variety	Sprinkler system						Drip system					
	No. of tubers/ plant	Av. Wt. of tuber (g)	Av. length of tuber (cm)	Av. width of tuber (cm)	Tuber yield/plant (g)	Tuber yield (q/ha)	No. of tubers/ plant	Av. Wt. of tuber (g)	Av. length of tuber (cm)	Av. width of tuber (cm)	Tuber yield/plant (g)	Tuber yield (q/ha)
Kufri Khyati	11.77	57.64	3.54	2.42	678.4	387.6	7.04	69.27	3.68	2.54	487.3	333.34
Kufri Garima	10.41	72.42	3.67	2.91	754.1	430.9	7.61	62.35	3.86	3.05	474.3	324.45
Kufri Chipsona4	14.57	64.23	4.35	3.55	935.8	534.8	6.31	99.30	4.52	3.72	626.7	428.67
Kufri Pukhraj	8.74	67.87	4.44	3.35	593.0	338.9	5.31	56.22	4.60	3.55	298.2	203.99
Kufri Frysona	13.45	62.40	4.37	2.51	839.5	479.7	8.87	71.75	4.54	2.67	636.5	435.37
Kufri Surya	11.14	62.62	4.43	2.32	697.6	398.6	5.67	87.92	4.69	2.54	498.6	341.06
Kufri Jyoti	12.13	67.12	3.52	2.72	813.9	465.1	6.76	74.67	3.65	2.83	504.7	345.18
Mean	11.74	62.66	4.05	2.83	758.9	433.7	6.79	74.15	4.22	2.99	503.8	344.58
SEm (±)	0.51	2.48	0.22	0.24	37.89	21.35	037	24.79	0.25	0.17	25.18	17.27
CD (p=0.05)	1.76	7.56	0.81	0.57	113.8	63.71	1.02	74.15	0.63	0.45	75.6	51.69

and total yield and also expressed in percentage for all cultivars grown under both systems. The yield under large- sized tuber was more than medium- sized and small - sized tubers. Mean data of tuber yield shown that out of total yield / ha (433.7 q), large sized tubers were 310.3 q, medium-size 94.4 q and small size were only 28.4 q under sprinkler system (Table 2). Whereas, under drip system, out of total yield / ha (344.58 q), large- sized tuber were (238.62 q), medium-size (86.55 q) and small-size was only 9.41 q. The grading distribution on percentage basis ranges from 62.16 to 76.16%, 17.45 to 30.46% and 5.46 to 7.9% as large, medium and small categories respectively under sprinkler system.

Similarly, under drip system, percentage of tuber grades ranges from 61.52 to 79.96%, 16.55 to 33.78% and 3.49 to 10.54% as large, medium and small categories respectively. The number of tubers in small grade category was some time either equal or higher than medium grade category but always less than large category irrespective of cultivars under both irrigation systems. Thereby yield (q / ha) in a specific grade is more reliable parameters than number of tubers. Overall, large to medium size grade tubers were produced under irrigated conditions, which is good indication for realizing higher return under hot arid region.

The flesh colour of Kufri Khyati and Kufri Pukhraj was cream, Kufri Frysona and Kufri Jyoti white and Kufri Garima whitish cream and Kufri Surya light yellow colour in both irrigation systems. As far as number of eyes / tuber is concerned, maximum number of eyes was recorded in Kufri Garima, *i.e.* 10.25 and 11.05, followed by Kufri Surya 8.92 and 9.15 and Kufri Pukhraj 8.

The dry-matter content of tubers was slightly higher in drip system of irrigation than sprinkler system of irrigation, probably due to high dry- matter accumulation in tubers under drip system the wetting zone in drip system was confined. The cultivar-wise dry-matter content varied significantly giving highest dry-matter in Kufri Frysona (22.22% and 22.58%), followed by Kufri Chipsona4 (20.54% and 21.56%) in sprinkler and drip system of irrigation respectively 90 days after planting. This further increased with advancing date of harvesting. Both cultivars (Kufri Chipsona 4 and Kufri Frysona) qualify the requisite value of dry-matter content for processing. Other cultivars also possess good amount of dry-matter content (15.09% to 18.78%) 90 days after planting. In general, Kufri Khyati has given lowest dry-matter content (15.09% and 15.79%) under both sprinkler and drip irrigation system respectively.

The highest net return was obtained by cultivation of Kufri Chipsona 4 under sprinkler system (₹ 1,17,664 / ha), followed by Kufri Frysona (₹ 98,403 / ha) and Kufri Jyoti (₹ 93,271 / ha) and minimum Kufri Khyati (₹ 66,172 / ha). Whereas, under drip system, highest net return was obtained by Kufri Frysona (₹ 82878 / ha), followed by Kufri Chipsona 4 (₹ 80,536 / ha) and Kufri Khyati (₹ 47,149 / ha). The highest B:C ratio was recorded in Kufri Chipsona 4 (2.69), followed by Kufri Fysona (2.42), under sprinkler system and Kufri Frysona (2.19), followed by Kufri Chipsona 4 (2.16) under drip irrigation system. The economic analysis of data reveals that potato cultivation under hot arid ecosystem is economically viable.

CONCLUSION

Thus it can be concluded that there is a good scope for cultivation of potato cultivars like Kufri Chipsona 4 and Kufri Frysona in hot arid region of north-western Rajasthan. These cultivars are most efficient in resource-poor conditions. The western Rajasthan is also most suitable area for establishment of processing units.

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Addition of pomace powder of Manjari Medika grapes *(Vitis vinifera)* improves nutraceutical and sensory properties of wheat bread

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ABSTRACT

The baking conditions were standardized to replace wheat flour by pomace powder of grapes *(Vitisvinifera)* of Manjari Medika as T_2, T_3, T_4 and T_5 and compared with control (T_1). Replacement of wheat flour by pomace powder tremendously improved nutritional and functional properties of breads compared with the control. The breads with pomace powered resulted in higher mineral contents. Available anthocyanins in pomace powder influenced colour intensity of breads. Evaluation of breads based on sensory properties, 5% replacement was found with maximum acceptance level followed by 10%. While 15 and 20% replacement were observed with lower score than the control. All levels of pomace powder scored better than the control for flavour. Thus, it is concluded that 10% replacement of wheat flour by pomace powder of Manjari Medika is well acceptable and can be adopted by bakery industries in bread-making.

Key Words: Wine, Juice, Baking, Functional properties, Natraceutical, Sensory

Grape *(Vitis vinifera)* is widely adopted globally. Grape pomace is the material that is discarded after juice or wine is extracted through pressing. This material consists of grape skins / pulp, seeds and either juice or wine depending on whether pressing occurred before or after fermentation. All those contain fairly good amount of flavanols, flavonoids, anthocyanins, and phenolic acids (Lafka *et al.*, 2007). Pomace of grapes have a good quantity of soluble dietary fiber (Llober and Canellas, 2007). To encourage and support the wine and juice industry in India, there is need to adopt practices for sustainable development and utilization of by-products generated during wine and juice making. It will help in opening of unlimited opportunities in this sector, same time support environment and consumers will get high valued products having foods with functional properties.

MATERIALS AND METHODS

The experiment was conducted at ICAR-NRC for Grapes, Pune, during 2018-19. Standard ingredients for bread making were collected and breads were prepared. To standardise baking conditions, a preliminary experiment was carried out with 10% white wheat flour replaced by pomace powder of Manjari Medika grapes. The dough was prepared by adding ingredients 900 g white wheat flour, 100 g pomace powder, 28 g sugar, 50g shortening, 30 g baking yeast, 20 g salt, 1 g calcium propionate, 5 g milk powder, 2 g bread improver and 2 g gluten. The straight dough method was opted with different temperature and time combinations of baking (160°C for 50, 45 and 40 min, at 170°C for 35, 30 and 25 min and at 180°C for 30, 25 and 20 min).

The suitable balking condition was identified based on organoleptic evaluation of breads by semi-trained panel using 9 point hedonic scale. Portion of white wheat flour was replaced by a linearly increasing quantity [5 (T_2), 10 (T_3), 15 (T_4) and 20% (T_5)] of pomace powder to finalize suitable combination.Prepared breads were analysed for nutraceutical and sensory properties compared with the controlsample(T_1) prepared without grape pomace powder. The straight dough method and baking parameters (170°C for 30 min) were finalized. The baked breads were cooled for 4 hr and sliced to give uniform shape and size to bread pieces.

Moisture content in bread was estimated by using hot air oven (Ranganna, 1995). The ash content was

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determined by ashing at 525±5°C for 6 hours (Ranganna, 1995). For fat, AOAC method (1995) was adopted. Two grams of samples were used. The protein content was estimated by method suggested by Lowry *et al.* (1951), carbohydrate content was determinedas method given by Hedge and Hofreiter (1962), phenol content against gallic acid (Slinkard and Singleton, 1977) and tannin content was measured by following method of Singleton *et al.* (1965). For anthocyanins content, method suggested by Picinelli *et al.* (1994) was adopted. Colour intensity was measured by the method of Sommers *et al.* (1997).

The mineral analysis samples were performed on ICP-MS (Agilent 7800). A semi-trained sensory panel of 20 members comprising 10 male and 10 females was involved in evaluation of sensory properties of breads. The sensory attributes, colour, texture and appearance, flavour, taste, mouth sensation and overall acceptability were considered. The products were sensory evaluated based on 9-point Hedonic scale. The data were collected from five biological replication of each treatment. The obtained data on different parameters were statistically analysed by using completely randomized design.

RESULTS AND DISCUSSION

Minimum score for sensory parameters was recorded when breads were baked at 160°C for 50 minutes, while bread prepared at 170°C for 30 minutes obtained maximum score, followed by baking at 170°C for 25 minutes. Besides, heat regulation and final moisture content are crucial in preparation of bakery products. Teshome *et al.* (2017) observed that quality of cookies affected by baking temperature and duration. Similar observations were noted by Saric *et al.* (2014). Baking temperature isbasic and most obvious factor, influence on heat transfer (convection, conduction, radiation). It affects various physical, chemical and biochemical changes during baking process (Mondal and Datta, 2008). Chul and Byung (2007) studied influence of baking time and temperature on quality characteristics of breads. Sharma *et al.* (2018) observed that dough matrices play an important role in optimizing baking conditions.

The data indicated that addition of pomace powder of Manjari Medika significantly improved quality of breads (Table 1). Moisture content was sharply decreased increased in T_2 compared to control *i.e.* T_1. But moisture contents again gradually increased by increasing pomace powder concentration. The ash, fat and protein content were increased by increasing pomace powder content, maximum content being in T_5 where 20% maida was replaced. Carbohydrate content increased by decreasing in all treatments except T_2 where 5% white wheat flour was replaced in comparison to T_1 and minimum carbohydrate (25.97%) was observed in T_5 and maximum (41.97%) was in T_2. Data on phenol, anthocyanins and tannin content in breads clearly indicate value-addition in breads in terms of functional properties.

Maximum levels of these parameters were recorded at maximum replacement of white wheat flour, 20% (T_5). Phenol and tannin content in the control was only 0.10 mg / 100 g, by replacement of white wheat flour, it increased and maximum content was observed in T_5 with values of 2.62 and 3.15 mg / 100 g, respectively. While NIL anthocyanins were estimated in the control (T_1) and increased upto level of 0.62 mg / 100 g in T_5. Anthocyanins contribute to colour confirmingthe present study. Colour intensity inwas zero in the

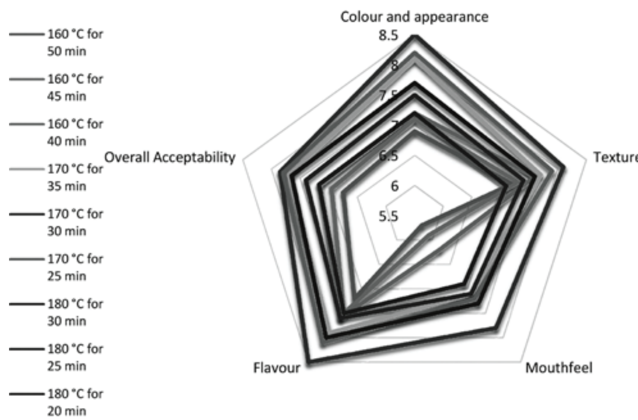

Fig. 1: Sensory qualities of breads with (Manjari Medika pomace powder) prepared under different baking conditions

Table 1. Physico-chemical properties of breads prepared by adding pomace powder

Pomace concentration	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Phenol (mg/100 g)	Tannin (mg/100 g)	Anthocyanins mg/kg	Colour intensity %
Control	36.45	17.43	3.81	4.44	38.05	0.10	0.10	0.0	0.0
5%	30.22	18.47	3.81	5.60	41.97	0.70	0.85	0.05	0.25
10%	35.94	18.54	4.65	8.27	33.11	1.25	1.65	0.13	0.52
15%	35.98	19.70	5.07	9.35	33.03	1.45	2.35	0.399	1.03
20%	36.30	19.73	5.21	13.11	25.97	2..62	3.15	0.62	1.97
LSD (5%)	0.226	0.018	0.131	0.089	0.021	0.208	0.174	1.485	0.014

Table 2. Mineral profiling of breads enriched by adding Manjari Medika pomace powder

Pomace concentration	Zinc (ppm)	Copper (ppm)	Calcium (ppm)	Iron (ppm)
Control	9.82	5.32	322.8	44.0
5%	17.20	18.05	521.5	55.4
10%	18.87	16.20	547.6	64.0
15%	18.90	9.17	581.6	66.3
20%	22.22	9.27	750.4	72.7
LSD (5%)	2.104	0.8209	52.74	3.10

control. By replacing maida, colour intensity showed increasing trend. Maximum value, (1.97) was observed in T_5. Similar observation was observed in anthocyanins (Table 2). Addition of pomace powder resulted in increased content of Zn, Cu, Ca and Fe. Breads contained maximum Zn, Ca and Fe in T_5 where 20% white wheat flour was replaced by pomace powder and T_1 (control) was found with minimum values. While irregularity was observed in Cu content and maximum quantity (18.05 ppm) was estimated in T_2. By increasing quantity of pomace powder was resulted in decreeing trend.

Based on blended flour matrices, even when wheat flour is replaced by non-gluten forming type flours result in technologically viable and higher level of sensory acceptability of bakery products. The replacement of wheat flour improves nutritional properties in comparison to 100% wheat flour counterparts (Collar *et al.*, 2014). It is well documented by researchers, dough rheology, product texture, nutritional and functional properties of bakery products are affected by addition of grape by-products (Gaita *et al.*, 2018; Maner *et al.*, 2017; Iuga and Mironeasa, 2020). Tolve *et al.*, (2021) concluded that the addition of grape pomace powder changed the chemical composition of bread including colour parameters. The nutritional composition of breads showed incremental trend by increased white wheat flour replacement.

As pomace powder is obtained from red grapes and having anthocyanins, so the colour was imparted to breads also. Smith and Yu (2015) concluded that addition of grape powder is good source of dietary polyphenols and fiber. Utilization of grape pomace flour in bread making is able to add nutritional value of grape powder to bread.The pomace powder of Manjari Medika grapes is observed with higher contents of functional compounds (Sharma *et al.*, 2018) and same were transferred to breads. Same trend was reported in mineral composition of breads. The breads prepared by white wheat flourreplacement enriched in Cu, Fe, Zn and Cu content as pomace powder is rich source of these minerals. Ahmed *et al.*, (2020) recorded mineral content in pomace powders of different grape varieties.

Replacement of white wheat flour by pomace powder of Manjari Medika impacted on sensory properties of breads. As pomace added nutraceutical values to breads an increased trend was noted with increased level of pomace powder. Replacement of 5% scored maximum acceptance level followed by 10%. While 15 and 20% found with lower score than control. All levels of pomace powder scored better than the control for parameter flavour.Pomace powder of grape varieties added to breads influenced bread volume, firmness, crumb and crust colour, and odour and taste intensity (Sporin *et al.*, 2018).

Walker *et al.* (2014) reported that bread fortified with 10% of Pinot Noir grape pomace was acceptable by consumers. Almost same results were recorded in present investigation also. However, level of grape pomace in dough and varietal type of pomaces are also very important for producing bakery products having acceptable among consumers (Smith and Yu, 2015, Sharma *et al.*, 2018).

Thus it may be concluded that replacement of white wheat flour by pomace powder improved nutraceutical and sensory properties of breads. Addition of pomace powder can be easily accepted by consumers, sustaining grape-growing areas.

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Effect of foliar application of organic liquids on yield and quality of turmeric (*Curcuma longa*)

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ABSTRACT

A field experiment was conducted to find out the effect of foliar application of organic liquids on growth, yield and quality of turmeric (*Curcuma longa* L.) cv. GNT-2 during 2019-20 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. Randomized Block Design with three replications and eleven treatments, *viz.* panchagavya @ 4% (T_1), panchagavya @ 5% (T_2), novel organic liquid nutrients @ 4% (T_3), novel organic liquid nutrients @ 5% (T_4), jeevamrut @ 4% (T_5), jeevamrut @ 5% (T_6), humic acid @ 0.1% (T_7), humic acid @ 0.2% (T_8), cow urine @ 4% (T_9), cow urine @ 5% (T_{10}) and the control (T_{11}) was followed. The novel organic liquid nutrients 5% (T_4) registered significantly maximum plant height (93.64 cm at 150 DAP and 120.71 cm at 210 DAP) and maximum number of leaves/plant (6.27, 6.83 and 8.33) at 90, 150 and 210 DAP, respectively. However, maximum length of leaves (60.46 cm and 73.07 cm) was recorded at 150 and 210 DAP. Application of humic acid 0.2% (T_8) gave maximum number of tillers/plant at 90, 150 and 210 DAP (1.27, 2.53 and 3.50, respectively). Substantial effect of foliar application of novel organic liquid nutrients at 5% (T_4) gave more number of mother rhizomes/plant (3.53), number of finger rhizomes/plant (18.20), weight of mother rhizome (52.73 g), weight of finger rhizomes (248.67 g) with lowest number of finger rhizomes: number of mother rhizomes ratio (5.15) as well as fresh weight of rhizome (301.40 g/plant) with fresh rhizome yield (32.29 t/ha). The curcumin content in rhizomes (3.86%) as well as essential oil of rhizomes (3.23%) was recorded in 0.2 % humic acid (T8). The foliar application of 5% novel organic liquid nutrients was found economical, profitable and highly remunerative with maximum net returns of ₹ 6,54,732 and maximum benefit:cost ratio (4.29) as compared to rest of the treatments.

Key Words: Foliar, organic, Growth, yield, Quality, Economics, Curcumin content

Turmeric (*Curcuma longa* L.) is native to South-East Asia. Gujarat occupies 4,425 ha area with 17,386 tonnes of production (MA and FW, 2020). Novel organic liquid nutrients provide essential macro and micronutrients as well as growth boosters (Jadhav *et al.*, 2014). Humic acid is one of the most important constituents of fertile soils containing S, N and P in varying amounts as well as metals such as Ca, Mg, Cu, Zn etc. which improves availability of nutrients to plants and thus influences plant growth and yield. Cow urine contains 95% water, 2.5% urea and the remaining 2.5%, a mixture of salts, hormones, enzymes and minerals. Thus, an experiment was conducted to find out the effect of foliar application of organic liquids on growth, yield and quality of turmeric cv. GNT-2.

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MATERIALS AND METHODS

The experiment was conducted on turmeric cv. GNT-2 during 2019-20 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India, in Randomized Block Design (RBD) with three replications and eleven treatments, *viz.* panchagavya @ 4% (T_1), panchagavya @ 5% (T_2), novel organic liquid nutrients @ 4% (T_3), novel organic liquid nutrients @ 5% (T_4), jeevamrut @ 4% (T_5), jeevamrut @ 5% (T_6), humic acid @ 0.1% (T_7), humic acid @ 0.2% (T_8), cow urine @ 4% (T_9), cow urine @ 5% (T_{10}) and the control (T_{11}). The first spray was applied at 60 DAP, second at 120 DAP and third at 180 DAP.The soil of the experimental site was dark greyish black type having medium to poor drainage and high water-holding capacity. The soil of the experimental plot was clay in texture. The pH values for 0-15 cm and 15-30 cm depths were 7.9 and 8.1, respectively.

The experimental plots were prepared by one deep ploughing followed by one harrowing. There were total 33 plots of 4.2 m × 4.4 m size having raised bed of 110 cm width were prepared at a spacing of 30 cm × 20 cm during the third week of May, 2019. The cultural practices and nutrient management, 20-25 t/ha and 60:60:60 kg NPK/ha) were carried out as par the recommendations. Observations on different growth parameters was recorded at three of crop periods, *viz.* 90, 150 and 210 days after planting from five randomly selected plants from each plots, whereas yield attributing characters were recorded after harvesting. The quality parameters, *viz.* curcumin content (%) of turmeric rhizomes was estimated by ASTA method (ASTA, 1968) modified by Manjunath *et al.* (1991) and expressed as percentage on moisture free basis. However, essential oil (%) was estimated by distillation methods. Statistical analysis was done as per Panse and Sukatme (1985).

RESULTS AND DISCUSSION

Effect of foliar application of organic liquids on plant height (73.73 cm) did not influence significantly at 90 DAP. However, 150 and 210 DAP treatment T_4 (novel organic liquid nutrients 5%) gave 93.64 cm and 120.71 cm and number of leaves at 90, 150 and 210 DAP showed significant results (6.27, 6.83 and 8.33, respectively). The length of leaves was significantly maximum (46.22 cm) at 90 DAP in 0.2% humic acid, whereas at 150 and 210 DAP noted significantly maximum length of leaves (60.47 cm and 73.07 cm) in 5% novel organic liquid nutrients (T_4). However, it also recorded significantly maximum breadth of leaves (12.54 cm, 13.40 cm and 13.60 cm) at 90, 150 and 210 DAP, respectively. The increase in growth of plant might be due to novel organic liquid nutrients containing plant growth regulators such as NAA, gibberellic acid, cytokinin, macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Mn, Cu, Zn) which enhanced cell division and cell elongation.

A novel organic liquid nutrient increased the auxin level of tissue or enhanced the conversion of tryptophan to IAA leading to enhanced activity of cell division and cell elongation through the effect of gibberellic acid and cytokinin singly or due to combine effect of both on increase in growth characters. These findings support to those of Kalariya *et al.* (2018) and Desai Supal *et al.* (2018). Subsequently, maximum number of tillers/plant was found with foliar application of 0.2% humic acd (T_8). This might be due to humic acid contains gibberllin like substances, which may lead to increased plant growth by producing more number of primary branches as well as more number of side shoots.

The treatment T_4 (novel organic liquid nutrients

Table 1. Effect of foliar application of organic liquid sources on yield-attributing characters of turmeric cv. GNT-2

Treatment	No. of mother rhizomes /plant	No. of finger rhizomes /plant	Weight of mother rhizomes (g/plant)	Weight of finger rhizomes (g/plant)	No. of finger rhizomes: No. of mother rhizomes ratio	Rhizome yield (g/plant)	Rhizome yield (t/ha)	Curcumin content (%)	Essential oil (%)
T_1: Panchagavya @ 4%	2.47	14.35	43.13	221.67	5.82	264.97	28.38	3.20	2.77
T_2: Panchagavya @ 5%	2.07	13.40	46.67	229.33	6.50	276.00	29.57	3.19	2.60
T_3: Novel organic liquid nutrients @ 4%	2.07	17.07	49.13	232.67	8.29	281.80	30.19	3.33	2.57
T_4: Novel organic liquid nutrients @ 5%	3.53	18.20	52.73	248.67	5.15	301.40	32.29	3.61	2.83
T_5: Jeevamrut @ 4%	1.93	15.27	48.93	222.33	7.91	271.27	29.06	3.14	2.53
T_6: Jeevamrut @ 5%	2.13	13.47	48.00	221.33	6.33	269.33	28.85	3.39	2.47
T_7: Humic acid @ 0.1%	2.07	15.47	47.80	230.00	7.50	277.80	29.76	3.36	2.73
T_8: Humic acid @ 0.2%	3.10	16.00	50.20	234.33	5.16	284.53	30.48	3.87	3.23
T_9: Cow urine @ 4%	1.87	14.93	45.67	219.33	8.01	265.00	28.39	3.57	2.43
T_{10}: Cow urine @ 5%	1.93	13.53	44.33	231.00	7.00	275.33	29.50	3.33	2.50
T_{11}: Control (No spray)	1.73	12.47	30.40	200.33	7.21	230.73	24.72	3.13	2.40
S Em (±)	0.06	0.40	1.29	5.56	0.32	6.09	0.65	0.12	0.08
CD (5 %)	0.19	1.18	3.81	16.41	0.94	17.96	1.92	0.36	0.23
CV (%)	4.89	4.63	4.85	4.24	8.14	3.87	3.87	6.35	5.15

Table 2. Economics of different treatments

Treatment	Marketable rhizomes yield (t/ha)	Cost of cultivation (₹/ha)	Treatment cost (₹/ha)	Fixed cost (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	B:C ratio
T_1: Panchagavya @ 4%	28.38	93,705	7,860	44,343	7,09,500	5,63,592	3.86
T_2: Panchagavya @ 5%	29.57	93,705	9,360	46,203	7,39,250	5,89,982	3.95
T_3: Novel organic liquid nutrients @ 4%	30.19	93,705	7,060	47,045	7,52,725	6,04,915	4.00
T_4: Novel organic liquid nutrients @ 5%	32.29	93,705	8,360	50,453	8,07,250	6,54,732	4.29
T_5: Jeevamrut @ 4%	29.06	93,705	5,060	45,406	7,26,500	5,82,329	4.00
T_6: Jeevamrut @ 5%	28.85	93,705	5,860	45,078	7,21,250	5,76,770	3.90
T_7: Humic acid @ 0.1%	29.76	93,705	2,275	46,500	7,44,000	6,01,520	4.22
T_8: Humic acid @ 0.2%	30.48	93,705	2,690	47,625	7,62,000	6,17,980	4.20
T_9: Cow urine @ 4%	28.39	93,705	3,460	44,359	7,09,750	5,68,226	4.01
T_{10}: Cow urine @ 5%	29.50	93,705	3,860	46,093	7,37,500	5,93,842	4.13
T_{11}: Control (No spray)	24.72	93,705	0	38,625	6,18,000	4,85,670	3.67

5%) recorded maximum number of mother rhizomes/plant (3.53), number of finger rhizomes/plant (18.20), weight of mother rhizomes/plant (52.73 g), weight of finger rhizomes/plant (248.67 g) with lowest number of finger rhizomes: number of mother rhizome ratio (5.15) (Table 1). It also exhibited maximum fresh rhizome yield (301.40 g/plant and 32.29 t/ha). The increase in yield probably may be due to novel organic liquid nutrients consisting of lavish amount of macro and micronutrients which ameliorate photosynthetic activity ultimately increased the yield and yield attributing characters (Singhal *et al.*, 2015).

The application of nutrients accelerated an uptake of water and nutrients, commanding higher photosynthesis and greater accumulation of photosynthesis which ultimately increased the production and productivity of crop (Singhal *et al.*, 2015). The results are in accordance with Shah (2019), Patil and Kolambe (2014), Salunkhe *et al.* (2013).

The maximum curcumin contain (3.86%) and essential oil (3.23%) were recorded in T_8 treatment (humic acid 0.2%). Application of humic acid helped in availability for more nitrogen in the form of NH4-N, which could have promoted hormonal activity of plants.

The higher net realization and maximum benefit:cost ratio, ₹ 6,54,732/ha and 4.29, respectively were recorded under 5% Novel organic liquid nutrients (T_4) (Table 2). This might be due to investment cost was less and yield was higher in this treatment which gives higher benefit:cost ratio. This finding is in agreement with Salunkhe *et al.* (2013).

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Genetic diversity in litchi (*Litchi chinensis*) for morphological and physico-chemical traits

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ABSTRACT

The genetic diversity in morphological and physico-chemicaltraits of nine genotypes of litchi (*Litchi chinensis* Sonn.) growing under the agroclimatic conditions of Bihar was studied during 2018-19. The genotypes IC-0614730 and IC-0614737 exhibited bright pink colour of young leave and others had yellowish green. Its fruit shape and colour was round and deep pink, respectively. Pink flushes genotypes were late, while yellowish green were early in maturity. These two genotypes showed lowest fruit weight (17.35 g and 16.38 g), TSS (17.86 and 18.35 Brix), seed content (10.66% and 11.97%) but higher pulp content (71.18% and 74.66%). Significant variations were recorded in phenolics and flavonoids contents among the genotypes with highest content in both IC-0614730 and IC-0614737. These two genotypes can be potentially exploited in litchi industry for pulp making and nutraceutical uses. The genotypes differed in most of the morphological characteristics which can be exploited for improvement in litchi.

Key Words: Bioactive compounds, Diversity, TSS, Phenolics, Morphological traits, Quality

Litchi (Litchi chinensis Sonn.) is most important members of family Sapindaceae. Identification of litchi based on morphological traits is highly acceptable and easily distinguishable as morphological diversity occurs. Morphological diversity has been also reported in beal (Singh *et al.* 2018) and ber (Chaudhary *et al.*, 2017) which is used for identification of cultivars. Therefore, study was undertaken to evaluate genetic diversity in morphological and physico-chemical traits of different genotypes of litchi.

MATERIALS AND METHODS

The present investigations were carried out during 2018-19 to describe various morphological characteristics of nine genotypes of litchi available at ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar. Five trees of each genotype (about 8 years old), uniform in size and vigour were selected. The observations were recorded on morphological characteristics of each genotype. Foliage colour, arrangement and shape were recorded by visual observation of trees. Leaf length, width, shape, number of leaflets / leaf, rachis length and petiole length were studied by taking ten leaves and flushes randomly from each genotype. Flower disc colour was visually observed. Panicle length and width were recorded by measuring ten panicles in each genotype.

Fruit colour and size were recorded by taking ten fruits randomly from each genotype. Quality parameter (TSS, total sugar, reducing sugar, ascorbic acid and titratable acidity) and bioactive compound (phenolics, flavonoids and anthocyanin) were estimated from different parts of fruits. Experiment was laid in Randomised Complete Block Design comprising nine treatments (genotypes) with five or ten independent replications. Only quantitative data were analysed statistically using Fisher's analysis of variance techniques. Least significant difference (LSD) test at 5% and probability level was applied to compare the differences among treatments means (Steel and Torrie, 1980).

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RESULTS AND DISCUSSION

The genotypes, IC-0614730 and IC-0614737, had bright pink while others had yellowish green colour of young leaf. Young emerging flushes ranged from yellowish green to deep pink (Lal, 2018) and pale green to pinkish to a copperish red in colour. The litchi cultivars can be distinguished based on colour of flush. Early ripening cultivars flushes pale green while late ripening flushes pink colour leaves. Matured leaf varied from light green to dark green. The foliage colour is a genetic character and also being used for identification of cultivars. The slight variation might be due to prevailing environmental condition of growing area. However, there was no variation in arrangement of leaflet, shape of leaf blade, leaf apex and base and venation. The genotype IC-0614737 had lowest number of leaflet (5.12), followed by IC-0614730 (5.23) and genotype IC-0614731 had highest number of leaflet (7.68)/leaf. Litchi leaves have 4-10 (2-5 pairs) leaflets, 4-8 leaflet depending upon cultivars. The maximum leaf length was recorded in IC-0614729 (15.68 cm), followed by IC-0614733 (15.17 cm), whereas minimum leaf length was in IC-0614737 (8.86 cm). It was at par with IC-0614730 (8.96 cm). The variations in leaf length were earlier reported by Wu *et al.* (2016).

The leaf width also showed significant differences among genotypes. The maximum leaf width was in IC-0614733 (4.35 cm). The minimum leaf width was in IC-0614737 (3.38 cm). Leaf size was also positively correlated with fruit size. Dwarf genotypes have small leaf, whereas vigorous genotypes have larger sized leaf. The genotypes showed wide variations in rachis with maximum in IC-0614732 (11.12 cm) and minimum in IC-0614737 (6.27 cm). Petiole length varied from 3.08 to 4.12 cm with maximum in IC-0614728 and minimum in IC-0614730. Lal (2018) also reported variations in rachis and petiole length in different genotypes. The maximum length of rachis and petiole were positively correlated with vigorous of plants, whereas least length of rachis and petiole were positively related with dwarf stature of plants as IC-0614730 and IC-0614737 exhibited low vigour and dwarf structure. Similarly, both genotypes exhibited bright pink colour of young leaf, least number of leaflet/leaf, minimum length and width of leaf. These traits can be used for identification of dwarf cultivars in litchi.

Maximum length of panicle (48.92 cm) was in IC-0614732, while minimum (24.56 cm) was recorded in IC-0614730. The maximum width of panicle (27.95 cm) was found in IC-0614728, while minimum (15.68 cm) was in IC-0614730. The difference is due to genetic make-up of genotypes. Chandola and Mishra (2015) reported maximum panicle length in Rose Scented (34.80). The intensity of flowering and panicle strength depend on previous years fruiting, temperature during floral bud differentiation, phenol content (Lal *et al.*, 2019b) and age of plants (Lal and Nath, 2020). Female flower varied from 11.23 to 22.58% with maximum in IC-0614735 and minimum in IC-0614730. The variation in female flowers varied from 155 in Early Seedless to 580 in Calcuttia (Chandola and Mishra, 2015). Yield varied from 3.86 to 8.75 kg/plant with maximum in IC-0614733 and lowest in IC-0614737. The difference in yield is due to genetic make-up of genotypes and depended on age of plants. Chandola and Mishra (2015) found variation in yield with maximum in Rose Scented (26.85 kg/plant) and minimum in Longia (12.57 kg/plant).

Number of fruits/panicle varied from 5 to 8.6 with maximum in IC-0614732 and minimum in IC-0614728. However, fruit retention depends on pollen-grains used in pollination and fertilization (Lal *et al.* 2019c and d) as well as age of plants. The maximum fruit weight was recorded in IC-0614728 (24.68 g) and minimum in IC-0614737 (16.38 g). Haq and Rab (2012) found maximum fruit weight in Gola (23.08 g) and lowest in Bedana (15.20 g). Fruit weight varied from 12 to 21.80 g with maximum in Rose Scented (Chandola and Mishra, 2015). The fruit weight inIC-0614728 was superior to IC-0614737 by 33.63%. The fruit weight in Gola was superior to Bedana by 34.14%. The maximum fruit length was recorded in IC-0614728 (36.86 cm) and minimum in IC-0614737 (27.74 cm). The maximum fruit diameter was recorded in IC-0614728 (32.56 cm) and minimum in IC-0614731 (29.76 cm). Calcuttia cultivar had large-sized fruits, while rest of the cultivars had medium-sized fruits. The maximum pulp weight was in IC-0614728 (14.56 g) and lowest in IC-0614737 (12.23 g), followed by IC-0614730 (12.35g) but pulp content was highest in IC-0614737 (74.66%), followed by IC-0614730 (71.18%). Pulp weight varied from 11.19 g (Bedana) to 16.58 g (Gola) in litchi and 7-14 g in other cultivars (Chandola and Mishra, 2015). The maximum pulp thickness was recorded in IC-0614730 (8.26 mm) and minimum in IC-0614729 (7.16 mm). The genotype IC-0614730 and IC-0614737 had round fruit shape and round tip shape, medium clustering habit, partial distribution of colour on fruit and smooth tubercles and others genotypes had elliptic shape, obtuse tip, heavy clustering, uniform distribution of colour and pointed tubercles, respectively. Fruit colour varied from red to deep pink. The colour of fruit varies depending upon the cultivars and is also influenced by growing conditions.

The maximum TSS was found in IC-0614731 (21.47) and minimum in IC-0614730 (17.86). Lal *et al.* (2018a) reported highest TSS in IC-0615610 (19.98 °Brix) and lowest in IC-0615589 (17.04°Brix) (Table 1). The variation in TSS was also reported by Haq and Rab (2012). The maximum ascorbic acid was recorded in IC-0614737 (35.68 mg/100g) and minimum in IC-0614728 (24.56 mg/100g). The differences in ascorbic acid might be due to genetic effect of the genotypes.

Highest total sugar was recorded in IC-0614732 (13.68%) and minimum in IC-0614730 (10.25%). Differences in sugar content might be due to maximum conversation of starch into sugar which might be related to inherent varietal character and heavy fruit load also affected fruit weight and quality in litchi (Nagraj *et al.*, 2019). The reducing sugar contents in litchi fruits varied significantly among different genotypes with highest (10.73%) in IC-0614738 and lowest in IC-0614737 (8.68%). Titratable acidity varied from 0.51 to 0.58% maximum being in IC- 0614730 and minimum in IC-0614732 (0.51%). The maximum seed length was recorded in IC-0614731 (24.58 mm) and minimum in IC-0614737 (16.58 mm). Seed weight varied from 1.85 to 4.56 g with maximum in IC-0614731 and minimum in IC-0614730. Mandal and Mitra (2016) reported maximum seed weight in cv. McLean (4.56 g). Lal *et al.* (2018b) found variation in seed content varied from 6.96 to 22.58% highest being in Coll. 38 and lowest in IC-0615613.

Total chlorophyll content in mature leaf varied from 7.12 to 9.56 mg/100g with maximum in IC-0614737 and lowest in IC-0614731 (Table 2). Total phenolics varied from 0.49 to 0.76 mg GAE/g, 15.24 to 54.56 and 26.78 to 44.32 mg GAE/g in pulp, pericarp and seed, respectively. The IC-0614731 had lowest phenolics content in pulp. Total phenolics in litchi varied from 7.5-62.2 mg GAE/g in pericarp with maximum in genotype IC-0615613 and 23.01 mg -85.57 mg GAE/g in seed with maximum in IC-0615597 (Lal *et al.*, 2018b). Phenolic content in plant depends on genetic, agronomic and environmental factors.

A great variation was seen in phenolics content in genotypes in different parts and pulp contains lower phenolics than pericarp and seed. The genotypes which

Table 1. Quality and seed characteristics in litchi

Genotype	TSS (Brix)	Ascorbic acid (mg/100g)	Total sugar (%)	Reducing sugar (%)	Titratable acidity (%)	Seed length (mm)	Seed width (mm)	Seed weight (g)	Seed (%)
IC-0614728	20.15	24.56	13.56	10.56	0.56	23.45	13.97	4.10	16.61
IC-0614729	20.75	26.57	10.86	10.36	0.54	24.38	14.26	4.17	18.39
IC-0614730	17.86	32.68	10.25	8.96	0.58	17.23	9.02	1.85	10.66
IC-0614731	21.47	26.57	12.86	9.86	0.55	24.58	14.12	4.56	21.43
IC-0614732	20.35	24.58	13.68	9.57	0.51	22.98	12.86	4.25	20.67
IC-0614733	20.86	26.57	14.25	10.25	0.55	23.56	13.34	4.22	20.34
IC-0614735	21.45	25.46	13.28	10.38	0.52	24.57	13.86	4.26	18.17
IC-0614737	18.35	35.68	11.45	8.68	0.54	16.58	10.35	1.96	11.97
IC-0614738	19.67	29.37	10.12	10.73	0.56	23.15	13.56	4.22	19.67
SE (d)	0.595	0.615	0.621	0.275	0.01	0.81	0.662	0.914	0.78
CD (0.05)	1.273	1.316	1.327	0.588	0.02	1.733	1.416	1.954	1.66

Table 2. Bioactive compound in litchi

IC Number	Total chlorophyll (mg/100g)	Phenolics in pulp (mg/g)	Phenolics in pericarp (mg/g)	Phenolics in seed (mg/g)	Flavonoids in pulp (mg/g)	Flavonoids in pericarp (mg/g)	Flavonoids in seed (mg/g)	Anthocyanin in pericarp (mg/100g)
IC-0614728	7.58	0.52	16.54	28.26	3.56	0.86	4.12	102.56
IC-0614729	8.14	0.57	15.29	29.37	4.12	0.75	3.86	98.56
IC-0614730	8.93	0.76	53.25	44.32	4.10	6.85	13.26	26.45
IC-0614731	7.12	0.49	15.48	29.37	3.85	0.92	3.75	98.25
IC-0614732	7.68	0.51	17.26	26.78	3.28	0.73	4.57	100.12
IC-0614733	8.75	0.57	15.24	29.38	4.27	0.79	4.25	99.45
IC-0614735	8.97	0.50	17.25	29.38	3.27	0.83	4.67	103.58
IC-0614737	9.56	0.73	54.56	43.57	4.56	5.86	13.28	28.26
IC-0614738	7.55	0.55	17.26	29.38	3.86	0.76	4.85	97.25
SE (d)	0.108	0.02	1.4	0.904	0.055	0.344	0.907	3.351
CD (0.05)	0.23	0.043	2.993	1.933	0.117	0.736	1.939	7.166

contain low phenolics in pulp might have diverted to pericarp and seed. Total flavonoids varied from 3.27 to 4.56 mg CE/g, 0.75 to 6.85 mg CE/g and 3.75 to 13.28 mg CE/g in pulp, pericarp and seed, respectively. Lal *et al.* (2018b) showed variation in flavonoids content from 0.73-96.62 mg CE/g in pericarp and 2.41-27.50 mg CE/g in seed. Pericarp and seed were major sources of flavonoids than pulp. Total anthocyanin content varied from 26.45 to 103.58 mg/100 g with maximum in IC-0614735 and minimum in IC-0614730. Mandal and Mitra (2016) reported maximum anthocyanin (41.75 mg 100 g) in Deshi, followed by Kasba (34.62 mg 100 g), whereas it was recorded minimum (15.78 mg 100 g) in Elaichi. The IC-0614730 and IC-0614737 was free from sun burn but suffered lower with fruit cracking (<3%). The maximum sun burn was recorded in IC-0614729 (26.35%). Sun burn is predisposed to fruit cracking in litchi in early cultivars. Sun burn parts of fruit turned into cracking as fruit growth was extended. The IC-0614729 had maximum fruit cracking (28.62%), whereas IC-0614737 showed least fruit cracking (2.14%). Sun burn and fruit cracking are genetic characters of genotypes and intensity of sun burn and fruit cracking are highly influenced by the age of plants. Young plants are severely affected with sun burn and fruit cracking than old ones.

It can be concluded that genotypes IC-0614730 and IC-0614737 exhibited bright pink colour of young leave and others had yellowish green. Pink flushes genotypes matured late while yellowish green matured early. These two genotypes showed lowest seed content (10.66% and 11.97%) but higher pulp content (71.18% and 74.66%) as well as higher phenolics and flavonoids contents with least affected by sun burn and fruit cracking. These genotypes exhibited low vigour, least number of leaflet/leaf, minimum length and width of leaf and dwarf structure. These traits can be used for identification of dwarf cultivars in litchi.

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Effect of weed management on yield-attributing characters of fennel *(Foeniculum vulgare)*

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ABSTRACT

The experiment was conducted to find out the effect of pendimethalin on growth and yield of fennel (*Foeniculum vulgare* Mill.) during 2018-19 and 2019-20 at Bharatpur, Rajasthan. The Pre-emergence application of Pendimethalin 30% EC @ 0.90 kg a.i./ha 2 days after sowing and one hand weeding 60 days after sowing recorded higher grain yield (20.15 q/ha) as compared to the control, i.e. one hand weeding 45 days after sowing (17.75 q/ha). There was 13.52% increase in yield over the control. The technology index value (19.4) was recorded, indicating the gap in potential and demonstration yield due to soil fertility and weather conditions. By conducting on- farm testing of proven technology of weed management, yield potential of fennel can be increased.

Key Words: On-farm testing, Pendimethalin, Technology, Yield potential

Fennel (*Foeniculum vulgare* Mill.) is most important seed spice grown in India. Rajasthan is the second largest producer of fennel after Gujarat, producing 25,620 tonnes from 26,250 ha (2019-20). Of several constraints weeds often pose a serious problem. Wider spacing, frequent irrigation and liberal use of manures and fertilizers provide favourable conditions for weed seeds. Therefore, control of weeds in initial stages appears imperative. Hence, pre -emergence application of Pendimethalin 30% EC hold a promise in controlling weeds effectively. Hence, an experiment was conducted.

MATERIALS AND METHODS

An on-farm testing was conducted in Bharatpur district to find out the effect of weed management on yield of fennel during *rabi* 2018-19 and 2019-20 at farmers' fields under irrigated conditions. Soils were sandy loam, medium in nitrogen, phosphorus and potash with saline reaction. All farmers were trained on various aspects of production technologies. The field was prepared by deep ploughing and harrowing after *kharif* crops. Fennel R.F-125 was sown in last week of October. All the recommended practices, i.e. seed treatment with fungicide Carbendazim @ 1.5 g/kg seed, spacing, and plant protection chemicals were used to control the insect, pests and diseases. Recommended dose of manure and fertilizers was applied as N:P:K @ 90:60:60 kg/ha.

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Full amount of phosphorous and potash and one-third nitrogen each as basal, 45 days after sowing and at flowering were applied with irrigation. Seeds were sown by seed drill at a row - row spacing of 45 cm and plant - plant 20-25 cm. The two treatment consisted of control (farmers practice- one hand weeding 45 days after sowing) and application of Pendimethalin 30% EC @ 0.90 Kg a.i./ha was applied using 1000 liters of water as pre-emergence 2 days after sowing and one hand weeding 60 days after sowing. Weed count was made using quadrate having the size of 1m × 1m area in both treatments 45 days after sowing and total dry weight of weeds was measured. Crop was harvested in second week of April.

The data on cost of cultivation, production, productivity, total return and net return were collected in both treatments as per schedule . Average of cost of cultivation, yield and net returns were analyzed by formula.

Average = $[F_1 + F_2 + F_3 .... Fn] / N$

where, F_1 = Farmer

N = Number of farmers

Technology index was operationally defined as the technical feasibility obtained due to implementation of demonstration (on-farm testing) in fennel. To estimate the technology gap, extension gap and technology index following formula used by Samui *et al.* (2000) have been used.

Technology gap = Pi (potential yield) – Di (demonstration yield)

Extension gap = Di (demonstration Yield) – Fi (farmers yield)

Technology index = [(potential yield-demonstration yield) / potential yield] × 100

The relative weed density was defined as dominance of a particular weed species over other species in number in a mixture of weed population and expressed in percentage.

RWD = NPW × 100

where, RWD = Relative weed density

NPTW NPW = Number of a particular species / unit area

NPTW = Number of total weed species / unit area

The weed control efficiency (WCE) was calculated to determine the variation in dry matter weight accumulated due to competition with fennel plants of treated plot or to estimate comparative ability of weeds at different stage as compared to farmers' practice (no use of weedicide) (Walia, 2013) and was computed as

WCE = DWC-DWT × 100 where, WCE = weed control efficiency

DWC = Dry weight of weeds in control plot

DWT = Dry weight of weeds in treated plot

RESULTS AND DISCUSSION

The pre-emergence application of Pendimethalin 30% EC @ 0.90 Kg a.i. / ha 2 days after sowing and one hand weeding 60 days after sowing recorded maximum weed control efficiency (100%), highest yield (20.15 q / ha) compared to farmers' practice (17.75 q / ha). The increase in yield (13.52 %) over farmers' was recorded. Pendimethalin was used as pre-emergengce (before weed seedlings have emerged) to control annual grasses and certain broad leaved weeds. After application of Pendimethalin, a thin layer was formed at soil surface which prevents germination of weeds. It inhibited root and shoot growth, control weed population and their emergence, particularly during the crucial development phase. The higher weed control efficiency in T_2 might be due to significant reduction in weed dry matter because effective weed control practices through application of pre-emergence herbicides. Significantly higher yield in demonstration as compared with farmers practice might be due to vigorous growth of crop due to availability of sufficient nutrient, moisture, light and space owing to absence of weed because of higher weed control efficiency. This enabled plants to efficiently utilize sunlight and water for photosynthesis leading higher plant height, increased number of leaves and yield.

Yield attributes were significantly superior by pre-emergence application of Oxadiargyl @ 75g / ha + one hand weeding at 45 days after sowing or Pendimethaline @ 1.0kg / ha + one hand weeding at 45 days after sowing in fennel (Meena and Mehta 2009). Pre-emergence application of Pendimethaline @ 0.75 kg a.i. / ha and one hand weeding 40 days after sowing recorded highest yield (Mehta *et al.*, 2010), Pre-emergence application of Pendimethaline @ 1.0kg / ha + one hand weeding at 45 days after sowing in coriander (Nagar *et al.*, 2009).

Similarly, Patel *et al.* (2016), Meena and Mehta (2010), Patel *et al.* (2007), Meena *et al.* (2013). Nagar and Jain (2017), also supported these things. The farmers were motivated by seeing the results in term of productivity.

The technology gap showed the difference between potential yields over demonstration (on-farm testing) yield. The potential yield was 25 q / ha with Technology gap 4.85 q / ha. There exist a gap between the potential yield and demonstration yield. This may be due to soil, fertitlity and weather condition. Hence, location-specific recommendations are necessary to bridge the gap. Comparative high extension gap (2.40 q / ha) indicates that there is a need to educate farmers and help them for optimizing the yield by adopting improved practices. The technology index value was 19.4 (Table 1). It means the technology is suitable for Bharatpur district of eastern Rajasthan. The result consonance with Paghadal *et al.* (2022).

Table 1. Yield, technology gap, extension gap and technology index

Variable		No. of trials	Yield (q/ha)	Increase over farmers' practice(%)	Extension gap (q/ha)	Techno-logy gap (q/ha)	Technology index (%)
T_1	Control (one hand weeding 45 days after sowing)	10	17.75	-	-	-	-
T_2	Pre-emergence application of Pendimethalin 30% EC @ 0.90 Kg a.i./ha 2 days after sowing and one hand weeding 60 days after sowing	10	20.15	13.52	2.4	4.85	19.4
	Additional in T_2 treatments application		2.4				

Table 2. Economics (average of 2 years) of fennel production under on-farm testing

Technology option	Yield q/ha)	Cost /ha (₹)	Gross return ₹/ha	Net return ₹/ha	Benefit : cost ratio
T_1- control (one hand weeding 45 days after sowing)	17.75	31350	118750	102233	1:3.79
T_2- pre-emergence application of Pendimethalin 30 % EC @ 0.90 Kg a.i./ha 2 days after sowing and one hand weeding 60 days after sowing	20.15	32900	134925	123500	1:4.10
Additional in T_2 treatment application	2.4	1550	16175	21267	* 13.72

* incremental benefit : cost ratio.

The economic analysis of fennel production revealed that treatment T_2- pre-emergence application of Pendimethalin 30% EC @ 0.90 kg a.i./ha 2 days after sowing and one hand weeding 60 days after sowing recorded higher gross return (₹ 1,34,925/ha) and net return (₹ 1,23,500/ha) with higher benefit: cost ratio (4:10) as compared to farmers' practice. These results are in accordance with findings of by Patel *et al.* (2016), Mehta *et al.* (2010), Paghadal *et al.* (2022). An additional cost of ₹ 1,550/ha has increased additional net return ₹ 16,175/ha with incremental benefit:cost ratio 13.72 suggesting higher profitability and economic viability of pre-emergence application of Pendimethalin 30% EC @ 0.90 Kg a.i./ha at 2 days after sowing and one hand weeding at 60 days after sowing. Mamatha *et al.* (2021), also reported similarly as pre-emergence application of Pendimethalin 30% EC @ 1.0 kg a.i./ha at and one hand weeding at 40 days after sowing is found to be beneficial for maximizing grain yield of coriander with high benefit:cost ratio. Pre-emergence application of pendimethalin at 1.00 kg/ha supplemented with one hand-weeding in onion gave the higher net return of ₹ 51,296/ha with maximum benefit:cost ratio of 8.77 (pre-emergence application of pendimethalin at 1.00 kg/ha supplemented with one hand-weeding in onion gave higher net return with maximum benefit cost ratio (Kumar and Gupta, 2021) (Table 2).

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Enhancement of callogenesis from plumular explants of coconut *(Cocos nucifera)* via exogenous supplementation of amino acids and casein hydrolysate

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ABSTRACT

The role of exogenous supplementation of amino acids and casein hydrolysate in enhancing callogenesis from plumular explants of coconut (*Cocos nucifera* L.) was studied at ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala, during 2020-21. The combination of three amino acids, *viz*. glutamine, asparagine, proline, and organic additive casein hydrolysate were supplemented in three types of basal media (Eeuwen's Y3, Murashige and Skoog (MS) and 1/2MS) containing 2, 4-D (16.5 mg/L), charcoal (0.1%) sucrose (3%) and agar (0.8%). A total of 19 treatments were formulated and tested for production of embryogenic colloid tissue. The explants in glutamine-supplemented medium generated better colloid tissue and showed positive effect on colloid tissue multiplication, compared to other combinations. Of three basal media, Y3 was better over 1/2MS and MS basal media. These results could be useful for improving the efficiency of *in-vitro* regeneration in coconut by somatic embryogenesis from plumular explants.

Key Words: Embryogenic calli, Amino acids, Basal media, Plumule, Callogenesis, Explants

Coconut (*Cocos nucifera* L., 2n=32) is propagated via seed/nut. Only a limited number of seedlings can be produced from a single mother palm and its uniformity is not guaranteed due to its cross-pollinating nature. Coconut is most. Improving the formation of callus or colloid-like tissue from the explant and multiplication of these are of major interest in recalcitrant palms like coconut for improving the existing clonal propagation protocol of coconut via somatic embryogenesis from plumular tissues. Exogenously added amino acids and additional organic supplements play a vital role in plant micropropagation. Culture mediums are rarely supplemented with additional amino acids and organic supplements. Use of amino acids enhanced the somatic embryogenesis and *in-vitro* regeneration potential in several monocots' species. Therefore, three amino acids and one organic supplement were tested along with three basal media to test the effect of these additional components on callogenesis from plumular explant of coconut.

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MATERIALS AND METHODS

Mature nuts of 11-12 months old nuts were harvested from West Coast Tall (WCT) palms. Embryos with endosperm were excised from split nuts using a cork borer and were washed thoroughly using tap water followed by one wash with distilled water. Washed endosperm plugs enclosing the embryos were subjected to sterilization with 0.01% $HgCl_2$ for 3 minutes and washed again with sterile distilled water to remove the traces of heavy metal. Subsequently, embryos were taken out carefully from endosperm plug using a surgical blade under laminar airflow chamber. Extracted embryos were further treated with 20% NaClO for 20 minutes under laminar airflow chamber, after decanting the NaClO, embryos were rinsed using sterile distilled water 5-6 times to remove the traces of NaClO. Afterwards, embryos were carefully sliced, and plumules were taken out and were inoculated on callus induction media following method established by (Neema *et al.*, 2022; Bhavyashree *et al.*, 2016).

Three amino acids (glutamine 200 mg/L, L-asparagine-100 mg/L, and proline-100 mg/L) and one organic additive compound, *i.e.* casein hydrolysate

(250 mg/L) were added individually or in combinations with basal medium (M) to form six different combinations along with 2, 4-D (16.5 mg/L), sucrose (3%), charcoal (0.1%) and agar (0.8%), *i.e.* MC1 to MC6 [MC1: M+2, 4-D-16.5 mg/L + 30 g/L sucrose+ activated charcoal- 1000 mg/L + agar 0.8%; MC2: M+ 2,4-D-16.5 mg/L+ glutamine-200 mg/L+ 30 g/L sucrose + activated charcoal- 1000 mg/L + agar 0.8%; MC3: M + 2, 4-D-16.5 mg/L + glutamine-200 mg/L+ casein hydrolysate -250 mg/L+ 30 g/L sucrose + activated charcoal- 1000 mg/L+ agar 0.8%; MC4: M + 2,4-D-16.5 mg/L+ casein hydrolysate -250 mg/L + 30 g/L sucrose+ activated charcoal 1000 mg/L+ agar 0.8%; MC5: M +2, 4-D-16.5 mg/L+ L-asparagine-100 mg/L+ proline 100 mg/L+ 30 g/L sucrose+ activated charcoal- 1000 mg/L+ agar 0.8%; MC6: M + 2,4-D 16.5 mg/L + L-Asparagine-100 mg/L + proline 100 mg/L + glutamine 200 mg/L + casein hydrolysate 250 mg/L+ 30 g/L sucrose+ activated charcoal 1000 mg/L+ agar 0.8%; MC: media combinations 1 to 6 and M: basal medium].

Each of the above combinations were tried with three basal medium, *i.e.* Murashige and Skoog (MS), 1/2MS (half-strength MS medium) and Eeuwens (1976) Y3 medium to form 18 different treatment combinations. ICAR-CPCRI Standardized media for callus initiation from coconut plumule *i.e.*, Tc: Eeuwen (1976) Y3 basal media +16.5 mg/L 2, 4 -D + 1 mg/L TDZ + 1000 mg/L charcoal + 0.8% agar was considered as a standard for comparing all 18 treatments (Rajesh *et al.*, 2014). All the treatment combinations of media were prepared and autoclaved at 121°C and 1.06 kg/cm^2 pressure for 20 minutes after adjusting pH to 5.8. Each treatment with along with control was replicated thrice and a total of 57 plates were inoculated, each with 10 WCT plumules and was kept under dark condition.

After a month, plumules from each treatment plate were subcultured into individual test tubes (50 ml test tubes containing 15 ml solid media) containing same media composition of respected treatments with reduced 2,4-D concentration (10 mg/L). These inoculated cultures were maintained in continuous dark condition for calloid tissue initiation and multiplication. Observations on plumule bulging, browning/necrosis, the formation of calloid clump and embryogenic calloid production were recorded on 7th day, 10th day, 15th and 45th days after inoculation, respectively.

Percentage of explant browning (number of browned plumules out of the total number of plumules inoculated), explant bulging (% plumular bulging) and formation of callus clumps were calculated and recorded for each treatment. Embryogenic calloid production and quantity of calloid tissue from each in response to different media combinations were tested based on visual measurements since the size of the explant is too small (≤ 1 mm) and its callusing capacity is found to be minimal. Measurements on explant and its response to callusing were taken on five different visual scales *i.e.* scale 0: plumules without bulging (plumule with browning) or no callusing, scale 1: bulged plumule without callusing, scale 2: bulged plumule with slow multiplication symptoms with initiated callus nodules, scale 3: bulged plumules with extended callus nodules, scale 4: bulged plumules with good callus growth with callusing nodules, scale 5: bulged plumules with high calli growth with extended callus nodules.

The values were individually observed for each replication, and the total value was averaged by dividing with the number of functional plumules present in that replication (functional plumules: plumules without browned or contaminated). The results were analyzed using SAS software and means were compared by Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

Symptoms of browning or necrosis of explant tissues was noticed after a week of inoculation in a callus initiation medium. In different treatments, explant browning was ranged 3.3% to 30% (Table 1). Media combinations were taken into consideration; MC2 displayed minimal browning of 9.99%, followed by MC1 and MC3 with 14.44% and 17.77% respectively. While highest browning of 25.55% was noticed in MC4 combination with all three basal media. The additional browning observed in MC4 combination might have triggered by the organic supplement 'casein hydrolysate'.

However, when casein hydrolysate was combined with other amino acids such as L-glutamine in MC3, or L-asparagine, proline, glutamine in MC6 combinations, percentage browning was reduced to 9.99% and 18.88% respectively from 25.55%. Though considerable browning was noticed with the addition of casein hydrolysate to the medium, it does not kill the explant tissue fully; instead, calloid tissue formation was seen on temporarily browned explant tissue. Casein hydrolysate is a complex, undefined natural organic substance popularly used in cell culture medium (Bhatia, 2015).

Organic substances are active sources of several amino acids, hormones, vitamins, fatty acids, carbohydrates, and several plant growth substances (Bhatia, 2015). Hydrolysates carry a rich amount of glutamine, proline, and lysine, along with other plant growth substances (Wang *et al.*, 2013). The positive influence of casein hydrolysate especially for callus initiation and multiplication was reported in several

Table 1. Browning (%) and embryogenic calloid production from plumular explants of coconut using different amino acids with three different basal media

Media	Treatment	Browning (%)	Plumular bulging and formation of callus clump (%)	Embryogenic callus (scale 0-5)
Control	T_c	13.33	86.66	1.60 DCEB
MS	T_1	13.33	80.00	1.41 DCEF
	T_2	16.66	83.33	1.58 DCEB
	T_3	23.33	76.66	1.09 EF
	T_4	26.66	73.33	1.29 DCEF
	T_5	26.66	73.33	1.17 DEF
	T_6	30.00	83.33	1.73 DCB
Y3	T_7	13.33	86.66	1.60 DCEB
	T_8	10.00	90.00	2.43 A
	T_9	10.00	90.00	2.00 AB
	T_{10}	23.33	76.66	1.00 F
	T_{11}	13.33	86.66	1.84 CB
	T_{12}	16.66	70.00	1.19 DEF
1/2 MS	T_{13}	16.66	83.33	1.48 DCEBF
	T_{14}	3.33	96.66	1.75 DCB
	T_{15}	20.00	80.00	1.00 F
	T_{16}	26.66	73.33	1.36 DCEF
	T_{17}	16.66	80.00	1.18 DEF
	T_{18}	13.33	86.66	1.38 DCEF
	SE	9.55	9.79	0.24
	CD (5%)	NS	NS	0.48

plant species (Cai *et al.*, 2013; Okumoto *et al.*, 2016; Murkute, 2020).

Of three tested basal media, used highest explant browning or necrosis was observed with MS media (21.99%) which was followed by 1/2MS (16.1%) and least browning was observed in combinations with Y3 basal media (14.44%). The superiority of Y3 basal media over MS was also proven by Muniran *et al.* (2008) for direct and indirect regeneration in oil palm. When basal media and additional media combinations were compared to highest browning of 30% was noticed in treatment T4, which had a combination of MS basal media with MC4 additional component 'casein hydrolysate'.

Increase in size of plumules (bulging) was noticed after 5, 7 days after inoculation. These plumular tissues further gave rise to calloid clumps instead of germinating into individual plantlet due to the higher concentration of the 2, 4-D, *i.e.* 16.5 mg/L. Plumular bulging, and clump formation were noticed in all 19 treatments, including control. In various treatments, this parameter varied from 70 to 96%. The highest percentage of bulging and calloid formation was observed in treatment containing 1/2MS media with MC2 combination where glutamine was present alone instead of different amino acids combination. This was followed by T_8 and T_9 with 90%, where Y3 media was present along with MC2 (Y3 + 2,4-D 16.5 mg/L+ glutamine 200 mg/L) and MC3 (MC3-Y3 + 2, 4-D 16.5 mg/L + glutamine200 mg/L + casein hydrolysate 250 mg/L) combination.

Considerable increase in calloid formation was noticed with the addition of glutamine to the Y3 and 1/2MS media, while the slightly lower response was noticed in MS basal media. Supple-mentation of basal media with glutamine facilitates higher nitrogen uptake by the tissue due to an increase in assimilation capacity as well as a nitrogen source (Okumoto *et al.*, 2016). Callus induction from immature cotyledons and embryos of walnut was enhanced with the use of glutamine (Cai *et al.*, 2013). Influence of glutamine on dedifferentiation and dedifferentiation process of cell cultures process was also noticed (Habib *et al.*, 2015).

Embryogenic calloid formation was observed from the plumular explants after 30 days of inoculation into the callus induction media. Calloid tissue from the explants was subsequently transferred to a media containing a reduced amount of 2, 4-D (10 mg/L) with the same media combinations. Highest percentage of embryogenic calloid production was obtained from the treatment T_8 (2.42) containing Y3 media with MC2 combination (MS +2, 4-D-16.5 mg/L+ glutamine 200 mg/L) which was followed by treatment T_9 with the visible value 2 consists of Y3 basal media with additional glutamine (Y3+2, 4-D 16.5 mg/L+ glutamine 200 mg/L+ casein hydrolysate 250 mg/L) followed by T_{11} (Y3 +2, 4-D 16.5mg/L+ L-asparagine 100 mg/L+ proline 100 mg/L) and T_{14} (1/2MS +2, 4-D 16.5mg/ L+ glutamine 200 mg/L) with the values 1.84 and 1.75 respectively.

The increase in calloid production in treatments T_8, T_9, T_{11} and T_{14} over control was 34%, 20%, 13% and 9% respectively and all four treatments were found to have a common additional nitrogen additive 'glutamine' with Y3 basal media. Previous studies have been reported that the addition of glutamine to the medium containing auxins and cytokinins or cytokinin's alone boosted the regenerative ability of the callus in wheat by 6 to 10%. Inclusion of glutamine (34.2 µM) enhanced the cell count in coconut suspension (Bhavyashree *et al.*, 2016).

Absence of glutamine in the callus tissue leads to the loss of embryogenic capacity in Cryptomeria japonica callus cultures (Ogita *et al.*, 2001). However, the positive influence of amino acids, asparagine and proline has been reported in several studies (Suekawa *et al.*, 2019), the influence of these amino acids (*i.e.*, asparagine and proline) in aforesaid concentrations had shown less response in coconut calloid production and multiplication in the present study.

CONCLUSION

Addition of amino acid glutamine (200 mg/L) to 2, 4-D (16.5%) positively influenced the calloid production from plumular explants of coconut. Trails on other amino acids with lower and higher concentrations may provide detail insight into the effect of embryogenic calloid production from plumular explants of coconut. Though all the additional components act as a nitrogen source to the media, glutamine exhibited higher response as compared to other tested compounds.

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Evaluation of potato *(Solanum tuberosum)* genotypes under heat stress condition

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ABSTRACT

Fifty-two potato (*Solanum tuberosum* L.) genotypes were evaluated in early crop season (75 days) at experimental field of ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Pradesh, during 2020 and 2021. Significant differences were recorded among for tuber yield and tuber attributes like plant vigour (1-5 scale), foliage maturity (1-5 scale), tuber colour, tuber shape, eye depth and flash colour. The pooled results of 2020 and 2021 crop seasons indicated that eight genotypes namely Kufri Mohan (260 g), Kufri Lima (256 g), CP4149 (252g), Kufri Garima (241g), Kufri Bahar (239 g), CP3273 (236 g), Kufri Neelkanth (221 g), CP4143 (212 g), CP1326 (208 g) and Kufri Arun (207 g), were found high-yielding in term of total tuber yield/ plant. The highest marketable tuber yield/plant was recorded in Kufri Lima (234g), CP4149 (230 g), Kufri Mohan (225 g), CP3273 (213 g), Kufri Bahar (211 g), Kufri Garima (208 g), CP4143 (190 g), Kufri Neelkanth (182 g), Atlantic (178 g) and Kufri Arun (177 g). The genotypes, CP1931, CP3319, CP3322, CP3450, CP3470, CP3499, CP4149, CP4238, Kufri Garima, Kufri Lima, Kufri Surya and Lady Rossetta, were found highly tolerant with 0% hopper burn incidence. Most of the genotypes were highly tolerant with 0% mite damage incidence except CP3495, CP3341and CP3472 (20%) and Kufri Sindhuri and Kufri Pukhraj (40%). On an overall basis CP4149, Kufri Mohan, Kufri Garima and Kufri Lima were found promising for high plant stand, plant vigour, marketable/ total tuber yield, marketable/total tuber number and nil/low incidence of hopper and mite burn.

Key Words: Genotypes, Yield, Heat stress, Hopper and Mite burn

Potato (*Solanum tuberosum* L.) is the most popular vegetable crop worldwide. The climate change has affected weather patterns, resulting in extremes of heat, drought, frequent frost and snow fall in high altitudes (Dahal *et al.*, 2019 and IPCC, 2014). The sub-optimal growth conditions associated with global warming and climate change negatively impact its plant growth, survival and crop yield (Lesk *et al.*, 2016). Such negative impact on yield are likely to be aggravated in future because continued greenhouse gas emissions will intensify crop plant's exposure to abiotic and biotic stresses (DeLucia *et al.*, 2012; IPCC, 2014). High temperature, drought, soil salinity and nutrient stresses adversely affect plant growth, tuberization, tuber bulking and tuber yield and quality (Minhas, 2012; Wang-Pruski and Schofield, 2012). Therefore, selection of desirable parents could generate progenies with in-built capacity of grow-ing well and producing tubers under high temperature is essential (Luthra *et al.*, 2020; Chaudhary *et al.*, 2021). Thus, to improve tuber yield under heat stress condi-tions, there is a need to develop new potato cultivars.

MATERIALS AND METHODS

A total of 52 potato genotypes were evaluated in early crop season at 75 days crop duration at experimental field of ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut, Uttar Predesh (29°N and 76°E; 222 masl) during 2020 and 2021 crop seasons. The soil of experimental field was sandy loam in texture. The soil reaction is slightly alkaline with pH 7.6. The experiment was planted in mid-September under irrigated condition. The genotypes were evaluated in a randomized block design in three replications (1.8 m^2) with 15 tubers per replication.

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Table 1. Mean performance of genotypesduring 2020 and 2021

Genotype	G%	PV	FM	Tubes/plant		Tuber yield (g/plant)		Burn (%)	
				Marketable	Total	Marketable	Total	Hopper	Mite
Atlantic	70	3.50	3.50	3.94	5.79	177.50	195.00	53.34	0.00
CP1137	53	2.50	4.40	2.25	3.75	76.75	103.57	50.00	0.00
CP1312	97	2.50	4.25	1.45	6.35	33.81	71.33	43.34	0.00
CP1326	43	2.50	3.25	1.88	5.21	45.83	207.50	50.00	0.00
CP1328	77	2.50	3.90	3.81	7.29	121.38	173.77	30.77	0.00
CP1526	63	2.50	4.25	3.60	5.43	146.07	176.19	51.67	0.00
CP1637	77	3.00	3.25	3.71	5.46	164.25	190.92	33.34	0.00
CP1814	80	2.50	4.50	2.25	3.21	72.45	87.69	31.82	0.00
CP1931	47	3.00	3.50	3.54	6.35	123.33	155.42	0.00	0.00
CP1991	73	2.25	4.00	3.41	9.09	116.82	191.82	70.00	0.00
CP2101	83	2.25	4.50	1.67	6.07	37.47	68.05	50.00	0.00
CP2135	70	3.00	4.25	2.64	3.89	110.56	133.61	80.00	0.00
CP2382	70	2.25	4.50	3.89	6.46	112.86	138.57	46.43	0.00
CP3005	53	3.00	3.50	3.55	6.06	139.09	173.18	31.82	0.00
CP3273	67	3.00	4.00	4.70	6.70	212.50	236.00	50.00	0.00
CP3282	83	3.00	3.25	2.53	3.67	98.94	117.05	10.00	0.00
CP3291	83	2.25	4.00	0.99	2.80	22.79	41.15	39.23	0.00
CP3319	80	3.00	3.75	2.90	6.25	93.43	131.54	0.00	0.00
CP3322	93	3.00	3.50	2.32	3.42	93.08	106.03	0.00	0.00
CP3325	80	2.25	4.50	2.48	5.87	92.34	133.60	70.00	0.00
CP3341	100	3.25	2.75	3.50	9.00	83.33	126.67	0.00	20.00
CP3346	53	2.50	4.15	2.00	4.17	85.67	118.00	60.00	0.00
CP3354	70	2.50	4.25	2.71	5.47	78.89	111.39	20.84	0.00
CP3368	50	2.75	3.50	1.44	3.21	59.23	89.62	50.00	0.00
CP3383	100	3.25	3.25	3.33	5.20	137.67	168.33	31.25	0.00
CP3450	80	3.50	3.25	3.07	4.43	120.93	141.36	0.00	0.00
CP3470	87	3.00	3.75	2.42	3.96	120.00	143.85	0.00	0.00
CP3472	80	3.00	3.25	3.17	5.10	147.41	181.19	20.00	20.00
CP3473	70	2.50	4.00	3.77	5.94	117.31	153.85	50.77	0.00
CP3495	80	2.75	4.00	1.79	6.35	55.59	95.56	0.00	20.00
CP3496	73	2.25	3.50	1.96	4.78	49.73	83.66	35.72	0.00
CP3497	70	2.75	3.75	3.03	5.75	112.21	151.44	45.00	0.00
CP3499	43	2.50	4.00	3.26	4.79	145.56	179.17	0.00	0.00
CP4143	83	2.25	4.00	3.34	4.84	189.74	212.31	50.00	0.00
CP4149	77	3.00	3.75	3.83	4.82	229.92	251.94	0.00	0.00
CP4236	63	2.50	4.25	3.07	4.12	118.75	142.78	70.00	0.00
CP4238	90	3.25	3.40	3.33	5.54	144.33	172.25	0.00	0.00
CP4243	70	2.50	4.25	3.33	5.78	116.25	141.25	60.00	0.00
K Arun	77	3.00	3.75	4.04	6.44	176.67	206.67	33.34	0.00
K Bahar	73	3.50	4.25	3.76	5.64	211.37	239.02	26.93	0.00
K Chipsona-3	87	3.25	4.00	3.27	7.38	146.82	192.42	33.34	0.00
K Ganga	70	2.25	4.00	4.37	6.58	165.00	189.76	20.00	0.00
K Garima	90	2.75	3.25	4.44	6.81	207.58	240.55	0.00	0.00
K Lalima	93	2.75	3.75	4.09	5.78	169.10	186.67	30.77	0.00
K Lalit	73	2.75	3.50	4.17	7.06	147.65	164.23	26.67	0.00
K Lima	90	3.25	2.75	3.54	5.11	234.40	256.21	0.00	0.00
K Mohan	93	3.00	3.50	4.35	7.83	225.26	259.74	6.67	0.00
K Neelkanth	87	2.75	3.25	4.23	6.96	182.38	220.54	17.86	0.00
K Pukhraj	97	2.75	3.50	3.10	6.57	78.45	122.26	0.00	40.00
K Sindhuri	98	2.38	3.90	3.38	6.62	79.23	105.46	0.00	40.00
K Surya	97	2.75	3.25	3.46	5.54	148.33	185.12	0.00	0.00
Lady Rossetta	87	2.50	3.90	3.35	7.00	85.00	125.00	0.00	0.00

G germination%; PV plant vigour; FM foliage maturity

The plants were spaced 20 cm within and 60 cm between rows. The crop was dehaulmed 75 days after planting. The recommended cultural practices were adopted. The application of insecticide was not done in order to allow the population build up of hoppers and mites so that data were recorded on tuber yield and tuber attributes like plant vigour (1-5 scale), foliage maturity (1-5 scale), marketable tuber yield (more than 20 gram), total tuber yield / plant (g), tubers / plant, mite and hopper burn (%). Data on genotypes were analysed for two years 2021 and 2022 on pooled basis.

RESULTS AND DISCUSSION

The pooled data on germination (%) ranged from 43 to 100. High germination was found in CP3341 and CP3383 (100%), Kufri Sindauri (98%), Kufri Pukhraj, Kufri Surya and CP1312 (97%), CP3322, Kufri Mohan, Kufri Lalima (93%), CP4238 Kufri Lima and Kufri Garima (90%).The data of foliage maturity was recorded in the scale of 1 (late) -5 (early) and ranged from 2.75 to 4.50. The genotypes CP1814, CP2101, CP3325, CP2382 (4.50), CP1137 (4.40), Kufri Bahar, CP2135, CP1312, CP3354, CP4243, CP1526, CP4236 (4.25), CP3346 (4.15), Kufri Chipsona3, CP3273, CP3495, CP3473, CP3499, CP3291, CP4143, CP1991and Kufri Ganga (4.00), Lady Rossetta, CP1328 and Kufri Sindhuri (3.90), CP3470, CP3319, Kufri Arun, CP4149, Kufri Lalima and CP3497 (3.75), Atlantic, CP3322, K Mohan and CP3005, CP1931, Kufri Pukhraj, Kufri Lalit, CP3368 and CP3496 (3.50) were found early maturing.

The plant vigour was recorded in scale of 1 (poor)-5 (very good) and ranged from 2.25 to 3.50. The genotypes, CP3450, Kufri Bahar and Atlantic were very good with scale of 3.50. The CP3341, CP3383, CP4238, Kufri Lima and Kufri Chipsona-3 showed medium plant vigour with 3.25. The genotypes CP3322, Kufri Mohan, CP3470, CP3282, CP3319, CP3472, CP1637, Kufri Arun, CP4149, CP2135, CP3273, CP3005 and CP1931 showed good plant vigour with scale of 3.00.

The total tuber yield (g / plant) ranged from 41.15 to 259.74g / plant and high total tuber yield was recorded in Kufri Mohan (259.74g), followed by Kufri Lima (256.21g), CP4149 (251.94g), Kufri Garima (240.55g), Kufri Bahar (239.22g), CP 3273 (236.00g), Kufri Neelkanth (220.54g), CP 4143 (212.31g), CP 1326 (207.50) and Kufri Arun (206.67g). The marketable tuber yield (g / plant) ranged from 22.79 to 234.40 g / plant and high marketable tuber yield was found in Kufri Lima (234.40g) followed by CP4149 (229.92g), Kufri Mohan (225.26g), CP3273 (212.50g), Kufri Bahar (211.37g), Kufri Garima (207.58g), CP4143 (189.74g), Kufri Neelkanth (182.38g), Atlantic (177.50g), Kufri Arun (176.67g), Kufri Lalima (169.10g) and Kufri Ganga (165.00g) respectively.

The total tuber number ranged from 2.80 to 9.09. The highest tuber number were recorded for the genotypes namely, CP1991 (9.09),CP3341 (9.0), Kufri Mohan (7.83), Kufri Chipsona 3 (7.38), CP1328 (7.29), Kufri Lalit (7.06), Lady Rossetta (7.00), Kufri Neelkanth (6.96), Kufri Garima (6.81), CP3273 (6.70), Kufri Sindauri (6.62), Kufri Ganga (6.58), Kufri Pukhraj (6.57), CP2382 (6.46), Kufri Arun (6.44), CP1931 (6.35), CP3495 and CP1312 (6.35), CP3319 (6.25), CP2101 (6.07), CP3005 (6.06), CP3473 (5.94), CP3325 (5.87), Atlantic (5.79), Kufri Lalima and CP4243 (5.78), CP3497 (5.75), Kufri Bahar, CP4238 and Kufri Surya (5.54).

The marketable tuber number ranged from 0.99 to 4.70. The highest tubers were recorded for CP3273 (4.70) followed by Kufri Garima (4.44), Kufri Ganga (4.37), Kufri Mohan (4.35), Kufri Neelkanth (4.23), Kufri Lalit (4.17), Kufri Lalima (4.09), Kufri Arun (4.04) Atlantic (3.94), CP2382 (3.89), CP4149 (3.83),CP1328 (3.81), CP3473 (3.77), Kufri Bahar (3.76), CP1637 (3.71), CP1526 (3.60), CP3005(3.55), CP1931 and Kufri Lima (3.54) and CP3341 (3.50).

The incidence of hopper burn ranged from 0.00 to 80.00. Total 16 genotypes Kufri Lima, CP4149, Kufri Garima, Kufri Surya, CP3499, CP4238, CP1931, CP3470, CP3450, CP3319, CP3341, Lady Rossetta, Kufri Pukhraj, CP3322, Kufri Sindauri and CP3495 were found highly tolerant with 0% hopper burn incidence. The 47 genotypes were found highly tolerant with 0% mite damage incidence Kufri Lima, CP4149, Kufri Garima, Kufri Surya, CP3499, CP4238, CP1931, CP3470, CP3450, CP3319, Lady Rossetta, CP3322, Kufri Mohan,CP3282, Kufri Neelkanth, Kufri Ganga, CP3354, Kufri Lalit, Kufri Bahar, Kufri Lalima, CP1328, CP3383,CP 3005, CP1814, Kufri Chipsona-3, CP1637, CP3496, CP3291, CP1312, CP3497, CP2382, CP3273, CP4143, CP1326, CP1137, CP3368, CP2101, CP3473, CP1526, Atlantic, CP4243, CP3346, CP1991, CP4236, CP3325 and CP2135.

On pooled data basis, genotypes CP4149, CP3273, CP4143, Kufri Lima, Kufri Mohan, Kufri Garima and Kufri Neelkanth were found promising for total tuber yield and total tuber number and nil hopper burn.

SUMMARY

The potato genotypes CP4149, CP3273, CP4143, Kufri Lima, Kufri Mohan, Kufri Garima and Kufri Neelkanth were found suitable for heat stress condition.

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Evaluation of bio-formulations for management of storage rot of seed tubers of Colocasia (*Colocasia esculenta*)

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ABSTRACT

The seed tubers of Colocasia (*Colocasia esculenta* L.) collected from different locations were treated with several bio-formulations, *viz*. Biofor PF-2, Biomonas, Bioveer and Biozin PTB at 5% concentration to evaluate their efficacy in protecting the seed tubers from rotting in storage. Biozin PTB was found to be the most effective with lowest incidence (8.84%) of rot among all bio-formulations. The seed tubers treated with Biozin PTB recorded highest reduction (80.94%) of rot incidence over the control.

Key Words: Bio-formulations, Cormlets, Rot incidence, Seed tubers, Storage rot

Colocasia (*Colocasia esculenta* L.) grown in Lakhimpur district. The multiple cropping systems also suprerss weeds, pests and diseases (Nedunchezhian *et al.*, 2022). Phytophthora blight *(Phytophthora colocasiae)* and Pythium root and corm rot (*Pythium* spp.) are most devastating fungal diseases. Post-harvest loss of tubers, particularly corms and cormels has become a serious problem, resulting in high price of seed tubers. Degeneration occurs due to successive accumulation of pathogens and pests (Paul *et al.*, 2022). The *A. niger*, *A. flavus*, *Geotrichum candidum*, *Rhizopus oryzae* were isolated from rotten tubers (Khatoon *et al.*, 2016). Botanicals were also found to be effective in controlling post-harvest decay of colocasia (Khatoon *et al.*, 2018). Therefore, study was undertaken to evaluate bio-formulations for prevention of storage rot of seed tubers in Agro-ecological condition of Lakhimpur District of Assam.

MATERIALS AND METHODS

Fresh samples of seed tubers were collected from different colocasia-growing areas of Lakhimpur district of Assam, *viz*. Shimaluguri, Bahupathar, Phulbari, Boginodi and Madhabpur during *rabi* season of 2016 and 2017. The experiment was conducted in a completely randomized block design with four replications. Six kg of seed tubers from each location were taken. Bio-formulations, *viz*. Biofor PF-2, containing *Pseudomonas fluorescens* and *Trichoderma harzianum*, Biomonas, containing *Pseudomonas fluorescens*, Bioveer, containing *Trichoderma viride,* and Biozin PTB, containing *Pseudomonas aeruginosa*, *Trichoderma harzianum*, and *Bacillus brevis* were collected from Biocontrol Laboratory, Department of Plant Pathology, Assam Agricultural University, Jorhat.

The seed tubers were treated with bio-formulations @ 5% (5 kg in 100 litres of water) for one hour and dried under shade and stored at room temperature till the time of planting in February. For control experiments, sterile water was used. The number of rotted seed tubers in each lot were recorded starting 15 days after storage and at 15 days intervals. The per cent rot incidence of seed tubers was determined by following to that of Gollifer and Booth (1973). The data were analyzed by the OPSTAT statistical software package after angular transformation wherever necessary. The data were subjected to analysis of variance, and the means were analyzed, using Duncan's new multiple range post-test at $p \leq 0.05$.

RESULTS AND DISCUSSION

All bio-formulations were found to be effective in managing storage rot of seed tubers after five months of storage (Table 1). The Biozin PTB was found most effective with the lowest incidence (8.84%) of rot, followed by Biofor PF and Biosona with 16.24% and 12.28% rot incidence, respectively. The seed tubers

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Table 1. Efficacy of bio-formulations on storage rot of seed tubers of colocasia

Treatment	Rot incidence (%)	Reduction of rot incidence over control (%)
Biozin PTB	8.84(20.473)[d]	80.94
Biofor PF	12.28(23.749)[c]	73.52
Biosona	16.24(28.82)[b]	64.98
Bioveer	23.26(42.923)[a]	49.85
Control	46.38(17.235)[e]	
CD (0.05)	2.68	

* Data within the parentheses are angular transformed values
** Data are mean of two years and four replications

treated with Bioveer recorded lowest (23.26%) incidence of rot. The highest reduction (80.94%) of rot incidence over the control was recorded in Biozin PTB treated samples, followed by Biofor PF and Biosona with 73.52%, and 64.98% reduction of rot incidence over the control, respectively. The lowest reduction (49.85%) of rot incidence over the control was observed in samples treated with Bioveer (Table 1). The combination of all three antagonists contained in bio-formulation (Biozin PTB) was found to be most effective.

The efficacy of *Trichoderma viride* as an effective biocontrol agent against *Fusarium oxysporum* was reported by several researchers (Kumari *et al.*, 2014). Talc formulation of *Pseudomonas flourescens* showed higher inhibitory action against *Fusarium oxysporum* f. sp. *cubense*. Akram *et al.* (2013) also reported that tomato plants inoculated with *Bacillus thuringiensis* had resulted in a significant reduction of fungal wilt caused by *Fusarium oxysporum*. Combination of *Trichoderma viride, Pseudomonas flourescens, Metarhizium anisopliae,* and *Bacillus thuringiensis* significantly inhibited the *Fusarium oxysporum* f. sp. *lactucae* isolated from hydroponically grown lettuce (Khan *et al.*, 2021).

A similar observation was also made by Bora *et al.* (2020). Among all, *Trichoderma viride, Pseudomonas flourescens*, and *Bacillus thuringiensis* were found to be most effective in inhibiting the pathogen *in vitro*. Keswani *et al.* (2016) reported that *Trichoderma* spp. induces systemic resistance in plants by releasing not only proteins but also secondary metabolites and controls plant diseases. The fungal biocontrol agent Trichoderma employs a variety of mechanisms such as hyper parasitism, antibiosis, and competition (Singh *et al.*, 2014; Bora *et al.*, 2013).

The bacterial biocontrol agent *Pseudomonas flourescens* inhibits plant pathogens through the production of antibiotics, siderophore, antifungal metabolites, and lytic enzymes (Sharma *et al.*, 2020). The bio-insecticide, *Bacillus thuringiensis* also can control plant pathogens such as *Fusarium oxysporum*, *F. sambocinum* and *F. graminearum* by secreting different types of enzymes (Baysal *et al.*, 2013). In our study, all the bioformulations showed promise in minimizing the storage rot of seed tubers with varying degrees of effectiveness. However, Biozin PTB was found to be most effective bioformulation.

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Response of upland taro *(Colocasia esculenta)* to varying water regimes under humid tropical conditions of India

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ABSTRACT

The field experiment was conducted on taro (*Colocasia esculenta* L. Schott) during 2017, 2018 and 2019 with three spells of irrigation (irrigation for 2 months and remaining period under stress, irrigation for 4 months and remaining period under stress, irrigation for 6 months) and four levels of drip irrigation, *viz.* 75%, 100%, 125% and 150% of water requirement of the crop (ETc) in factorial design. Pooled analysis of three years data revealed significant difference in growth and yield as well as water-use efficiency under stress and non-stress conditions. Moisture stress two and four months after planting resulted in reduction in leaf area index (-21 and -19%), number of tillers (-27 and -6%), root to shoot ratio (-60 and -43%), cormel to corm ratio (-69 and -53%), cormel yield (-58 and -28%), water-use efficiency (-32 and -36%) and increase in corm yield (+34 and +52%) respectively, compared to no stress. Drip irrigation for six months @ 100% ETc recorded optimum growth, cormel yield (21.08 tonnes/ha) with water-use efficiency (0.4 g/L) in upland condtion.

Key Words: Cormel yield, Drip irrigation, Water stress, Water-use efficiency

Taro or colocasia (*Colocasia esculenta* L. Schott) is mostly cultivated with monsoon rains, quite often needs supplemental irrigation using furrow system. Andhra Pradesh, Odisha, Uttar Pradesh, Madhya Pradesh, Telengana, North-eastern hilly areas are main states growing taro. Most of the varieties and land races are season insensitive and can be grown in any part of the year, provided sufficient soil moisture is assured. The information on its water needs, water-use efficiency and response under different water regimes at various stages of growth is limited. Therefore, an experiment was conducted to evaluate its yield and water-use efficiency under different water regimes under humid tropical conditions of India.

MATERIALS AND METHODS

Field trials were conducted during 2016- 2017, 2017-2018 and 2018-2019 at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, which lies between 8.54° North latitude and 76.91° East longitude with an altitude of 50 m above mean sea-level. The soil site was sandy clay loam having 62% sand, 10% silt and 28% clay content. The soil was acidic (pH 4.96), medium in available nitrogen (252 kg/ha) and potassium (188 kg/ha) and high in phosphorus (121 kg/ha).

The experiment was laid out as 3 × 4 factorial experiment in randomized block design, with factor 1 as the duration of irrigation and factor 2 as levels of drip irrigation, replicated three times. Three duration of irrigation were irrigation up to 2 months and stress from 3-6 months (D_1), irrigation for 4 months and stress from 5-6 months (D_2) and irrigation for 6 months without any stress (D_3). The four levels of drip irrigation were: 75 (I_1), 100 (I_2), 125 (I_3) and 150% (I_4) of crop water requirement (ETc). Improved variety, "Muktakeshi" having 6-7 months duration was used. Irrigation schedule was fixed based on reference evapotranspiration (ET_0) and the crop factor. Crop water requirement was calculated based on ET_0 and crop coefficient (Allen *et al.*, 1998).

Observations on number of days taken for first sprouting, and 50% sprouting, growth parameters, *viz.* plant height, number of tillers, number of leaves, and leaf area, total biomass production at senescence, yield and yield attributes (corm yield, cormel yield, total yield, average number and weight of cormels, and cormel to corm ratio) were recorded. Water-use efficiency (WUE) was recorded as the ratio of total

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plant dry biomass and total water used per plant, expressed in g/L (Ganança *et al.*, 2018).

The data over the seasons were pooled and analysed statistically, following SAS procedure (SAS, 2010) by applying the technique of Analysis of Variance (ANOVA) for Factorial experiment in RBD and multiple comparison of treatment means was done by least significant difference.

RESULTS AND DISCUSSION

During all the seasons, The cormels started sprouting almost uniformly, irrespective of treatment factors. On an average, crop took 23-29 days for initiating sprouting. Under different irrigation levels, irrigation at 75% ETc took 27.2 days for sprouting, though difference was not statistically significant. 50% sprouting was achieved 6-7 weeks after planting in all treatments (Fig. 1). The 125% ETc resulted in better and early sprouting. Drip irrigation ensures smaller percentage of wetted surface to save water (Unlu *et al.*, 2006) which in turn would hasten sprouting with adequate moisture near the plant zone. Rate of emergence may vary with different levels of drip irrigation (Mabhaudhi *et al.*, 2013). It is also reported that under dry land conditions Taro takes about 70 days for emergence (Mare, 2010).

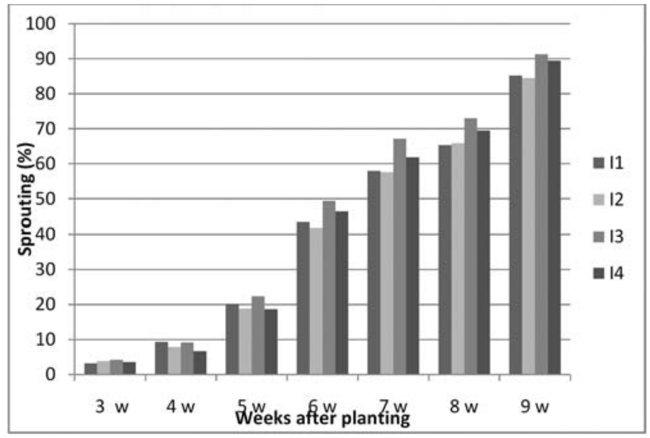

Fig. 1: Sprouting of taro cormels under different irrigation levels

The height, number of leaves and leaf area were more under higher levels of irrigation, but were statistically insignificant with lower levels. However, growth significantly reduced due to stress after two and four months. There was no significant difference in height, number of leaves or leaf area indices among irrigation levels in any of the season. Number of tillers were statistically higher in 150% ETc 4 and 5 months after planting, however, 6 months, number was high in 75% ETc, as the plants started senescence. The LAI

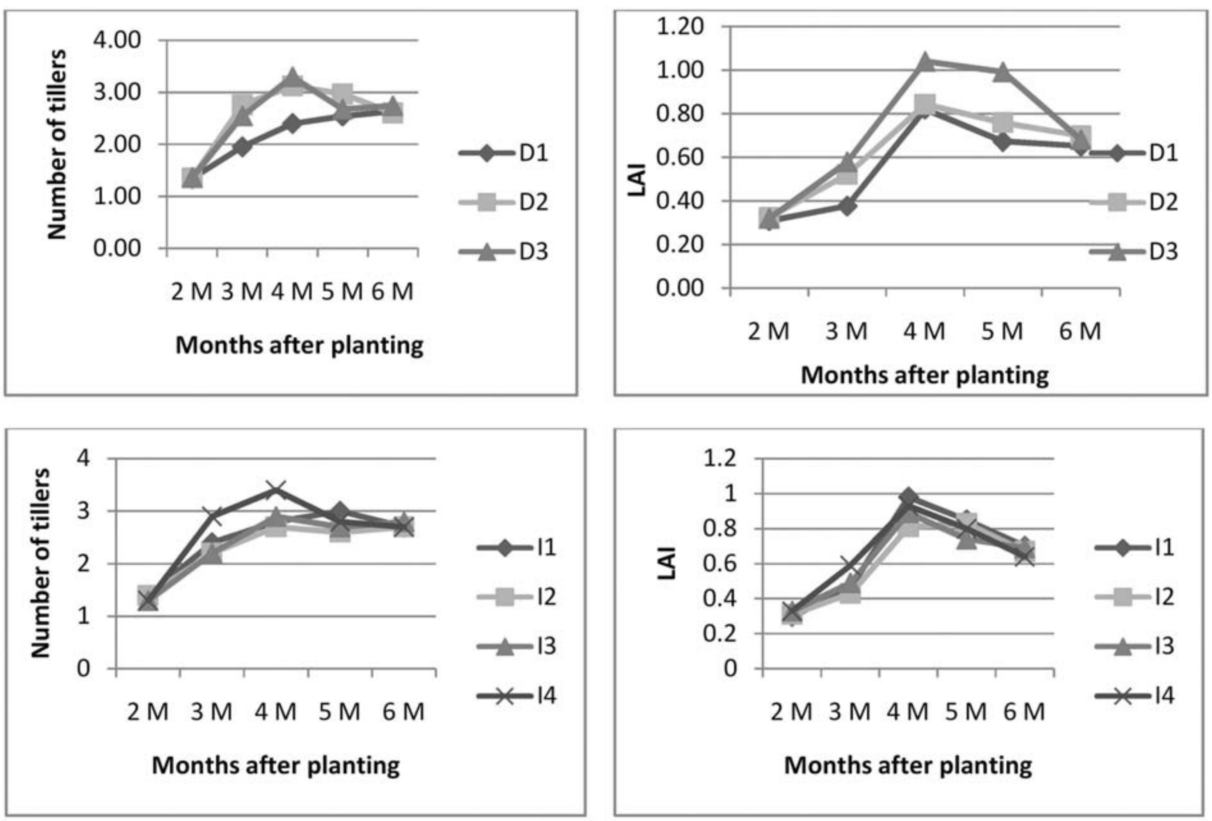

Fig. 2: Number of tillers and leaf area index under different duration and levels of irrigation

was maximum with D_3 and I_4 2, 3 and 4 months after planting. At 5 and 6 months, maximum LAI was recorded by D_3 at I_1 level of irrigation, but was on a par with other irrigation levels (Fig. 2).

Reduced growth in taro with limited water availability was reported by earlier workers (Mabhaudhi *et al.*, 2013). As the initial leaves started drying towards physiological maturity, decrease in plant height was noted in all the treatments. Water stress also resulted in reduced number of leaves subsequently as a result of premature senescence as reported by Mabhaudhi *et al.* (2013). Under drought, reduced growth and biomass production in taro as a mechanism for drought avoidance is reported (Gouveia, *et al.*, 2020). Under unstress conditions, leaf number and LAI increased gradually and reached the peak at 5 months after planting depicting the importance of moisture almost throughout the life-cycle. Similarly increase in LAI values with sufficient soil moisture is reported in taro by Manyatsi *et al.* (2011). In potato, the most sensitive stages of water stress is reported as vegetative and tuberization stage (Cameron *et al.*, 2021), having negative impact on crop.

Biomass partitioning at senescence indicated clear difference among duration of irrigation, not with irrigation levels. Cormel yield ranged from 11.5 to 69.9 g from D_1 to D_3 on dry weight basis. There was an increase of 1.4 and 5 times the dry matter yield of cormels under no stress compared to stress for two and four months (Fig. 3). Cormel yield constituted 47, 62 and 74% of total biomass under D_1, D_2 and D_3 respectively.

Root: shoot ratio increased from 7.9 to 20 from D_1 to D_3. Among the irrigation levels, there was no statistical variation (10-12.7). Root-shoot ratio depicts the plant's ability to maintain dynamic balance between functionally interdependent organs such as corm + cormel and the shoot. A lower ratio indicates an increase investment in shoot development due to stress. Adequate soil moisture assured decrease in shoot growth, efficient translocation of starch to corms and cormels, in detriment to underground parts. Such a

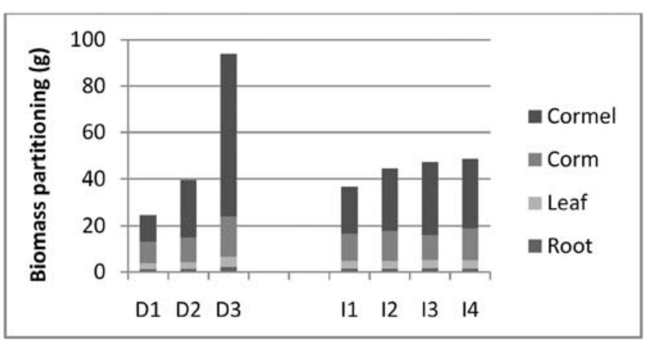

Fig. 3: Biomass partitioning under different treatments

decrease in root-shoot ratio in taro accessions under drought has been reported (Gouveia, *et al.*, 2020).

Number of cormels increased by 65% and 94% as the crop was irrigated up to 4 months (D_2) and 6 months (D_3) respectively, compared to 2 months (D_1). However, a corresponding increase was not noted with increasing levels of irrigation, I_1 to I_4. Drip irrigation at 75% ETc produced maximum number of cormels per plant (22.11) and irrigation at 150% ETc resulted in minimum number of cormels (14.44).

Average cormel weight per plant ranged from 5-26.5 g among the treatment combinations which showed significant difference among duration of irrigation as well as levels of irrigation. Plants without any stress after two and four months resulted in significantly more average cormel weight per plant and were 31 and 35% superior compared to irrigation up to 2 months, which has undergone stress after two months growth. Average cormel weight was maximum with irrigation at 150% ETc (18.13 g) and minimum with 100% ETc (13.43 g). Similar production of larger tubers with fully irrigated crop and water shortage leading to more number of smaller tubers and less tuber yield is common in potato also (Mattar *et al.*, 2021).

Cormel to corm ratio was minimum when the crop was under stress after two months and the highest with irrigation at 125% ETc for 6 months. Corm yield was almost double the cormel yield, when stress was imposed after two months. Corm yield and cormel yield were almost equal when stress was imposed after four months. Unstressed plants resulted in almost double the cormel yield than corm yield. However, there was no significant variation in cormel to corm ratio among the drip irrigation levels.

Moisture stress resulted in the production of more mother corm yield than cormel yield. The highest corm yield was recorded when stress was imposed after 4 months, on par with stress after 2 months. There was 34 and 52 % increase respectively in mother corm yield with stress after two months and four months compared to unstressed plants. Among the irrigation levels, corm yields were more with lower levels of irrigation (ETc 75 and 100%), but the effects were not significant.

There was a corresponding increase in cormel yield when irrigation was given up to six months, followed by irrigation upto four months and two months in all the seasons. Pooled data analysis showed comparable cormel yields under all the irrigation levels. No stress (D_3) produced 140% and stress after four months (D_2) produced 41% more cormel yield, compared to stress after two months of planting (D_1) (Fig. 4). The interaction effect of D_3I_2 recorded the highest cormel yield, at par with other higher irrigation levels.

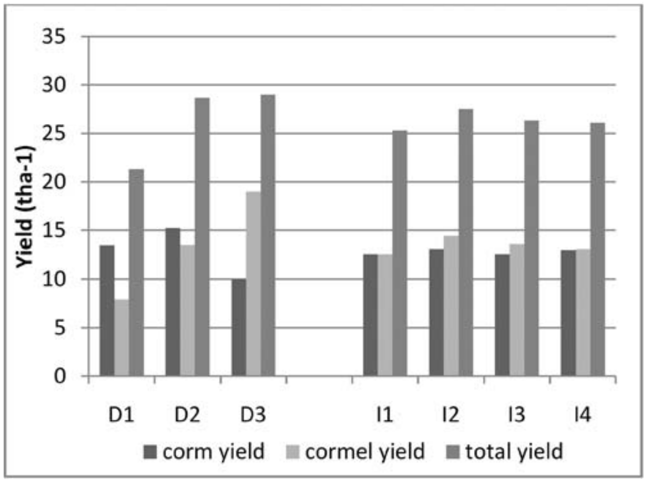

Fig. 4: Yield of taro under different durations and levels of irrigation

Similarly, the total yield per ha (mother corm + cormel yield) also varied with moisture stress, the maximum being recorded for irrigation for six months without any stress, followed by stress after four months and two months.

In all the seasons, the cormel yield was above the word average of 5.39 t / ha and slightly above the Asian average of 16.5 t / ha^{-1}. Low land production systems and the upland production supplemented with irrigation is a must for realising good yield in taro. Irrigation would be beneficial for taro production in drier months as well as low rainfall areas as reported by Bussel and Bonin, (1998). In field experiment in taro with different irrigation water levels of 50, 75 and 100% ETc, ETc at 50% recorded the highest reduction in terms of vegetative growth, yield characteristics, yield and bio constituents compared to 75% of ETc level and unstressed plant (100% of ETc) (Abd El Aal *et al.*, 2019). In yet another study, *in-situ* moisture conservation methods tested influenced soil water availability and subsequent vegetative growth and yield of taro under upland conditions (Manyatsi, *et al.*, 2011).

Inducing stress after two months of planting reduced the water use efficiency (0.32 g / L) and there was 47% increase in WUE with no stress. Increasing levels of irrigation resulted in decrease in WUE from 0.36 to 0.28 g / L, as there was no corresponding increment in total plant biomass with the higher level of water used. Lower levels of drip irrigation resulting in higher WUE in taro are reported (Vieira *et al.* 2018). It is also reported that drought tolerant taro accessions can increase or maintain WUE, resulting in a small decrease in total biomass and yield (Ganança *et al.*, 2018; Gouveia *et al.*, 2019).

Taro when cultivated under upland conditions, require continuous soil moisture up to six months. Soil moisture stress after two months of vegetative establishment led to more mother corm yield and stress after two and four months caused 58 and 28 % reduction in cormel yield compared to unstressed conditions. Though different drip irrigation levels did not record much variation in growth and yield, irrigation at 100% ETc was found optimum for highest cormel yield and water use efficiency under upland conditions.

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Evaluation of coconut *(Cocos nucifera)* for tender nut quality in Maidan tracts of Karnataka

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ABSTRACT

Evaluation of coconut (*Cocos nucifera* L.) varieties for growth and tender nut quality was carried out at Horticulture Research and Extension Centre (UHS, Bagalkot), Arsikere, Karnataka. The highest palm height (2.35 m) was recorded in Kalpa Dhenu, whereas it was lowest (1.22 m) in COD at the age of nine years. Palm girth (101.78) and leaf length (4.73 m) were maximum in variety Kalpatharu. Higher amount of tender nut water (605 ml/nut) in Kalpa Dhenu, whereas, Gautami ganga (551.7 ml/nut) and COD (520 ml/nut) had optimum quantiy of water. Gauthami Ganga recorded highest TSS (6.1°Brix) and lowest titrable acidity (0.05%). COD recorded maximum total sugars (6.79 g/100 ml) and lowest acidity (0.05%). Gauthami Ganga had optimum quantity of mineral content (61.47 mg/100 ml calcium, 10.87 mg/100 ml magnesium, 2023.33 ppm potassium and 23.33 ppm sodium). Organoleptic evaluation indicated that Gauthami Ganga (8.5) and COD (7.23) were the best for tender nut purpose as both of them ranked good for taste of water.

Key Words: Tender nut, Organoleptic, Mineral content, Plant height, TSS, Bevarage

Coconut (*Cocos nucifera* L.) is a monocotyledonous palm. Tender coconut water is a refreshing and hydrating drink. It has a unique composition of vitamins, minerals, amino acids, phytohormones and sugars. Chemical composition and volume of nut water change during maturation (Jayalakshmi *et al.*, 1986). Quality and quantity of coconut water as well as consumer acceptability of tender nut is more at 7 months of maturity (Sudarsana Rao *et al.*, 2008). Evaluationof varieties suitable for tender nut is an important area in the circumstances of importance of natural beverages in recent pasts. Research work on evaluation of recently released varieties suitable for tender nut purpose is meagre and hence this study was undertaken to see the performance of different varieties for tender nut quality in maidan tracts of Karnataka.

MATERIALS AND METHODS

The experiment was conducted at Horticulture Research and Extension Centre, Arsikere, (UHS, Bagalkot) during 2020-2021. The material consisted of 10 varieties, *viz.* Kera Keralam, Kera Bastar, Konkan Bhatye Coconut Hybrid-1, Kalpa Dhenu, Kalpa Pratibha, Kalpa Mitra, Kalyani Coconut-1, Kalparaksha, Gauthami Ganga and Chowghat Orange Dwarf with the control variety Kalpatharu of nine-year-old palms. The randomized complete block design with three replications was used. The varieties were planted at a distance of 7.5 m × 7.5 m. Recommended package of practices were followed for all the varieties. The palm height and girth were recorded from April 2021 to April 2022 and number of functional leaves, total leaf length, petiole length and number of leaflets were recorded during April 2021. The tender nut samples were randomly selected from each replication at the age of seven months.

The TSS was recorded with portable refractometer and pH of nut water was determined with digital pH meter. The total free sugars were calculated using a calorimeter and nitrogen estimation by Lowry's method. Minerals like potassium and sodium were estimated using a flame photometer. Phosphorus was determined using spectrophotometer. Calcium and magnesium levels in tender nut water were measured using an atomic absorption spectro-photometer

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(Tondon, 1993). With the use of a nine-point hedonic scale (Amerine *et al.*, 1965) for overall acceptability, a sensory evaluation of tender coconut water of different varieties was carried out by a 10-member semi-trained panel.

RESULTS AND DISCUSSION

There was significant difference in palm height and palm girth at one year intervals. The maximum palm height (2.35 m) was observed in Kalpa Dhenu, followed by Kera Bastar (2.01 m) during October 2020. The lowest palm height (1.22 m) was recorded in COD. During October 2021, maximum palm height (2.45 m) was recorded in the Kalpa Dhenu, followed by Kera Bastar (2.11 m) and minimum palm height in COD (1.29 m). There was an increase in 0.10-0.07 m (7-10 cm) length in palm height during one year. The results are in conformity of Bhalerao *et al.* (2016), Ramanandam *et al.* (2018), Tripura *et al.* (2018) and Mohanalakshmi and Arunkumar (2019).

During October 2020, highest palm girth (101.78 cm) was recorded in Kalpatharu, whereas lowest palm girth (74.55 cm) was recorded in COD. During October 2021, maximum palm girth (102.01 cm) was recorded in Kalpatharu and lowest in COD (74.75 cm). There is an increment of 0.18-0.46 cm in palm girth. Similar results were obtained by Tripura *et al.* (2018) and Nath *et al.* (2017).

The number of leaves was maximum in Gauthami Ganga (22.4) and lowest number in COD (20.2). The maximum leaf length (4.73 m) was in Kalpatharu, whereas Gowthami Ganga recorded least length (3.98 m). The highest petiole length was recorded in Kalpa Dhenu (154.78 cm), whereas COD recorded least petiole length (119.56 cm). Similar findings were also reported by Nath *et al.* (2017), Ghoshand Bandopadhyay (2015) and Ramanandam *et al.* (2018).

Tender nut water content was significantly highest in Kalpa Dhenu (605 ml) and lowest in Kalyani Coconut-1 (325 ml). Apshara *et al.* (2007) reported the large quantity of nut water in COD (358.8 ml), followed by COD × WCT (347.2 ml). Similar findings were also reported by Poduval *et al.* (1998) and Mali *et al.* (2004).

The TSS of tender nut water was maximum in Gauthami Ganga (6.1°Brix), followed by COD (5.77°Brix) (Table 1). The synthesis and accumulation of sugars could cause an increase in TSS in tender nut water. However, Kalyani Coconut-1 recorded the lowest TSS (3.9°Brix). According to Nandanasabapathy and Kumar (1999), TSS was maximum in Chowghat Green Dwarf (5.17°Brix), followed by Chowghat Orange Dwarf (4.90°Brix) and minimum in Tiptur Tall (4.56°Brix). Ghosh and Bandopadhyay (2015) also reported similar findings of TSS in tender water.

Table 1. Performance of coconut varieties with respect tender nut water

Treatment	Volume of water (ml/nut)	TSS (°Brix)	pH	Titrable acidity (%)	Total sugars (g/100 ml)	Protein (%)	Phosphorous (mg/100 ml)	Sodium (ppm)	Potassium (ppm)	Calcium (mg/100 ml)	Magnesium (mg/100ml)
T_1: Kera Keralam	448.3	5.10	4.91	0.07	4.82	0.91	11.81	22.63	2099.00	63.20	12.53
T_2: Konkan Bhatye Coconut Hybrid-1	300.0	5.50	4.87	0.05	4.93	0.77	7.79	22.63	2110.00	63.47	10.30
T_3: Kera Bastar	500.0	4.60	4.83	0.07	5.14	0.99	10.54	21.53	2072.33	62.60	12.30
T_4: Kalpatharu	401.7	4.90	4.76	0.08	5.18	1.04	7.34	32.53	2933.33	73.40	12.87
T_5: Kalpa Dhenu	605.0	5.10	4.99	0.06	5.05	0.99	11.05	24.53	2659.00	47.60	12.63
T_6: Kalpa Pratibha	416.7	3.90	4.74	0.11	5.76	0.97	8.41	21.37	2149.33	64.77	21.63
T_7: Kalpa Mitra	426.7	5.20	4.92	0.06	6.00	1.01	12.10	23.77	2134.67	65.40	8.53
T_8: Kalyani Coconut -1	325.0	3.90	4.89	0.11	4.80	0.98	9.97	27.03	2343.33	63.10	8.86
T_9: Kalparaksha	300.0	4.60	4.88	0.08	4.57	0.95	13.88	19.60	2103.33	62.40	10.13
T_{10}: Gauthami Ganga	551.7	6.10	4.98	0.05	6.67	1.03	7.56	23.33	2023.33	61.47	10.87
T_{11}: COD	520.0	5.70	4.95	0.05	6.79	1.00	13.37	20.37	2009.33	61.73	11.00
SEm±	50.81	0.14	0.01	0.01	0.21	0.02	0.61	0.60	7.27	0.87	0.42
CD @ 5%	149.88	0.42	0.03	0.02	0.61	0.06	1.80	1.77	21.45	2.55	1.24
CV (%)	20.19	5.00	0.31	17.38	6.62	3.86	10.19	4.42	0.56	2.39	6.08

Maximum pH (4.99) was recorded in Kalpa Dhenu and minimum was recorded in Kalpa Pratibha (4.74). The highest titrable acidity was recorded in Kalpa Pratibha and Kalyani Coconut-1 (0.11%), whereas the lowest titrable acidity was recorded COD (0.05%) (Table 1). Similar results were reported by Sahoo et al. (2021), that the tender nut water content was maximum in hybrid GBGD × PHOT (362.0 ml / nut) and minimum in ECT (257.7 ml / nut). The TSS was maximum in ECT × GBGD and LCT × GBGD (6.9° Brix). Similar findings were also earlier reported by Apshara *et al.* (2017) and Tripura *et al.* (2018).

Total sugar content was maximum in COD (6.79 g / 100 ml) and the minimum values were recorded in Kalparaksha (4.57 g / 100 ml) (Table 1). Dhamodaran et al. (1993) also had observed the highest total sugar value (7.09 g / 100 ml) in COD and the lowest in Fiji Longtongwan (4.9 g / 100 ml). Similar findings were reported by Tripura *et al.* (2018). Kalpatharu recorded significantly higher protein content (1.04%), while lowest was found in Konkan Bhatye Coconut Hybrid-1 (0.77%). The maximum phosphorous content in tender nut water was noticed in Kalparaksha (13.88 mg / 100 ml), whereas, minimum was in Kalpatharu (7.34 mg / 100 ml). According to Mali *et al.* (2004) amongst the hybrids, T × D showed maximum phosphorous content (15.76 mg / 100 ml). The results were similar to the findings reported by Poduval *et al.* (1998) and Nakum *et al.* (2009).

The maximum sodium content was noticed in variety Kalpatharu (32.53 ppm), while, minimum was in Kalparaksha (19.6 ppm). Maximum and minimum value for potassium was recorded in Kalpatharu (2933.33 ppm) and COD (2009.33 ppm), respectively. Generally, less to optimum levels of sodium and potassium content were preferred for best tender nuts. According to Dhamodaran *et al.* (1993), potassium was minimum in COD (2003 ppm) and maximum in WCT (2797 ppm). The lowest level of sodium was recorded in COD (20 ppm) and maximum was recorded in Spikeless (38 ppm) (Mali *et al.* (2004). Kalpatharu and Kalpa Dhenu recorded highest (73.4 mg / 100 ml) and lowest (21.15 mg / 100 ml) calcium content, respectively. Kalpa Pratibha recorded significantly highest magnesium content (21.63 mg / 100 ml), whereas, it was minimum in Kalpa Mitra (8.53 mg). Similar findings were also reported by Mali *et al.* (2004); Nakum *et al.* (2009).

The highest score for tender nut water was recorded in Gauthami Ganga (8.5), ranking extremely good, followed by COD (7.23) and Kalpa Mitra (7). The lowest score (4.83) was recorded by Kalpa Pratibha. The taste of nut water, which is a result of sugar content and TSS can be attributed to its overall acceptability. According to Nandanasabapathy and Kumar (2009) highest organoleptic score was attained by COD, followed by MYD (Mali *et al.*, 2004).

CONCLUSION

Thus, Gauthami Ganga and COD performed well for tender nut quality with dwarfness. Hence, these are suitable for cultivation in maidan tracts of Karnataka.

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Analysis of benefit: cost ratio in drip irrigation and fertigation in greater yam *(Dioscorea alata)* + maize *(Zea mays)* intercropping system

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ABSTRACT

A field experiment was conducted at Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2015-16 and 2016-17 to study drip irrigation and fertigation in greater yam (*Dioscorea alata* L.) + maize (*Zea mays* L.) intercropping system. The treatments I_2F_4 and I_2F_3 resulted in 31.8 and 29.9% higher tuber equivalent yield, respectively than the control. Drip irrigation increased fertilizer responsiveness in greater yam + maize intercropping system. However, response to fertilizer was higher under partial deficit irrigation. Thus 20% more fertilizers can be recommended under drip fertigation than surface irrigation with soil application. Drip irrigation reduced cost on weeding and irrigation. The total cost reduction (excluding capital cost, harvesting and threshing) was about 8.3% (₹ 11,500 / ha) and 7.1% (₹ 9,900 / ha) due to drip irrigation at I_1F_2 and I_2F_2, respectively compared to surface flood irrigation at the same level of fertilizer application (control). The gross and net returns in treatment I_1F_2 were 5.2 and 3.1% higher, respectively than the control, saving 21.2% irrigation water. The treatment I_3F_2 resulted in 21.1 and 24.7% higher gross and net returns, respectively than the control. Thus, drip fertigation increased water- and fertilizer-use efficiency (20%).

Key Words: Tuber equivalent yield, Gross return, Net return, Intercropping, Fertigation, Drip irrigation

Greater yam (*Dioscorea alata* L.) + maize (*Zea mays* L.) intercropping system is getting popular in irrigated areas due to its higher productivity and returns. However, providing surface flood irrigation and top dressing of fertilizer to greater yam + maize intercropping system at later stage of crop growth period (after 4 months) is difficult due to drying and lodging of maize and coverage of ground by greater yam crop (Nedunchezhiyan *et al.*, 2021a). Irrigation efficiency in drip irrigation is as high as 90% compared to 30-50% in surface irrigation. However, when irrigation water priced, surface flood irrigation become is costlier. Also, additional costs are incurred for weeding and frequent irrigations (Gangaiah *et al.*, 2019). Drip fertigation results in 25-50% savings in fertilizer dose and increase in productivity of 50-75% in coconut (Maheswarappa and Krishnakumar, 2019). Nedunchezhiyan *et al.* (2018) and Bhargavi *et al.* (2019) also reported similar report. Hence, keeping in view, an experiment was conducted to evaluate the benefit: cost ratio of drip irrigation and fertigation in greater yam + maize intercropping system.

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MATERIALS AND METHODS

A field experiment was conducted at Regional Centre, ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2015-16 and 2016-17 on alfisols. The location is characterized by a hot and humid summer, and a cool and dry winter. The soil (top 0.30 m) was having pH 6.8, organic carbon 0.39%, and available N (196 kg / ha), P (21.4 kg / ha) and K (265 kg / ha). The experiment was conducted in split plot design with three replications. The main and sub-plots treatment consisted of three drip irrigation [I_1- at 80% of cumulative pan evaporation (CPE) during 1-270 days after planting (DAP), I_2-at 100% of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP and I_3-at 100% of CPE during 1-270 DAP] and four fertigation [F1- N-P_2O_5-K_2O 100-90-100 kg / ha, F_2- N-P_2O_5-K_2O 120-90-120 kg / ha, F_3- N-P_2O_5-K_2O 140-90-140 kg / ha and F_4- N-P_2O_5-K_2O 160-90-160 kg / ha], respectively.

A control (surface irrigation at 100% of CPE; soil application of N-P_2O_5-K_2O 120-90-120 kg / ha) was also included to compare drip irrigation and fertigation treatments. Water soluble N, P and K fertilizers (urea, urea phosphate and potassium sulphate) applied in five equal splits (basal, 30, 60, 90 and 120 DAP) through drip irrigation. In control, full dose of P_2O_5 (single superphosphate) was applied as basal. The N (urea) and K (muriate of potash) were applied in three split applications, basal (40%), 45 DAP (30%) and 90 DAP (30%). Drip irrigation on alternate days and surface irrigation once every seven days were given as per treatment based on CPE considering pan factor 0.7.

Ridges were formed at 90 cm distance and 200 g cut tubers of greater yam variety 'Da 293 (Sree Nidhi)' were planted at 90 cm spacing on ridges. On the same day hybrid maize 'MRM 3777' seeds were sown at 30 cm spacing in between two greater yam plants in the intra-rows. Maize cobs were harvested 3 months after planting (MAP) and left the haulms in the field. Prior to harvesting of greater yam (290 DAP), irrigation was withheld 20 days before.

The tuber equivalent yield (TEY) data was computed taking into the consideration of selling price of maize seeds and greater yam tubers along with their yield. The effective rainfall was calculated as per Reddy and Reddi (2010). During cropping season 2015-16, it was 439, 396 and 396 mm at I_1, I_2 and I_3, respectively. During 2016-17, it was 470, 448 and 441 mm at I_1, I_2 and I_3, respectively. The amount of water applied through drip irrigation was 383, 432 and 451 mm at I_1, I_2 and I_3, respectively during first season. The amount of water applied through drip irrigation was 274, 301 and 345 mm at I_1, I_2 and I_3, respectively during second season. During first and second cropping season, 451 and 345 mm of water, respectively was applied in the control treatment.

The data were analyzed in a randomized block design using SAS statistical software (SAS, 2010). The homogeneity of error variance was tested using Bartlett's χ^2-test. As the error variance was homogeneous, pooled analysis of two years data was done. Comparison of treatment means for significance at 5% level of probability was done using the critical differences (CD) as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The tuber equivalent yield was increased with increasing level of drip irrigation and fertilizers but decreased at highest level of drip irrigation (I_3) (Fig. 1). The treatment I_2F_4 resulted in maximum tuber equivalent yield and it was followed by I_2F_3. This was due to higher maize and greater yam yield (Fig. 1). The treatments I_2F_4 and I_2F_3 resulted in 31.8 and 29.9% higher tuber equivalent yield, respectively than the control. Similarly, the treatments I_3F_4 and I_3F_3 resulted in 24.7 and 21.1% higher tuber equivalent yield, respectively than the control. The marginal decline in tuber equivalent yield at higher drip irrigation level might be due to more vegetative growth.

Higher tuber equivalent yields at higher level of fertilizer application indicated that with drip irrigation, fertilizer responsive-ness of the greater yam + maize intercropping system can be increased. Increasing 16.6% N and K_2O fertilizers increased 21.1-29.9% tuber equivalent yield, whereas 33.3% increasing N and K_2O fertilizers increased 24.7-31.8% tuber equivalent yield under drip irrigation than the recommended soil application. This also indicated that response to fertilizer was higher under partial deficit irrigation. Sunitha *et al.* (2016) also observed similar results in cassava. Drip fertigation is considered to be most efficient in improving the yield (Behera *et al.*, 2013).

Cost of cultivation was calculated for various treatments. Cost of irrigation (both labour and other costs) was substantially less under drip irrigation because of the requirement of labour was less and water saving was high, and it substantially reduced the working hours of pump-set which extensively reduced the cost on electricity. The cost of irrigation (excluding capital cost) to the cost of cultivation was 2.9 and 3.1% under I_1F_2 and I_2F_2, respectively compared to 9.2% under the control. The operation-wise cost of cultivation clearly pointing out that cost reduction was high in operations like weeding and irrigation under drip irrigation.

The total cost reduction (excluding capital cost, harvesting and threshing) was about 8.3% (Rs. 11,500/ha) and 7.1% (Rs. 9,900/ha) due to drip irrigation at I_1F_2 and I_2F_2, respectively when compared to surface flood irrigation at same level of fertilizer application (control). The harvesting and threshing cost excluded

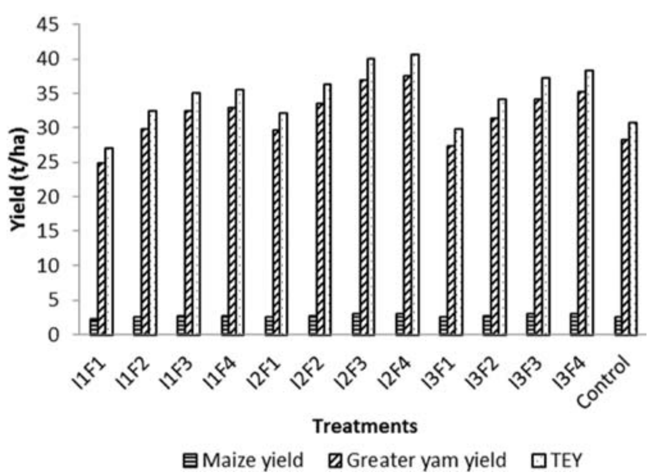

Fig. 1: Yield of greater yam + maize intercropping system under drip irrigation and fertigation [CD (0.05): maize 0.1; greater yam 2.4; TEY 2.4]

because it was influenced by system productivity. Bhargavi *et al.* (2019), Gangaiah *et al.* (2019) and Nedunchezhiyan *et al.* (2021 b) also reported that weeding and frequent irrigation was expensive under surface flood irrigation.

The gross and net returns were increased with increasing level of drip irrigation and fertilizers but decreased at highest level of drip irrigation (I_3) (Fig. 2). The treatment I_2F_4 and I_2F_3 resulted in higher gross and net returns. This was due to higher yields in these treatments (Fig. 1). The treatments I_2F_4 and I_2F_3 resulted in 31.8 and 29.9% higher gross return, and 40.2 and 38.2% higher net return, respectively than the control. This higher gross and net income is purely because of yield effect though cost of cultivation was higher due to capital cost of drip irrigation. Similar result in sugarcane was reported by Narayanamoorthy (2005). Similarly, the treatments I_3F_4 and I_3F_3 resulted in 24.7 and 21.1% higher gross return, and 29.1 and 24.7% higher net return, respectively than the control. The marginal decline in gross and net return at higher drip irrigation level was might be due to lower yield (Fig. 1).

The tuber equivalent yield in treatment I_1F_2 was found near to the control among all the treatments (Table 1). Irrigation water applied in this treatment was 69.5 mm lesser than the control (Table 1) which saved 21.2% water, *i.e.* 0.21 ha additional area of greater

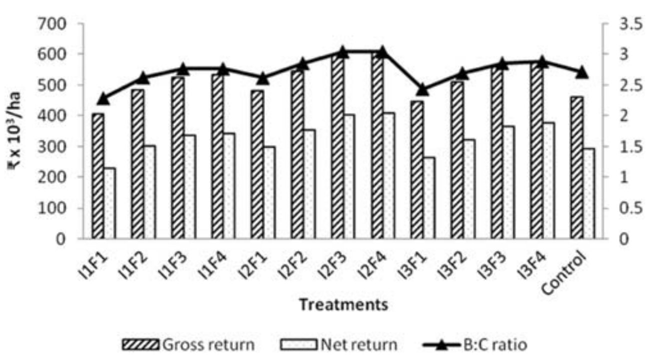

Fig. 2: Economics of greater yam + maize intercropping system under drip irrigation and fertigation[CD (0.05): gross return 21.2; net return 19.5; B:C ratio 0.14]

yam + maize intercropping can be irrigated. The fertilizers applied in both the treatments were equal ($N-P_2O_5-K_2O$ 120-90-120 kg/ha). The gross and net returns in the treatment I_1F_2 were 5.2 and 3.1% higher respectively than the control (Table 1).

The benefit: cost (B:C) ratio was marginally declined due to higher cost of cultivation owing to capital cost of drip system. Maheswarappa and Krishnakumar (2019) reported that among the irrigation methods, drip irrigation is the best, which ensures water saving without affecting productivity. Further, application of fertilizer through drip system (fertigation) resulted in increased fertilizer-use efficiency and savings in fertilizer dose 25 to 50%. Nedunchezhiyan *et al.* (2016) also reported similar report in elephant-foot yam.

In treatments I_3F_2 and control, same level of water (398 mm) and fertilizer ($N-P_2O_5-K_2O$ 120-90-120 kg/ ha) were applied (Table 2). The former was through drip and fertigation, and the latter was on surface and soil. In treatment I_3F_2 resulted in 21.1% higher tuber equivalent yield than the control (Table 2). Singh and Singh (2021) reported that 57.1% higher yield in soybean under drip fertigation over conventional furrow-irrigated crop with soil application of fertilizers. Nedunchezhiyan *et al.* (2022) also reported higher yield in tuber crops under drip fertigation than surface irrigation with soil application of fertilizers. The gross and net returns in the treatment I_3F_2 were 21.1 and 24.7% higher respectively than the control. The cost of cultivation was higher in treatment I_3F_2 than the control (Table 2) owing to high capital cost of drip system and harvesting and threshing cost. The B:C ratio of the treatment I_3F_2 was 5.1% higher than the control in-spite of higher cost of cultivation (Table 2). Nedunchezhiyan (2017) and Sunitha *et al.* (2018) also reported higher B:C ratio under drip fertigation than soil application in elephant-foot yam.

CONCLUSION

When same quantity of water and fertilizer was applied through drip, it increased 21.1% higher tuber equivalent yield, 21.1 and 24.7% higher gross and net

Table 1. Comparison of drip fertigation vs control at same level of greater yam+maize intercropping system yield

Particulars	Treatment (I_1F_2)	Control
Tuber equivalent yield (t/ha)	32.4	30.8
Irrigation water application (mm)	328.5	398.0
Fertilizer application ($N-P_2O_5-K_2O$ kg/ha)	120-90-120	120-90-120
Cost of cultivation (₹ × 10^3/ha)	184.9	170.0
Gross return (₹ × 10^3/ha)	486	462
Net return (₹ × 10^3/ha)	301.1	292
B:C ratio	2.63	2.72

Table 2. Comparison of drip fertigation vs control at same level of water and fertilizer application in greater yam+maize intercropping system

Particulars	Treatment (I_3F_2)	Control
Tuber equivalent yield (t/ha)	37.3	30.8
Irrigation water application (mm)	398.0	398.0
Fertilizer application (kg/ha)	120-90-120	120-90-120
Cost of cultivation (₹/ha)	195.4	170.0
Gross return (₹/ha)	559.5	462
Net return (₹/ha)	364.1	292
B:C ratio	2.86	2.72

returns, respectively than soil application. When same quantity of fertilizer was drip fertigated, it saved 21.2% water and resulted in 5.2 and 3.1% higher gross and net returns, respectively. Thus, drip fertigation increased water and fertilizer-use efficiency 20%.

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Short Communication

Current Horticulture **11**(1): 61–63, January–April 2023

Effect of salt stress on seed and seedling characters of tomato *(Lycopersicum esculentum)* genotypes

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To alleviate the deleterious effects of salinity, reclamation of salinized lands, improvement of irrigation with saline water and the cultivation of salt-tolerant variety have been applied. The positive changes as crop cultivars, local climate, soil nutrients, type of salt, salinity levels, irrigation methods and water management practices (Datta *et al.*, 2015). However, information on effect of salinity on seed germination, shoot length, root length, seedling length, vigour index etc. is limited. Therefore, experiment was conducted to evaluate tomato genotypes with different concentration of NaCl.

The experiment was conducted to find out the effect of salt stress on tomato (*Lycopersicum esculentum* L.) yield at HC & RI, TNAU, Coimbatore during 2018-19. The 38 genotypes were germinated under moderate salinity level of 80 mM. The highest seed germination percentage (66.66%), shoot length (6.60 cm) and root length (7.70 cm), highest seedling length (13.56) and seedling fresh weight (0.247) were observed in LE-14 respectively. The lowest seed germination and seedling parameters were recorded in Pharna Baskar under moderate saline condition. The seven level of salinity treated (0 mM to 120 mM) tomato genotypes, seed germination, seedling parameters well in moderate saline level (80 mM) and least performance were observed in 100 m and 120 mM respectively.

The germination and seedling studies were imposed under roll towel method under laboratory condition. The salt concentration levels of T_1-0 mM, T_2-20 mM, T_3-40 mM, T_4-60 mM, T_5-80 mM, T_6-100 mM and T_7-120 mM with three replication were used. Seeds were kept under different salt concentration. The observations were recorded after 15 days on seed germination and seedling parameters. The data were statistically analyzed in a randomized block design and ANOVA tables was only considered significant at $p < 0.05$.

There were significant variation in different salt concentrations in all genotypes. Seed germination ranged from 93.33% (0 mM) to 6.66% (120 mM) 50 genotypes. Nasrin and Abdul Mannan, (2019) recorded similar results among 50 genotypes only 38 genotypes were germinated under moderate salinity level of 80 mM. Highest germination was recorded (66.66%) in LE-14 followed by EC-88783 (62.22%) in 80 mM. The moderate NaCl concentrations decreased in seed germination in 12 genotypes. At higher salt concentration, only a few genotypes were able to germinate with low percentage. The seed germination percentage was high in low salt concentration and drastically declined when concentration increased. The genotypes which are least affected may be potential source of salinity tolerance for breeding. The effect of external salinity on seed germination may be partially osmotic or ion toxicity, which can alter physiological processes such as enzyme activities.

The result showed that, per se performance of shoot length LE-14 was recorded 5.67% (T_1), 7.80% (T_2), 5.83% (T_3), 6.30% (T_4), 6.60% (T_5), 4.20% (T_6) and 0.0 (T_7). Among 38 genotypes, highest shoot length (6.60 cm) was observed LE-14, followed by LE-1020 (5.67 cm) and LE-1 (4.83 cm) and the lowest shoot length was observed in Pharna Bhaskor (0.17 cm) and P-1 (0.27 cm). The combined effect of genotypes and salinity levels showed also significant variation in of shoot length. Similar results were obtained by Nasrin and Abdul Mannan, (2019). The lowest shoot length was recorded in Punjab Bagkoa (0.70 cm) in 120 mM.

The root length in LE-14 was recorded 7.77 cm (T_1), 3.07 cm (T_2), 5.50 cm (T_3), 8.57 cm (T_4), 7.70 cm (T_5), 5.97 cm (T_6) and 5.90 cm (T_7). Among 38 genotypes highest root length was observed LE-14 (7.70 cm) under moderate salinity followed by LE-1020 (7.43 cm) IIVR-

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Table 1. Salinity level of 80 mM to influence germination and seedling characters of tomato genotypes

Genotype	Seed germination (%)	Shoot length (cm)	Root length (cm)	Seedling length (cm)	Vigour index
LE-1	46.66	6.60	6.97	9.90	645.1
Angarlata	31.11	2.93	2.37	8.80	162.9
EC-163606	6.66	1.80	3.70	13.10	36.9
ArkaAbhay	11.11	3.50	2.63	0.00	67.3
EC-164863	4.44	1.73	2.77	13.57	30.0
LCR-2	11.11	1.23	1.93	6.00	21.1
P-1	4.44	0.27	0.17	7.97	3.1
Kashi	0.00	0.00	0.00	6.93	0.0
CLNR-2123	15.55	4.77	4.97	12.53	148.6
IIVR-DN-2016	6.66	3.27	5.53	3.40	56.9
LE-14	66.66	4.83	7.70	9.73	806.2
LE-1020	57.77	5.67	7.43	5.90	761.7
LE-411	51.11	4.33	6.50	0.00	554.4
IIVR-1740047	0.00	0.00	0.00	1.17	0.0
Swarna	6.66	1.77	3.40	8.90	34.7
H-24	26.66	3.77	5.80	7.97	250.6
LE-116	15.56	1.17	2.23	0.60	90.7
EC-63003	2.22	0.33	0.83	5.17	7.8
Pharna Bhaskor	2.22	0.17	0.43	5.17	4.0
F-7-1	0.00	0.00	0.00	5.30	0.0
IIVR-88783	62.22	3.50	7.27	10.77	671.5
LE-104	37.77	3.10	6.13	5.50	344.6
Punjab Bas	11.11	1.77	3.40	9.57	68.9
IIVR-EC-2798	28.89	2.77	6.13	3.70	260.4
PKM-1	8.88	0.50	0.70	10.83	8.0
VGR-89	11.11	1.73	2.30	5.93	53.8
EC-326146	20.00	3.00	3.07	1.20	119.8
Pb-Rathak	44.44	3.03	4.93	6.13	351.8
Azota-1	13.33	1.57	2.13	7.73	61.5
EC-164838	0.00	3.77	4.20	3.83	0.0
LE-828	0.00	0.00	0.00	6.07	0.0
LE-90	0.00	0.00	0.00	0.00	0.0
IIVR-Pb-Khogri	35.55	3.13	4.60	2.80	272.2
EC-164677	0.00	2.50	3.43	1.63	0.0
IIVR-EC-2495	57.77	4.00	5.90	4.03	577.7
Punjab Bagkoa	33.33	3.20	3.73	1.50	231.3
Pusatha-2	15.55	2.07	3.43	4.50	89.5
CH-155	0.00	0.00	0.00	0.00	0.0
LE-15	0.00	0.00	0.00	0.67	0.0
LE-470	0.00	0.00	0.00	5.50	0.0
LE-231	2.22	0.67	0.00	0.00	2.0
LE-88	0.00	0.00	0.00	9.23	0.0
IIVR-EC-163894	6.66	0.60	0.90	1.13	8.4
LE-12	17.78	1.67	2.17	3.17	58.0
EC-165690	4.44	0.53	1.10	0.00	8.9
Kasamar	4.44	1.77	4.13	0.43	38.2
LE-355	4.44	1.03	1.77	0.00	17.8
LE-70	4.44	1.97	4.03	0.00	40.9
LE-20	0.00	0.00	0.00	0.00	0.0
EC-567346	6.66	0.37	0.77	0.00	15.1
Mean	15.95	1.93	2.83	4.76	139.6
SEd	5.61	0.75	1.35	2.04	60.0
CD(0.05)	11.14	1.49	2.68	4.06	119.0

88783 (7.27 cm) and P-1 (0.17 cm) and Pharna Bhaskor (0.43 cm). The combined effect of genotypes and salinity levels also showed significant variation in root length. The lowest root length were recorded in Punjab Bagkoa (1.10 cm) in 120 mM level of salinity. Salinity not only slows root growth, but also increases length of dead roots in those genotypes very sensitive to salt 'Neelavathi *et al.*' (2015).

The highest seedling length was observed LE-14 (13.56 cm) under moderate salinity level, followed by LE-1020 (13.10 cm) and LE-1 (12.53 cm). The combined effect of genotypes and salinity levels also highly significant variation seedling length. The highest seedling length (18.96 cm) was recorded in IIVR-Pb-Khogri with 0 mM salinity level, followed by LE-12 (18.00 cm) and Kasamer (17.66 cm). Whereas, lowest seedling length were recorded in Punjab Bagkoa (1.80 cm) in 120 mM level of salinity. Similar kind of result obtained by Kazemi *et al.* (2014), Nasrin and Abdul Mannan, (2019).

The highest vigour index was observed LE-14 (806.2) under moderate salinity level, followed by LE-1020 (761.7) and IIVR-88783 (671.5). Nasrin and Abdul Mannan, (2019), reported highest seedling vigour index in lower salt concentration and lowest seedling vigour index in higher concentration of salt. The combined effect of genotypes and salinity levels also had significant variation in vigour index. The highest vigour index (1730.0) was recorded in genotype IIVR-Pb-Khogri with 0mM salinity level, followed by LE-12 (1641.1) and Kasamer (1608.4). Similar kind of results obtained by Nasrin and Abdul Mannan, (2019), highest seedling vigour index was recorded in lowest salinity level and seedling vigour index. The lowest vigour index was recorded in Punjab Bagkoa (17.3) in 120 mM level of salinity. The result in agreement with Kazemi *et al.* (2014), Nasrin and Abdul Mannan (2019).

CONCLUSION

The highest seed germination percentage (66.66%), shoot length (6.60 cm) and root length (7.70 cm), highest seedling length (13.56 cm), seedling fresh weight (0.247 cm), seedling dry weight (0.04), highest vigour index (806.2) were observed in LE-14 respectively. The lowest seed germination and seedling parameters were recorded Pharna Baskar under moderate saline condition. LE-14 utilisation of tolerant genotypes as a donor for breeding programme

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Determinants influencing adoption of improved sericulture practices in Jammu

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The average yield of 25 kg of cocoons/100 dfls in the recent past has increased to 65 kg/100 dfls (Chouhan *et al.*, 2016). In India, Jammu abd Kashmir is one of the leading bivoltine silk producing state. The

Table 1. Variables affecting adoption of improved mulberry and silkworm rearing practices (Binary Logistic Regression)

Dependent variable	Independent variables	Coefficient B	S.E.	Wald	P-value	Exp (B)
Plantation of recommended varieties	Constant	-6.617	3.909E4	.000	1.000	.0001
	Annual Income	.000	.000	6.291	.012	1.000*
	No. of mulberry trees	-.022	.009	6.142	.013	.978*
	Experience	.099	.045	4.853	.028	1.104*
	Training acquired	-3.025	1.418	4.552	.033	20.599*
	Type of Rearing House	1.369	.546	6.278	.012	3.930*
Training of mulberry plants	Constant	47.419	4.151E4	.000	.999	3.927E20
	No. of mulberry trees	-.080	014	33.649	.000	.923**
Pruning of mulberry trees	Constant	-2.687	2.911	.852	.356	.068
	Education	.226	.066	11.558	.001	1.253**
	No. of mulberry tree	.036	.010	14.180	.000	1.037**
FYM application	Constant	79.314	4.557E4	.000	.999	2.790E34
	No. of mulberry tree	-.012	.003	12.146	.000	.988**
Fertilizers application	Constant	72.800	4.593E4	.000	999	4.137E31
	No. of mulberry tree	-.014	.004	13.306	.000	.986**
	Annual Income	.000	.000	4.447	.035	1.000*
Instar-wise mulberry leaf selection	Constant	-42.070	4.610E4	.000	.999	.000
	Age	-.036	.018	4.086	.043	.965*
	No. of mulberry tree	-.009	.003	10.867	.001	.991**
Feeding frequency during late age rearing	Constant	-.299	3.153	.009	.925	.742
	Occupation	-.492	.225	4.763	.029	.612*
Care during moult	Constant	-.023	2.822	.000	.993	.977
	Rearing Kit	1.241	.388	10.218	.001	3.461**
Hygiene measures during rearing	Constant	40.474	4.107E4	.000	.999	3.780E17
	Occupation	1.218	.273	19.900	.000	3.381**
	Annual Income	.000	.000	7.683	.006	1.000**
	No. of mulberry tree	-.008	.003	6.258	.012	.992*
	Type of rearing house	-.594	.198	8.947	.003	.552**
Proper disposal of silkworm rearing waste	Constant	41.015	4.029E4	.000	.999	6.496E17
	Occupation	1.115	.263	18.003	.000	3.051**
	Annual Income	.000	.000	5.713	.017	1.000*
	No. of mulberry tree	-.011	.004	8.171	.004	.989**
	Rearing kit	-.857	.370	5.373	.020	.424*
	Type of house	-.644	.192	11.217	.001	.525**

(** and * refers significance level at 1% and 5%)

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main silk production districts are Anantnag, Kupwara, Pulwama, Baramula, Gandarbal, Udhampur, Rajouri, Kathua and Reasi. The gap between potential and actual yield obtained by silkworm rearers are not fully exploited. Keeping in view, socio-economic profile of silkworm rearers and deviations in adoption of recommended package of practices were identified to know the factors influencing same in three potential areas of Jammu province.

The data on age, occupation, experience, education, land holding, type of area, area under mulberry plantation, type of rearing house, possession of rearing appliances, training on sericulture improved practices and net annual income and adoption of improved sericulture practices with respect to mulberry and silkworm rearing were collected from randomly selected 225 sericulturists from three major cocoon-producing districts, *viz*. Kathua, Udhampur and Rajouri. A well-designed pre-tested questionnaire was used for collection of primary data from silkworm rearers. The data were statistically analysed using SPSS software with techniques, *viz.* percentage, Chi-square method and binary logistic regression model was employed for studying the effect of variables on decision making of adoption of recommended package of practices and Nagelkerke's R^2 values were used to measure variations due to predictors. Secondary data were obtained from different government reports available offline as well as online.

The results of binary logistic regression model (Table 1) indicated that out of all independent variables, number of mulberry trees owned by respondents was most influencing factor which significantly affected farmer decision to adopt training, pruning, FYM and fertilizer application, instar-wise leaf selection, hygiene measures during rearing and proper disposal of silkworm rearing. The results are almost in accordance with Lakshmanan *et al*. (2011), Sreenivasa and Hiriyanna (2014) and Sharma *et al.* (2019 and 2020). Thus, it is concluded that mulberry plantation with quality leaf was the most influencing factor for adoption of sericulture which ultimately affects the successful cocoon crop production. The possession of rearing kits, type of rearing houses, trainings so received were other factors.

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Basidiomycete *(Pseudolagarobasidium acaciicola)* in coconut *(Cocos nucifera)* suspension culture — a report

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Coconut (*Cocos nucifera* L.), a monospecific woody tree is recalcitrant to *in-vitro* culture. Doubling the yield through technological interventionshas been reported in many palm species (Manorama *et al.*, 2019). Even though most of the *in-vitro* protocols use solid media, suspension cultures utilizing liquid media for establishing embryogenic cells with high regenerative capacity is reported (Al-Khayri, 2012). As the liquid media provide uniform conditions of nutrient availability to explants, mass multiplication of coconut embryogenic cells from plumular explant via suspension culture was attempted.

The explants used were plumules from 10-month-old nuts, harvested from 50-year-old palms of West Coast Tall variety planted at ICAR - CPCRI, Kasaragod, Kerala. The endosperm plugs were scooped out from the dehusked coconuts and sterilized with mercuric chloride, 0.1% (w / v), for three minutes. The embryos were excised and further sterilized using 20% sodium hypochlorite solution for 15 minutes and washed using double-distilled autoclaved water 5-6 times. Plumules are extracted from embryo and were inoculated in Y3 medium with 16.5 mg / l 2,4-Dichlorophenoxyacetic acid, 1 mg / l Thidiazuron, 0.1% (w / v) activated charcoal. The gelling agent used was agarose @ 7.5g / l. The plates were kept in dark condition at 27°C. After three weeks of inoculation, callus initiation was observed and small quantity of friable calli, whenever obtained was used for initiating suspension culture. Suspension culture medium was Y3 medium supplemented with biotin 1 mL / L, myoinositol 100 mg / L, malt extract 100 mg / L, L-glutamine 100 mg / L, sucrose 30 g / L supplemented with auxin picloram @ 1mg / L and activated charcoal @ 1 g / l. The suspensions were placed in an orbital shaker (Lab-line orbit environ - shaker, India) @ 100 rpm, 27°C temperature in dark condition. The friable callus tissues inoculated into suspension culture media dissociated into small granular clumps which were then plated on suspension medium gelled using agarose @ 7.5 g / L (Figs. 1-6).

Semi-transparent outgrowth was observed in few clumps which resembled friable calli of coconut plumular explants. Microscopic observations (Diaplan Microscope, LeitzWetzlar Type 307-148.002 at magnification of 40x, stained with acetocarmine) showed that these cultures contained two types of cells: longer (about 20 µm) and shorter (about 2 µm). The big cells were angular and elongated while the small were mostly circular in shape. The internal cellular components were visible in larger cells and in certain slides smaller cells appeared to ooze out from these larger cells (Fig. 6).

For identification of fungus, it was grown in 1.5 ml eppendorf tube containing 0.5 ml of Sabouraud Dextrose Broth supplemented with chloramphenicol and incubated in an orbital shaker (Innova, USA) at 150 rpm and 30°C for 4-5 days. The mycelia were then harvested by filtration and mechanically disrupted followed by genomic DNA extraction using Invitrogen gDNA isolation kit. Manufacturer's instructions were followed which was based on selective binding of dsDNA to silica-based membrane and subsequent elution of DNA in low salt Elution Buffer. The quality and quantity of gDNA was checked by Nanodrop ND8000.

Extracted DNA was amplified using an Eppendorf Master Cyclerthermal cycler (Eppendorf, US). The primers used were ITS1 (5′ TCC GTA GGT GAA CCT GCG G 3′) and ITS4 (5′TCC TCC GCT TAT TGA TAT GC 3′) which hybridize at the end of 18S rDNA and at the beginning of 28S rDNA, respectively. The PCR mixture (50 µl) contained 10 µl of DNA template, 6 µl of 25 mM $MgCl_2$, 5 µl of PCR buffer without $MgCl_2$; 200 µM each deoxynucleoside triphosphate, 25 pmol each of forward and reverse primer and 1 U of Taq

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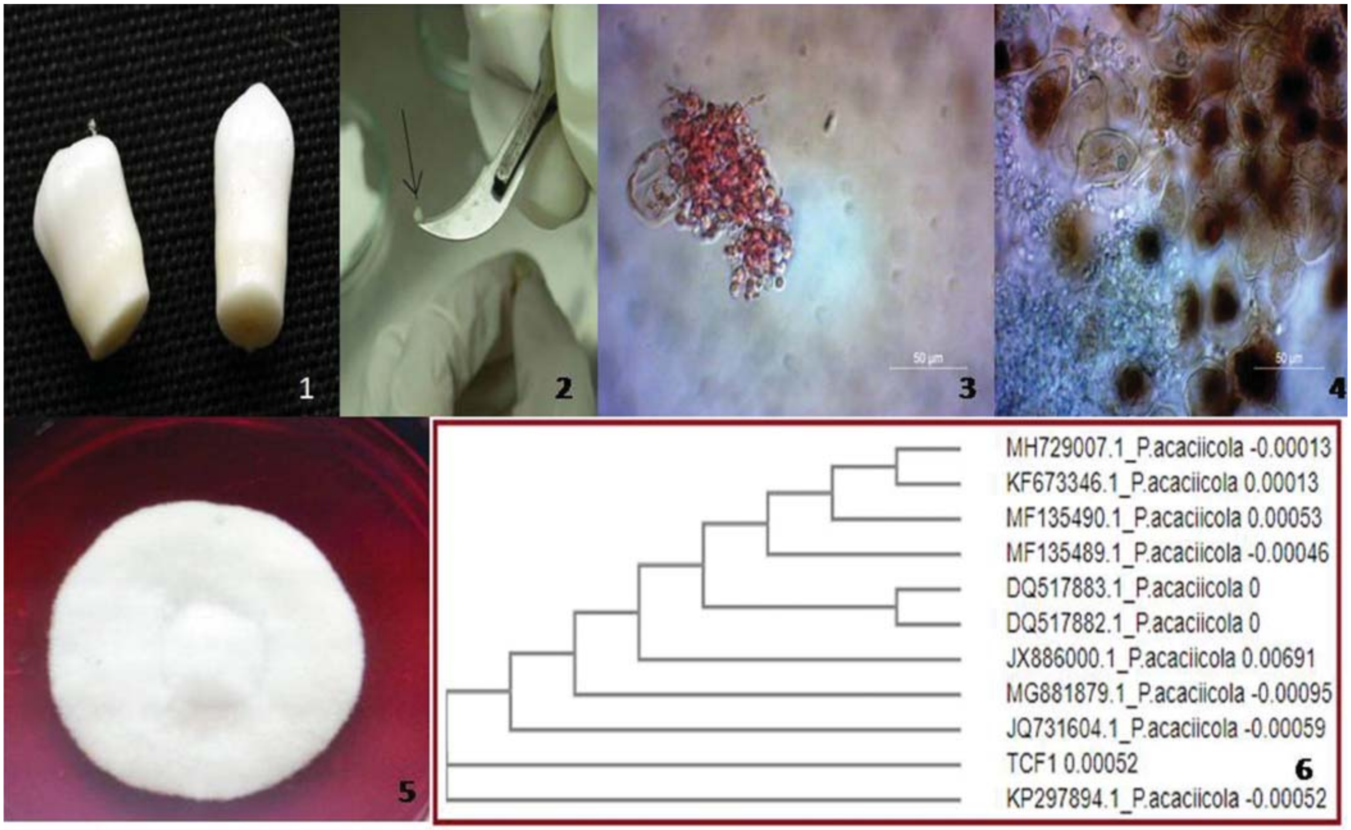

Fig. 1: Coconut embryos; **2.** extracted plumule; **3.** microscopic observation; **4.** two different types of cells; **5.** fungus isolated and purifed on Martin's Rose Bengal Agar medium; **6.** phylogeny of *Pseudolagarobasidium acaciicola* TCF1.

DNA polymerase. Reactions involved 1 cycle at 95°C for 5 min, followed by 35 cycles with a denaturation step at 95°C for 30 s, an annealing step at 55°C for 1 min, and an extension step at 72°C for 1 min, followed by 1 cycle at 72°C for 6 min.

A negative control of sterile water was included. The amplicon was electrophoretically separated in 1% agarose gel in 1× Tris-borate-EDTA buffer and visualized using ethidium bromide under UV illumination and its concentration was checked in a Nanodrop ND 8000. Molecular weight ladder (100-bp DNA) was included in the run. The amplified DNA from PCR was purified using PureLink PCR Purification Kit (Invitrogen) as specified by the manufacturer.

The amplicon was cycle sequenced with forward and reverse primers using the BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) in ABI 3730×l DNA Analyzer. After sequencing, forward and reverse rDNA sequences were assembled and contig was generated after trimming the low quality bases. The generated contig was analyzed by using the BLAST alignment program of the GenBank database (National Institutes of Health). The computer alignment provided a list of matching organisms, ranked in order of similarity between unknown sequence and sequence of corresponding organism from database.

The rDNA sequence analysis using Basic Local Alignment Search Tool (BLAST) of National Centre for Biotechnology Information (NCBI) demonstrated that it was derived from the fungal ITS regions and revealed the organism to be *Pseudolagarobasidium acaciicola*. The sequence was deposited in NCBI Genbank database with Accession number MK163558. Based on maximum identity score, first few sequences were selected and aligned using Clustal Ω and a dendrogram was constructed.

Based on homology and phylogenetic analysis, fungal hyphae growing in *in-vitro* cultured coconut plumular cell clumps belonged to a monophyletic genus, *Pseudolagarobasidium*, in *Polyporales* clade. The fungus *Pseudolagarobasidium acaciicola*, reported here, was first described from South Africa as a plant pathogen. It was widely used as a myco herbicide to control the invasion of Acacia species in South Africa (Barathikannan *et al.*, 2017).

The contaminations occurring during coconut meristem culture was reported (Neema *et al.*, 2022). But this is the first report of basidiomycete, known for white rot, thriving inside living coconut tissues maintained on artificial medium. Another noticeable fact was that unlike the fungal contamination in suspension cultures, which forms ball-like structures when suspensions are incubated in the shakers, the clumps observed in the study was grain like, much like the suspension cell clumps, which might mislead the researchers.

This resupinate fungus,though has an ecological range spanning from saprotrophy to parasitism, is also reported as an endophyte of healthy, living cocoa trees (Crozier *et al.*, 2006). Largely known as a saprophyte, its existence in coconut host could be seen as a survival strategy switching from one mode to another, indicating its nutritional plasticity and hence, ecologically important. In conclusion, this is to our knowledge the first reported case of the presence of *Pseudolagaro-basidium acaciicola* in coconut *in-vitro* suspension culture.

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Short Communication

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Dr YSRHU Year of Banana 2022-23

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Dr YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, is taking up many new initiatives focusing over all development of able horticultural in crops Andhra Pradesh. With the initiative of Dr T Janakiram, Vice-Chancellor, Sri Kakani Govardhan Reddy garu, Hon'ble Minister for Agriculture, Cooperation, Marketing & Food Processing, Government of Andhra Pradesh announced the year 2022-23 as 'Dr YSRHU Year of Banana 2022-23' with the released of the Logo on 20 October 2022. Under this, the university proposes to take up following activities targeting all the stakeholders in Andhra Pradesh.

Action Plan

- Planting of ten (10) banana seedlings in block or border rows in all Colleges, Polytechnics, Research Stations and KVKs including Private Affiliated Colleges and Polytechnics.
- Conducting training programmes on banana production / protection / value-added products to Village Horticultural Assistants / Village Agricultural Assistants of Rythu Bharosa Kendras, Farmers and field / level extension personnel.
- Awareness programmes on banana technologies, especifically in adopted villages under 'Vice-Chancellor to Village Programme'.
- Every Monday Phone-in-programmes and "Udyana Vani" programmes (community radio) on banana.
- Programmes on banana under "Udyana Mitra"- a supportive e-extension to RBK channel.
- Phone-in-live on banana at Doordarshan.
- Webinars on banana technologies.
- Student READY programme on banana.
- Technological backstopping for banana FPOs in Andhra Pradesh.
- Documentation of success stories of banana farmers / entrepreneurs marketing personnel.
- International level seminars on banana in collaboration with ICAR-NRCB, Trichi.
- Organization of 'Banana Kisan Mela'.
- Student rallies by displaying placards on banana technologies.
- Encouraging students / staff to write songs / poems on banana.
- Honouring progressive successful banana farmers and eminent scientists.
- Identification of Innovative farmers.
- Commercialization of banana technologies
- Supply of quality planting material to farmers.
- Posters on banana technologies for display at Rythu Bharosa Kendras.
- Articles on banana technologies
- Release of souvenir on banana.

In Andhra Pradesh, banana is cultivated in both the Rayalaseema (Kadapa, Ananthapur, Kurnool districts) and Coastal (West Godavari, East Godavari, Krishna, Guntur and Vizianagaram districts) regions. Grand Naine variety occupying more than 90% area in Rayalaseema region is being exported to other countries while in coastal regions, polyclonal banana cultivation is prevalent with traditional varieties like Tella Chekkara Keli, Karpura Chekkara Keli, Martman, Red banana and Kovvur bontha (Culinary). Banana cultivation has been transformed due to introduction of Cavendish banana variety Grand Naine, tissue culture plant material production, crop management through drip and fertigation system etc. Though productivity of banana is much higher than the national average, scope still exists for area expansion and to increase the productivity.

The area expansion has been accompanied by rampant spread of pests and diseases, the most important among which are sigatoka leaf spot, panama wilt caused by *Fusarium oxysporum* f. sp. *cubense* (Foc Race 1), bacterial rhizome rot and viral diseases like BBrMV *(Banana bract mosaic virus)*, CMV *(Cucumber mosaic virus)* and BBTV *(Banana bunchy top virus)*. Farmers also facing challenges from abiotic factors like

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higher temperatures, cyclones, droughts, gales and accumulation of salts in the soils. All these biotic and abiotic challenges are continuously addressed by Dr. Y S R Horticultural University by extensively conducting research work for the last 50 years at Dr YSRHU - Horticultural Research Station, Kovvuru. Further, to strengthen research and to address the needs of stakeholders of Rayalaseema region, a new Banana research station under the aegis of Dr YSRHU has been established at Pulivendula of YSR Kadapa district.

Technologies developed

- Identified promising banana cultivars, viz. Godavari bontha, Yangambi km 5, FHIA 3, Popoulu, Kavery Kalki through MLT and recommended for cultivation in Andhra Pradesh.
- Standardized package of practices for all commercial banana cultivars of the state.
- Standardized tissue culture protocols for Grand naine, Dwarf Cavendish and also the traditional varieties of Andhra Pradesh *viz.* Tella Chakkera Keli, Red Banana, Karpura Chakkera Keli and Kovvur bontha by using apical meristem as explant.
- Standardized in vitro protocols for mass multiplication of banana cv. Karpura Chakkera Keli by using immature male flower buds as explants.
- Standardized macro-propagation technology in Grand naine and Tella Chakkera Keli and evaluated the field performance of the macro-propagated plants.
- Standardized integrated nutrient and weed management practices in banana
- Standardized drip irrigation and fertigation schedules for banana
- Standardization of stage wise water requirement of banana in different seasons
- Standardization of organic nutrient management of banana in Grand naine and other native banana genotypes of Andhra Pradesh.
- Developed banana based cropping systems
- Standardized bunch management practices in banana cv. Karpura Chakkera keli.
- Standardized the technologies for improving the shelf-life of banana cultivars Grand Naine and Tella Chakkera Keli.
- Developed disease maps and calendar for banana in Andhra Pradesh
- Documented geographical distribution and time of occurrence of diseases in different banana growing areas of Andhra Pradesh.
- Correlations between weather and major banana diseases were worked out.
- Banana accessions of different genomes and sub groups were screened for their reaction to diseases such as Fusarium wilt (Race-1), Sigatoka leaf spot and viral diseases.
- ELISA protocols for serodiagnosis of banana bract mosaic virus and cucumber mosaic virus (causes infectious chlorosis) were developed.
- Developed package for management of viral diseases in Banana
- Standardized prophylactic and curative fungicide management measures for Sigatoka and other foliar diseases.
- Identified parasitic nematode genera associated with banana namely, *Pratylenchus, Radopholus, Meloidogyne, Hoplolaimus* and *Helicotylenchus.*

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New varieties from CHES (ICAR-CIAH), Godhra, Gujarat

BAEL: Thar Srishti – Its average yield in 9th year is 91.50 kg / tree with fruit weight (1.55 kg), fruit size (21.00 cm × 14.00 cm), fruit girth (43.53 cm), shell thickness (0.20 cm), number of locules in cross section (14.00), peel weight (200.00 g), pulp weight (1.20 kg), fibre weight (62.32 g), total seed weig ht (19.00 g), total number of seed / fruit (98.15), TSS of pulp (36.75 °Brix), TSS of mucilage (51.50°Brix), total sugar (21.40 %), acidity (0.35 %) and TSS / acidity ratio (128.33) recorded under rainfed semi-arid conditions. It belongs to mid-maturity group (April) with highly centric locule arrangement. Its fruits are rich in fine fibres, less in seeds, attractive pulp colour, very less odour compared to others. It is suitable for table purpose.

BAEL: Thar Prakriti – With an average yield of 115.75 kg / tree in 12th year, its fruits weigh 1.40 kg each, fruit size 14.05 cm x 15.10 cm, fruit girth 44.10 cm, shell thickness0.14cm, total number of seeds 60.23, locules in cross section (14-17) and TSS 38.00 °Brix,. The fruits have good flavour and aroma. Rich in antioxidants, its fruit are highly suitable for sharbat, murabba and powder making. It matures in 1st week of May.

BAEL: Thar Shivangi – It provides 109.15 kg fruits / tree in 11th year with fruit weight of 1.35 kg, fruit size 15.50 cm x12.87 cm, fruit girth 44.80 cm and total number of seeds 75.32. The TSS is 37.100Brix. Being small in stature, it is highly suitable for high-density planting.

ACID LIME: Thar Vaibhav – A precocious and prolific bearer Thar Vaibhav has vigorous and spreading growth habit. Fruits are round with attractive yellowish smooth peel. Fruit is juicy (49 %), acidic (6.84 %) with less number of seeds / fruit (6-8). Its yield is 60.15 kg / plant in 6th year under rainfed hot semi-arid conditions. Its average fruit weight is 42.57 g; fruit size 42.71 mm × 42.82 mm, peel thickness 1.59 mm, TSS 7.34°Brix and ascorbic acid 43.45 mg / 100 ml. Fruit ripens in 125-135 days in summer while rainy season and winter season crop may take 145-155 days from fruit setting with excellent keeping quality at ambient storage.

IVY GOURD: Thar Sadabahar – Its vine grows up to 3.76 m with pentalobed leaves. Its yield potential is 26.86 t / ha with average fruit weight of 29.3g. The total numbers of fruits / vine are 1124. The fruits have discontinuous strips, green colour and round oblong fruit shape. The fruits are rich in vitamin C (49.2 mg / 100 g). It bears fruits round the year.

IVY GOURD: Thar Dipti – Its fruits are attractive with shining dark green stripeless fruit appearance, trilobe leaf shape, small-medium size and pointed styler end. The total numbers of fruits / vine are 1497. The average fruit weight and length of fruit are 14.2 g and 4.7 cm, respectively, with total yield 24.4kg / plant. It is tolerant to both powdery mildew and fruit fly under field conditions. The edible fruits are rich in vitamin C (51.4 mg / 100 g).

BOTTLE GOURD: Thar Avani – Its plants are highly vigorous with dense foliage. The male and female flowers emerge from 7th and 11th nodes, respectively. Each plant produces 24-32 female flowers and set sized fruits 57-62 days after sowing. The fruits are round in shape, with 22.8 cm in length and each fruit weighing 750-860 g. The fruits have high flesh thickness, high TSS (8.1-8.7°Brix), with attractive creamy-white flesh. Each plant produces 12.91 kg / plant with yield of 43.0 tones / ha. The fruits are ready for harvesting 54-63 days after sowing and 120-140 days for seed purpose.

CUSTARD APPLE: Thar Amrit – With spreading growth habit, it starts flowering in 2nd year. It is regular

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bearer and its fruits ripen in 1st fortnight of November. The average fruit yield is 24.80kg / plant in 11th year after planting. The fruit is rich in ascorbic acid (45-50 mg), iron (1.70 mg), phosphorous (26.0 mg), potassium (285.55 mg) and calcium (18.21 mg) content. Fruits emit strong aroma at full ripening stage. It is late-maturing (2nd week of November) and its fruit may be used for both table and processed purposes.

WOOD APPLE: Thar Prabha – It gives yield 124.36 kg / plant in 12th year.The fruit weight, fruit size, pulp, shell weight, TSS, acidity, total sugar, reducing sugars, fruit pectin, fruit protein, seed protein, phosphorous, potassium, calcium and iron are 452.25g, 103.67 mm × 96.66 mm, 50.92%, 180.12%, 14.12°Brix, 3.85%, 3.07%, 1.42%, 1.76%, 18.13%, 24.38%, 0.07%, 1.73, 0.30% and 16.72 mg, respectively. Its fruits are bigger in size with shelf life of 12-15 days at normal conditions. The fruit is rich in pectin (1.76%) and protein (pulp, 18.13% and seed, 24.38%), phosphorous (0.07%), potassium (1.73%), calcium (0.30%) and iron (16.72 mg) content. The fruit may be used as table purpose and for value-added products.

INDIAN BEAN: Thar Kiran – Its plants have climbing (pole type) growth habit, grow up to 3.5-4.0 m.The pods are medium having an average pod length, pod girth and pod weight of 10.8 cm, 5.33 cm and 8.4 g respectively. The fresh purple pods are ready 100 - 110 days after sowing. It gives 1100-1600 pods / plant with an average yield of 7-9 kg / plant of fresh purple pods. It is resistant to dolichos bean yellow mosaic virus disease under field conditions.

INDIAN BEAN: Thar Ganga – Its plants have climbing (pole type) growth habit, growing up to 4.5-4.7 m. The pods are extra-long with an average pod length of 17.5 cm and pod girth 5.21 cm with pod weight of 15.2 g. The harvesting of fresh pods starts at 98-110 days after sowing with total of 800-1200 pods / plant and an average yield of 8-10 kg / plant of fresh pods can be obtained. This variety is moderately resistant to dolichos bean yellow mosaic virus disease under field conditions.

VEGETABLE COWPEA: Thar Jyothi – It is a high-yielding variety and photo insensitive cowpea. It grows up to of 50-56 cm height with dark green leaves and pods. It is a short statured (bushy growth habit) growing up to 50-56 cm height. It is an early flowering and early maturing variety. The fruits ready 48-50 days after sowing for harvesting. The total number of pods varies (120-150) with an average yield of 1.5 - 2.0 kg / plant of fresh pods.

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